Ashburton Infrastructure Project

Air Quality Assessment

Final Report
Version 2

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Ashburton Infrastructure Project

Final | Report

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Executive Summary

Mineral Resources Limited commissioned Environmental Technologies & Analytics Pty Ltd (ETA) to undertake an air quality assessment for the Ashburton Infrastructure Project (AIP). The purpose of this air quality assessment is to assess the potential air quality impacts associated with landside facilities to be developed and operated at the Port of Ashburton.

Study Overview

The AIP involves the construction of a new private haul road connecting an open cut mining area to landside facilities at the Port of Ashburton, and export via marine facilities at the Port. The Ashburton Haul Road will be a fully sealed private road commencing at the boundary of the approved Buckland mine about 45 kilometres (km) southwest of Pannawonica, and continuing for about 150 km westward towards Onslow. The Port Facilities will be located at the Port of Ashburton, about 12km southwest of the Onslow township.

For the purposes of the air quality assessment, the AIP (port facilities) consists of the following:

- Truck unloading shed
- Fully enclosed storage shed containing, Overhead tripper, stockpile (220,000 tonnes), Bridge reclaimer and Conveyors
- Transfer stations and conveyors
- New jetty with a ship loader and marine transhipping
- Dredge spoil deposition, and
- Power generation using gas fired engines (12 MW power station).

The potential air quality impacts of the AIP were determined through a dispersion modelling study, which incorporated site-specific meteorological data, and emissions information estimates for the project based on equipment design specifications supplied by MRL. The scope of the modelling assessment is summarised below.

Modelled meteorological period	1 January to 31 December 2013
Model selection	WRF/CALMET/CALPUFF model suite
Key Pollutants	• nitrogen dioxide (NO_2) • particulate matter (PM) - including TSP, PM_{10} and $PM_{2.5}$ size fractions, and dust deposition
Meteorological data	Three-dimensional prognostic meteorological data developed using the Weather Research and Forecasting (WRF) model.

Background Air Quality	Published air quality monitoring data for the Pilbara has been reviewed and used as a suitable proxy of existing (baseline) concentrations for key pollutants. Modelling of other approved industry (operating) in close proximity has been used to assess the incremental cumulative contribution.
Project Emissions	Emissions from the AIP under maximum material handling assumptions formed the basis of the modelling assessment for operational configuration with 4 inloaders. Abnormal operating conditions for project power generation (start-up and shutdown, control equipment failure) are not expected to significantly increase emissions, due to plant design and proposed emission control contingency measures. Construction related emissions are excluded from this assessment due to their intermittent nature and will be considered with a construction dust management plan.
Sensitive Receptors	Discrete receptor locations were nominated to represent: • closest non-project related sensitive receptors - community • project related receptors – project worker accommodation • industrial receptors – sensitive to dust deposition due to nature of operations
Model Scenarios	The model scenarios that have been included in the assessment consider the Project only (in isolation), as well as a cumulative scenarios: • **Scenario 1** - AIP with operations at 30 Mtpa (4 inloaders) o AIP Project only (in isolation of other sources) o AIP Project inclusive of background air quality (ie cumulative impact) • **Scenario 2** - AIP with operations at 40 Mtpa (4 inloaders) o AIP Project only (in isolation of other sources) o AIP Project inclusive of background air quality (ie cumulative impact)

Key findings

The key findings of the assessment are:

- For Scenario 1 (30 Mtpa)
  - TSP
    - The maximum predicted 24-hour ground level concentration, with background (ie cumulative), is 95 µg/m^3 at the Chevron receptor. It is important to note that this receptor is not classified as a sensitive receptor.
    - For Onslow the maximum predicted 24-hour ground level concentration, with background included (ie cumulative), is 47 µg/m^3.
  - PM_{10}
    - The maximum predicted concentration (from Project only) at the receptors within Onslow is 1.7 µg/m^3 increasing up to 23.1 µg/m^3 when the background concentration is included.
    - No excursions of the PM_{10} assessment criteria are predicted to occur.

- $PM_{2.5}$
  - The maximum predicted concentration (from Project only) at the receptors within Onslow is 0.5 µg/m^3 increasing up to 8.3 µg/m^3 when the background concentration is included.
  - No excursions of the $PM_{2.5}$ assessment criteria are predicted to occur.
- Dust deposition
  - The criterion for potential deposition effects (2 g/m^2/month) is not exceeded at any sensitive receptor.

- For Scenario 2 (40 Mtpa)
  - TSP
    - The maximum predicted 24-hour ground level concentration, with background concentration included (ie cumulative), is 101 µg/m^3 at the Chevron receptor. It is important to note that this receptor is not classified as a sensitive receptor.
    - For Onslow the maximum predicted 24-hour ground level concentration, with background concentration included (ie cumulative), is 49 µg/m^3.
  - PM_{10}
    - The maximum predicted concentration (from Project only) at the receptors within Onslow is 2.2 µg/m^3 increasing up to 23.6 µg/m^3 when the background concentration is included.
    - No excursions of the PM_{10} assessment criteria are predicted to occur.
  - $PM_{2.5}$
    - The maximum predicted concentration (from Project only) at the receptors within Onslow is 0.7 µg/m^3 increasing up to 8.5 µg/m^3 when the background concentration is included.
    - No excursions of the $PM_{2.5}$ assessment criteria are predicted to occur.
  - Dust deposition
    - The criterion for potential deposition effects (2 g/m^2/month) is not exceeded at any sensitive receptor.
- For NO_2 from power generation:
  - The predicted annual average and maximum 1-hour ground level concentrations are well within the relevant assessment criteria for the Project operating in isolation of other sources.
  - The annual and 1-hour assessment criteria are not exceeded at the nominated sensitive receptors when cumulative emissions are included in the modelling.

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1 Introduction

1.1 Background

Mineral Resources Limited (MRL) is undertaking planning for iron ore mining and export developments in the West Pilbara region of Western Australia (WA). The proposed Ashburton Infrastructure Project (AIP) (the Project) will support this development, and involves a new private haul road connecting an open cut mining area to landside facilities at the Port of Ashburton, and export via marine facilities at the Port.

The Ashburton Haul Road will be a fully sealed private road commencing at the boundary of the approved Buckland mine (Bungaroo South) (MS906 and MS1147), about 45 kilometres (km) southwest of Pannawonica, and continuing for about 150 km westward towards Onslow. The Port Facilities will be located at the Port of Ashburton, about 12 km southwest of the Onslow township (Figure 1-1), and will include:

- Truck unloading shed
- Fully enclosed storage shed containing:
  - Overhead tripper
  - Stockpile (220,000 tonnes)
  - Bridge reclaimer
  - Conveyors
- Transfer stations and conveyors
- New jetty with a ship loader and marine transhipping
- Dredge spoil deposition, and
- Power generation using gas fired engines (12 MW power station).

As part of this investigation, MRL commissioned Environmental Technologies & Analytics (ETA) to undertake an assessment of the air emissions from the AIP, and to determine the potential air quality impacts on the surrounding area following the introduction of the AIP. This report presents the results of the air quality assessment conducted.

Figure 1-1: Project location and setting.

1.2 Scope of work

The potential air quality impact of the Project has been determined through a dispersion modelling study, which incorporated site-specific meteorology, and emissions information estimated for the AIP for the defined operational capacity, with power generation at the port (12 MW power station). The scope of the modelling has been developed, taking into account the regulatory context, available meteorological and ambient air quality monitoring data, and the nature of emissions expected from the AIP when operating.

Reference has been made to the following key regulatory policy and guidance:

- Air Quality Modelling Guidance Notes (DoE, 2006)
- Guideline - Air Emissions, draft for external consultation (DWER, 2019)
- Environmental Factor Guideline – Air Quality (EPA, 2020)
- *Environmental Protection Act, 1986, as amended, and*
- Environmental Protection Act Regulations 1987.

1.3 Structure of report

This report describes the methods and findings of an assessment of the potential impacts to the air environment arising from the Project. The assessment includes:

- The study approach and methodology in Section 3.
- Atmospheric dispersion modelling of the emissions using CALPUFF (Section 4).
- Project emission estimation and inventory in Section 5.
- An evaluation of the modelled change in air quality and interpretation of the potential impact from the Project, for particulates and NO_2 (Section 6).
- Conclusions of the assessment are presented in Section 7.

The appendices contain supporting information, specifically:

- The analysis to determine the representative meteorological year for modelling.
- The detailed configuration for WRF and CALMET.
- Emission parameters and emission rates for each source modelled.

2 Project description

2.1 Process overview

As outlined in the Section 1.1 MRL is planning to develop iron ore mining and exports in the West Pilbara region and the proposed AIP will support this development for the export of up to 40 Million tonnes per annum (Mtpa) from the Port of Ashburton. The products will be received at the proposed AIP through road haulage and loaded onto Cape class vessels via transhipment.

An example of the currently proposed process flow is presented in Figure 2-1 and a description of the process flow that is relevant to this assessment, including proposed pollution abatement, is briefly outlined in the following sections.

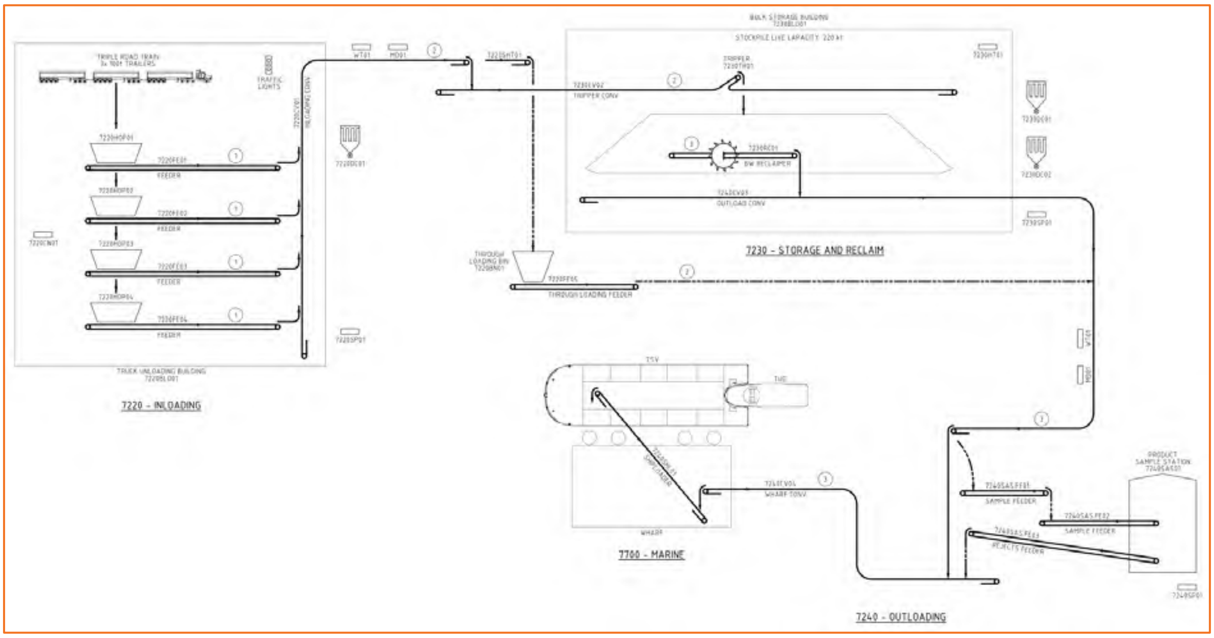

Figure 2-1: Process flow diagram of proposed AIP (MRL, 2021).

2.1.1 Inload circuit

The in-loading facilities for the proposed AIP will include delivery of iron ore fines via road hauled side-tipping triple trucks. The trucks will deliver to receival bins, located within a partially enclosed shed facility. A hybrid belt feeder at the underside of each bin will feed material from the bin onto a single outgoing inclined conveyor for delivery to the storage area.

Details of the proposed system, that are relevant to this assessment include:

- Road haulage:
  - Road transport of product will be via a new sealed private haul road.
  - Road trains will consist of side tipping triple road trains with a combined mass of 335 tonnes.
- Truck unloading:
  - Truck unloading will be undertaken in a partially enclosed steel structure with a drive-in/drive-out unloading arrangement.

- Inload conveyor and transfer points:
    - Material from the in-loading system will be feed onto a single belt conveyor.
    - Conveyors shall include carry side covers, over material burden and idlers, to prevent generation of dust.
    - Scrapers will be fitted at the head pulley to limit material carry back and belt ploughs at the tail-end to prevent belt damage.
    - Transfer stations shall include dust suppression sprays. Concrete slabs and kerbs will be provided at areas where spillage is likely (i.e. transfer points).

2.1.2 Bulk storage

The bulk storage facilities for the proposed AIP will include a single storage shed complete with tripper, rail mounted bridge reclaimer and direct out-loading (bypass) option. The storage shed will be a steel structure with a dust collection system in the shed to mitigate dust escape and provide ventilation to permit the use of mobile equipment.

2.1.3 Outload circuit

The outload circuit at the proposed AIP will include a series of conveyors, sample station, wharf and transhipment loader. Details of the proposed system, that are relevant to this assessment include:

- Outload conveyor and transfer points:
    - Material from the in-loading system will be feed onto a single belt conveyor.
    - Conveyors shall include carry side covers, over material burden and idlers, to prevent generation of dust.
    - Scrapers will be fitted at the head pulley to limit material carry back and belt ploughs at the tail-end to prevent belt damage.
    - Transfer stations shall include dust suppression sprays. Concrete slabs and kerbs will be provided at areas where spillage is likely (i.e. transfer points).
- Shiploading:
    - Consists of a single fixed boom shiploader, with both slewing and luffing capability to optimise clearance to the vessel loading point to assist in dust reduction.
    - The shiploader will deliver material to a single point loading (SPL) hopper mounted on the tranship vessels for even distribution within the vessel.

2.1.4 Power generation

The power supply for the Project will be derived from a new power generation station that will be constructed within the Project boundary. This new power station will comprise seven Cummins reciprocating gas generators, each with a capacity of 2 MW, though only six generators will be operational under normal working conditions.

2.2 Air pollutants of interest from the AIP

Based on the description of the Project and key processes considered, the key pollutants of interest to be assessed are summarised in

Table 2-1.

Table 2-1: Air pollutants of interest from the AIP.

<table>
<tr><th colspan="3">Pollutant to be Assessed</th></tr>
<tr><td rowspan="5">Particulate Matter</td><td colspan="2">Airborne particles are a broad class of diverse substances that may be solid or liquid (liquid particles are often called aerosols) and are produced by a wide range of natural and human activities. Airborne particles are commonly classified by their size as total suspended particles (TSP), visibility reducing particles (PM_2), and inhalable particles (coarse fraction PM_{10} and fine fraction $PM_{2.5}$).
Project sources are principally from the handling of ore and wind generated surface erosion.</td></tr>
<tr><td>PM_{10}</td><td>Inhalable particles are grouped into two size categories: those with a diameter of up to 10 µm (PM_{10}) and those with a diameter of up to 2.5 µm ($PM_{2.5}$).
Inhalable particles are associated with increases in respiratory illnesses such as asthma, bronchitis and emphysema, with an increase in risk related to their size, chemical composition and concentration.
Particles in the PM_{10} size fraction have been strongly associated with increases in the daily prevalence of respiratory symptoms, hospital admissions and mortality.</td></tr>
<tr><td>$PM_{2.5}$</td><td>Particles in the $PM_{2.5}$ size fraction can be inhaled more deeply into the lungs than PM_{10}, and have been associated with health effects similar to those of PM_{10}. There is some evidence to suggest that $PM_{2.5}$ might be more deleterious to health than other size fractions. No lower limit for the onset of adverse health effects has yet been observed.</td></tr>
<tr><td>TSP</td><td>Total suspended particulates (TSP) refers to the total amount of the PM suspended in air, typically up to 50 µm. These larger particles are primarily associated with amenity or visibility issues and are likely to be removed by gravitational settling within a short time of being emitted (i.e. they settle to the ground or other surfaces fairly quickly).</td></tr>
<tr><td>Deposited Dust</td><td>Deposited matter refers to any dust that falls out of suspension in the atmosphere.</td></tr>
<tr><td>Combustion Gases</td><td>Nitrogen dioxide</td><td>Nitrogen dioxide (NO_2) is a brownish gas with a pungent odour. It exists in the atmosphere in equilibrium with nitric oxide. The mixture of these two gases is commonly referred to as nitrogen oxides (NOx). Nitrogen oxides are a product of combustion processes, and can arise when flame staging is non-ideal and nitrogen present in air is oxidised.
Nitrogen dioxide can cause damage to the human respiratory tract, increasing a person's susceptibility to respiratory infections and asthma. Sensitive populations, such as the elderly, children, and people with existing health conditions are most susceptible to the adverse effects of nitrogen dioxide exposure.
Nitrogen dioxide can also cause damage to plants, especially in the presence of other pollutants such as ozone and sulphur dioxide.
Nitrogen oxides are also present in the reactions that lead to photochemical smog formation.
Project sources are principally from power generation.</td></tr>
</table>

The appendices contain supporting information.

3 Assessment methodology

This section outlines the air quality study and assessment approach. It includes the methodology applied to define the meteorological characteristics of the Project area relevant to the assessment, the emission estimation, the dispersion, and the ambient assessment criteria selected for the purposes of determining the significance of the dispersion model results, and therefore the potential impact.

The simplified study structure is shown in Figure 2-1 and detailed in the following subsections.

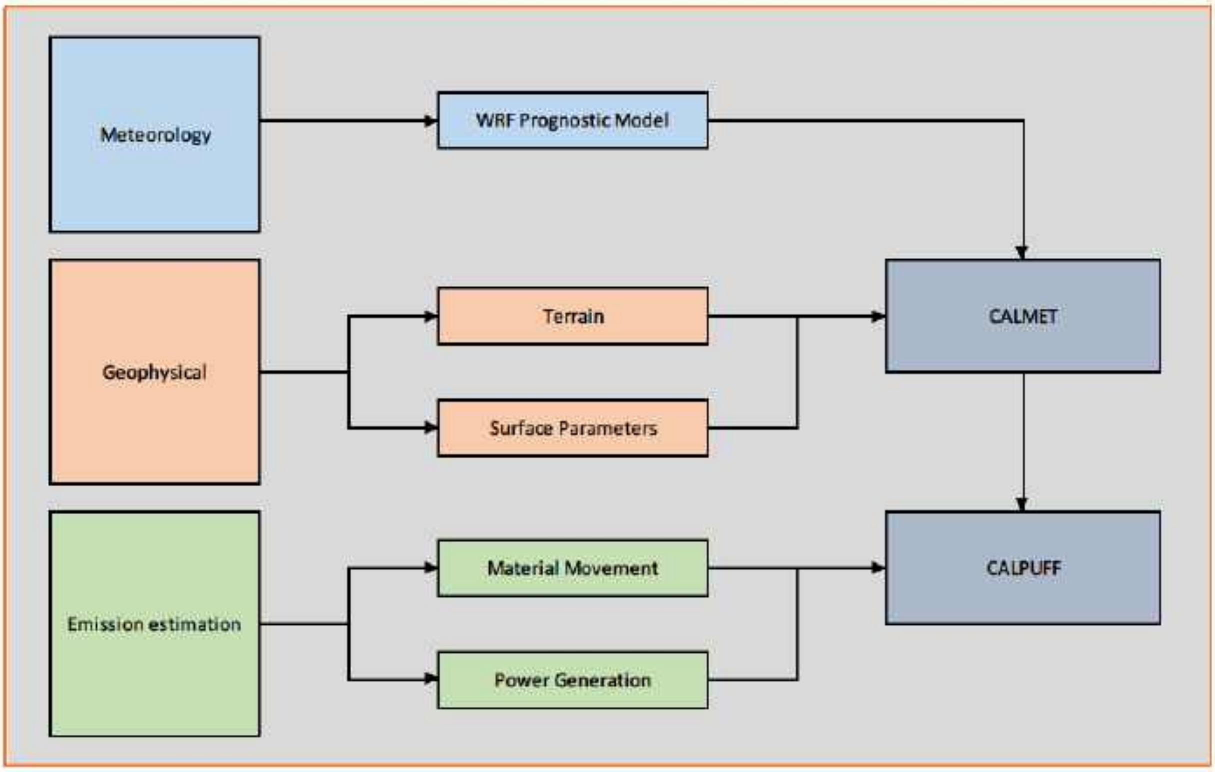

Figure 3-1: Air quality assessment – study approach.

3.1 Existing environment – meteorology, air quality and receptors

The climate and meteorological characteristics of the region control the dispersion, transformation and removal (or deposition) of pollutants from the atmosphere, and therefore ambient air quality. This section outlines the key characteristics for the project location, including the receptors identified within the region.

3.1.1 Local climate and meteorology

The meteorology component of a dispersion model is a key element for the effectiveness or representativeness of the dispersion model outputs.

A review of 10 years (2011 to 2020) of historical surface observations obtained from the Bureau of Meteorology (BoM) for the Onslow Airport weather station concluded that the 2013 calendar year being the most representative against longer term climatic averages. The 2013 calendar years was selected on this basis. The analysis is detailed in Appendix A.

Both upper air and surface information are needed for modelling. In the absence of adequate onsite meteorological data, the Weather Research and Forecast (WRF V3.7) model (http://wrf-model.org/index.php) was used to generate hourly 3-dimensional data for the region. The 3-Dimensional meteorological data generated by WRF was input to CALMET for further processing to the finer resolution used in the dispersion modelling. This procedure will be referred to as the 'WRF-CALMET methodology'. The output from the CALMET meteorological model is then used to drive the pollution dispersion in the CALPUFF model. Configuration of WRF is detailed in Appendix B, with the configuration of CALMET detailed in Appendix C.

3.1.2 Existing | background air quality

There is no ambient particulate or NO_2 monitoring data for the Onslow region publicly available for this assessment. Data from the Port Hedland Industries Council (PHIC) Yule River monitoring station, has been assumed to be a reasonable proxy or approximation for PM_{10} and $PM_{2.5}$. Although this monitor is located approximately 380 km to the northeast of the AIP the data can be considered to be representative of the background particulates in a coastal location in the Pilbara region.

Representative ambient air quality is summarised in Table 3-1.

Table 3-1: Existing | background air quality for assessment.

Parameter	Averaging Period	Concentration	Reference
PM_{10}	24-hour	21.4 μg/m³	Yule River FY16 70th percentile
	Annual average	18.5 μg/m³	Yule River FY16
$PM_{2.5}$	24-hour	7.8 μg/m³	Yule River FY16 70th percentile
	Annual average	6.0 μg/m³	Yule River FY16
TSP	-	-	Not available
Dust deposition	-	-	Not available
NO_2	-	-	Not available

3.1.3 Sensitive receptors and environmental values

This modelling assessment considers the potential air quality impacts on relevant environmental values and sensitive receptors, consistent with EPA (EPA, 2020), and DWER (DWER, 2019). This includes sensitive (human) receptors, including locations where people are residing either on a temporary or permanent basis, noting that the current DWER guidelines excludes the consideration of on-site project related receptors as sensitive receptors. Other receptor locations have been included for information purposes to inform the assessment process. The key receptors locations considered are:

- The Township of Onslow
- Chevron Accommodation camp
- Onslow Salt evaporation ponds, and
- Chevron Wheatstone gas processing facility.

The location of the nominated receptors in the region are presented in Figure 5-4 relative to the AIP project, and summarised in Table 3-2.

Figure 3-2: Receptor locations (GDA94, Zone 50).

Table 3-2: Receptor coordinates (GDA94, Zone 50).

Receptor	Easting	Northing	Environmental Value | Receptor Type	Assessment Criteria	Pollutant Impact Assessed				
					NO_2	PM_{10}	$PM_{2.5}$	TSP	Dust deposition
Onslow 1	304,167	7,605,925	Sensitive receptor – community	Human health and amenity	✓	✓	✓	✓	✓
Onslow 2	304,755	7,604,926	Sensitive receptor – community	Human health and amenity	✓	✓	✓	✓	✓
Camp	297,256	7,590,549	Receptor of interest – workforce accommodation	Human health and amenity	✓	✓	✓	✓	✓
Salt 1	297,776	7,598,660	Receptor of interest – industry	Amenity | Nuisance	-	-	-	-	✓
Salt 2	299,239	7,599,656	Receptor of interest – industry	Amenity | Nuisance	-	-	-	-	✓
Chevron	293,413	7,599,720	Receptor of interest – industry	Amenity | Nuisance	-	-	-	✓	✓

3.2 Emissions estimation

Emission rates were estimated using recognised and accepted methods of emissions estimation, which included published emission factors from the National Pollutant Inventory (NPI) Emission Estimation Technique Manual (EETM) for Mining (EA, 2012). Further detail is contained in Section 5.

3.3 Modelling

The modelling has been conducted using the Weather Research and Forecasting (WRF) model, a mesoscale numerical weather prediction model coupled with the CALMET/CALPUFF model suite.

The WRF model was used to develop a three-dimensional wind field across the model area, which in turn was used as input to CALMET to form the final meteorological dataset used for modelling. Air dispersion modelling was conducted using CALPUFF. The model has been used to predict ground level concentrations across the model domain and at identified receptor locations of relevance to the assessment. Modelling setup is further detailed in Section 4.

The potential air quality impacts associated with the AIP at two annual tonnage handling rates have been considered in isolation of other emission sources, as well as in conjunction with background air quality and existing emission sources, to represent potential cumulative impacts.

Air dispersion modelling was conducted using CALPUFF - the dispersion module of the CALMET/CALPUFF suite of models.

3.4 Impact assessment

Ground-level particulates concentrations, dust deposition and NO_2, predicted at nominated receptors and the surrounding environment were compared with the relevant air quality assessment criteria. This assessment has considered the potential impact attributable to the AIP, as well as the cumulative (background) impact (i.e. in conjunction with the existing emission sources in the area. The basis for this is summarised in Table 3-2.

Modelling results, at nominated receptors, are compared to the numerical value of the criteria, and assessed as being either above or below the numerical value. It is important to note that, as a risk based assessment approach is normally applied to the assessment of air quality, a modelled result above the numerical value is not an indicator of unacceptable impact, but is an indication that the potential risk for impact requires further consideration.

3.4.1 Assessment criteria

Modelled ground level concentrations for particles and NO_2 have been compared to ambient air quality assessment criteria to determine the potential changes in ground level concentrations resulting from the AIP.

