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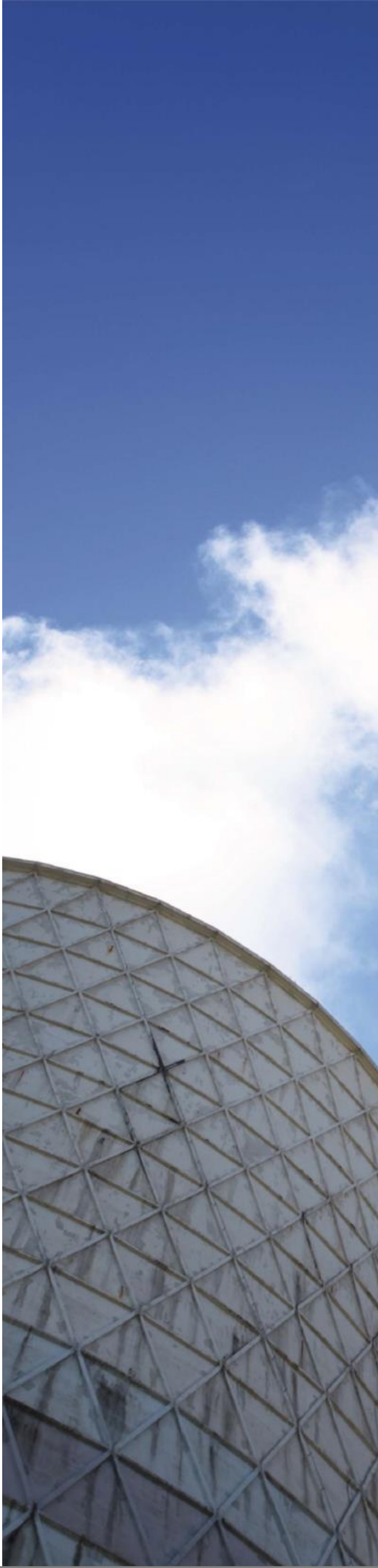

FINAL REPORT

(COMMERCIAL INFORMATION VERSION)

PILBARA STRATEGIC ENVIRONMENTAL ASSESSMENT – CUMULATIVE AIR QUALITY ASSESSMENT

BHP Billiton Iron Ore Pty Ltd

Job No: 8299

22 September 2015

PROJECT TITLE:	Pilbara Strategic Environmental Assessment – Cumulative Air Quality Assessment
JOB NUMBER:	8299
PREPARED FOR:	BHP Billiton Iron Ore Pty Ltd
APPROVED FOR RELEASE BY:	Jon Harper
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DOCUMENT CONTROL

VERSION	DATE	PREPARED BY	REVIEWED BY
A	16/10/2013	S. Lam	J. Harper
B	29/7/2014	L. Gowrisanker	J. Harper
C	8/9/2014	S. Lam, L. Gowrisanker, J. Villamizar	J. Harper & D. Tuxford
D	16/2/2014	S. Lam	J Villamizar
E	20/5/2015	D. Perez	S. Lam
F	25/8/2015	D. Perez, J. Villamizar	J. Harper
Rev0	3/9/2015	S. Lam	J Villamizar
Rev1	17/9/2015	S. Lam, J. Villamizar	J. Harper
Rev2 (Final)	22/9/2015	S. Lam, J. Villamizar	J. Harper

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EXECUTIVE SUMMARY

PROJECT DESCRIPTION

BHP Billiton Iron Ore has been developing mines and infrastructure within its Pilbara operations since 1968. The proposed future development activities include development of greenfield mines and infrastructure and expansion of brownfields mines and infrastructure, which are collectively referred to as the BHP Billiton Iron Ore Strategic Proposal (the Proposal).

A strategic approach to assessment of the Proposal has the following key advantages:

- environmental approval certainty;
- simplification of environmental compliance; and
- optimal environmental outcomes.

This report outlines the methodology for predictive modelling of dust impacts associated with the long term development of mining operations in the Pilbara region (i.e. Highest Use Scenario).

Modelling of current and proposed future operations was undertaken as part of this assessment. Modelling of cumulative emissions has demonstrated the potential impact of the BHP Billiton Iron Ore operations operating both with and without dust control measures in place.