The assessment criteria adopted for this study are primarily based on the DWER (2019) guidelines, which also reference the numerical values from the ambient air quality standards specified in the Ambient Air Quality NEPM (NEPC, 2021). The more stringent Ambient Air Quality NEPM standards for NO_2 (as varied 15 April 2021) are not reflected in the DWER (2019) guidelines, however the later have been adopted here to inform the assessment in regard to future regulatory requirements.

In their current form, the DWER (2019) guidelines for NO_2 and TSP/PM_{10}/$PM_{2.5}$ (defined as *criteria pollutants* in the guideline) require the criteria to generally be '…met at all existing and future offsite sensitive receptors in the modelling domain'. DWER (2019) guidelines do not address the settling or deposition of dust, therefore the New South Wales and Victorian State Government specified criteria is referenced.

The ambient air quality assessment criteria adopted in this study are shown in Table 3-3.

Table 3-3: Summary of adopted assessment criteria.

Pollutant	Air quality assessment criteria				Reference
	Concentration [1]	Averaging Period	Allowable Exceedances	Environmental value protected	
NO_2	164 µg/m³	1-hour	none	Human health	NEPM (NEPC, 2021)
	31 µg/m³	annual	none		
PM_{10}	50 µg/m³	24-hour	exception event		DWER (2019) consistent with NEPM (NEPC, 2021)
	25 µg/m³	annual	none		
$PM_{2.5}$	25 µg/m³	24-hour	exception event		
	8 µg/m³	annual	none		
TSP	90 µg/m³	24-hour	none	Human health and amenity	DWER (2019)
Dust deposition	2 g/m²/month	Month	Maximum increase above background	Amenity | Nuisance	EPAV, 2007

Notes:

1 Concentrations referenced to 0ºC (excluding reference to dust deposition)

4 Modelling

For this assessment, air dispersion modelling has been conducted using CALPUFF (Version 6.42, Level: 110325) with meteorological data produced from the WRF prognostic model. Although simplistic steady state models, such as AERMOD, would be suitable to model particulate emissions from the proposed AIP the CALMET/CALPUFF suite was chosen to ensure that the model is suitable for more complex assessments to take account of features such as power stations and additional processing.

The model has been used to predict ground level concentrations across the model domain. The potential air quality impacts associated with the AIP have been considered in isolation of other emission sources, for particulates and in conjunction with existing sources of NOx. The model was configured to predict the ground-level concentrations on a rectangular grid. The model domain was defined with the Southwest corner of the grid cell at 283.543 km Easting and 7587.579 km Northing (GDA94, Zone 50).

The 2013 calendar year was selected based on the results of the statistical study presented in Appendix A.

Specifics for the modelling configuration are described further in this section.

4.1 Meteorological model (WRF and CALMET)

The meteorology component of a dispersion model is a key element for the effectiveness or representativeness of the dispersion model outputs. Both upper air and surface information are needed for modelling (or assumptions).

4.1.1 WRF model

In the absence of adequate onsite meteorological data, the Weather Research and Forecast (WRF V3.7) model (http://wrf-model.org/index.php) was used to generate hourly 3-dimensional data for the region. WRF is the next-generation mesoscale numerical weather prediction system. The model was primarily designed to serve both operational forecasting and atmospheric research. WRF features multiple dynamical cores, a 3-dimensional variational data assimilation system and a software architecture allowing for computational parallelism and system extensibility. Further details on WRF modelling are provided in Appendix B.

4.1.2 CALMET

The 3-Dimensional meteorological data generated by WRF was input to CALMET (Version 6.33 Level: 110324) for further processing to the finer resolution used in the dispersion modelling. This procedure will be referred to as the 'WRF-CALMET methodology'. The output from the CALMET meteorological model is then used to drive the pollution dispersion in the CALPUFF model.

CALMET is a three-dimensional meteorological pre-processor that includes a wind field generator containing objective analysis and parameterised treatments of slope flows, terrain effects and terrain blocking effects. The pre-processor produces fields of wind components, air temperature, relative humidity, mixing height and other micro-meteorological variables to produce the three-dimensional, spatially and temporal-varying meteorological fields that are utilised in the CALPUFF dispersion model.

CALMET requires several datasets to resolve the surface and upper air meteorology occurring for each hour of the year:

- surface observations and upper air observations or gridded prognostic meteorological model data
- land use and topographical data.

CALMET was run for a 199 x 199 grid domain at a spatial resolution of 120 m. Vertically, the model consisted of 12 levels extending to 3,000 m. The southwest corner coordinates of the domain were 283.543 km Easting and 7587.579 km Northing (GDA94, Zone 50).

The 90 m resolution Shuttle Radar Topography Mission (SRTM) dataset was used as input into the CALMET model to indicate terrain heights within the model domain (Figure 5-1). CALMET also requires geophysical data including gridded fields of land use categories. The CALMET land use is sourced from the European Space Agency Climate Change Initiative (ESACCI) dataset.

The CALMET results are provided in Appendix C.

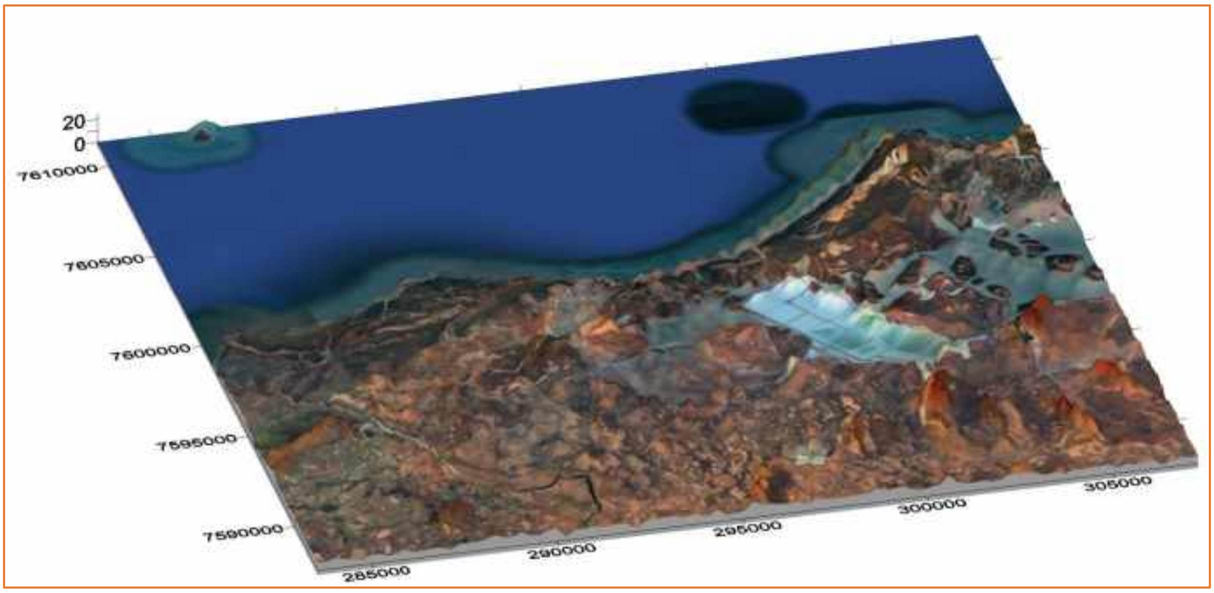

Figure 4-1: Image of SRTM terrain elevation used in CALMET (vertical height is exaggerated) (GDA94, Zone 51).

4.2 CALPUFF

CALPUFF is the dispersion module of the CALMET/CALPUFF suite of models. It is a multi-layer, multi species, non-steady-state puff dispersion model that can simulate the effects of time-varying and space-varying meteorological conditions on pollutant transport, transformation and removal. The model contains algorithms for near-source effects such as building downwash, partial plume penetration, sub-grid scale interactions as well as longer range effects such as pollutant removal, chemical transformation, vertical wind shear and coastal interaction effects. The model employs dispersion equations based on a Gaussian distribution of pollutants across released puffs and considers the complex arrangement of emissions from point, area, volume and line sources (Scire et al., 2000).

The CALPUFF model was set to calculate concentrations on a set grid (gridded receptors). The model domain was defined as 23.9 km in the east–west and north-south direction at a spacing of 120 m x 120 m. Given the relatively flat terrain of the region (Figure 5-1) this grid spacing is appropriate to capture potential topographical impacts and dispersion characteristics.

4.3 Conversion of NO_x to NO_2

The atmospheric transformation of nitric oxide (NO) must be accounted for in the modelling, and in particular the estimation of NO_2 from modelled NO_x concentrations. The amount of NO_2 in the exhaust stream as it is released from combustion sources is typically in the order of 5-10% of total NO_x (expressed as NO_2 equivalents). However, following release, the NO_2 proportion of the emitted NO_x changes through complex photochemical reactions of atmospheric ozone (O_3) and NO_x.

There are several alternative approaches to account for the transformation of NO to NO_2 that occurs after the exhaust gases are discharged. For this assessment, the ambient ratio method (ARM) was used to calculate the concentration of NO_2. In this method an empirical NOx /NO_2 relationship can be derived from monitoring data and used as an alternative to the ozone limiting method (OLM), which is not feasible for this location owing to a lack of ozone measurement data.

With an absence of data local to the Onslow area, the conversion used for the BHP Yarnima Power Station in Newman (ETA, 2019) was utilised as a suitable proxy or approximation. Hourly NO_2 and NO_x measurement data, referenced from the South Hedland monitoring station was filtered for wind directions blowing directly from the Port Hedland power station to the monitor. This serves to exclude any other sources and allows a degree of confidence in NO_x to NO_2 conversion rates within a gas-fired power station plume. Figure 4-2 shows the NO_x to NO_2 ratio for the Port Hedland power station plume used in this study (ETA, 2019). As the relationship between NO_x to NO_2 is non-linear, especially for higher NOx concentrations, a table of NO_2/NO_x ratios varying with NOx concentration is interpolated from the values in Figure 4-2 (Table 4-1). The tabulated ratios are then applied within the CALPOST postprocessor to determine NO_2 values from the range of modelled NO_x concentrations.

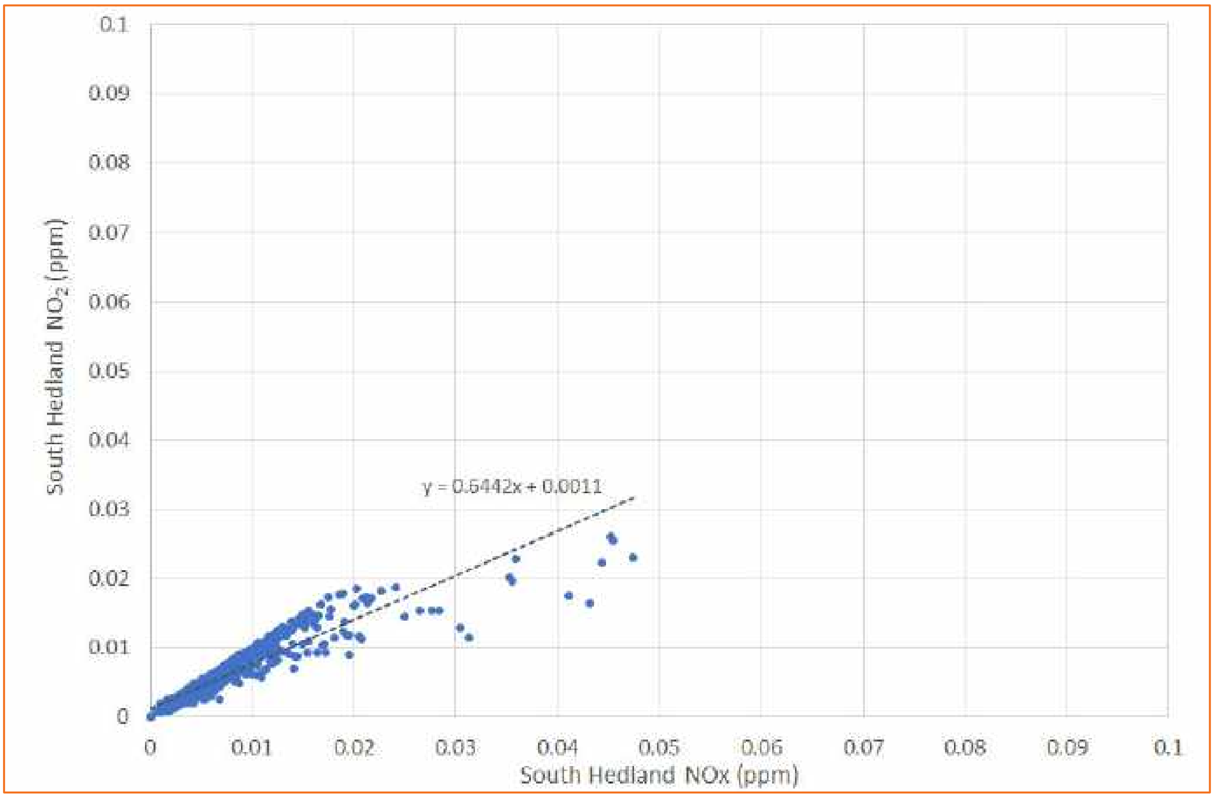

Figure 4-2: Scatterplot of measured NO_x and NO_2 at South Hedland within the power station plume (ETA, 2019).

Table 4-1: Ratio of NO_2 to NO_x ratio with varying NO_x concentration (ppb).

NO_x	0.73	1	1.2	1.9	3.9	7.3	12.3	16.8	22.1	27.7	32.5	35.9	44	50
NO_2:NO_x	1	1	0.93	0.93	0.91	0.89	0.86	0.82	0.74	0.71	0.61	0.51	0.5	0.44

4.4 Particle sizing | gravitational settling

Since particulate matter is subject to gravitational settling, assumptions need to be made regarding particle sizes. Source specific particle size distribution information is required to define the relative PM_{10} and $PM_{2.5}$ component of total emitted PM and to simulate gravitational settling of particles present in emissions. Project specific particle size distribution information was not available for the emission sources.

A particle size distribution for modelling PM/dust dispersion was therefore estimated using composite data from the USEPA for dust emissions from "unpaved roads (USEPA, 2006)", "aggregate handling and storage piles (USEPA, 2006b)", and "industrial wind erosion (USEPA, 2006c)". These categories are considered the most appropriate for mining sources and are relevant to the AIP sources. The resulting distributions are shown as percentages for each size range in Table 4-2.

Table 4-2: Particle size distribution (%).

Size range (µm)	Representative size	TSP	PM_{10}	$PM_{2.5}$
<2.5	1.3	9	30	100
2.5 – 5.0	3.8	8	27	-
5.0 – 7.5	6.3	7	23	-
7.5 – 10.0	8.7	6	20	-
10.0 – 15.0	12.5	14	-	-
15.0 – 23.0	19	15	-	-
23.0 – 30.0	26	15	-	-
30.0 – 40.0	35	15	-	-
40.0 – 50.0	45	11	-	-

5 Emissions to air estimation

This section outlines the emission estimation process for the AIP. Emission estimates are sourced from this inventory for inclusion in the dispersion model. Emissions from all key sources associated with the Project have been identified according to accepted methods. The emphasis of the emission estimation and modelling is on the potential impact from the operating phase of the Project.

Emission estimation of construction activities, including the road train access road, is excluded from the assessment due to their intermittent nature over the life of the Project. Potential emissions, and abatement, from construction related activities will be considered within a construction dust management plan.

The following sections outline the emission estimation process used to develop the hourly variable emission file for the project.

For this assessment two standalone scenarios were modelled:

- Scenario 1: The facility operating with an annual throughput of 30 Mtpa.
- Scenario 2: The facility operating with an annual throughput of 40 Mtpa.

5.1 Emission sources

The key emission sources for the operating phase of the Project are generally associated with:

- Material unloading from road trains into bunkers
- Transfer stations and conveyors
- Shiploading (SL)
- Wind erosion from open areas, and
- Power generation.

Sources have been characterised as either point, area or volume sources in the dispersion model. Area sources were assigned to open areas while volume sources were assigned to unloading operations, transfer stations, conveyors and shiploading. The locations of the volume emission sources for the proposed AIP are presented in Figure 5-1. The coordinates, and source parameters, for each source within the model are contained in Appendix D.

Figure 5-1: Location of volume sources for proposed AIP.

5.2 Emission assumptions - particulates

5.2.1 Tonnage

The incoming tonnage at the proposed AIP operations was determined using the following assumptions:

- The incoming operations are assumed to be continuous (8760 hours).
- The incoming ore was split evenly into the number of inloaders
- For the 30 Mtpa scenario:
    - 3,452 tonnes/hr divided into 856.6 tonnes/hr for four inloaders.
- For the 40 Mtpa scenario:
    - 4,566 tonnes/hr divided into 1,141.6 tonnes/hr for four inloaders.

For the outgoing ore the tonnage was assigned a loading rate of 6,500 tonnes/hr, which was randomly assigned throughout the year to achieve the required export tonnage of either 30 Mtpa or 40 Mtpa.

5.2.2 Emission factors

This section outlines the emission estimation process for the AIP. Emission estimates are sourced from this inventory for inclusion in the dispersion model. It includes the emissions from all identified emissions within the AIP according to accepted methods primarily the NPI EETM for Mining (EA, 2012) has been referenced for emission equations and values.

The emphasis of the emission estimation and modelling is on the potential impact from the operating phase of the various operations within the AIP.

5.2.2.1 Truck unloading

Emissions for unloading ore and waste have been calculated using the default values the EETM for Mining[1] (EA, 2012) of:

- TSP: 0.012 kg/t
- PM_{10}: 0.0043 kg/t.

The emission factor for $PM_{2.5}$ emissions is taken as 30% of the PM_{10} emissions as per the fraction of $PM_{2.5}$ in PM_{10} from the particle sizes in Table 4-2. The statistics of the annual emissions for loading for PM_{10} are contained in Appendix C.

5.2.2.2 Transfer stations and shiploading

Emissions for both transfer stations and shiploading were calculated using the default PM_{10} values for handling and transferring noted in the EETM for Mining (EA, 2021) of:

- High moisture content ores: 0.0043 kg/t
- Low moisture content ores: 0.03 kg/t

The statistics of the annual emissions for transfer stations and shiploading for PM_{10} are contained in Appendix D.

5.2.2.3 Wind erosion

The default emission factor for wind erosion in the EET for Mining (EA, 2012) is a constant emission of 0.2 kg/ha/hr which, while potentially suitable for the calculation of annual emissions, is not suitable for inclusion in atmospheric modelling. The primary reason for this is that it assumes a constant emission rate, regardless of the wind speed.

This assessment used the modified Shao equation outlined in SKM (2005) which allows for both a wind speed threshold (wind speed at which wind erosion commences) and an increase in emissions with increasing wind speed. The modified Shao equation is represented as Equation 1:

Equation 1: $$PM_{10_{(g/m^2/s)}} = k \times \left\{WS^3 \times \left(1 - \left(WS_0{}^2/WS^2\right)\right)\right\} \qquad WS > WS_0$$

$$PM_{10_{(g/m^2/s)}} = 0 \qquad WS < WS_0$$

Where: WS = wind speed (m/s)

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[1] Section 1.1.6 of Appendix A of EA (2012).

WS_0 = threshold for particulate matter lift off (m/s)
K is a constant

For this assessment the wind speed threshold (WS_0) was set at 6 m/s and the **k** constant was set at **1.1** x 10^{-6}. This emission rate is higher than the emission rate of 0.2 kg/ha/hr specified in the EETM for Mining (EA, 2012) which, as outlined in SKM (2005), is suitable for the Hunter Valley region of New South Wales (NSW). The higher emission rate utilised in this assessment is considered appropriate due to a number of factors including the increased wind speed, lower rainfall and higher evaporation rates in the Pilbara region. The higher wind erosion factors also ensures that the model remains conservative.

The emission factor for TSP is taken as twice that of the PM_{10} emissions while $PM_{2.5}$ emissions are taken as 30% of the PM_{10} emissions (Table 4-2).

5.2.3 Emission controls

Emissions controls (for dust abatement) were included in the emissions estimation, there are based on information provided by MRL and the default control factors outlined in Table 4 in the EETM for Mining (EA, 2012). These controls are summarised in Table 5-1, along with the percentage reduction applied to each source type.

Table 5-1: Project dust abatement in place (included in model).

Source	Dust abatement description	Emission Reduction
Unloading	Partial enclosure	70%
Transfer stations	Enclosure and water sprays	85%
Conveyors	Enclosure	80%
Shiploading	Luffing/slewing	75%
Wind erosion (open area)	Watering	50%

5.2.4 Emission summary

A summary of the estimated PM_{10} annual emissions, for each of the scenarios, is shown in Table 5-2.

Table 5-2: Estimates of PM_{10} emissions from AIP for each scenario (kg/year).

Source	Scenario 1 (30 Mtpa)	Scenario 1 (40 Mtpa)
Unloading	38,700	51,600
Conveyors	30,076	40,027
Transfer stations	27,560	36,872
Shiploading	15,048	20,017
Stack emissions	30,905	30,905
Wind erosion	3,416	3,416
TOTAL	145,705	182,837

5.3 Power generation

To provide power for the proposed AIP, a 12 MW power station (peak load), utilising gas fired engines, will be constructed. The power station will comprise 7 Cummins reciprocating gas generators, each with a capacity of 2 MW. The principal emission of concern is NO_2 resulting from the combustion of natural gas.

The emission rates for the generators were derived from information provided by MRL, which includes operations information and technical specifications of the generators. Conservative assumptions were applied as appropriate to provide over - rather than under - estimates of air pollutant emission rates used in the dispersion modelling.

The source parameters and emission rates used in the dispersion modelling are summarised in Table 5-3 for peak operations. These parameters assume that all generators are operational, as opposed to the expected normal operations when only up to six of the seven generators would be operational. This estimation approach ensures that the modelling remains conversative and therefore is an over-statement of the emissions and therefore potential impact.

Table 5-3: AIP power generation source parameters.

Units	Easting	Northing	Stack Height	Stack Radius	Exit Velocity	Exit Temperature	Emission Rate (NO_x)
	mE	mN	m	m	m/s	K	g/s
1	294562	7600372	7.4	0.23	40.00	743.15	1.57
2	294576	7600376	7.4	0.23	40.00	743.15	1.57
3	294587	7600380	7.4	0.23	40.00	743.15	1.57
4	294600	7600383	7.4	0.23	40.00	743.15	1.57
5	294612	7600387	7.4	0.23	40.00	743.15	1.57
6	294600	7600383	7.4	0.23	40.00	743.15	1.57
7	294587	7600379	7.4	0.23	40.00	743.15	1.57

To evaluate the potential NO_2 cumulative impacts, emission sources at the adjacent Chevron Wheatstone and Domgas plants have also been considered. The emission source parameters for these two non-project related sources, were referenced from Chevron (2010) and are presented in Appendix D. Please note that for Chevron Wheatstone a total of five gas processing trains have been modelled while, at the time of this assessment for AIP, only two processing trains have been constructed and are operational. This approach ensures that the modelling of potential impacts from oxides of nitrogen is conservative.

6 Predicted air quality impact

This assessment has used the WRF/CALMET/CALPUFF modelling suite to estimate the air quality impacts associated with the Project. To assess the potential air quality impact, modelled concentrations of particulates (as TSP, PM_{10}, $PM_{2.5}$ and deposition) and NO_2 concentrations are compared to the criteria outlined in Table 3-3.

Note that the comparison of the modelling results to nominated ambient air quality assessment criteria has been done as an indicator for potential changes in conditions at the nominated receptor locations. It should be noted that the nominated receptors are locations of interest for the Project and are not all consistent with the DWER definition of a "sensitive receptor". The assessment criteria applicable to a sensitive receptor has been applied at all receptor locations as a conservative comparison approach.

For this assessment two standalone scenarios were modelled:

- Scenario 1: The facility operating with an annual throughput of 30 Mtpa.
- Scenario 2: The facility operating with an annual throughput of 40 Mtpa.

6.1 Scenario 1: AIP 30 Mtpa

The predicted ground level concentrations of particulates for the proposed Project operating at 30 Mtpa are presented in the following sections.

6.1.1 Particulates as PM_{10}

The statistics of the predicted ground level concentrations of PM_{10}, at the nominated receptors are presented in Table 6-1 as standalone impacts (AIP ie. project only) and cumulatively (ie including background concentrations) in Table 6-2. The results at the nominated receptors indicate that:

- The maximum predicted 24-hour concentration, from the AIP (ie without background), is predicted to be 20.2 $\mu g/m^3$ at the Chevron receptor, and increases up to 42 $\mu g/m^3$ when the background concentration is included for potential cumulative impact.
- The predicted concentration at the Chevron receptor approaches but does not exceed the PM_{10} assessment criterion.
- The maximum predicted concentration, without background (ie Project only), at the receptors within Onslow is 1.7 $\mu g/m^3$ increasing up to 23.1 $\mu g/m^3$ when the background concentration is included (ie cumulatively).
- No excursions of the PM_{10} assessment criteria are predicted to occur.

Table 6-1: Predicted PM_{10} concentrations at receptors ($\mu g/m^3$) – Project only – Scenario 1 (30 Mtpa).

Receptor	Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average
Onslow 1	1.7	0.9	0.5	0.2	0.1	0.1
Onslow 2	1.7	0.5	0.4	0.2	0.1	0.1
Camp	0.8	0.3	0.2	0.0	0.0	0.0
Salt 1	3.2	1.6	1.3	0.4	0.1	0.2
Salt 2	3.5	1.8	1.0	0.4	0.2	0.2
Chevron	20.2	5.2	4.6	1.1	0.2	0.5

Receptor	Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average
Assessment criteria: 50 µg/m³ 24-hour average (based on DWER (2019) consistent with NEPM (NEPC (2015))						

Table 6-2: Predicted PM_{10} concentrations at receptors (µg/m³) – Cumulative – Scenario 1 (30 Mtpa).

Receptor	Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average
Onslow 1	23.1	22.3	21.9	21.6	21.5	18.6
Onslow 2	23.1	21.9	21.8	21.6	21.5	18.6
Camp	22.2	21.7	21.6	21.4	21.4	18.5
Salt 1	24.6	23.0	22.7	21.8	21.5	18.7
Salt 2	24.9	23.2	22.4	21.8	21.6	18.7
Chevron	41.6	26.6	26.0	22.5	21.6	19.0
Assessment criteria: 50 µg/m³ 24-hour average (based on DWER (2019) consistent with NEPM (NEPC (2015))						

The predicted isopleths (contours) for ground level concentrations of particulates (as PM_{10}) are presented as follows:

- Annual average PM_{10} concentrations for the proposed facility in isolation (Figure 6-1) and cumulatively with background concentrations (Figure 6-2).
- Maximum predicted 24-hour PM_{10} concentrations for the proposed facility in isolation (Figure 6-3) and cumulatively with background concentrations (Figure 6-4).

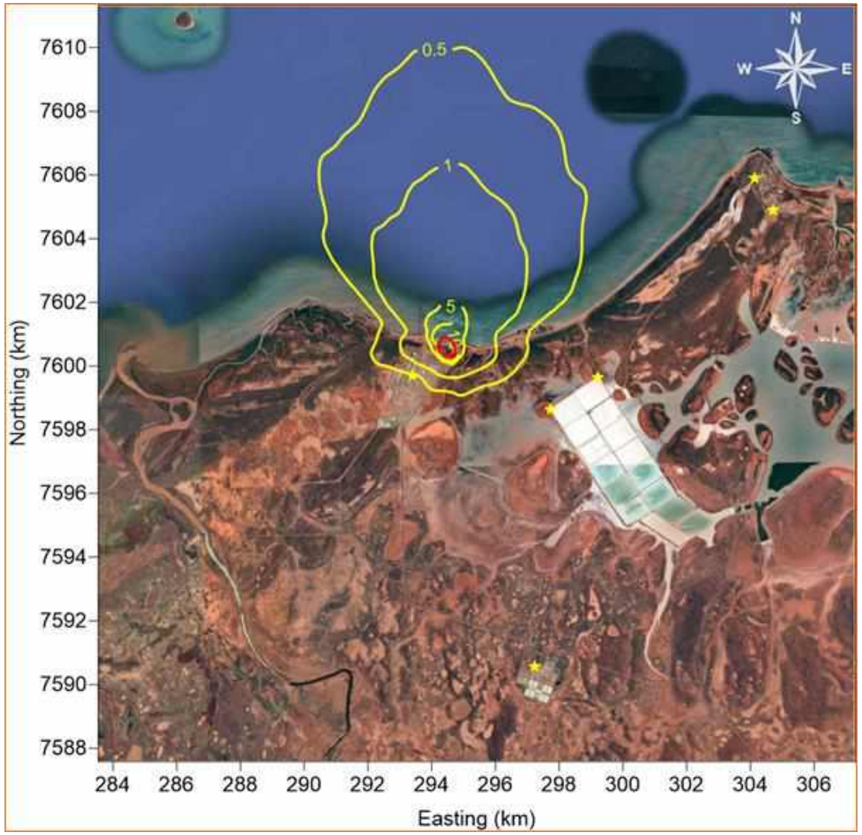

Figure 6-1: Annual average PM_{10} concentration – Project only (excluding background) – Scenario 1 (30 Mtpa).

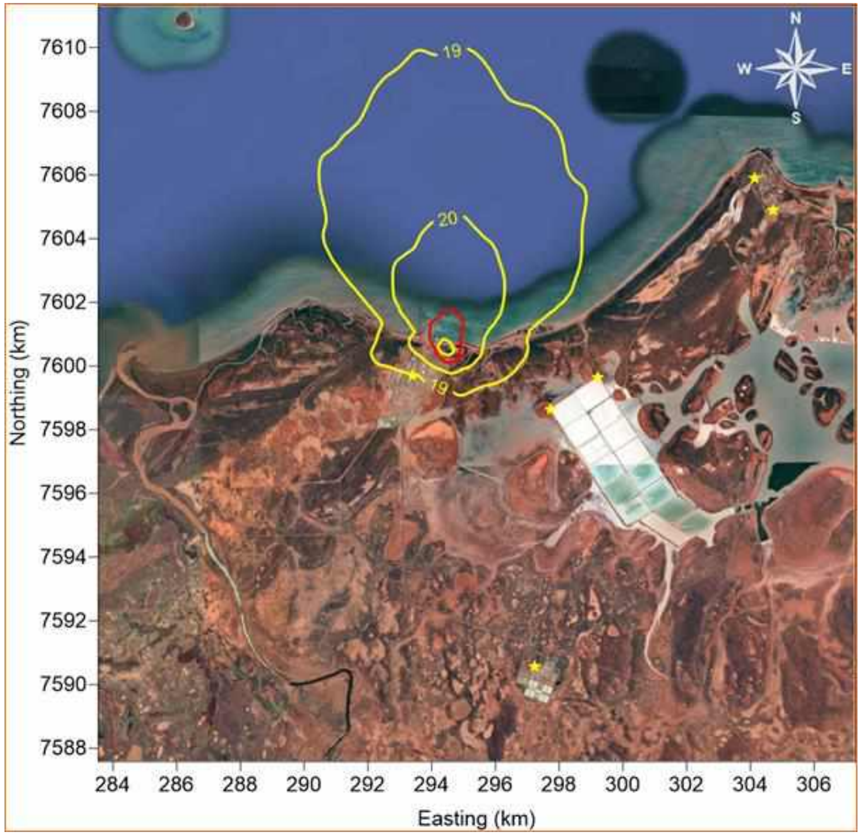

Figure 6-2: Annual average PM_{10} concentration – Cumulative (including background) – Scenario 1 (30 Mtpa).

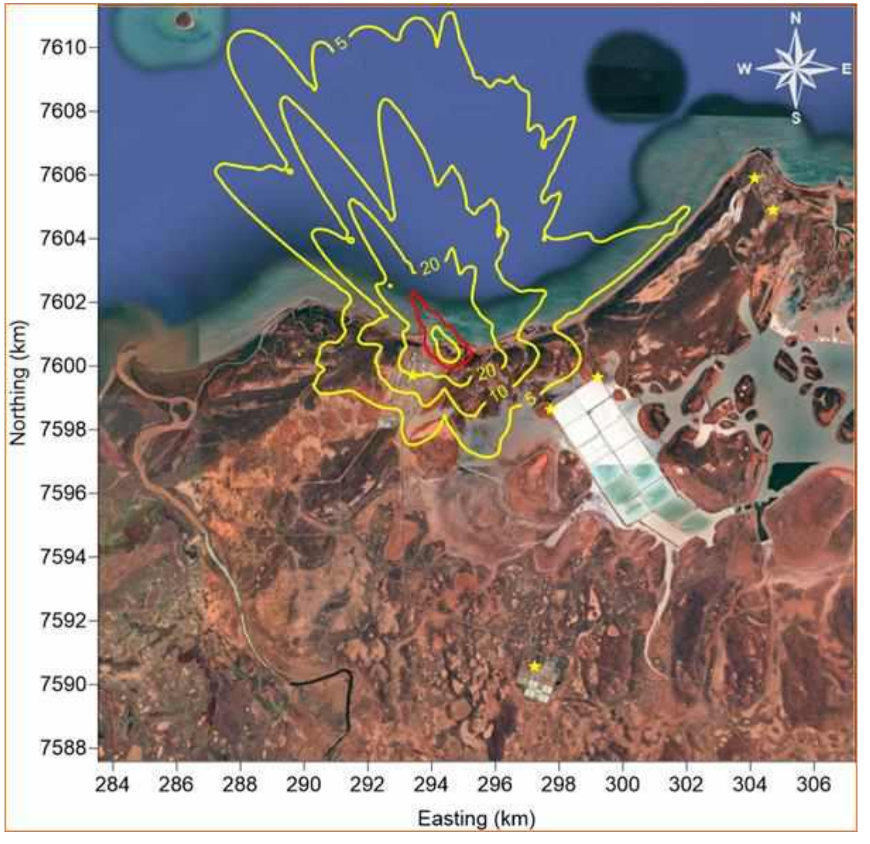

Figure 6-3: Maximum 24-hour PM_{10} concentration – Project only (excluding background) – Scenario 1 (30 Mtpa).

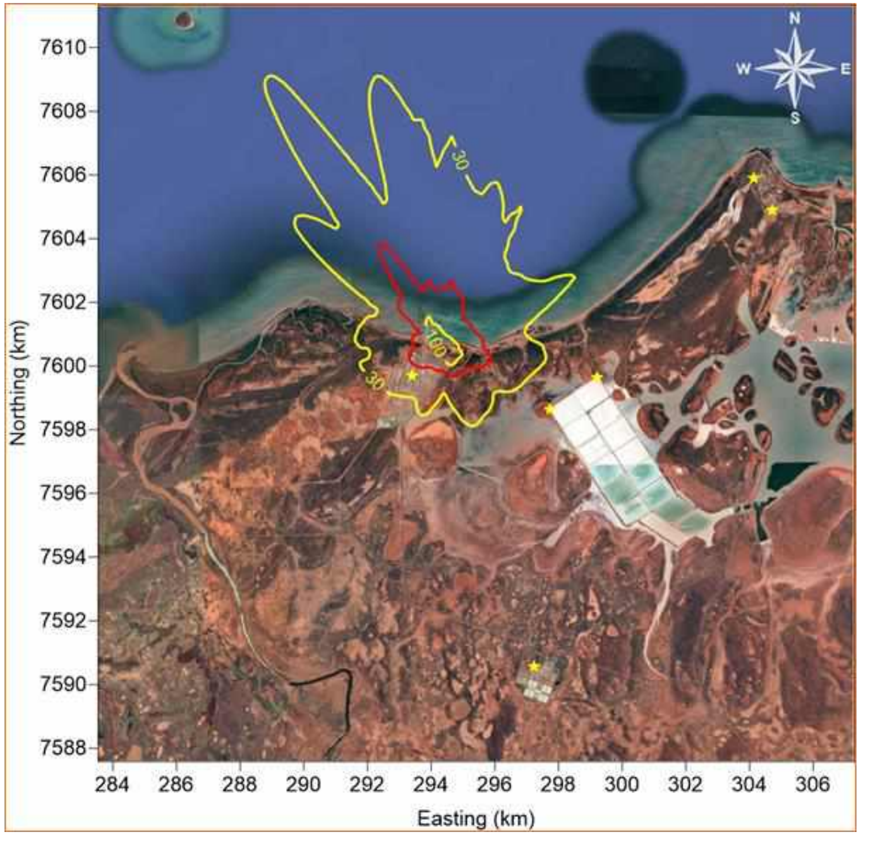

Figure 6-4: Maximum 24-hour PM_{10} concentration – Cumulative (including background) – Scenario 1 (30 Mtpa).

6.1.2 Particulates as $PM_{2.5}$

The statistics of the predicted ground level concentrations of $PM_{2.5}$, at the nominated receptors are presented in Table 6-3 as standalone impacts (AIP, ie. Project only) and cumulatively (including background concentrations) in Table 6-4. The results at the selected receptors indicate that:

- The maximum predicted 24-hour concentration, for Project only, is predicted to be 6 µg/m³ at the Chevron receptor, which increases up to 13.8 µg/m³ when the background concentration is included.
- The predicted concentration at the Chevron receptor is well below the assessment criteria for $PM_{2.5}$.
- The maximum predicted concentration, without background concentrations (ie Project only), at the receptors within Onslow is 0.5 µg/m³ increasing up to 8.3 µg/m³ for cumulative when the background concentration is included.
- No excursions of the $PM_{2.5}$ assessment criteria are predicted to occur.

Table 6-3: Predicted $PM_{2.5}$ concentrations at receptors (µg/m³) – Project only – Scenario 1 (30 Mtpa).

Receptor	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average
Onslow 1	0.5	0.3	0.1	0.1	0.0	0.03
Onslow 2	0.5	0.2	0.1	0.1	0.0	0.03
Camp	0.2	0.1	0.0	0.0	0.0	0.01
Salt 1	1.0	0.5	0.3	0.1	0.0	0.05
Salt 2	1.0	0.6	0.2	0.1	0.0	0.05
Chevron	6.0	2.0	0.9	0.3	0.1	0.15
Assessment criteria: 25 µg/m³ 24-hour average (based on DWER (2019) consistent with NEPM (NEPC (2015))						

Table 6-4: Predicted $PM_{2.5}$ concentrations at receptors (µg/m³) – Cumulative – Scenario 1 (30 Mtpa).

Receptor	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average
Onslow 1	8.3	8.1	7.9	7.9	7.8	6.0
Onslow 2	8.3	8.0	7.9	7.9	7.8	6.0
Camp	8.0	7.9	7.8	7.8	7.8	6.0
Salt 1	8.8	8.3	8.1	7.9	7.8	6.0
Salt 2	8.8	8.4	8.0	7.9	7.8	6.0
Chevron	13.8	9.8	8.7	8.1	7.9	6.1
Assessment criteria: 25 µg/m³ 24-hour average (based on DWER (2019) consistent with NEPM (NEPC (2015))						

The predicted isopleths (contours) for ground level concentrations of particulates (as $PM_{2.5}$) are presented as follows:

- Annual average $PM_{2.5}$ concentrations for the proposed facility in isolation (Figure 6-5) and cumulatively with background concentrations (Figure 6-6).
- Maximum predicted 24-hour PM_{10} concentrations for the proposed facility in isolation (Figure 6-7) and cumulatively with background concentrations (Figure 6-8).

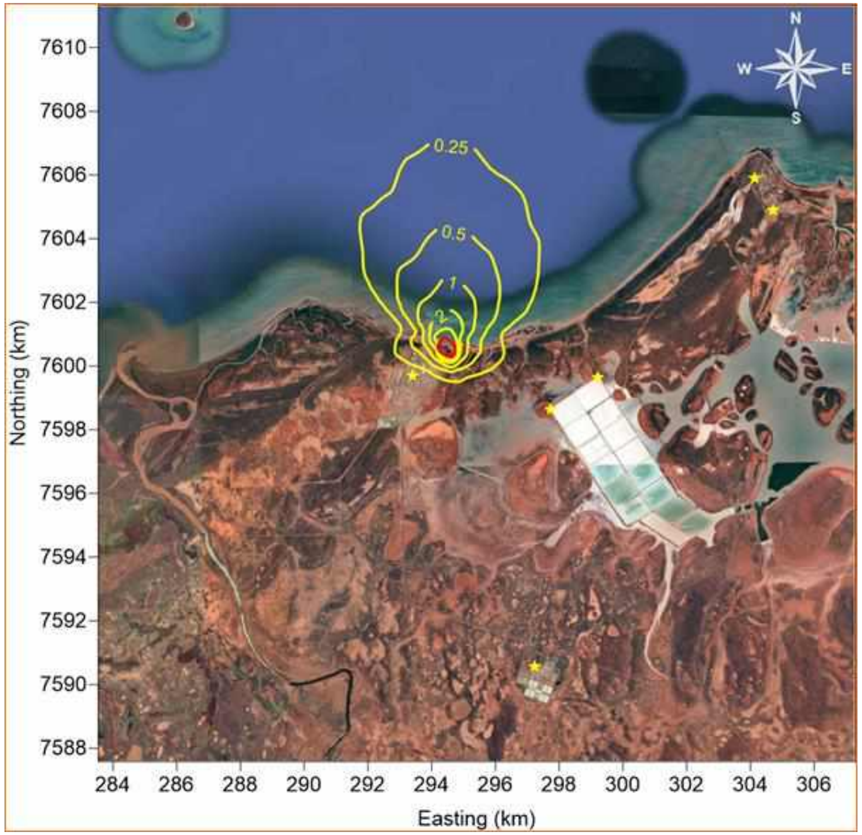

Figure 6-5: Annual average $PM_{2.5}$ concentration – Project only (excluding background) – Scenario 1 (30 Mtpa).

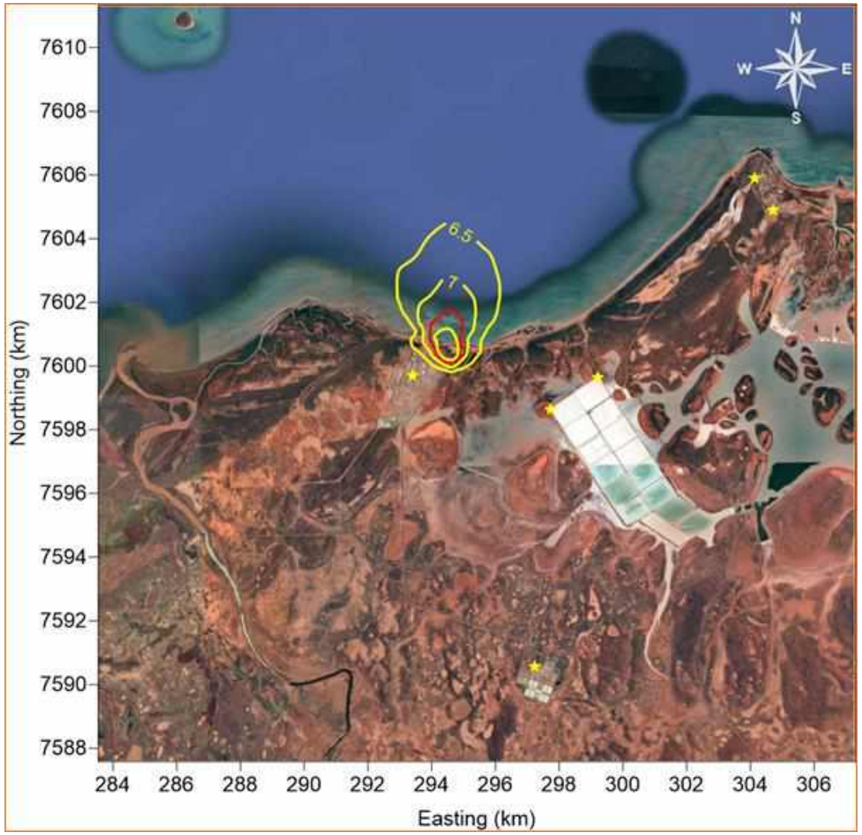

Figure 6-6: Annual average $PM_{2.5}$ concentration – Cumulative (including background) – Scenario 1 (30 Mtpa).

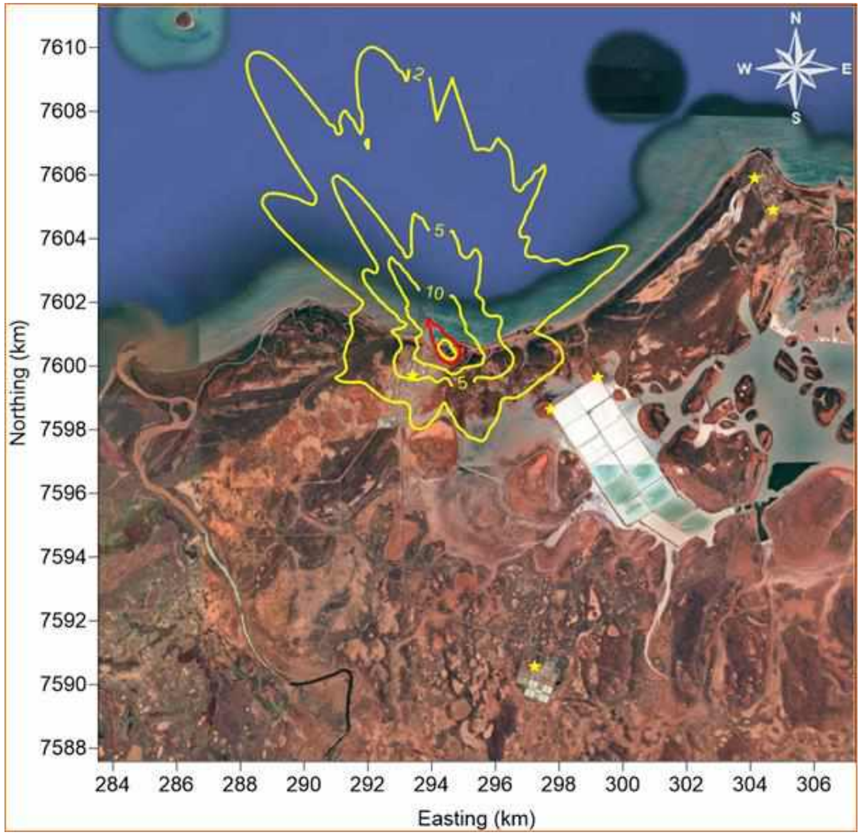

Figure 6-7: Maximum 24-hour $PM_{2.5}$ concentration – Project only (excluding background) – Scenario 1 (30 Mtpa.

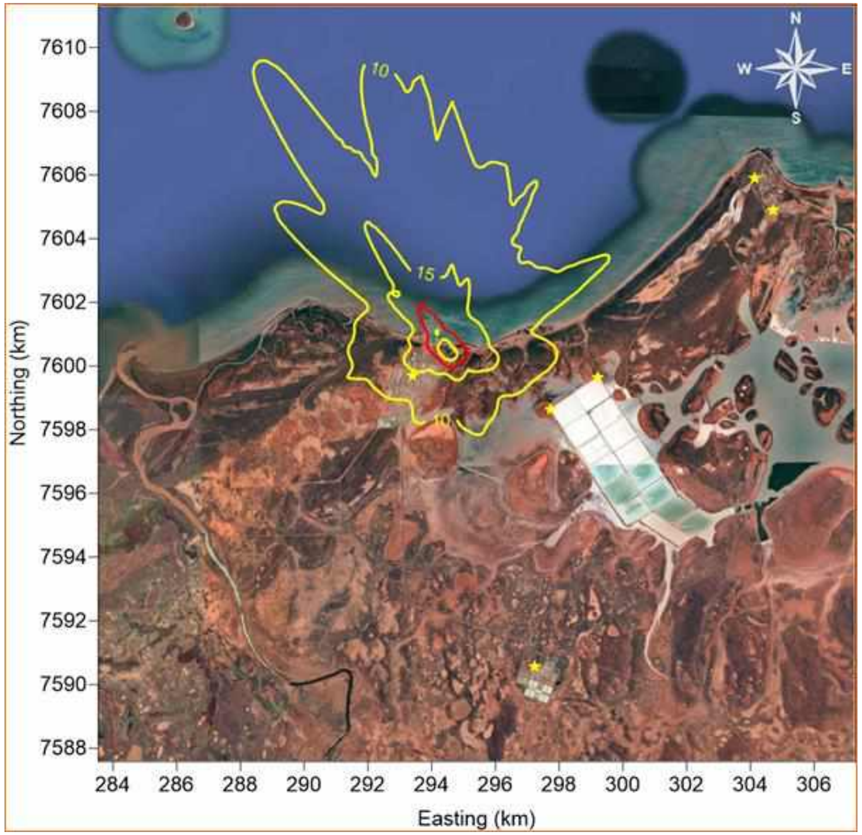

Figure 6-8: Maximum 24-hour $PM_{2.5}$ concentration – Cumulative (including background) – Scenario 1 (30 Mtpa).

6.1.3 Total suspended particulates

The statistics of the predicted ground level concentrations of TSP at the nominated receptors are presented in Table 6-5 as standalone impacts (Project only) and cumulatively (including background concentrations) in Table 6-6. The results at the selected receptors indicate that:

- The highest predicted 24-hour TSP concentration of approximately 52.1 µg/m³ occurs at the Chevron receptor, located adjacent to the proposed Project.
- The two Onslow receptors have predicted maximum 24-hour TSP concentrations between 4.2 µg/m³and 4.5 µg/m³, and the predicted maximum 24-hour concentration at the Camp is 2 µg/m³.
- For cumulative impacts, the inclusion of a background concentration of 42.8 µg/m³ increases the predicted 24-hour TSP concentration at the Chevron receptor to 95 µg/m³. Although this is above the assessment criteria (Section 3.4.1) the Chevron receptor is not classified as a sensitive receptor, and the results is included to inform the assessment.
- Inclusion of the background concentration results in a predicted ground level concentration of approximately 47 µg/m³ at the two Onslow receptors, and 45 µg/m³ at the Camp receptor.
- There is no exceedance of the assessment criterion at any of the nominated sensitive receptors.

Table 6-5: Predicted TSP concentrations at receptors (µg/m³) – excluding background – Scenario 1 (30 Mtpa).

Receptor	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average
Onslow 1	4.2	2.2	0.8	0.6	0.3	0.3
Onslow 2	4.5	1.6	0.8	0.5	0.2	0.2
Camp	2.0	1.2	0.3	0.1	0.0	0.1
Salt 1	8.3	4.2	2.5	1.0	0.3	0.4
Salt 2	9.1	4.8	1.4	1.0	0.4	0.4
Chevron	52.1	16.7	7.2	2.7	0.5	1.3

Assessment criteria: 90 µg/m³ 24-hour average (based on DWER (2019))

Table 6-6: Predicted TSP concentrations at receptors (µg/m³) – including background – Scenario 1 (30 Mtpa).

Receptor	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average
Onslow 1	47.0	45.0	43.6	43.4	43.1	43.1
Onslow 2	47.3	44.4	43.6	43.3	43.0	43.0
Camp	44.8	44.0	43.1	42.9	42.8	42.9
Salt 1	51.1	47.0	45.3	43.8	43.1	43.2
Salt 2	51.9	47.6	44.2	43.8	43.2	43.2
Chevron	94.9	59.5	50.0	45.5	43.3	44.1

Assessment criteria: 90 µg/m³ 24-hour average (based on DWER (2019))

The predicted ground level concentrations of particulates (as TSP) are presented as follows:

- Maximum predicted 24-hour TSP concentrations for the proposed facility in isolation (Figure 6-9) and cumulatively with background concentrations in Figure 6-10.