OVERVIEW OF THE ASSESSMENT

Air quality criteria provide the framework to assess the effects of existing and predicted emissions on human health, amenity and the environment. The criteria used for the study have been derived from a number of references with preferential selection of criteria consistent with the hierarchy used by the Department of Environment Regulation and the Environmental Protection Authority.

Air quality impacts from operations have been modelled using the CALPUFF model. CALPUFF has been configured using meteorological parameters sources from the Weather Research Forecast model (WRF) and validated with measured data.

The dust modelling used the following key assumptions:

- estimated emissions and source characteristics are based on previous BHP Billiton Iron Ore site specific air quality assessments;
- dust generated from the mining activities is modelled as an constant rate area source based on the latest disturbance footprint; and

The greenhouse gas emissions were calculated using an average fuel use per tonne of material moved for existing BHP Billiton Iron Ore operations. This weighted average combined with the tonnage of material moved for future operations was used to calculate the greenhouse gas emissions.

KEY FINDINGS OF THE ASSESSMENT

Emission estimation for the Proposal indicates that:

- PM_{10} and TSP are proportional to the total tonnage of mining operations. Ratios of 168 (No Control), 91 (Standard Controls) and 29 (Leading Controls) were obtained for the PM_{10} emissions (tonne/year) to the total tonnage for BHP Billiton Iron Ore mining operations for this study. That means for every million tonne per annum (Mtpa) mined (ore and waste); 168, 91 and 29 tonnes of PM_{10} will be generated for No Control, Standard Control and Leading Control scenarios respectively.

- Greenhouse gas assessment was carried out for the Highest Use scenario (i.e. mine and rail for BHP Billiton Iron Ore 'Alternative 3A' mine plan with current operations). The worst case scenario accounted for 0.8% of the national greenhouse gas level (including Land Use, Land Use Change and Forestry (LULUCF)) and 6.2% of Western Australia levels (including LULUCF).

It is worth noting that the modelling results for the Proposal are indicative of the potential impacts from the proposed development in a regional context. This conceptual model includes both BHP Billiton Iron Ore operations and other third party operations across the 100 year development timeframe. Individual projects within the assessed area are defined on a "typical" or indicative basis to accommodate the absence of certainty around specific project definition. Therefore, the results from this study are not accurate predictions of air quality impacts but can be used as an indicator for prioritising dust mitigation strategy in the Pilbara Region. It is noted that BHP Billiton Iron Ore has a long history of implementing dust mitigation measures to minimise impacts at sensitive receptors. Modelling of the strategic development indicates that:

- Without any dust control, the dust levels (PM_{10} and TSP) may exceed relevant guidelines at sensitive receptors.
- Without any dust control, there is generally a medium to low risk for visibility reduction along sections of the Great Northern Highway between Cloudbreak and Davidsons Creek.
- To reduce the impact to the air quality and to meet assessment criteria selected for this study, it is essential for BHP Billiton Iron Ore to implement dust controls at all mines in the Pilbara Region.
- This study provides an indication of higher risk locations that may require an increased focus on dust controls in the future.

The conceptual model indicates that implementation of a combination of Standard and Leading Practice controls should be considered at all mines in the Pilbara Region to achieve:

- 50% control for loading of ore and waste into trucks (accounting for use of water truck during operations of Front End Loader/Truck and the use of fogging sprays).
- 95% control for stockpiles exposed to wind erosion by using water trucks.
- 90% control (accounting for the use of chemical binding agents) for haul roads.