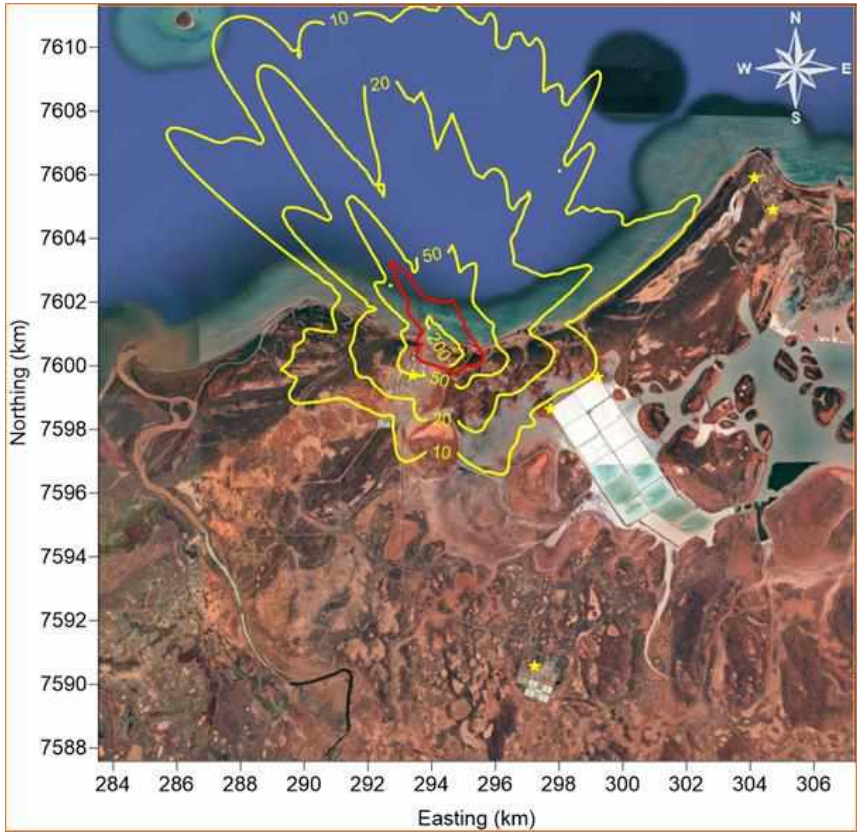

Figure 6-9: Maximum 24-hour TSP concentration – Project only (excluding background) – Scenario 1 (30 Mtpa).

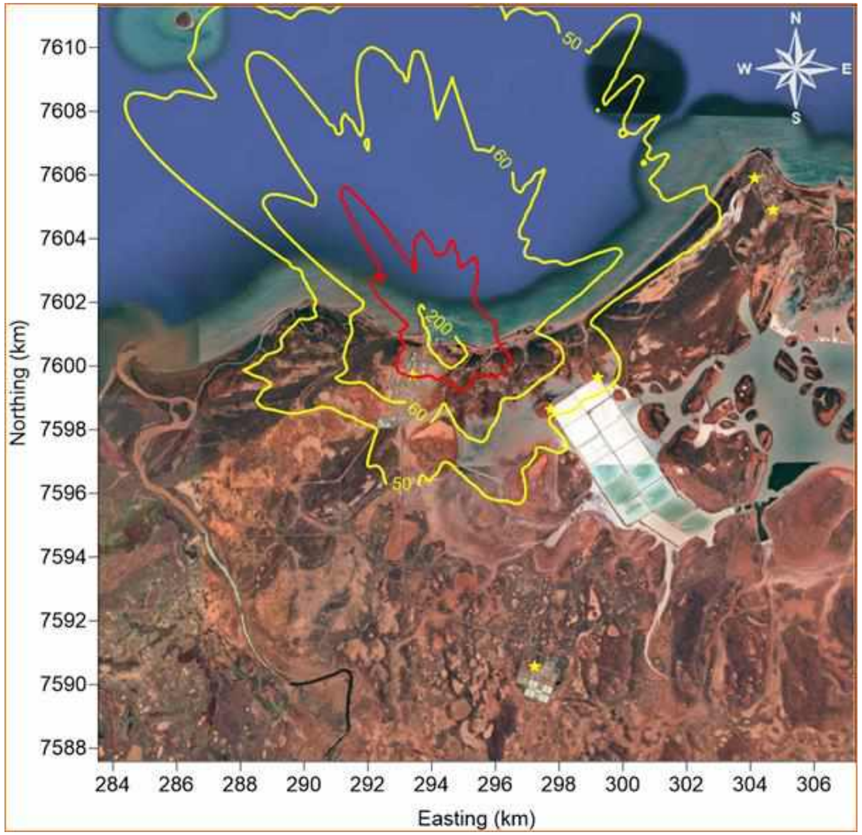

Figure 6-10: Maximum 24-hour TSP concentration – Cumulative (including background) – Scenario 1 (30 Mtpa).

6.1.4 Dust deposition

The predicted monthly dust deposition (based on annual average predicted flux rates) is presented in Figure 6-11. The contour plot shows that while monthly deposition doubles in magnitude from Scenario 2, exceedance of the adopted criterion is still limited to the proposed facility footprint.

The criterion for potential deposition effects (2 g/m^2/month), is not exceeded at any nominated sensitive receptor (Table 6-7).

Table 6-7: Predicted dust deposition at receptors (g/m^2/month) – Scenario 1 (30 Mtpa).

Receptor	Maximum
Onslow 1	0.0003
Onslow 2	0.0010
Camp	0.0004
Salt 1	0.0068
Salt 2	0.0066
Chevron	0.0307

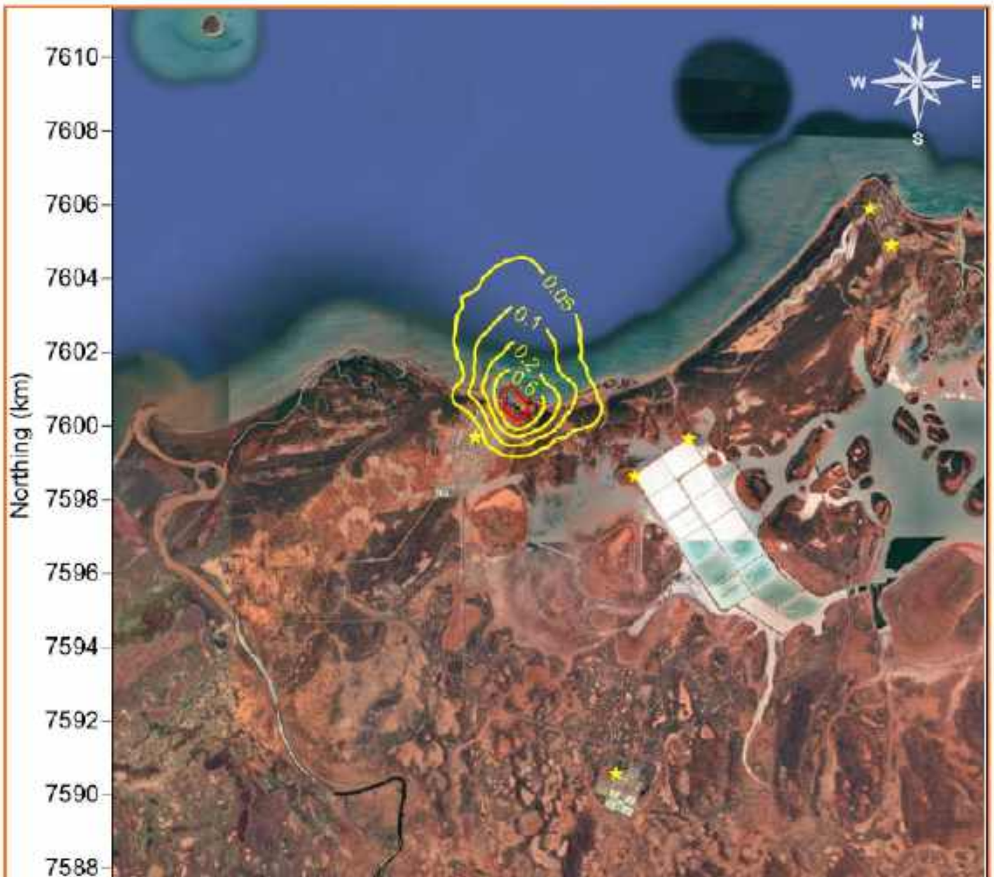

Figure 6-11: Total monthly dust deposition – Project only - Scenario 1 (30 Mtpa).

6.2 Scenario 2: AIP 40 Mtpa

The predicted ground level concentrations of particulates for the proposed Project operating at 40 Mtpa (ie four inloaders) are presented in the following sections.

6.2.1 Particulates as PM_{10}

The statistics of the predicted ground level concentrations of PM_{10}, at the nominated receptors are presented in Table 6-8 as standalone impacts (AIP ie. project only) and cumulatively (ie including background concentrations) in Table 6-9. The results at the nominated receptors indicate that:

- The maximum predicted 24-hour concentration, from the AIP (ie without background), is predicted to be 22.2 μg/m^3 at the Chevron receptor, and increases up to 43.6 μg/m^3 when the background concentration is included for potential cumulative impact.
- The predicted concentration at the Chevron receptor approaches but does not exceed the PM_{10} assessment criterion.
- The maximum predicted concentration, without background (ie Project only), at the receptors within Onslow is 2.2 μg/m^3 increasing up to 23.6 μg/m^3 when the background concentration is included (ie cumulatively).
- No excursions of the PM_{10} assessment criteria are predicted to occur.

Table 6-8: Predicted PM_{10} concentrations at receptors (μg/m^3) – Project only – Scenario 2 (40 Mtpa).

Receptor	Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average
Onslow 1	2.0	1.1	0.7	0.3	0.2	0.1
Onslow 2	2.2	0.7	0.6	0.3	0.1	0.1
Camp	0.9	0.4	0.3	0.0	0.0	0.0
Salt 1	4.8	1.9	1.7	0.7	0.1	0.2
Salt 2	4.1	2.2	1.2	0.5	0.2	0.2
Chevron	22.2	6.2	5.3	1.5	0.3	0.6
Assessment criteria: 50 μg/m^3 24-hour average (based on DWER (2019) consistent with NEPM (NEPC (2015))						

Table 6-9: Predicted PM_{10} concentrations at receptors (μg/m^3) – Cumulative – Scenario 2 (40 Mtpa).

Receptor	Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average
Onslow 1	23.4	22.5	22.1	21.7	21.6	18.6
Onslow 2	23.6	22.1	22.0	21.7	21.5	18.6
Camp	22.3	21.8	21.7	21.4	21.4	18.5
Salt 1	26.2	23.3	23.1	22.1	21.5	18.7
Salt 2	25.5	23.6	22.6	21.9	21.6	18.7
Chevron	43.6	27.6	26.7	22.9	21.7	19.0
Assessment criteria: 50 μg/m^3 24-hour average (based on DWER (2019) consistent with NEPM (NEPC (2015))						

The predicted isopleths (contours) for ground level concentrations of particulates (as PM_{10}) are presented as follows:

- Annual average PM_{10} concentrations for the proposed facility in isolation (Figure 6-12) and cumulatively with background concentrations (Figure 6-13).
- Maximum predicted 24-hour PM_{10} concentrations for the proposed facility in isolation (Figure 6-14) and cumulatively with background concentrations (Figure 6-15).

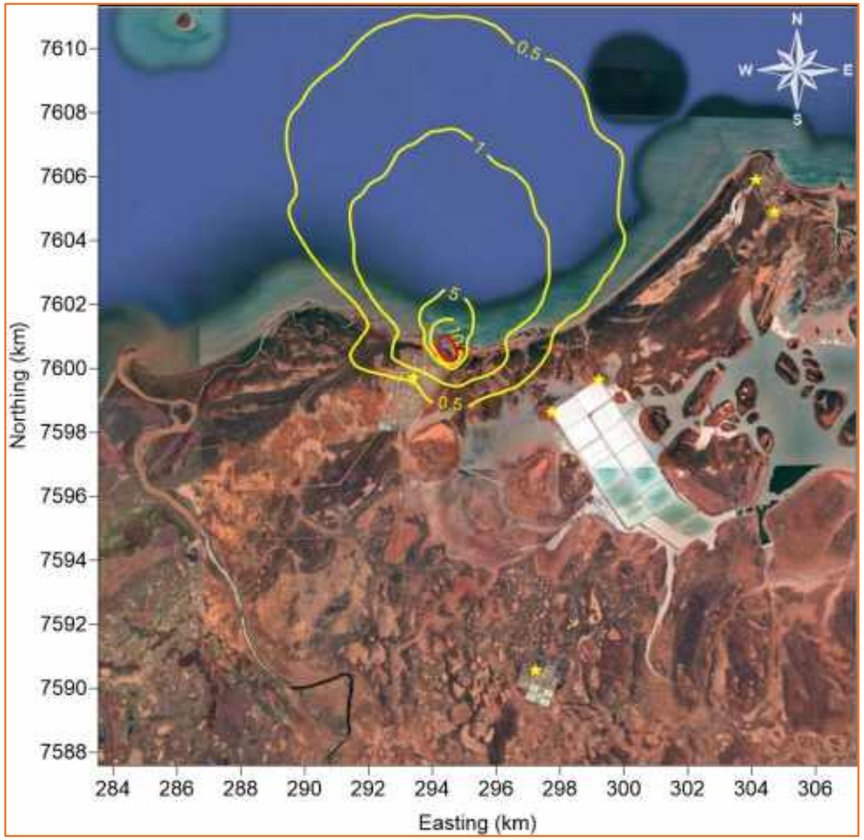

Figure 6-12: Annual average PM_{10} concentration – Project only (excluding background) – Scenario 2 (40 Mtpa).

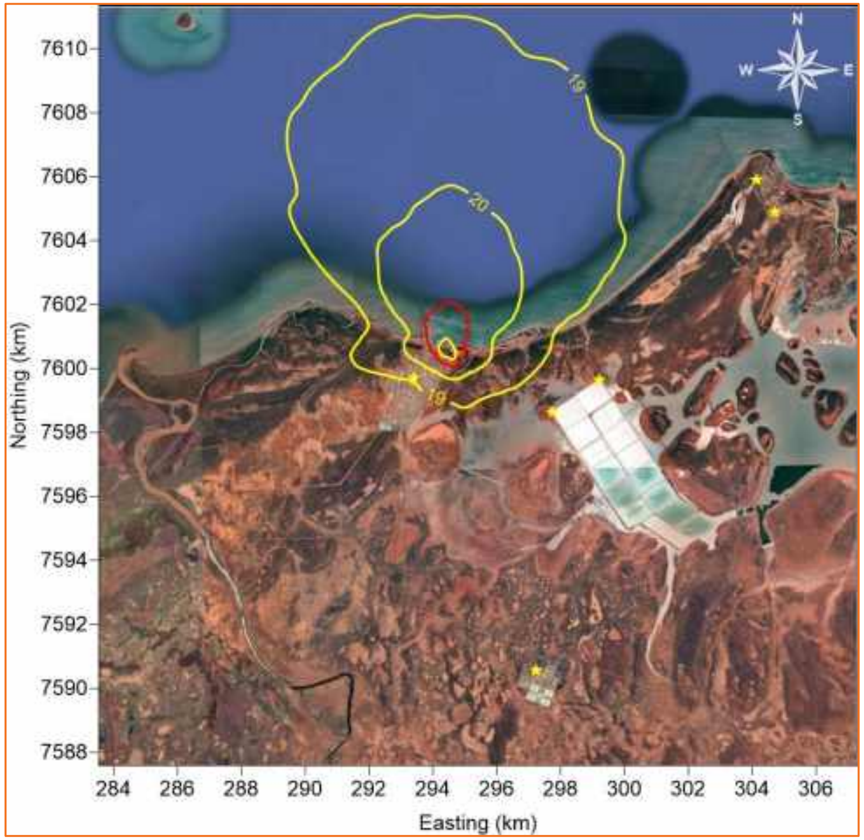

Figure 6-13: Annual average PM_{10} concentration – Cumulative (including background) – Scenario 2 (40 Mtpa).

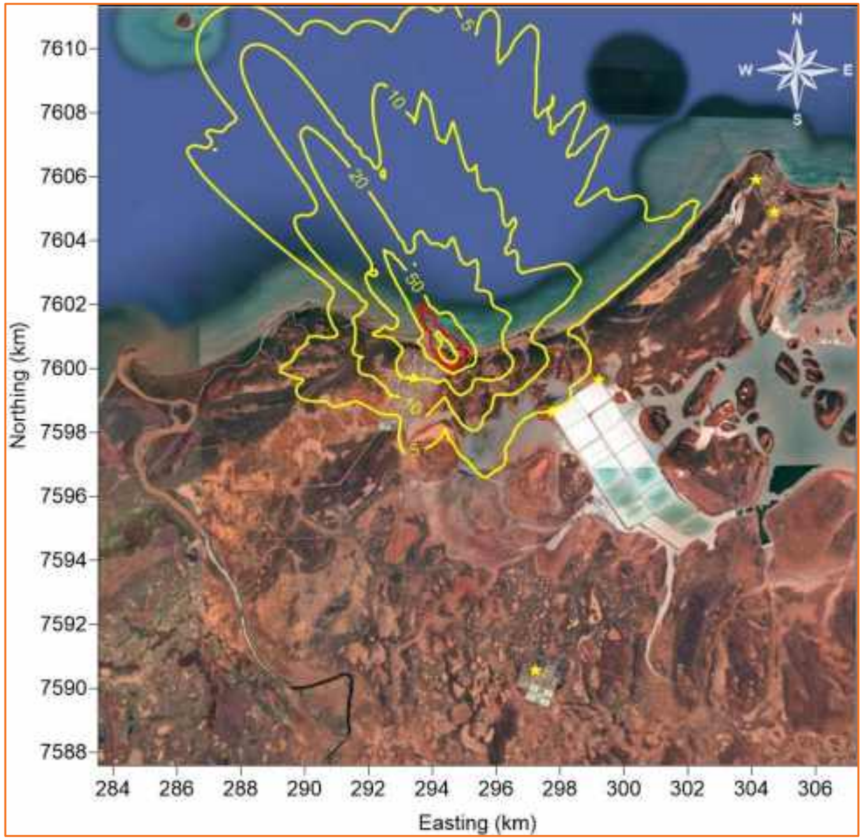

Figure 6-14: Maximum 24-hour PM_{10} concentration – Project only (excluding background) – Scenario 2 (40 Mtpa).

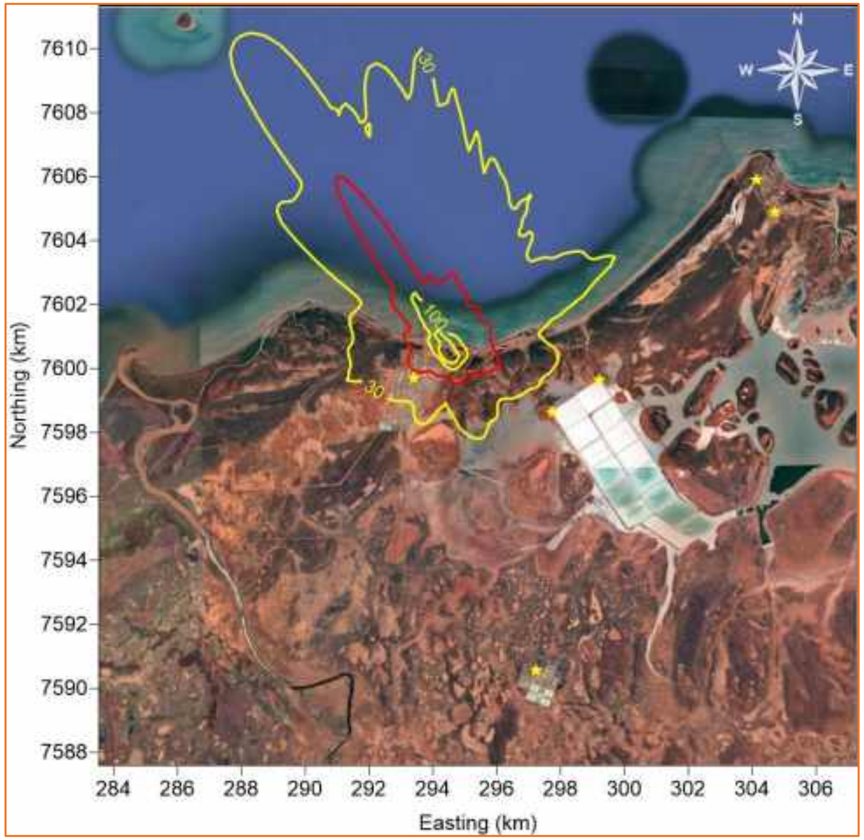

Figure 6-15: Maximum 24-hour PM_{10} concentration – Cumulative (including background) – Scenario 2 (40 Mtpa).

6.2.2 Particulates as $PM_{2.5}$

The statistics of the predicted ground level concentrations of $PM_{2.5}$, at the nominated receptors are presented in Table 6-10 as standalone impacts (Project only) and cumulatively (including background concentrations) in Table 6-11. The results at the selected receptors indicate that:

- The maximum predicted 24-hour concentration, for Project only, is predicted to be 6.7 µg/m³ at the Chevron receptor, which increases up to 14.5 µg/m³ when the background concentration is included.
- The predicted concentration at the Chevron receptor is well below the assessment criteria for $PM_{2.5}$.
- The maximum predicted concentration, without background (ie Project only), at the receptors within Onslow is 0.7 µg/m³ increasing up to 8.5 µg/m³ for cumulative when the background concentration is included.
- No excursions of the $PM_{2.5}$ assessment criteria are predicted to occur.

Table 6-10: Predicted $PM_{2.5}$ concentrations at receptors (µg/m³) – Project only – Scenario 2 (40 Mtpa).

Receptor	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average
Onslow 1	0.6	0.4	0.1	0.1	0.0	0.04
Onslow 2	0.7	0.2	0.1	0.1	0.0	0.03
Camp	0.3	0.2	0.0	0.0	0.0	0.01
Salt 1	1.5	0.6	0.3	0.2	0.0	0.07
Salt 2	1.2	0.7	0.2	0.2	0.1	0.07
Chevron	6.7	2.3	1.1	0.5	0.1	0.19
Assessment criteria: 25 µg/m³ 24-hour average (based on DWER (2019) consistent with NEPM (NEPC (2015))						

Table 6-11: Predicted $PM_{2.5}$ concentrations at receptors (µg/m³) – Cumulative – Scenario 2 (40 Mtpa).

Receptor	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average
Onslow 1	8.4	8.2	7.9	7.9	7.8	7.8
Onslow 2	8.5	8.0	7.9	7.9	7.8	7.8
Camp	8.1	8.0	7.8	7.8	7.8	7.8
Salt 1	9.3	8.4	8.1	8.0	7.8	7.9
Salt 2	9.0	8.5	8.0	8.0	7.9	7.9
Chevron	14.5	10.1	8.9	8.3	7.9	8.0
Assessment criteria: 25 µg/m³ 24-hour average (based on DWER (2019) consistent with NEPM (NEPC (2015))						

The predicted isopleths (contours) for ground level concentrations of particulates (as $PM_{2.5}$) are presented as follows:

- Annual average $PM_{2.5}$ concentrations for the proposed facility in isolation (Figure 6-16) and cumulatively with background concentrations (Figure 6-17).
- Maximum predicted 24-hour PM_{10} concentrations for the proposed facility in isolation (Figure 6-18) and cumulatively with background concentrations (Figure 6-19).

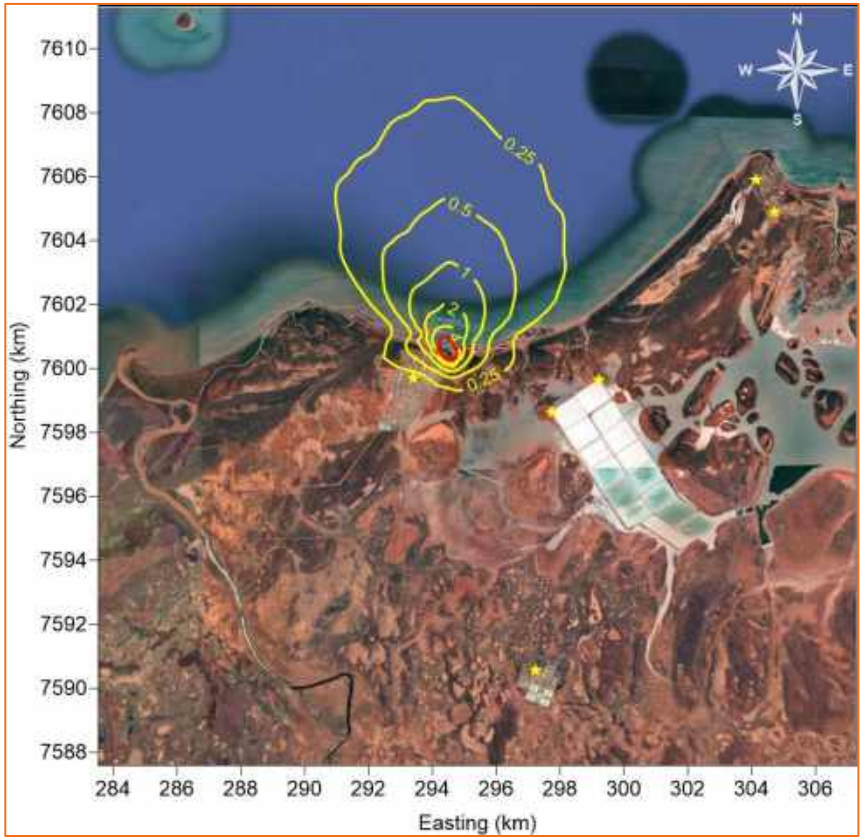

Figure 6-16: Annual average $PM_{2.5}$ concentration – Project only (excluding background) – Scenario 2 (40 Mtpa).

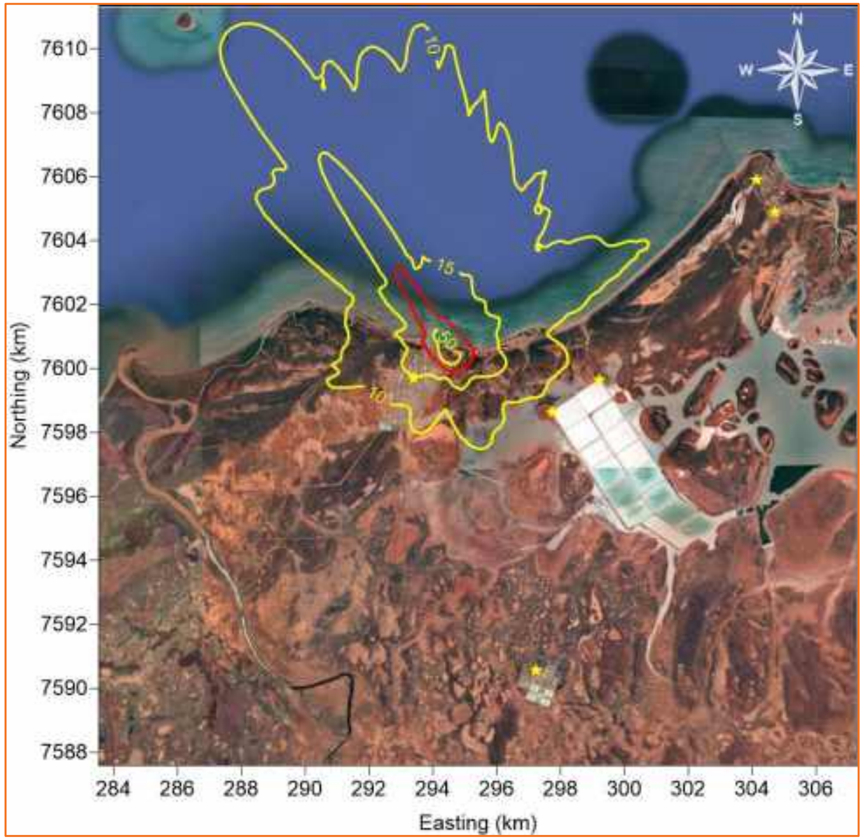

Figure 6-17: Annual average $PM_{2.5}$ concentration – Cumulative (including background) – Scenario 2 (40 Mtpa).

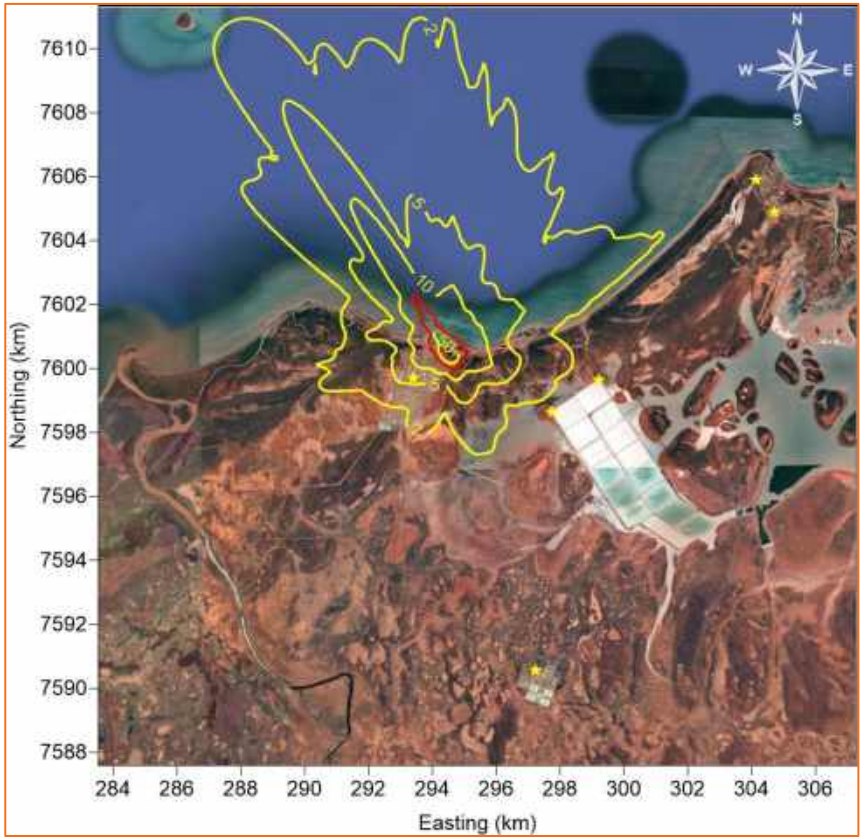

Figure 6-18: Maximum 24-hour PM2.5 concentration – Project only (excluding background) – Scenario 2 (40 Mtpa).

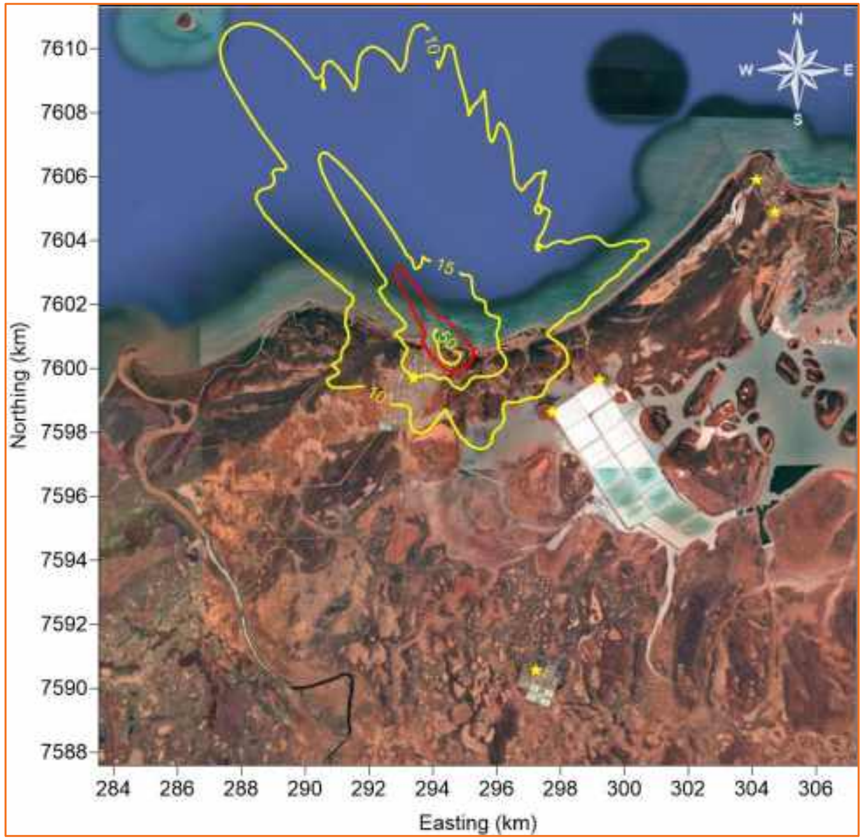

Figure 6-19: Maximum 24-hour PM2.5 concentration – Cumulative (including background) – Scenario 2 (40 Mtpa).

6.2.3 Total suspended particulates

The statistics of the predicted ground level concentrations of TSP at the nominated receptors are presented in Table 6-12 as standalone impacts (AIP ie. Project only) and cumulatively (including background concentrations) in Table 6-13. The results at the selected receptors indicate that:

- The highest predicted 24-hour TSP concentration of approximately 57.7 µg/m³ occurs at the Chevron receptor, located adjacent to the proposed Project.
- The two Onslow receptors have predicted maximum 24-hour TSP concentrations between 5.1 µg/m³and 5.7 µg/m³, and the predicted maximum 24-hour concentration at the Camp is 2.3 µg/m³.
- For cumulative impacts, the inclusion of a background concentration of 42.8 µg/m³ increases the predicted 24-hour TSP concentration at the Chevron receptor to 100.5 µg/m³. Although this is above the assessment criteria (Section 3.4.1) the Chevron receptor is not classified as a sensitive receptor, and the results is included to inform the assessment.
- Inclusion of the background concentration results in a maximum predicted ground level concentration of approximately 48.5 µg/m³ at the Onslow 2 receptor and 45.1 µg/m³ at the Camp receptor.
- There is no exceedance of the assessment criterion at any of the nominated sensitive receptors.

Table 6-12: Predicted TSP concentrations at receptors (µg/m³) – excluding background – Scenario 2 (40 Mtpa).

Receptor	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average
Onslow 1	5.1	3.1	1.2	0.8	0.4	0.4
Onslow 2	5.7	1.9	1.1	0.7	0.3	0.3
Camp	2.3	1.4	0.4	0.1	0.0	0.1
Salt 1	12.5	5.5	3.0	1.7	0.3	0.6
Salt 2	10.7	6.4	2.2	1.3	0.5	0.6
Chevron	57.7	19.7	9.0	4.0	0.7	1.6

Assessment criteria: 90 µg/m³ 24-hour average (based on DWER (2019))

Table 6-13: Predicted TSP concentrations at receptors (µg/m³) – including background – Scenario 2 (40 Mtpa).

Receptor	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average
Onslow 1	47.9	45.9	44.0	43.6	43.2	43.2
Onslow 2	48.5	44.7	43.9	43.5	43.1	43.1
Camp	45.1	44.2	43.2	42.9	42.8	42.9
Salt 1	55.3	48.3	45.8	44.5	43.1	43.4
Salt 2	53.5	49.2	45.0	44.1	43.3	43.4
Chevron	100.5	62.5	51.8	46.8	43.5	44.4

Assessment criteria: 90 µg/m³ 24-hour average (based on DWER (2019))

The predicted ground level concentrations of particulates (as TSP) are presented as follows:

- Maximum predicted 24-hour TSP concentrations for the proposed facility in isolation (Figure 6-20) and cumulatively with background concentrations in Figure 6-21.

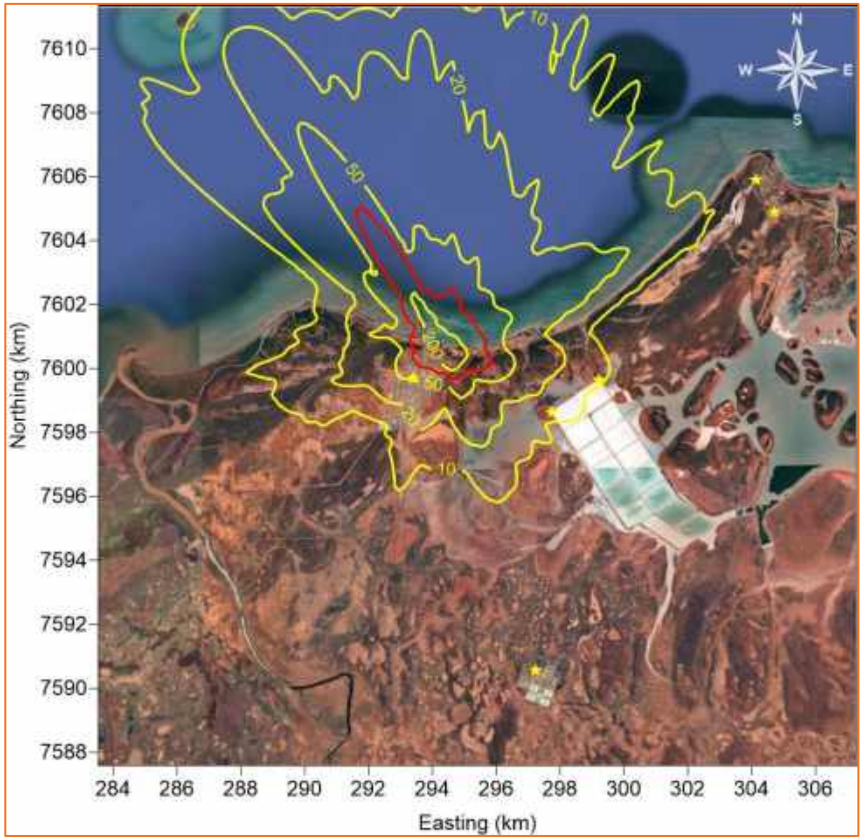

Figure 6-20: Maximum 24-hour TSP concentration – Project only (excluding background) – Scenario 2 (40 Mtpa).

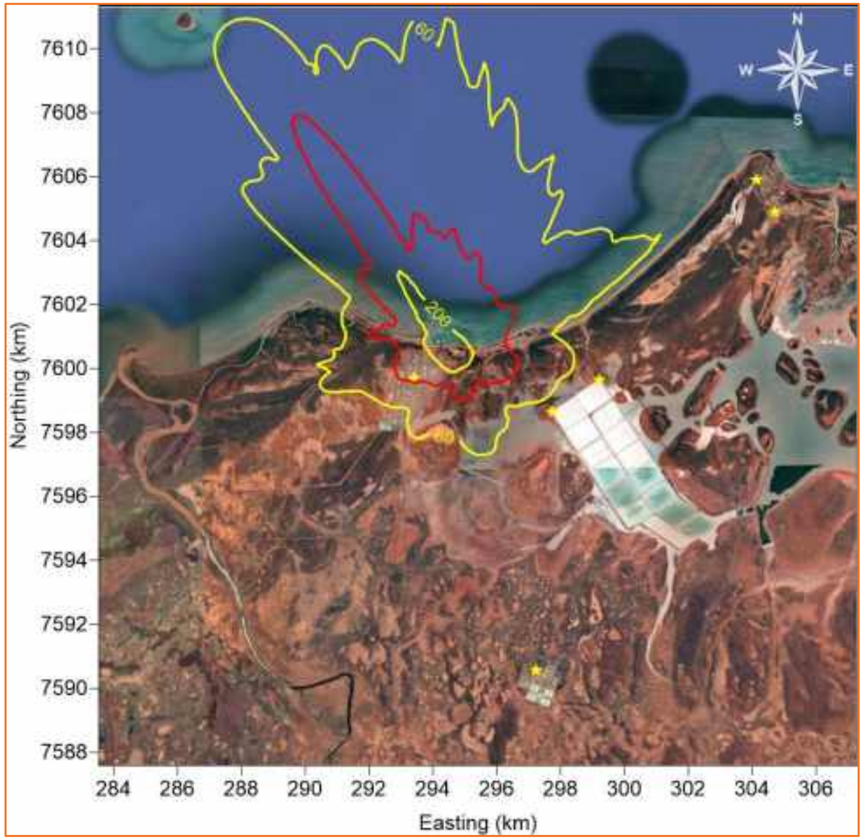

Figure 6-21: Maximum 24-hour TSP concentration – Cumulative (including background) – Scenario 2 (40 Mtpa).

6.2.4 Dust deposition

The predicted monthly dust deposition (based on annual average predicted flux rates) is presented in Figure 6-22. The contour plot shows that while monthly deposition doubles in magnitude from Scenario 2, exceedance of the adopted criterion is still limited to the proposed facility footprint.

The criterion for potential deposition effects (2 g/m²/month), is not exceeded at any nominated sensitive receptor (Table 6-14).

Table 6-14: Predicted dust deposition at receptors (g/m²/month) – Scenario 2 (40 Mtpa).

Receptor	Maximum
Onslow 1	0.003
Onslow 2	0.004
Camp	0.001
Salt 1	0.015
Salt 2	0.015
Chevron	0.042

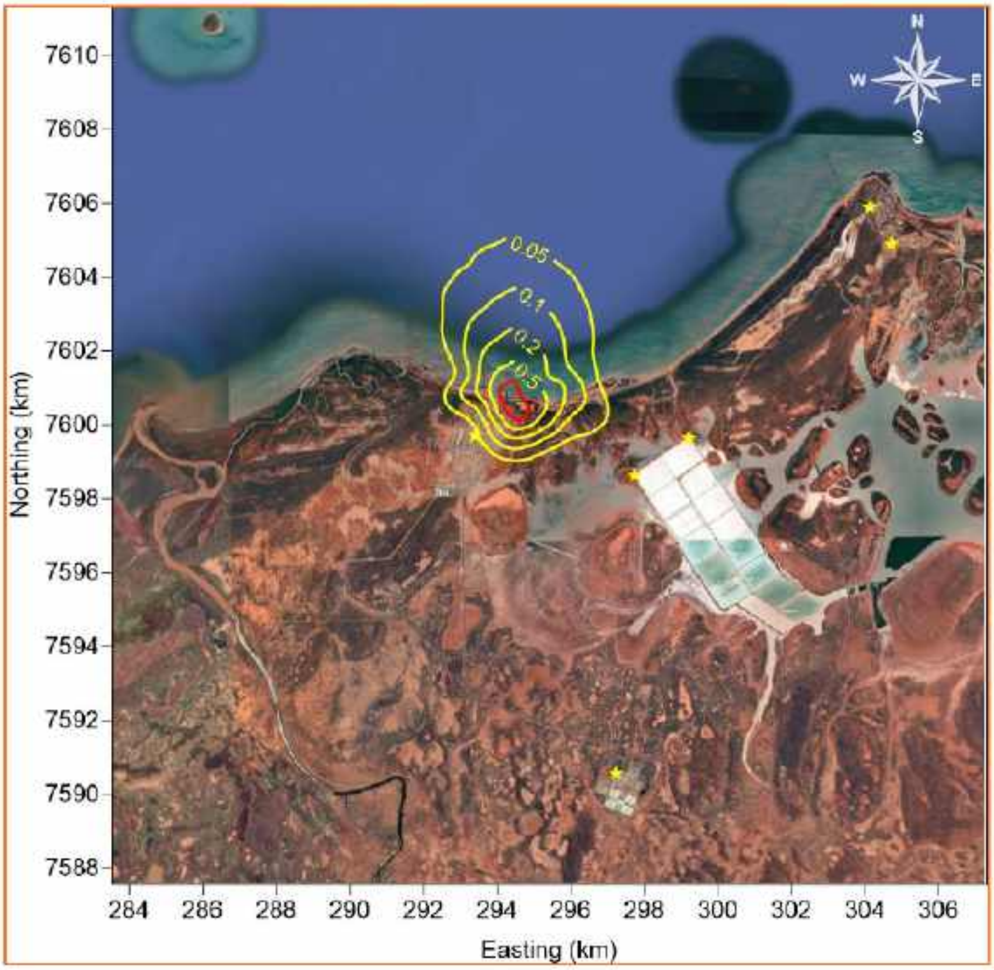

Figure 6-22: Total monthly dust deposition – Project only - Scenario 2 (40 Mtpa).

6.3 Power generation

The modelled results for NO_2, for power generation from the proposed Project, at the nominated receptors are presented statistically in Table 6-15. The cumulative modelled results, which includes the Chevron and Domgas facilities (Section 5.3) are presented in Table 6-16. The modelled results indicate that:

- The predicted annual average and maximum 1-hour ground level concentrations are well within the relevant assessment (NEPM) criteria for the Project operating in isolation.
- The annual and 1-hour assessment criteria are not exceeded at any nominated sensitive receptor when cumulative emissions are included in the modelling.
- Impacts from the other facilities (emission sources) dominate the predicted impacts.

Table 6-15: Predicted NO_2 concentrations at nominated receptors (µg/m³) – Project only.

Receptor	Maximum	2nd Highest	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average
Onslow 1	13.5	11.7	4.8	0.9	0.1	0.0	0.18
Onslow 2	12.2	10.7	4.2	0.7	0.1	0.0	0.16
Camp	10.0	9.0	0.7	0.1	0.0	0.0	0.04
Salt 1	25.8	24.3	3.2	1.2	0.2	0.0	0.20
Salt 2	18.4	17.9	7.8	1.3	0.5	0.0	0.28
Chevron	37.4	36.8	12.7	1.1	0.0	0.0	0.40

Assessment criteria: 31 µg/m³ annual average (based on NEPM (NEPC (2021))
Assessment criteria: 168 µg/m³ 1-hour average (based on NEPM (NEPC (2021))

Table 6-16: Predicted NO_2 concentrations at receptors (µg/m³) – Cumulative (including background)

Receptor	Maximum	2nd Highest	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average
Onslow 1	37.4	37.1	13.8	3.6	1.0	0.0	0.62
Onslow 2	37.4	32.9	11.4	3.3	0.9	0.0	0.54
Camp	41.5	26.8	7.9	1.0	0.0	0.0	0.29
Salt 1	41.1	38.9	26.3	11.3	2.8	0.0	1.49
Salt 2	37.3	37.3	20.6	9.2	3.0	0.0	1.21
Chevron	133.4	109.9	39.5	18.5	7.1	0.3	2.72

Assessment criteria: 31 µg/m³ annual average (based on NEPM (NEPC (2021))
Assessment criteria: 168 µg/m³ 1-hour average (based on NEPM (NEPC (2021))

The predicted isopleths (contours) for ground level concentrations of NO_2 are presented as follows:

- Annual average concentrations for the proposed facility in isolation (Figure 6-23) and cumulatively with nearby facilities (Figure 6-24).
- Maximum predicted 1-hour concentrations for the proposed facility in isolation (Figure 6-25) and cumulatively with background concentrations (Figure 6-26).

Figure 6-23: Annual average NO_2 concentrations – Project only.

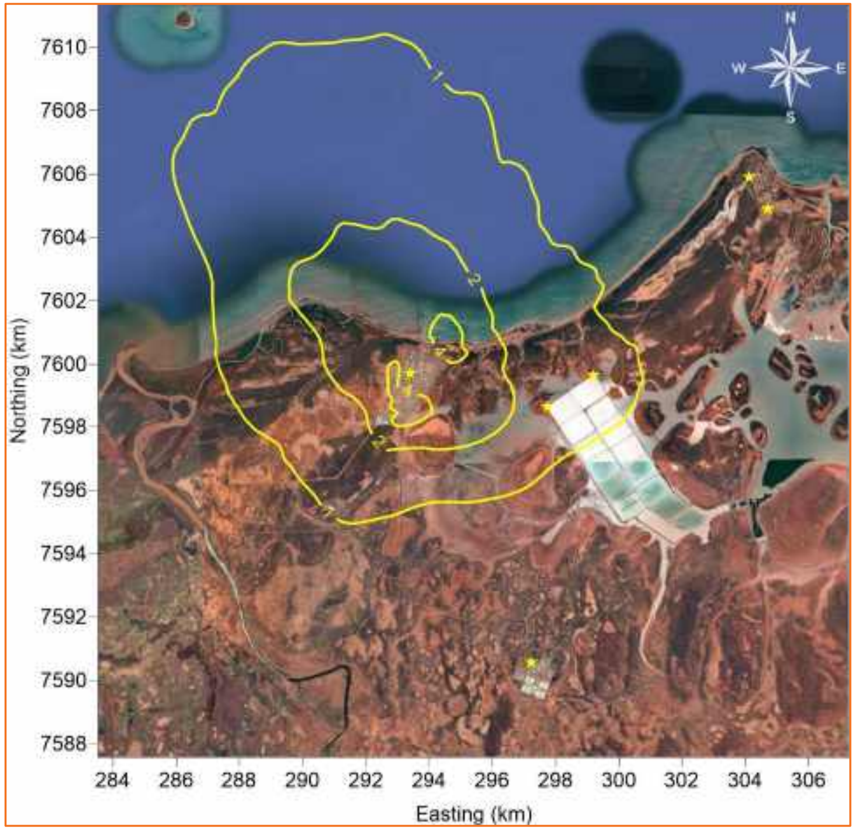

Figure 6-24: Annual average NO_2 concentrations – Cumulative.

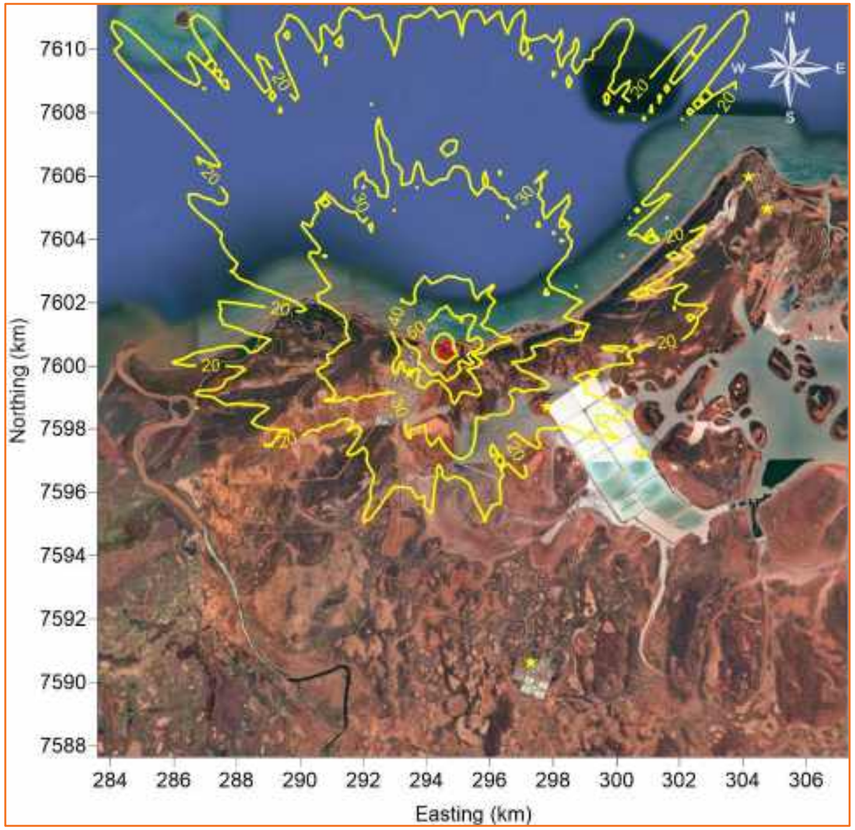

Figure 6-25: Maximum 1-hour NO_2 concentrations – Project only.

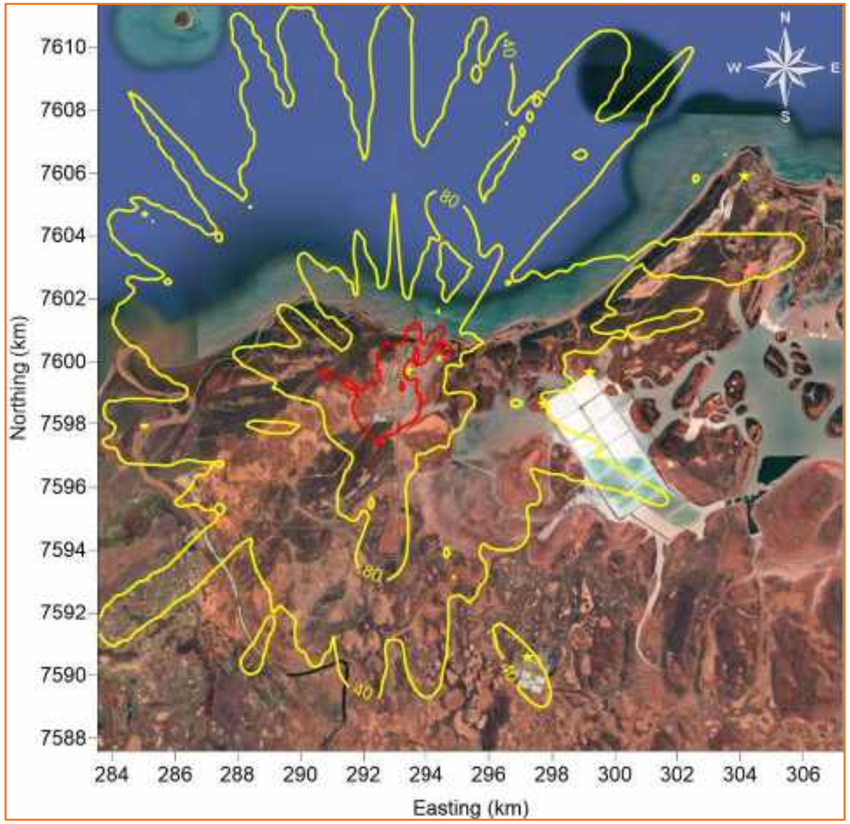

Figure 6-26: Maximum 1-hour NO_2 concentrations – Cumulative.