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Glossary

Term	Definition
Asset	A specific component of the biophysical environment which supports one or more environmental and/or social values. Examples include the Karijini National Park and Fortescue Marsh.
Assessment boundary	Refer to 'region'
Attribute	Quantifiable components that can be monitored, measured or assessed directly. Attributes contribute to environmental or social values. Examples of attributes include the abundance of a species and diversity of a population.
Conceptual modelling	A type of diagram which shows of a set of relationships between factors within a system.
Derived Proposal	A derived proposal is a future proposal which was identified in the strategic proposal, which has been referred to and considered by the EPA, and which is then declared to be a derived proposal.
Environmental Scoping Document	The document that presents the proposed studies and investigations to be carried out as part of the preparation for the SPEA. The results of the studies and investigations outlined in the ESD will be presented in PERSP.
Landscape	A spatially heterogeneous area, scaled relative to the process of interest. Within landscapes it is usually possible to define a series of different ecosystems, landforms, habitats and natural or man-made features.
Leading practice	Flexible and innovative approaches to developing and implementing environmental management solutions that match site-specific requirements.
Operational hub	A location of mining activities on BHP Billiton Iron Ore tenure. The operational hub may contain one or more processing hubs within it, depending on the mining strategy.
Operations	Collective term for operational hubs
Predictive modelling	A statistical technique used to expand on existing data and predict a greater spatial extent and future states.
Processing hub	A location within a BHP Billiton Iron Ore operational hub, where mined ore is processed, stockpiled and loaded for transport. Typically comprised of crushers, ore handling plant/s, stockyard/s, train loadout and/or conveyors.
Regional scale	At the scale of the region (refer to definition for 'region').
Region	The range, area or scope relevant to a specific asset, value or factor of interest. In the SPEA, the region will vary according to the asset, value or factor being examined, and may include ecohydrogeological boundaries, ecological assets, IBRA regions, species distributions, catchments, watersheds, air sheds.
Strategic Proposal	The proposal for future developments.

1 INTRODUCTION

BHP Billiton Iron Ore has been developing mines and infrastructure within its Pilbara operations since 1968 and proposes to continue to do so. The proposed future development activities include development of greenfield mines and infrastructure and expansion of brownfields mines and infrastructure, which are collectively referred to as the BHP Billiton Iron Ore Public Environmental Review Strategic Proposal (the Proposal).

A strategic approach to assessment of the Proposal has the following key advantages:

- environmental approval certainty;
- simplification of environmental compliance; and
- optimal environmental outcomes.

A cumulative impact assessment of air quality is required to provide indicative or conceptual air quality impacts (pre and post mitigation), on sensitive receptors.

1.1 Project Description

The Proposal is defined as all proposed mining and associated infrastructure development activities in the Pilbara. Subject to express exclusions, the Proposal includes all greenfields mine development, involving resources in which BHP Billiton Iron Ore currently has an interest or may acquire an interest in in the future, and brownfields development of existing assets. An indicative and non-exhaustive depiction of the likely hub configuration in respect to currently known resources is presented in Figure 1-1. The location of mining operations may change in the future, for example, in response to newly identified resources as a result of technology advances or to avoid potential environmental impacts.

Detailed engineering has not yet been undertaken for all of the elements of the Proposal. Elements of the Proposal will include infrastructure typically used in Pilbara iron ore operations including crushers, conveyors, ore-handling and screening plants, stockpiles and train load-out facilities, rail loops, workshops, warehousing, concrete batching plants, administration facilities, refuelling facilities, laydown and storage areas, power and water distribution infrastructure, waste disposal, wastewater treatment, dangerous goods and hazardous materials storage facilities, water treatment facilities and surface water management infrastructure. Beneficiation facilities with associated tailings dams may also be proposed for some operations. Road and rail networks to access these operations and allow the transportation of ore will also be required.

The Proposal also includes supporting infrastructure related to these operations including, but not limited to rail spurs, conveyors, worker accommodation, water and gas pipelines, powerlines, access roads, telecommunications, airports or helipads and water bores.

The alignments of rail corridors as shown in Figure 1-1 are conceptual only, and may change in the future in response to resource knowledge, processing design and size of plants, commercial agreements with other parties, and/or technology change. A conceptual rail spur linking the proposed Rocklea operations to BHP Billiton Iron Ore's rail network (existing or proposed) has not been identified. Development of any future rail corridors will seek to avoid impacts on areas of high environmental value and conservation estate.

The Proposal also encompasses potential capacity upgrades of the Newman to Port Hedland rail line, from the Newman mining hub to the 26 km chainage mark near Port Hedland. This mark represents the boundary of the proposed BHP Billiton Iron Ore Outer Harbour development rail spur (the Western rail spur) connection to the Newman to Port Hedland mainline (approved in Ministerial Statement 890). Collectively, these operations and associated infrastructure broadly define the scope of the Proposal being considered for the SEA.

No specific timeframe applies to the Proposal. It is anticipated that operations will be progressively developed over the next 100 years.