7 Conclusions

MRL is undertaking planning for proposed Ashburton Infrastructure Project (AIP) which involves the development of a new private haul road connecting an open cut mining area to landside facilities at the Port of Ashburton, located approximately 12 km southwest of Onslow. The proposed landside facilities will include:

- Truck unloading shed
- Fully enclosed storage shed containing:
  - Overhead tripper
  - Stockpile (220,000 tonnes)
  - Bridge reclaimer
  - Conveyors
- Transfer stations and conveyors,
- New jetty with a ship loader and marine transhipping
- Power generation (gas fired generators).

This modelling assessment determined the potential air quality impacts associated with operating both the port operations and power generation. Modelling impacts of particulates (as TSP, PM_{10}, $PM_{2.5}$ and deposition) and NO_X emissions was undertaken using the CALMET/CAPUFF modelling suite. Three-dimensional meteorological fields in the region of the mine were created, in the absence of weather station data, from 3-dimensional data generated by the WRF prognostic meteorological model. Fine resolution terrain elevation (SRTM) data with 90 m resolution was used in conjunction with ESACCI land-use data to characterise the geophysical environment.

For this assessment two standalone scenarios were modelled:

- Scenario 1: The facility operating with an annual throughput of 30 Mtpa.
- Scenario 2: The facility operating with an annual throughput of 40 Mtpa.

Emissions were estimated for the port operations for both scenarios using methodologies outlined in the NPI EET for Mining manual and input into the CALPUFF dispersion model as volume sources to simulate port operations, area sources to simulate wind-blown dust or point sources for stack emissions (power generation).

Modelled ground level concentrations for the key pollutants as particulates (as TSP, PM_{10}, $PM_{2.5}$ and dust deposition) and combustion gases (NO_2) have been compared to relevant ambient air quality assessment criteria, derived from the DWER draft Air Emissions Guideline (DWER, 2019), and Ambient Air Quality NEPM, to determine the potential impacts.

7.1 Modelling results – comparison to air quality assessment criteria

The key findings of the assessment are:

- For Scenario 1 (30 Mtpa)
  - TSP
    - The maximum predicted 24-hour ground level concentration, with background (ie cumulative), is 95 µg/m^3 at the Chevron receptor. It is important to note that this receptor is not classified as a sensitive receptor.
    - For Onslow the maximum predicted 24-hour ground level concentration, with background (ie cumulative), is 47 µg/m^3.

- PM_{10}
  - The maximum predicted concentration (from Project only) at the receptors within Onslow is 1.7 µg/m^3 increasing up to 23.1 µg/m^3 when the background concentration is included.
  - No excursions of the PM_{10} assessment criteria are predicted to occur.

- $PM_{2.5}$
  - The maximum predicted concentration (from Project only) at the receptors within Onslow is 0.5 µg/m^3 increasing up to 8.3 µg/m^3 when the background concentration is included.
  - No excursions of the $PM_{2.5}$ assessment criteria are predicted to occur.

- Dust deposition
  - The criterion for potential deposition effects (2 g/m^2/month) is not exceeded at any sensitive receptor.

- For Scenario 2 (40 Mtpa)
  - TSP
    - The maximum predicted 24-hour ground level concentration, with background (ie cumulative), is 100.5 µg/m^3 at the Chevron receptor. It is important to note that this receptor is not classified as a sensitive receptor.
    - For Onslow the maximum predicted 24-hour ground level concentration, with background (ie cumulative), is 48.5 µg/m^3.
  - PM_{10}
    - The maximum predicted concentration (from Project only) at the receptors within Onslow is 2.2 µg/m^3 increasing up to 23.6 µg/m^3 when the background concentration is included.
    - No excursions of the PM_{10} assessment criteria are predicted to occur.

  - $PM_{2.5}$
    - The maximum predicted concentration (from Project only) at the receptors within Onslow is 0.7 µg/m^3 increasing up to 8.5 µg/m^3 when the background concentration is included.
    - No excursions of the $PM_{2.5}$ assessment criteria are predicted to occur.

  - Dust deposition
    - The criterion for potential deposition effects (2 g/m^2/month) is not exceeded at any sensitive receptor.

  - For NO_2 from power generation:
    - The predicted annual average and maximum 1-hour ground level concentrations are well within the relevant assessment criteria for the Project operating in isolation of other sources.
    - The annual and 1-hour assessment criteria are not exceeded at the nominated sensitive receptors when cumulative emissions are included in the modelling.

8 References

BoM (2021): http://www.bom.gov.au/climate/averages/tables/cw_005017.shtml

Chevron (2010). Draft Environmental Impact Statement/Environmental Review and Management Programme for the Proposed Wheatstone Project, Technical Appendices A1, B1, C1, E1 and F1. https://www.epa.wa.gov.au/sites/default/files/PER_documentation/wheatstone-draft-eis-ermp-technical-appendices-a1-b1-c1-d-web.pdf

DoE (2006). Air Quality Modelling Guidance Notes. Department of Environment, Western Australia.

DWER (2019). Guideline – Air Emissions – Activities regulated under the Environmental Protection Act 1986, Environmental Protection Regulations 1987, Draft for external consultation, Department of Water and Environment Regulation, October 2019.

EA, 2012. National Pollutant Inventory Emission Estimation Technique Manual for Mining Version 3.1, Environment Australia, Canberra, Australia. http://www.npi.gov.au/handbooks/approved_handbooks/mining.html

Environmental Protection Authority (1992) *Environmental Protection (Kwinana) (Atmospheric Wastes) Policy 1992*. Accessed: https://www.legislation.wa.gov.au/legislation/statutes.nsf/law_s4417.html

Environmental Protection Authority (1999) Environmental Protection (Kwinana) (Atmospheric Wastes) Policy Approval Order 1999. Accessed: https://www.epa.wa.gov.au/sites/default/files/Policies_and_Guidance/EPP_KAW99.pdf

EPA (1999). Environmental Protection (Kwinana) (Atmospheric Wastes) Policy Approval Order, 1999. https://www.epa.wa.gov.au/sites/default/files/Policies_and_Guidance/EPP_KAW99.pdf

EPAV (2007). Protocol for environmental management: mining and extractive industries. Environmental Protection Authority Victoria. Australia

ESACCI. (2020). European Space Agency Climate Change Initiative (ESACCI) dataset. https://climate.esa.int/en/projects/land-cover/

Golder, D (1972). Relations among Stability Parameters in the Surface Layer, *Boundary-Layer Meteorology*, **3**: 47-58

Kottek, M., J. Grieser, C. Beck, B. Rudolf, and F. Rubel (2006): World Map of the Köppen-Geiger climate classification updated. Online at: http://koeppen-geiger.vu-wien.ac.at/

NEPC. (1998). National Environment Protection (Ambient Air Quality) Measure. National Environment Protection Council, Australia.

NEPC. (2015). National Environment Protection (Ambient Air Quality) Measure. National Environment Protection Council, Australia, as amended.

NEPC (2016). Variation to the National Environment protection (Ambient Air Quality) Measure – Impact statement.

NERDDC (1988). Air Pollution from Surface Coal Mining: Measurement, Modelling and Community Perception, Project No. 921, National Energy Research Development and Demonstration Council, Canberra.

NSW EPA (2017). Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales. New South Wales Environment Protection Authority. Online at: https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/air/approved-methods-for-modelling-and-assessment-of-air-pollutants-in-nsw-160666.pdf?la=en&hash=D4131297808565F94E13B186D8C70E7BD02B4C3D

Qld Government (2020). State Government of Queensland, Australia. Accessed online: https://www.qld.gov.au/environment/pollution/monitoring/air/air-pollution/pollutants/particles, 30 May 2017.

Scire, J. S., Robe, F. R., Fernau, M. E., Yamartino, R. J., (2000). A User's Guide for the CALPUFF Dispersion Model (Version 5). Earth Tech Inc., Concord, Massachusetts.

Scire, J. S., Robe, F. R., Fernau, M. E., Yamartino, R. J., (2011). CALPUFF Modeling System Version 6 User Instructions. Earth Tech Inc., Concord, Massachusetts.

SKM. (2005). Improvement of NPI Fugitive Particulate Matter Emission Estimation Techniques. http://www.npi.gov.au/system/files/resources/d9d46a4c-f76e-fdc4-5d59-fd3f8181c5b8/files/pm10may05.pdf

USEPA (1998). Western surface coal mining, AP-42 Chapter 11.9, United States Environment Protection Agency Office of Air Quality Planning and Standards.

USEPA (2006). Unpaved Roads, AP-42 Chapter 13.2.2, United States Environment Protection Agency Office of Air Quality Planning and Standards.

USEPA (2006b). Aggregate handling and storage piles, AP-42 Chapter 13.2.4, United States Environment Protection Agency Office of Air Quality Planning and Standards.

USEPA (2006c). Industrial wind erosion, AP-42 Chapter 13.2.5, United States Environment Protection Agency Office of Air Quality Planning and Standards.

USEPA (2016). Guideline on Air Quality Models (Appendix W to 40 CFR Part 51). U United States Environment Protection Agency, December 2016.

9 Acronyms and Glossary

Acronym	Description
AFWA	Air Force Weather Agency
BAM	Beta Attenuation Monitor
BoM	Bureau of Meteorology
BWh	Koppen-Geiger classification - hot desert climate, with no distinct rainy season
BWS	Belt wash station
C	Degrees Celsius (temperature)
COS	Coarse ore stockpile
CV	Conveyor
DSD	Department of State Development
DWER	Department of Water and Environmental Regulation
EA	Environment Australia
EE	Emissions estimation
EET	Emissions Estimation Technique
EET	Emissions Estimation Technique Manual
EF	Emission factor
EPAV	Environmental Protection Authority Victoria, Australia
EPPA	Environmental Protection Policy
ESACCI	European Space Agency Climate Change Initiative
ETA	Environmental Technologies& Analytics Pty Ltd
FAA	Federal Aviation Administration
FEL	Front end loader
FSL	Forecast Systems Laboratory
FY	Financial Year
GDA94	Geocentric Datum of Australia 1994
GLC	Ground Level Concentration
g/m^2/month	Grams per square metre per month
g/s	Grams per second

Acronym	Description
h/yr	Hours per year
kg	Kilogram
kg/t	Kilogram per tonne
kg/yr	Kilograms per year
kPa	KiloPascals
km	Kilometre
LSM	Land Surface Model
m	Metre
m^2	Metres squared
m/s	Metres per second
MKS	Mt Keith Satellite
mm	Millimetre
MOST	Monin-Obukhov Similarity Theory
Mt	Million tonnes
Mtpa	Million tonnes per annum
NCAR	National Center for Environmental Prediction
NEPC	National Environment Protection Council
NEPM	National Environmental Protection Measure
Nickel West	BHP Nickel West
NMK	Nickel West Mt Keith nickel mine
NOAA	National Oceanic and Atmospheric Administration
NOx	Oxides of nitrogen
NPI	National Pollutant Inventory
NSW	New South Wales, Australia
PBL	Planetary Boundary Layer
PEM	The Victorian Protocol for Environmental Management
PM	Particulate matter, small particles and liquid droplets that can remain suspended in air.

Acronym	Description
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of 10 µm or less.
PM_{10}	Particulate matter with an aerodynamic diameter of 2.5 µm or less.
Qld	Queensland, Australia
ROM	Run of mine
SAG	Semi-autogenous grinding
SEA	Strategic Environmental Assessment
SRTM	Shuttle Radar Topography Mission
t	Tonnes
t/h	Tonnes per hour
tpa	Tonnes per annum

Acronym	Description
tph	Tonnes per hour
TS	Transfer station
TSP	Total suspended particulates
$\mu g/m^3$	Micro grams (one millionth of a gram) per cubic metre
µm	Micrometre
USEPA	United States Environment Protection Agency
USGS	United State Geological Services
WA	Western Australia, Australia
WHO	World Health Organisation
WRF	Weather Research Forecast Model

10 Appendices

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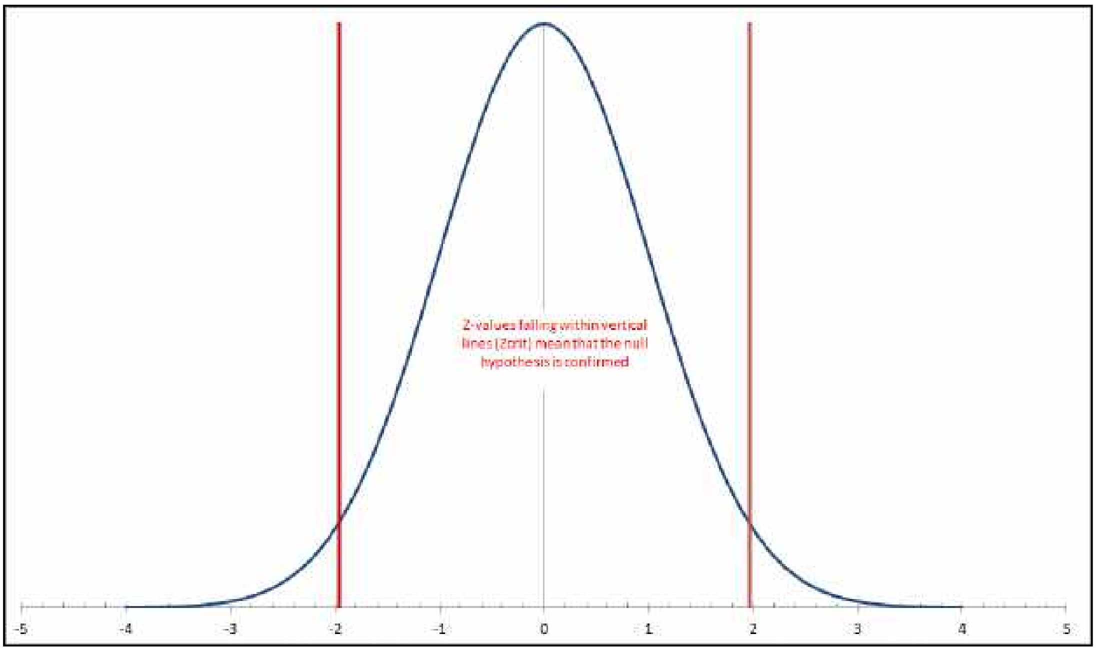
Appendix A –Selection of Representative Meteorological Year for Modelling

Generally, a minimum of one year of meteorological data is acceptable for dispersion modelling in Australia and New Zealand. The data must, however, adequately represent worst-case meteorological conditions and the data should be assessed in terms of representativeness against climatic averages. In other words, the meteorology for selected years must be deemed representative of the "normal" range of conditions in the area.

To determine the year of meteorological data to use for the dispersion modelling, 10-years of historical hourly [2] surface observations from the nearest BoM station at Onslow Airport (2011 to 2020 inclusive) were reviewed. The Mann-Whitney U and Pearson's Chi^2 tests were used to statistically identify the representative modelling year based on recorded scalar meteorological parameters including wind speed, wind direction, temperature, and rainfall.

The null hypothesis is that there is no significant difference between hourly values in an individual year and the hourly averages for long term average values. If values fall within the vertical lines (at 5% confidence interval, two tailed), then accept the null hypothesis (Appendix Figure 1). The null hypothesis is that there is no significant difference between hourly values in an individual year and the hourly averages for long term average values. The graph below shows that if values fall within the vertical lines (at 5% confidence interval, two tailed), then accept the null hypothesis. Note that only scalars were assessed (i.e. temperature and wind speed). Wind direction was assessed through radar plots.

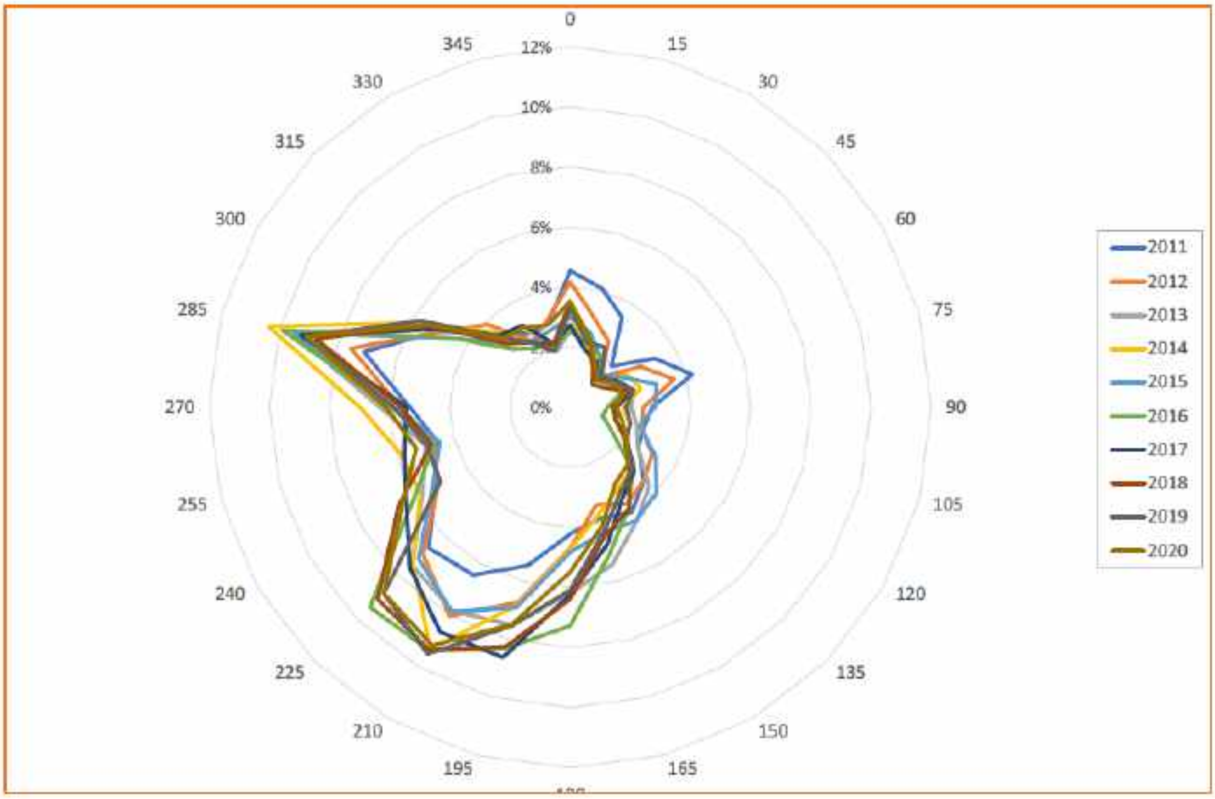


Appendix Figure 1: Null Hypothesis for Mann-Whitney U test.

[2] Calculated from 1-minute data

Wind Direction

The average wind direction radar plots for 2011 to 2020 at Onslow Airport are compared in Appendix Figure 2. Generally, the wind direction pattern is consistent across all years. There are minor differences apparent, especially during 2011 and 2012, where there is a slight increase in northeasterly and easterly winds and a decrease in westerly winds and in 2011 with a decrease (<2%) in southwesterly winds compared to other years.



Appendix Figure 2: Wind direction radar plot for Onslow Airport (2011-2020).

Wind Speed

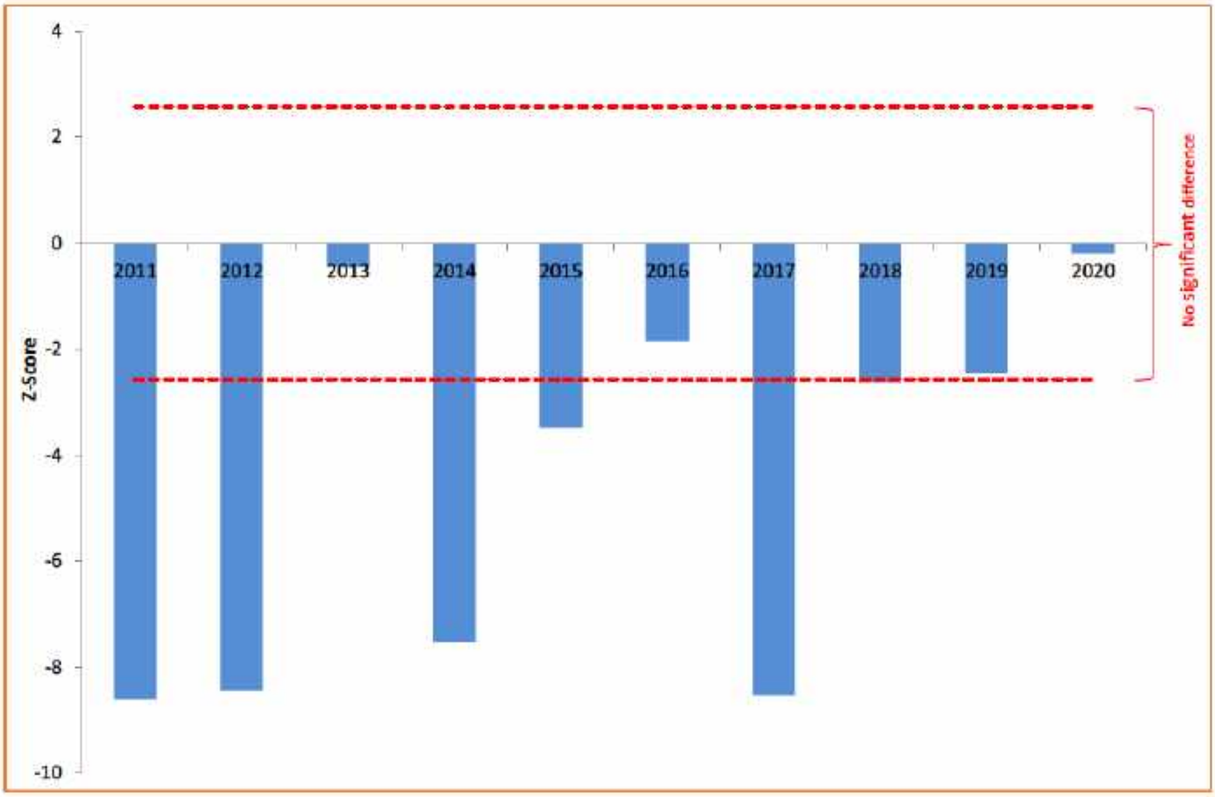
The basic statistics for average wind speed for the 10-year period and individual years are shown in Appendix Table 1. Overall there is minimal difference between the chosen years though the average and standard deviations during 2013, 2015 and 2019 are closest to long term averages. Similarly, the frequency of stronger (>8 m/s) and lighter (<1 m/s) winds during those years are close to long term average values.

Appendix Table 1: Annual wind speed statistics.

Year	Mean	Standard Deviation	% >8 m/s	% <1 m/s
10-yr average	5.5	2.2	13%	1%
2011	5.4	2.4	13%	1%
2012	5.3	2.1	11%	1%
2013	5.5	2.2	13%	1%

Year	Mean	Standard Deviation	% >8 m/s	% <1 m/s
2014	5.4	2.2	14%	1%
2015	5.5	2.3	13%	1%
2016	5.6	2.1	14%	1%
2017	5.3	2.2	12%	1%
2018	5.6	2.2	15%	1%
2019	5.5	2.1	13%	1%
2020	5.6	2.3	15%	1%

The Mann-Whitney U test results for wind speed are presented in Appendix Figure 3. This figure indicates that 2013, 2016, 2019 and 2020 were representative of 10-year average conditions at the 5% confidence interval. Wind speed data for 2011, 2012, 2014 and 2017 show significant difference from the 10-year average conditions according to the two-tailed Mann-Whitney test.



Appendix Figure 3: Mann-Whitney U test result for wind speed.

Temperature

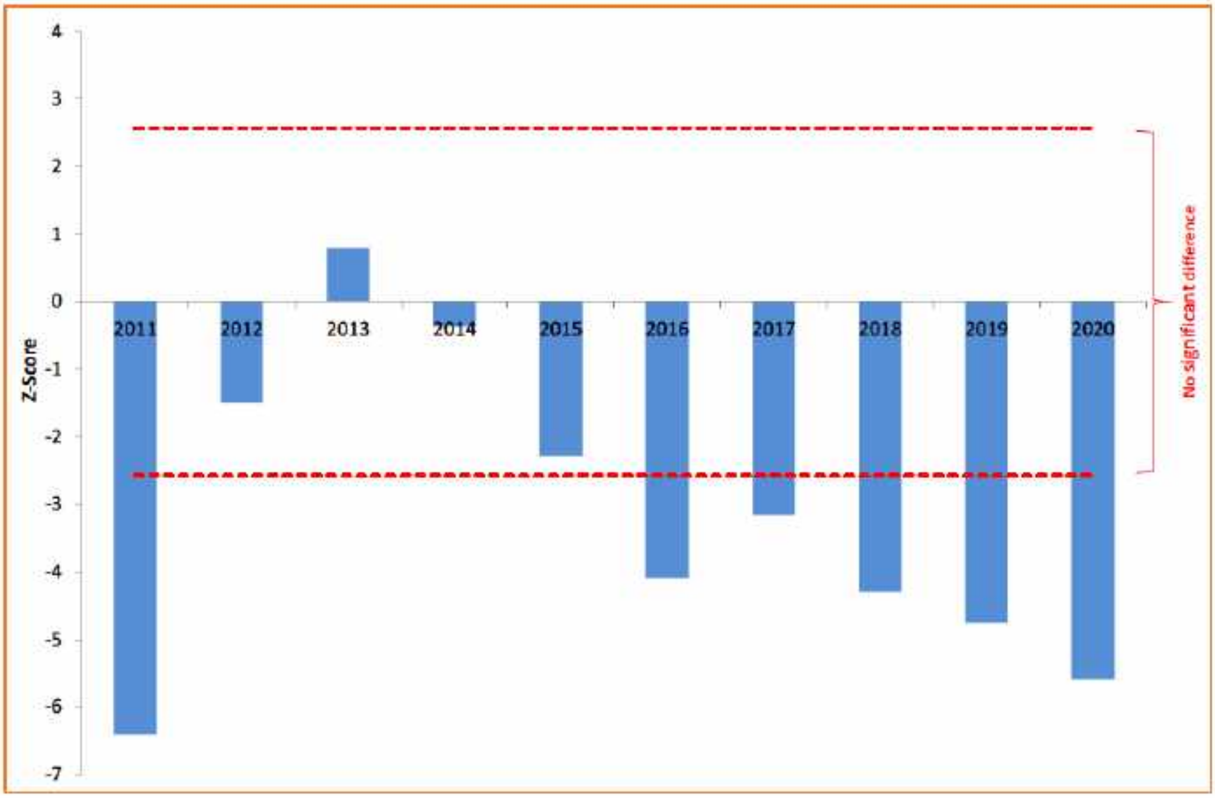
The basic statistics for average temperature for the 10-year period and individual years are shown in Appendix Table 2. The average temperature for the years 2011 to 2018 are relatively close to the 10-year average while both 2019 and 2020 were 0.6°C above the annual average. These 2 years also had a higher percentage of temperatures above 3.5°C.

Appendix Table 2: Annual temperature statistics.

Year	Mean	Standard Deviation	% >35°C	% <5°C
10-yr average	25.6	5.9	5%	0%
2011	25.1	5.5	3%	0%
2012	25.5	5.8	4%	0%
2013	25.8	5.9	5%	0%
2014	25.6	5.9	5%	0%
2015	25.6	5.6	5%	0%
2016	25.4	5.8	6%	0%
2017	25.4	5.8	5%	0%
2018	25.3	6.2	6%	0%
2019	26.2	6.2	8%	0%
2020	26.2	5.6	6%	0%

The Mann-Whitney U test results for temperature is presented in Appendix Figure 4. From this figure it is apparent that the hourly temperature values from 2012 to 2015 were not significantly different to the hourly long term average values.

The Mann-Whitney U test results for temperature indicate that hourly temperature values during 2013, 2015, and 2018 were not significantly different to the hourly long term average values.

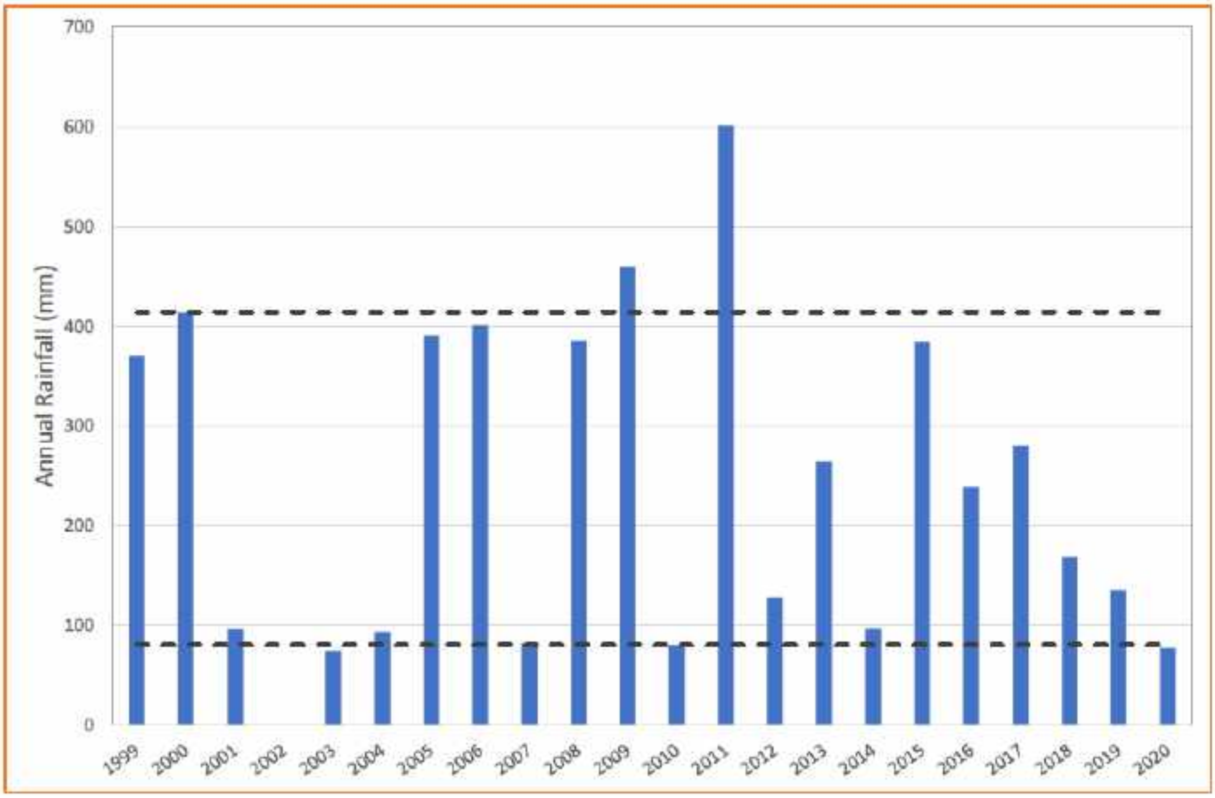


Appendix Figure 4: Mann-Whitney U test result for temperature.

Rainfall

The annual rainfall at the Onslow Airport for the period 1999-2020 is displayed in Appendix Figure 5, noting that there is no available data for 2002. There is a significant variation in rainfall between each year which is to be expected as rainfall in the region is highly dependent on tropical cyclones. The years 2003, 2009, 2010, 2011 and 2020 have total rainfalls that fall outside the 10^{th} and 90^{th} percentile[3] long-term (22 year) rainfall totals.

[3] The 10^{th} and 90^{th} percentile values are classed as well below and well above average according to the Bureau of Meteorology



Appendix Figure 5: Annual rainfall at Onslow Airport between 1999 and 2020[4].

Conclusions

It is important to note that it is highly unusual for multiple climatological parameters to all fall within "representative" levels. With that in mind, the following conclusions can be made:

- Wind direction displayed little interannual variability but 2011 and 2012 displayed wind directions that varied from the other 8 years.
- For wind speed 2013, 2016, 2019 and 2020 were not statistically different to longer term conditions.
- For temperature 2012, 2013, 2014 and 2015 were not significantly different to longer term average values.
- Rainfall, although highly variable, showed that all years between 2012 and 2019 fell within the 10th and 90th percentile of 24-year rainfall totals.

This analysis shows that 2013 can be considered largely representative of longer-term average conditions. The meteorological variables affecting dispersion, namely wind speed, temperature and direction compare favourably to the long-term average conditions.

[4] Dotted lines indicate the 22 year 10th and 90th percentile rainfall values.

Appendix B– Weather Research and Forecast (WRF) Model Configuration

WRF was developed (and continues to be developed) in the United States by a collaborative partnership including the National Center for Atmospheric Research (NCAR), the National Oceanic and Atmospheric Administration (the National Center for Environmental Prediction (NCEP), the Forecast Systems Laboratory (FSL), the Air Force Weather Agency (AFWA), the Naval Research Laboratory, the University of Oklahoma, the Federal Aviation Administration (FAA) and others. (WRF, 2012).

WRF is a fully compressible, Eulerian, non-hydrostatic meso-scale numerical model developed by the National Center for Atmospheric Research (NCAR) and the National Oceanic and Atmospheric Administration (NOAA) in the United States. WRF is suitable for a broad spectrum of applications across scales ranging from metres to thousands of kilometres. The model utilises global reanalysis[5] data to produce fine-scale 3-dimensional meteorological fields that considers local terrain and land-use effects.

WRF was run with a three-nest structure (25 km, 5 km, and 1 km horizontal grid space resolution) centred on 21.692°S and 115.028°E. This is shown in Figure A-6. The model vertical resolution consists of 34 hybrid-eta levels.

Physics options in WRF are to represent atmospheric radiation, surface and boundary layer as well as cloud and precipitation processes. The physics options selected for the modelling are summarised in Appendix Table 3.

Appendix Table 3: WRF Physics Options Selected for Model.

	Domain 1	Domain 2	Domain 3	Explanatory Notes
mp_physics	3	3	3	WRF single moment 3-class scheme
ra_lw_physics	1	1	1	Rapid radiative transfer model scheme
ra_sw_physics	1	1	1	Dudhia scheme for cloud and clear sky absorption and scattering
Radt	30	15	5	Time step for radiation schemes
sf_sfclay_physics	1	1	1	MM5 based on MOST
sf_surface_physics	2	2	2	Noah land surface model with 6 soil layers
bl_pbl_physics	1	1	1	Non-local K-scheme with entrainment layer
bldt	0	0	0	Boundary layer time step (0=every time step)
cu_physics	1	1	1	Kain-Fritch scheme using mass flux approach for domain 1 only.
cudt	5	5	5	Cumulus physics time step (minutes)

[5] Global modelling using observed climate data for temperature, wind speed, and pressure. The observations are analysed; interpolated onto a system of grids and the model initialised with this data.

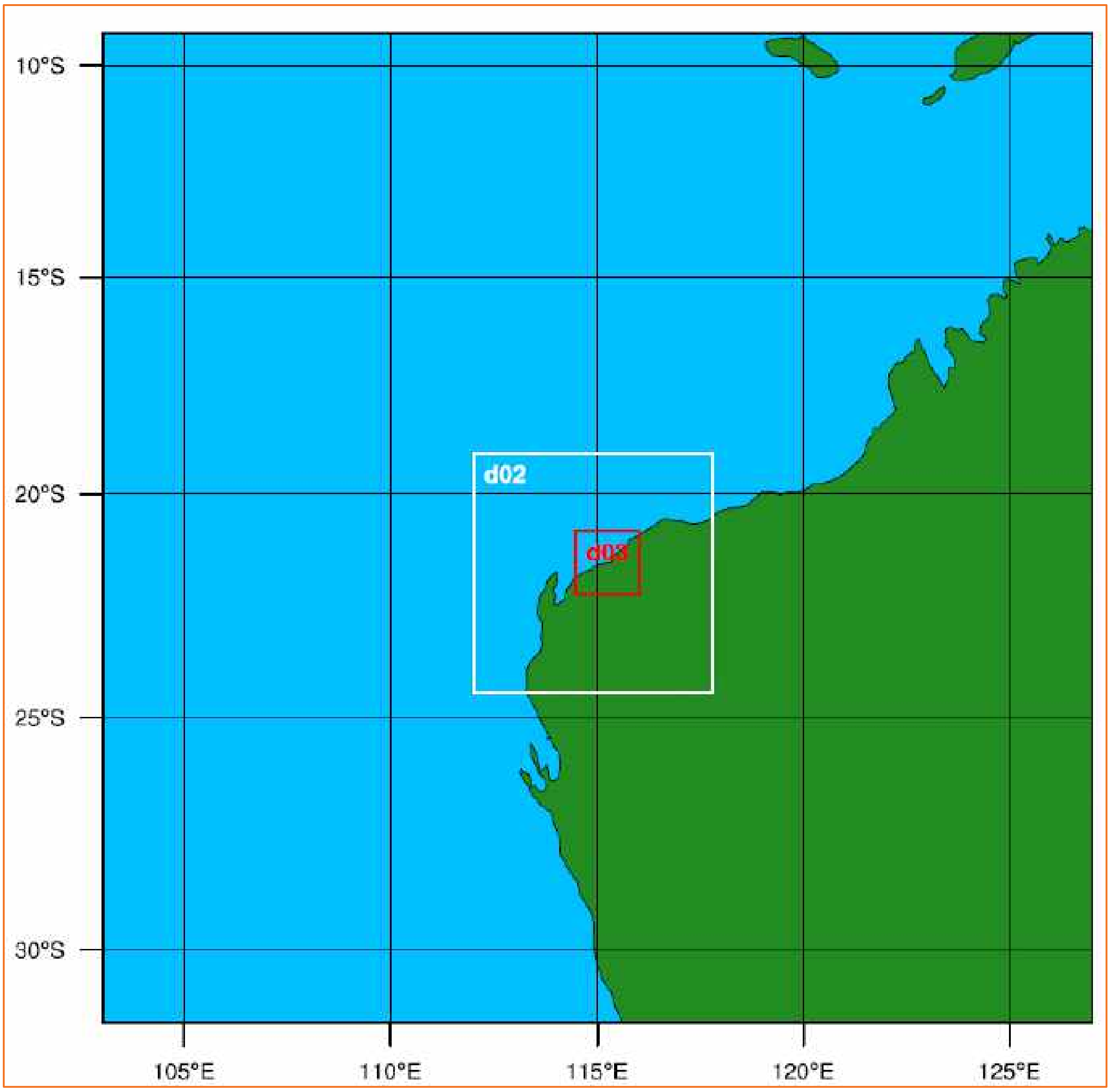


Figure A-6: Three nest structure, WRF model.

Six-hourly global final analysis synoptic data (from http://nomads.ncdc.noaa.gov/data/gfsanl/) was used to initialise the model and provide boundary conditions.

Land-use and terrain data was sourced from the United State Geological Services (USGS) database. Inspection of the land-use indicates an acceptable resolution and category for the model area with shrub land being the dominant vegetation type. A review of the Vegparm.tbl[6] reveals that these are based on North American parameterisations, with marked seasonal differences to allow for winter snow cover. These are clearly

[6] A table consisting of land-use specific surface roughness, albedo and Bowen ratio.

inappropriate for Australia. A non-seasonally varying roughness length value of 0.4 m was assigned to the shrub land category based on a study by Peel *et al*. (2005) for Spinifex vegetation. Albedo was also set to 0.2 based on values cited in Peel *et al*. (2005). Other parameters such as Bowen ratio were adjusted to allow for the drier climate of the region.

The selection of an appropriate Land Surface Model (LSM) is critically important to provide the boundary conditions at the land-atmosphere interface because:

- The Planetary Boundary Layer (PBL) schemes are sensitive to surface fluxes.
- The cloud/cumulus schemes are sensitive to the PBL structures.
- There is a need to capture mesoscale circulations forced by surface variability in albedo, soil moisture/temperature and land use.

The Noah Land-Surface Model was selected in this case to account for the sub-grid-scale fluxes. This sophisticated scheme provides 4 quantities to the parent atmospheric model (WRF), namely:

- surface sensible heat flux
- surface latent heat flux
- upward longwave radiation, and
- upward (reflected) shortwave radiation.

Appendix C – CALMET Configuration

Wind Direction and Speed

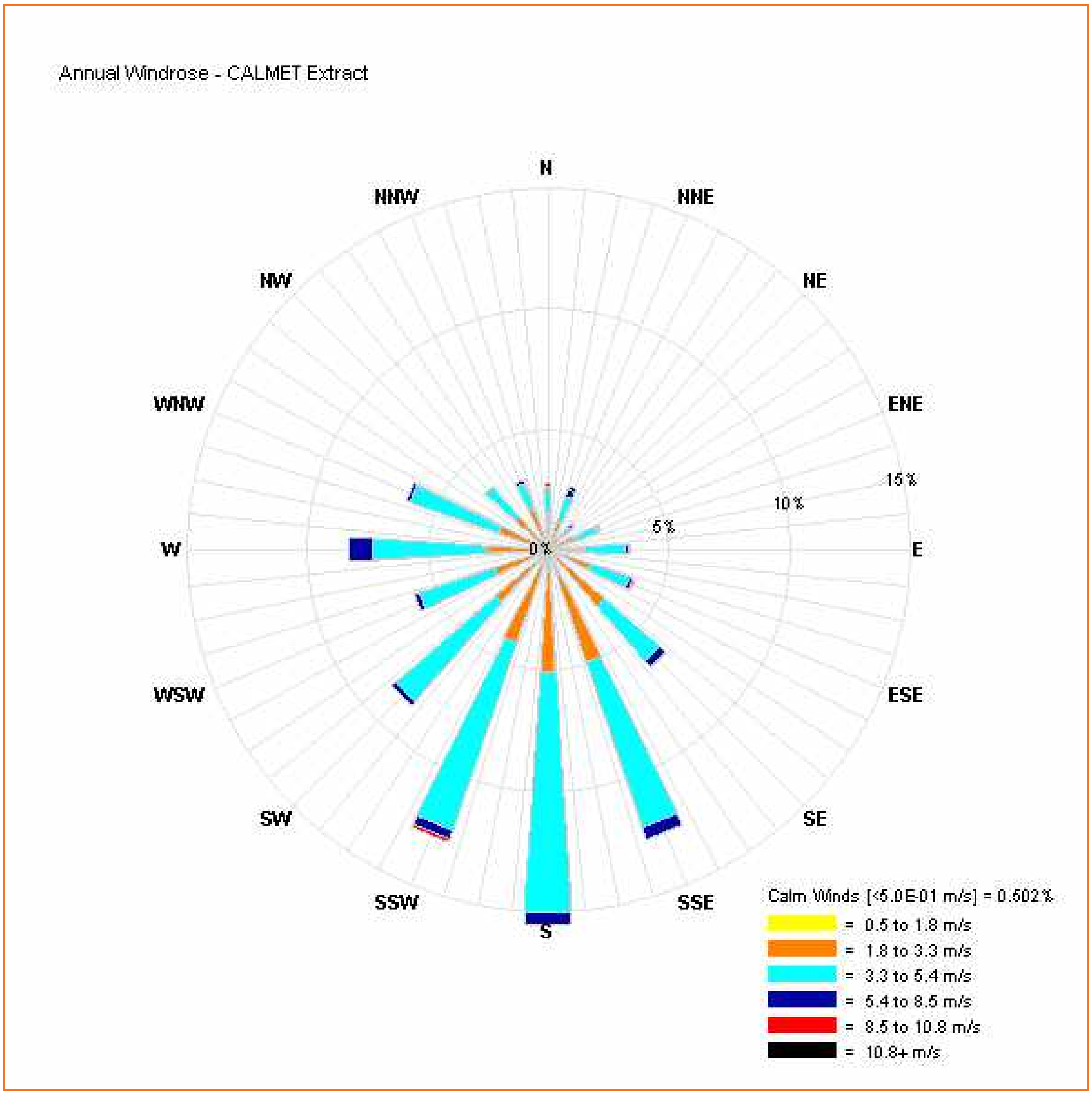
The general features of the 10 m winds illustrated in the annual wind rose diagrams for the 12-month period from January 2013 – December 2013[7] are shown in Appendix Figure 7. The wind roses show the frequency of occurrence of winds by direction and strength. The bars correspond to the 16 compass points – N, NNE, NE, etc. The bar at the top of each wind rose diagram represents winds blowing from the north (i.e., northerly winds), and so on. The length of the bar represents the frequency of occurrence of winds from that direction, and the widths of the bar sections correspond to wind speed categories, the narrowest representing the lightest winds.

The major features of the wind roses are as follows:

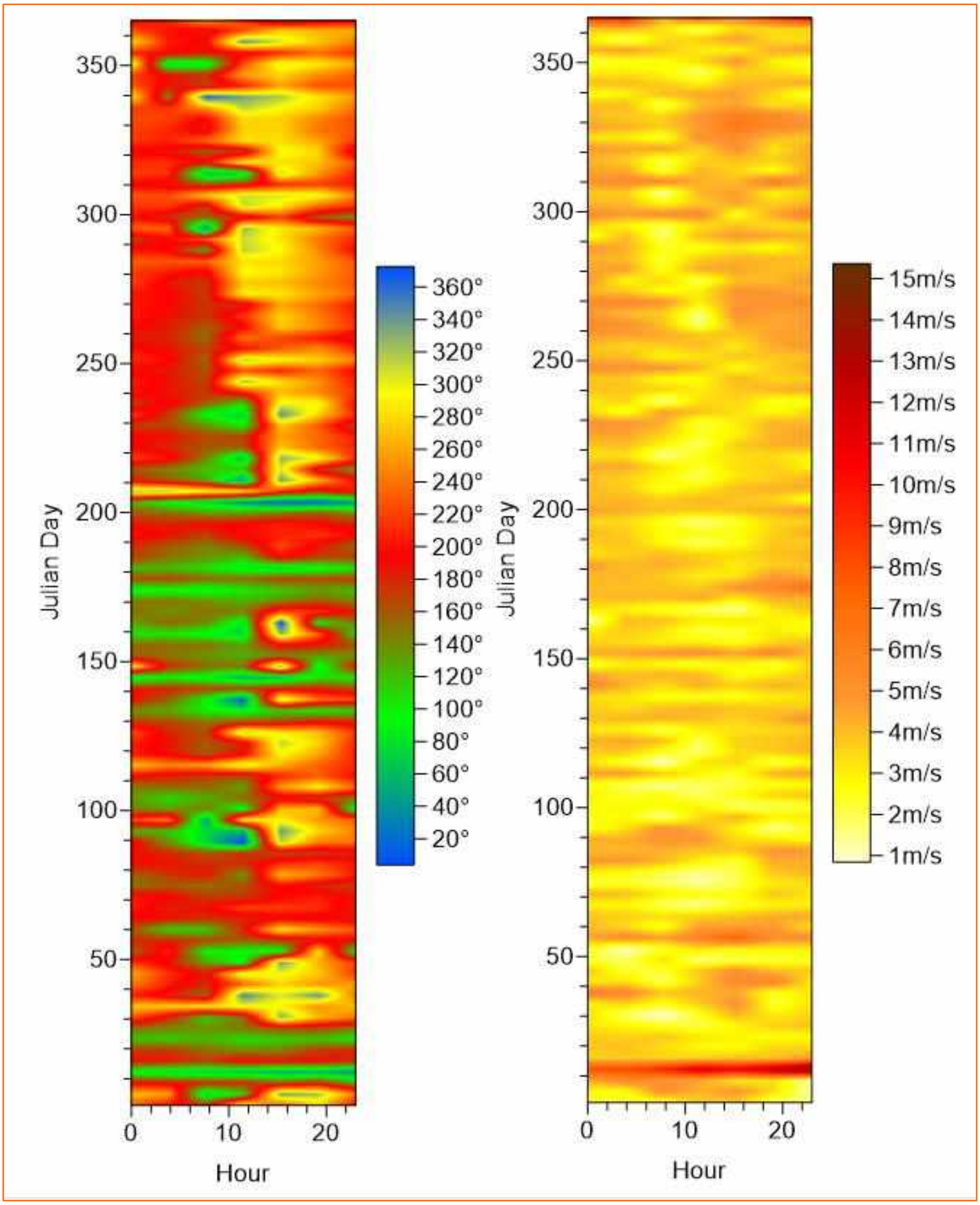
- Wind direction is predominantly from the south-southeast to south-southwest.
- The highest frequency of stronger winds is from the west and highest frequency of light winds from the south-southeast.
- Strongest winds (> 14 m/s) are from the northeast.
- Average annual wind speed is 3.6 m/s.
- Calm conditions (taken as winds < 0.2 m/s) occur for 0.5 % (~44 hours) during the year.

The time-date[8] diagrams for wind direction and wind speed are shown in Appendix Figure 8. The diagrams depict wind direction and speed by hour of the day on the x-axis and day of the year on the y-axis. The figures show that from late winter to early summer, winds are generally from the south-southeast to southwest at night with westerly to north-westerly sea breezes from mid-morning. Easterly to south-easterly winds are more common during the autumn. Wind speeds show little diurnal or annual pattern. The period of strong winds (> 14 m/s) is most likely due to the effects of tropical cyclone Narelle that passed Onlsow approximately 500 km offshore.

[7] The selected representative meteorological year (as determined in Appendix A).
[8] Also known as Hovmöller diagrams, and are useful for displaying large amounts of data in a meaningful and understandable form.



Appendix Figure 7: Wind roses generated from WRF/CALMET for Onslow.



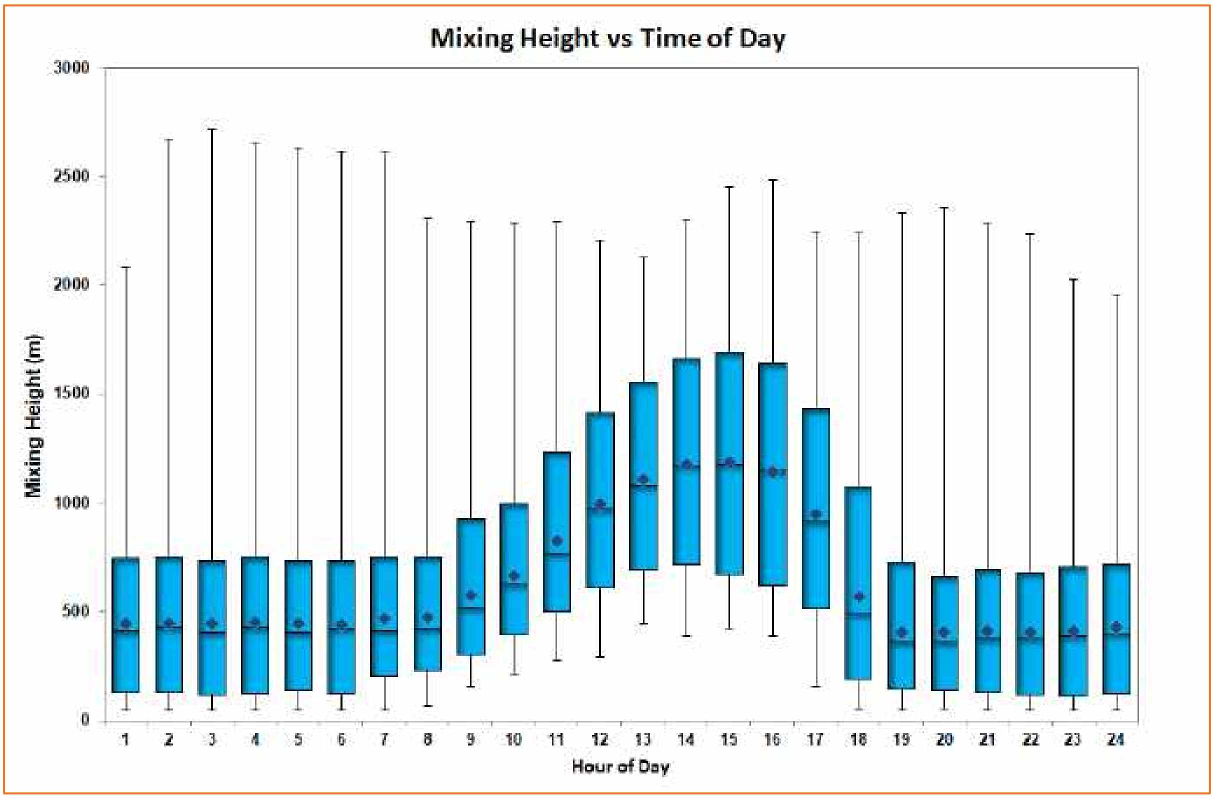
Appendix Figure 8: Date-time plot of wind direction (left) and wind speed (right) generated from WRF/CALMET.