The SEA is defined at a regional scale. Individual projects within the assessed area are defined on a "typical" or indicative basis to accommodate the absence of certainty around specific project definition. The conceptual model developed to represent the potential air quality impacts at the regional scale includes both BHP Billiton Iron Ore operations and other third party operations across the 100 year development timeframe.

1.2 Strategic Assessment/Approval Process

The SEA comprises of the Strategic Proposal and Strategic Assessment, which are being undertaken under State and Commonwealth environmental legislation respectively.

For the State environmental assessment process, BHP Billiton Iron Ore will submit a Strategic Proposal to the Environmental Protection Authority (EPA) for formal environmental impact assessment under the *Environmental Protection Act 1986*. The Strategic Proposal considers the environmental impacts and issues at a regional scale and provides regional management strategies for the Proposal.

Any future developments proposed to be undertaken within the scope of the Strategic Proposal are referred to the EPA along with a request that it be declared a Derived Proposal. This provides a step where additional information may be presented to the EPA where required to support the Derived Proposal declaration.

The Commonwealth assessment process under Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* is conducted in parallel under a Strategic Assessment process; however the assessment is limited to Matters of National Environmental Significance.

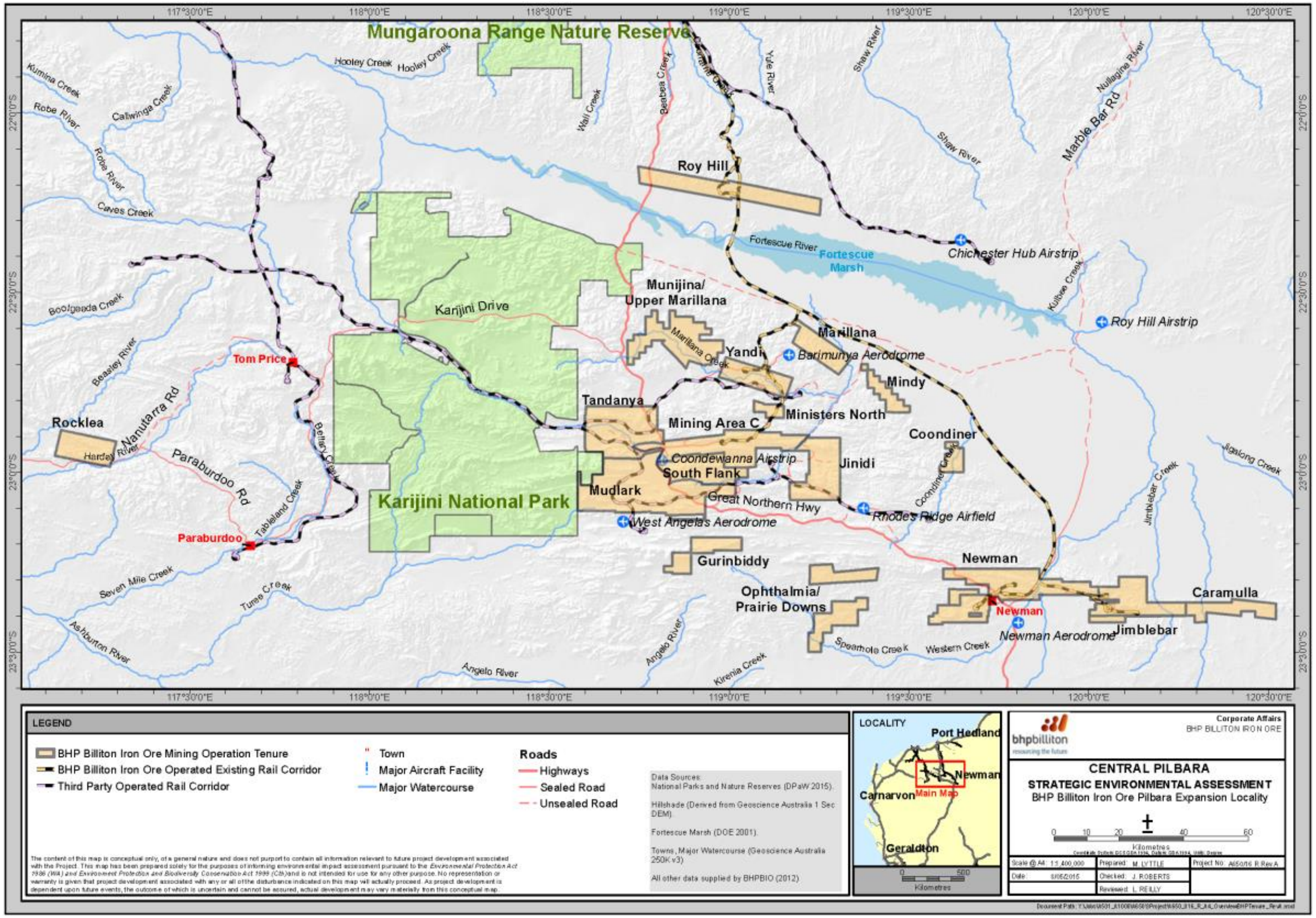

Figure 1-1: Regional Context – Strategic Environmental Assessment Conceptual Operation Locations (BHP Billiton Iron Ore, 2015)

1.3 Objectives and Scope of the Study

Pacific Environment Limited was commissioned by BHP Billiton Iron Ore to undertake an air quality assessment to support the strategic environmental assessment. The scope of work included:

- Developing a base model for the region, using CALPUFF. This includes identifying and validating the representative model year, emissions estimation of sources within the study area based on determining an emission rate for the operation, and modelling of the emission sources for a pre-determined set of scenarios.
- Interpretation of the modelling results in the context of cumulative impacts on a regional scale, for BHP Billiton Iron Ore future operations (both with and without dust mitigation measures in place).
- Assessment of the modelling results (for each scenario) in terms of potential impact and comparison to the assessment criteria at agreed sensitive receptor locations to determine the acceptability of the predicted impacted.

Dust is the main pollutant assessed in this study and incorporates the following:

- Total Suspended Particulate (TSP) – refers to the total amount of the PM suspended in air (regardless of size). Particles in air are subject to gravitational settling; particles larger than about 30 µm in aerodynamic diameter 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). These larger particles are primarily associated with amenity or visibility issues.