Mixing Height

Mixing height is the depth of the atmospheric surface layer beneath an elevated temperature inversion. It is an important parameter within air pollution meteorology. Vertical diffusion or mixing of a plume is limited by the mixing height, as the air above this layer tends to be stable, with restricted vertical motion.

A series of internal algorithms within CALMET is used to calculate mixing heights for the subject site where it is assumed that mixing height is formed through mechanical means (wind speed) at night and through a mixture of mechanical and convective means (wind speed and solar radiation) during the day (Scire et al. 2011). During the night and early morning when the convective mixed layer is absent or small, the full depth of the planetary boundary layer (PBL) may be controlled by mechanical turbulence. During the day, the height of the PBL during convective conditions is then taken as the maximum of the estimated (or measured if available) convective boundary layer height and the estimated (or measured if available) mechanical mixing height. It is calculated from the early morning potential temperature sounding (prior to sunrise), and the time varying surface heat flux to calculate the time evolution of the convective boundary layer.

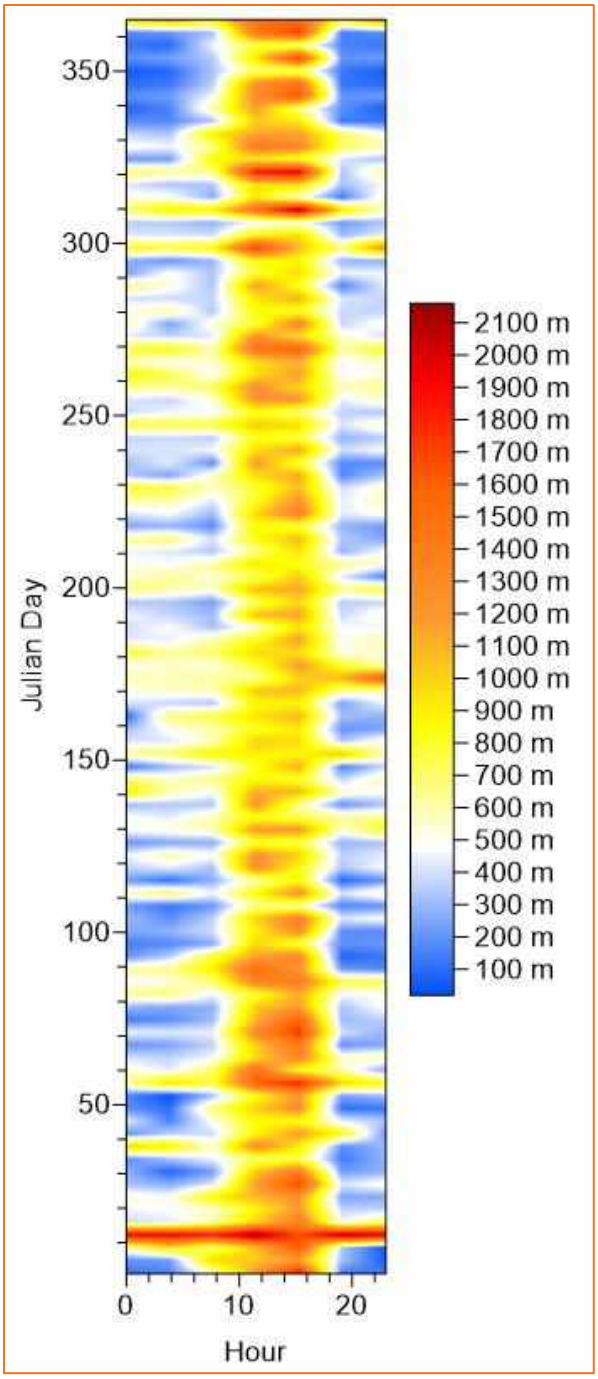
The hourly variation of mixing height at Onslow is summarised in Appendix Figure 9 with the diurnal cycle clearly evident. At night, mixing height is normally low and after sunrise it typically increases to between 700 m and 1,700 m in response to convective mixing generated by solar heating of the Earth's surface. A rapid reduction in mixing height commences around sunset when convective mixing ceases and a mechanical mixing regime is re-established. The impact of the nearby ocean is evident by the supressed maximum mixing heights during the day and higher mixing height at night due to mechanical mixing by wind.



Appendix Figure 9: Simulated annual statistics [9] of hourly mixing heights, Onslow.

The date-time plot of mixing height shows that, as expected, mixing heights are greatest during the summer months when convection is stronger (Appendix Figure 10). A cyclical pattern is also evident in maximum mixing heights, with periods of high mixing height interspersed with periods of lower mixing heights. This most likely reflects the progression of synoptic scale systems across Australia.

[9] The bars in the figure depicts 10^{th} and 90^{th} percentile values while the tringles show the average conditions. The whiskers indicate minimum and maximum values.



Appendix Figure 10: Date-time plot of mixing height generated from WRF/CALMET.

Stability

An important aspect of pollutant dispersion is the level of turbulence in the lowest 1 km or so of the atmosphere, known as the planetary boundary layer (PBL). Turbulence controls how effectively a plume is diffused into the surrounding air and hence diluted. It acts by increasing the cross-sectional area of the plume due to random motions. With stronger turbulence, the rate of plume diffusion increases. Weak turbulence limits diffusion and contributes to high plume concentrations downwind of a source.

Turbulence is generated by both thermal and mechanical effects to varying degrees. Thermally driven turbulence occurs when the surface is being heated, in turn transferring heat to the air above by convection. Mechanical turbulence is caused by the frictional effects of wind moving over the earth's surface and depends on the roughness of the surface as well as the flow characteristics.

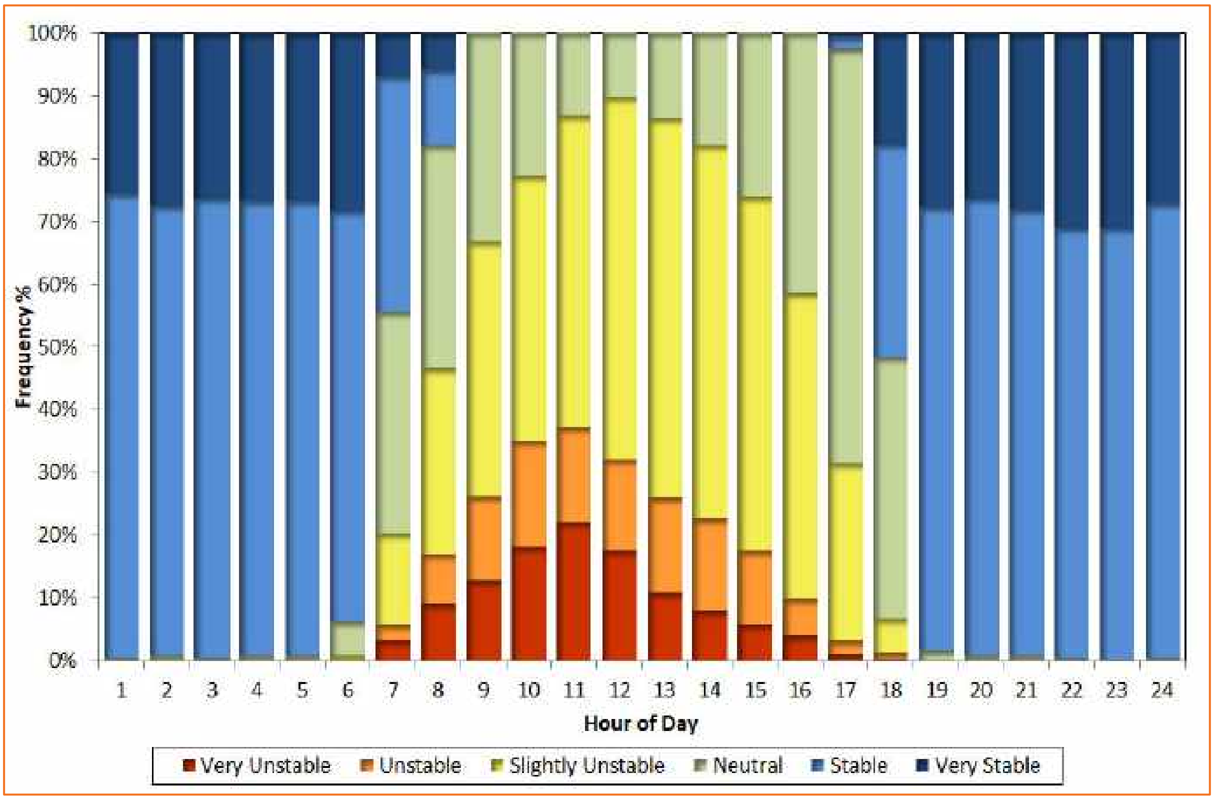
Turbulence in the boundary layer is influenced by the vertical temperature gradient, which is one of several indicators of stability. Plume models use indicators of atmospheric stability in conjunction with other meteorological data to estimate the dispersion conditions in the atmosphere.

Stability can be described across a spectrum ranging from highly unstable through neutral to highly stable. A highly unstable boundary layer is characterised by strong surface heating and relatively light winds, leading to intense convective turbulence and enhanced plume diffusion. At the other extreme, very stable conditions are often associated with strong temperature inversions and light winds, which commonly occur under clear skies at night and in the early morning. Under these conditions, plumes can remain relatively undiluted for considerable distances downwind. Neutral conditions are linked to windy and/or cloudy weather, and short periods around sunset and sunrise, when surface rates of heating or cooling are very low.

The stability of the atmosphere plays a significant role in determining the dispersion of a plume and it is important to have it correctly represented in the dispersion model. CALPUFF uses the Monin-Obukhov Similarity Theory (MOST) to characterise turbulence and other processes in the PBL. One of the measures of the PBL is the Monin-Obukhov length (L), which approximates the height at which turbulence is generated equally by thermal and mechanical effects (Seinfeld and Pandis 2006). It is a measure of the relative importance of mechanical and thermal forcing on atmospheric turbulence.

Because values of L diverge to + and - infinity as stability approaches neutral from the stable and unstable sides, respectively, it is often more convenient to use the inverse of L (i.e., 1/L) when describing stability.

The hourly averaged 1/L for Mt Keith computed from all data in the CALMET surface file is presented in Appendix Figure 11. This plot indicates that the PBL is stable to very stable overnight becoming unstable (reaching maximum instability between 11:00 am and 12:00 pm) as radiation from the sun heats the surface layer of the atmosphere and drives convection.

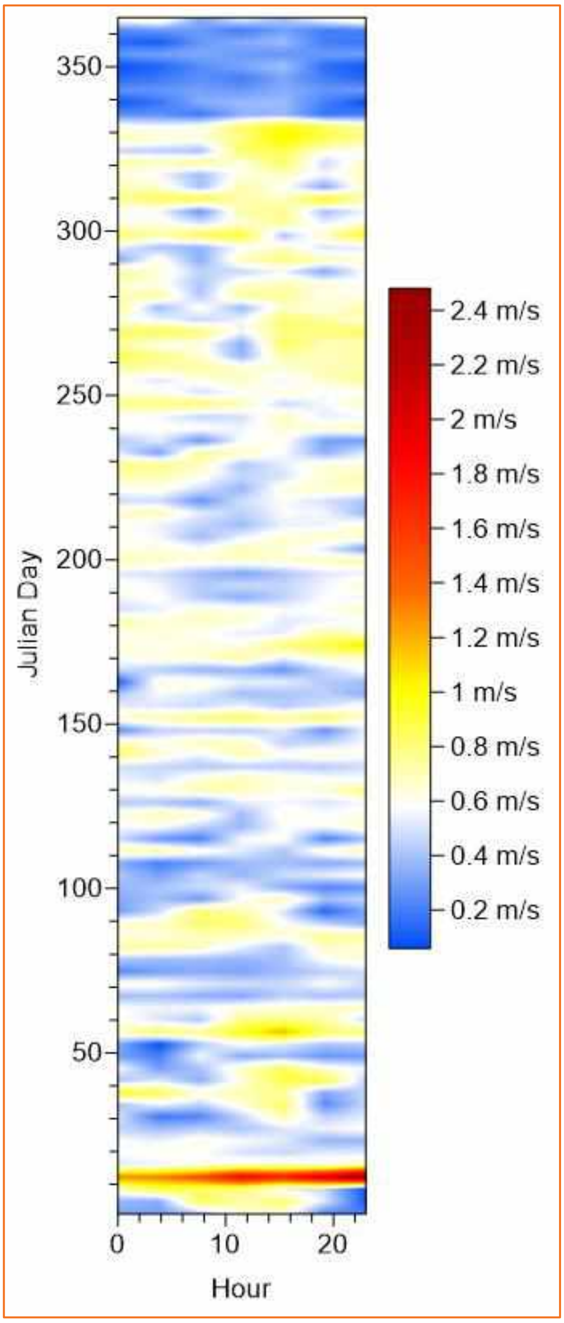


Appendix Figure 11: Figure A-12: Simulated annual statistics of hourly stability, Onslow.

Friction Velocity

An important quantity in wind erosion studies is threshold friction velocity u_{*t}, which describes the capacity of the surface to resist wind erosion. u_{*t} is the minimum friction velocity (u_*) required for the initiation of mobilization of sand particles from the ground into the atmosphere. Friction velocity is affected by a range of factors, such as wind speed, vegetation cover, and other roughness elements.

The Hovmöller diagram of CALMET-generated friction velocity shows that while the highest friction velocity (and therefore dust lift-off potential) occurs during the day during the warmer months, it can also occur at any time at night during the other seasons (Appendix Figure 13).



Appendix Figure 13: Hour-Date-time plot of friction velocity generated from WRF/CALMET.

Appendix D – Emission Parameters

A summary of the volume sources (statistical characteristics for emission rates) input into the model are shown in:

- Appendix Table 4 for volumes sources, and
- Appendix Table 5 for wind erosion sources.

Appendix Table 4: Emission parameters for volume sources.

Source Id	Easting	Northing	Effective Height	Sigma Y	Sigma Z
Unload1	294539	7600310	1	3.8	0.47
Unload2	294539	7600300	1	3.8	0.47
Unload3	294538	7600289	1	3.8	0.47
Unload4	294539	7600280	1	3.8	0.47
InTS1	294528	7600583	10	2.0	4.65
InTS2_BP	294528	7600607	8	2.0	3.72
OutTS1	294294	7600608	4	2.0	1.86
OutTS2	294297	7600867	4	2.0	1.86
SL	294308	7600893	10	2.0	4.65
InConv1	294528	7600486	5	25.0	2.33
OutConv1	294406	7600607	1	25.0	0.47
OutConv2	294293	7600746	1	25.0	0.47

Appendix Table 5: Wind Erosion model parameters.

Source Id	Easting1	Easting2	Easting3	Easting4	Northing1	Northing2	Northing3	Northing4
WE1	294593	294593	294631	294632	7600313	7600272	7600272	7600313
WE2	294410	294408	294486	294486	7600310	7600263	7600263	7600313
WE3	294646	294646	294800	294800	7600465	7600420	7600419	7600465
WE4	294308	294307	294511	294511	7600616	7600580	7600578	7600619

Appendix E – Emission Rates

A summary of the emission parameters for AIP source, used as input into the model is shown in Appendix Table 6.

Appendix Table 6: PM_{10} emission rates for sources for the AIP 30 Mtpa scenario.

Source Id	Maximum (g/s)	99th Percentile (g/s)	95th Percentile (g/s)	90th Percentile (g/s)	70th Percentile (g/s)	Average (g/s)
TD1	0.31	0.31	0.31	0.31	0.31	0.31
TD2	0.31	0.31	0.31	0.31	0.31	0.31
TD3	0.31	0.31	0.31	0.31	0.31	0.31
TD4	0.31	0.31	0.31	0.31	0.31	0.31
InConv1	0.19	0.19	0.19	0.19	0.19	0.19
InTS1	0.29	0.29	0.29	0.29	0.29	0.29
InTS2_BP	0.29	0.29	0.29	0.00	0.00	0.02
OutTS1	0.54	0.54	0.54	0.54	0.54	0.29
OutTS2	0.54	0.54	0.54	0.54	0.54	0.29
OutConv1	0.72	0.72	0.72	0.72	0.72	0.38
OutConv2	0.72	0.72	0.72	0.72	0.72	0.38
SL	0.90	0.90	0.90	0.90	0.90	0.48
WE1	2.96	0.19	0.00	0.00	0.00	0.01
WE2	6.91	0.45	0.00	0.00	0.00	0.02
WE3	13.03	0.85	0.00	0.00	0.00	0.04
WE4	14.11	0.93	0.00	0.00	0.00	0.04
Stack1	0.98	0.98	0.98	0.98	0.98	0.98

Appendix Table 7: PM_{10} emission rates for sources for the AIP 30 Mtpa scenario.

Source Id	Maximum (g/s)	99th Percentile (g/s)	95th Percentile (g/s)	90th Percentile (g/s)	70th Percentile (g/s)	Average (g/s)
TD1	0.41	0.41	0.41	0.41	0.41	0.41
TD2	0.41	0.41	0.41	0.41	0.41	0.41
TD3	0.41	0.41	0.41	0.41	0.41	0.41
TD4	0.41	0.41	0.41	0.41	0.41	0.41
InConv1	0.25	0.25	0.25	0.25	0.25	0.25
InTS1	0.38	0.38	0.38	0.38	0.38	0.38
InTS2_BP	0.38	0.38	0.38	0.00	0.00	0.03
OutTS1	0.54	0.54	0.54	0.54	0.54	0.38
OutTS2	0.54	0.54	0.54	0.54	0.54	0.38
OutConv1	0.72	0.72	0.72	0.72	0.72	0.51
OutConv2	0.72	0.72	0.72	0.72	0.72	0.51
SL	0.90	0.90	0.90	0.90	0.90	0.63
WE1	2.96	0.19	0.00	0.00	0.00	0.01
WE2	6.91	0.45	0.00	0.00	0.00	0.02
WE3	13.03	0.85	0.00	0.00	0.00	0.04

Source Id	Maximum (g/s)	99th Percentile (g/s)	95th Percentile (g/s)	90th Percentile (g/s)	70th Percentile (g/s)	Average (g/s)
WE4	14.11	0.93	0.00	0.00	0.00	0.04
Stack1	0.98	0.98	0.98	0.98	0.98	0.98

Appendix F – Power Generation Emission Rates

A summary of the power generation emission rates, for non-project related emission sources in the region, was obtained from Chevron (2010). The emissions, as used in the assessment, are shown in:

- Appendix Table 8 for Chevron sources
- Appendix Table 9 Exxon sources, and
- Appendix Table 10 DOMGAS sources.

Appendix Table 8: Emission parameters for Chevron sources.

Train	Source Id	Easting	Northing	Stack Height (m)	Stack Radius (m)	Exit Temperature (K)	Exit Velocity (m/s)	NO_X (g/s)
Train 1	Compressor LM6000	293197	7599464	50	1.33	732	31	5.5
	Compressor LM6000	293211	7599461	50	1.33	732	31	5.5
	Compressor LM6000	293226	7599457	50	1.33	732	31	5.5
	Compressor LM6000	293240	7599453	50	1.33	732	31	5.5
	Compressor LM6000	293255	7599449	50	1.33	732	31	5.5
	Compressor LM6000	293269	7599445	50	1.33	732	31	5.5
	Power Generator LM6000	292972	7599423	36	1.33	802	31.2	4.4
	Power Generator LM6000	292966	7599400	36	1.33	802	31.2	4.4
	Dry gas flare	292678	7599340	125	0.7	1273	20	0.31
	Wet gas flare	292678	7599340	125	0.7	1273	20	0.31
	Marine flare	293070	7600001	25	0	0	0	0
	Start up oil heater	293005	7599653	50	1.25	0	0	0
	Domgas acid gas incinerator	293343	7599781	35	0.42	624	13.2	0.1
	Acid gas thermal oxidiser	293085	7599581	35	0.42	624	13.2	0.05
Train 2	Compressor LM6000	293137	7599245	50	1.33	732	31	5.5
	Compressor LM6000	293152	7599241	50	1.33	732	31	5.5
	Compressor LM6000	293166	7599237	50	1.33	732	31	5.5
	Compressor LM6000	293181	7599233	50	1.33	732	31	5.5
	Compressor LM6000	293195	7599229	50	1.33	732	31	5.5
	Compressor LM6000	293210	7599225	50	1.33	732	31	5.5
	Power Generator LM6000	293149	7599795	36	1.33	802	31.2	4.4
	Power Generator LM6000	293134	7599769	36	1.33	802	31.2	4.4
	Domgas acid gas incinerator	293437	7599756	35	0.42	624	13.2	0.1
	Acid gas thermal oxidiser	293026	7599362	35	0.42	624	13.2	0.05
Train 3	Compressor LM6000	293079	7599025	50	1.33	732	31	5.5
	Compressor LM6000	293093	7599021	50	1.33	732	31	5.5
	Compressor LM6000	293108	7599018	50	1.33	732	31	5.5
	Compressor LM6000	293122	7599014	50	1.33	732	31	5.5
	Compressor LM6000	293137	7599010	50	1.33	732	31	5.5

Train	Source Id	Easting	Northing	Stack Height (m)	Stack Radius (m)	Exit Temperature (K)	Exit Velocity (m/s)	NO_x (g/s)
	Compressor LM6000	293151	7599006	50	1.33	732	31	5.5
	Compressor LM6000	293266	7599002	50	1.33	732	31	5.5
	Power Generator LM6000	292841	7598935	36	1.33	802	31.2	4.4
	Power Generator LM6000	292826	7598909	36	1.33	802	31.2	4.4
	Dry gas flare	292594	7599030	125	0.7	1273	20	0.31
	Wet gas flare	292594	7599030	125	0.7	1273	20	0.31
	Marine flare	293043	7599904	25	0	0	0	0
	Start up oil heater	292874	7599165	50	1.25	0	0	0
	Domgas acid gas incinerator	293530	7599731	35	0.42	624	13.2	0.1
	Acid gas thermal oxidiser	292967	7599142	35	0.42	624	13.2	0.05
Train 4	Compressor LM6000	293020	7598806	50	1.33	732	31	5.5
	Compressor LM6000	293034	7598802	50	1.33	732	31	5.5
	Compressor LM6000	293049	7598798	50	1.33	732	31	5.5
	Compressor LM6000	293063	7598794	50	1.33	732	31	5.5
	Compressor LM6000	293078	7598791	50	1.33	732	31	5.5
	Compressor LM6000	293092	7598787	50	1.33	732	31	5.5
	Compressor LM6000	293106	7598783	50	1.33	732	31	5.5
	Power Generator LM6000	292834	7598912	36	1.33	802	31.2	4.4
	Domgas acid gas incinerator	293625	7599703	35	0.42	624	13.2	0.1
	Acid gas thermal oxidiser	292967	7599142	35	0.42	624	13.2	0.05
Train 5	Compressor LM6000	292961	7598587	50	1.33	732	31	5.5
	Compressor LM6000	292976	7598583	50	1.33	732	31	5.5
	Compressor LM6000	292990	7598579	50	1.33	732	31	5.5
	Compressor LM6000	293005	7598575	50	1.33	732	31	5.5
	Compressor LM6000	293019	7598571	50	1.33	732	31	5.5
	Compressor LM6000	293034	7598567	50	1.33	732	31	5.5
	Compressor LM6000	293048	7598563	50	1.33	732	31	5.5
	Power Generator LM6000	292828	7598888	36	1.33	802	31.2	4.4
	Power Generator LM6000	292822	7598865	36	1.33	802	31.2	4.4
	Dry gas flare	292511	7598721	125	0.7	1273	20	0.31
	Wet gas flare	292511	7598721	125	0.7	1273	20	0.31
	Start up oil heater	292747	7598690	50	1.25	0	0	0
	Domgas acid gas incinerator	293719	7599678	35	0.42	624	13.2	0.1
	Acid gas thermal oxidiser	292850	7598704	35	0.42	624	13.2	0.05

Appendix Table 9: Emission parameters for Exxon sources.

Source Id	Easting	Northing	Stack Height (m)	Stack Radius (m)	Exit Temperature (K)	Exit Velocity (m/s)	NO_X (g/s)
Compressor LM6000	292881	7598387	28	1.3	772	23.1	3.49
Compressor LM6000	292896	7598383	28	1.3	772	23.1	3.49
Compressor LM6000	292910	7598379	28	1.3	772	23.1	3.49
Compressor LM6000	292925	7598375	28	1.3	772	23.1	3.49
Compressor LM6000	292939	7598371	28	1.3	772	23.1	3.49
Compressor LM6000	292954	7598367	28	1.3	772	23.1	3.49
Power Generation LM6000	292678	7598488	28	1.3	893	31.2	3.49
Power Generation LM6000	292672	7598465	28	1.3	893	31.2	2.58
Dry Gas Flare	292421	7598471	87	0.6	1273	20	0.22
Wet Gas Flare	292421	7598471	87	0.6	1273	20	0

Appendix Table 10: Emission parameters for Domgas sources.

Source Id	Easting	Northing	Stack Height (m)	Stack Radius (m)	Exit Temperature (K)	Exit Velocity (m/s)	NO_X (g/s)
Power Generator 1	292528	7598088	13	0.8	783	23.5	0.75
Power Generator 2	292522	7598065	13	0.8	783	23.5	0.75
Compressor 1	292801	7598187	13	0.8	633	16	0.75
Compressor 2	292816	7598183	13	0.8	633	16	0.75
Elevated Flare	292331	7598221	48	0.8	1273	20	0.77
Ground Flare	292331	7598221	20	0.8	1273	20	0.77

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