- PM_{10} refers to the total of suspended particulate matter less than 10 µm in aerodynamic diameter. Particles in this size range can enter bronchial and pulmonary regions of the respiratory tract and can impact human health. Particles in this size range can remain suspended for many days in the atmosphere.
- Visibility – relates to the reduction in visual distance due to suspended particle light scattering.

In addition to this the greenhouse gas emissions associated with the BHP Billiton Iron Ore operations were also estimated for comparison purposes.

1.4 Structure of this Report

This report outlines the methodology for conducting the air quality cumulative impact assessment to support the Strategic Proposal (Section 2). The report also presents the results of emission estimation (Section 6), model configuration and validation (Section 7, Appendix B and Appendix C), model results (Section 8) along with conclusions of the modelling study (Section 9).

2 STUDY APPROACH AND METHODOLOGY

An overview of the study approach and methodologies applied is summarised here.

The intent of the assessment is to determine the potential impacts of the Proposal at a regional scale. It accommodates consideration of projects in a 'typical' state of definition rather than specific detail on the basis that specific details are not reliably defined at this stage of the process. The projects incorporated into the Proposal are identified here, including the emission estimation framework applied. The context of historical modelling (project specific basis) is also discussed, along with the approach applied for developing the new model suitable so that it represents the potential impacts at the regional scale as required for the strategic proposal.

2.1 Study Area

The conceptual locations and regional setting of the study area is highlighted in Figure 1-1. Current operations, 30% Development and Highest Use scenario have been identified for the purposes of emission estimation and inclusion in the dispersion modelling. The disturbance areas for these scenarios are shown in Figure 2-1, Figure 2-2 and Figure 2-3 (BHP Billiton Iron Ore, 2015). It is worth noting that the content of these figures is conceptual only, of a general nature and does not purport to contain all information relevant to future project development in Pilbara region. The figures have been prepared solely for the purposes of informing environmental impact assessment pursuant to the *Environmental Protection Act* 1986 (WA) and *Environment Protection and Biodiversity Conservation Act* 1999 (Cwlth) and are not intended for use for any other purpose. No representation or warranty is given that project development associated with any or all of the disturbance indicated on these figures will actually proceed. As project development is dependent upon future events, the outcome of which is uncertain and cannot be assured, actual development may vary materially from these conceptual maps.

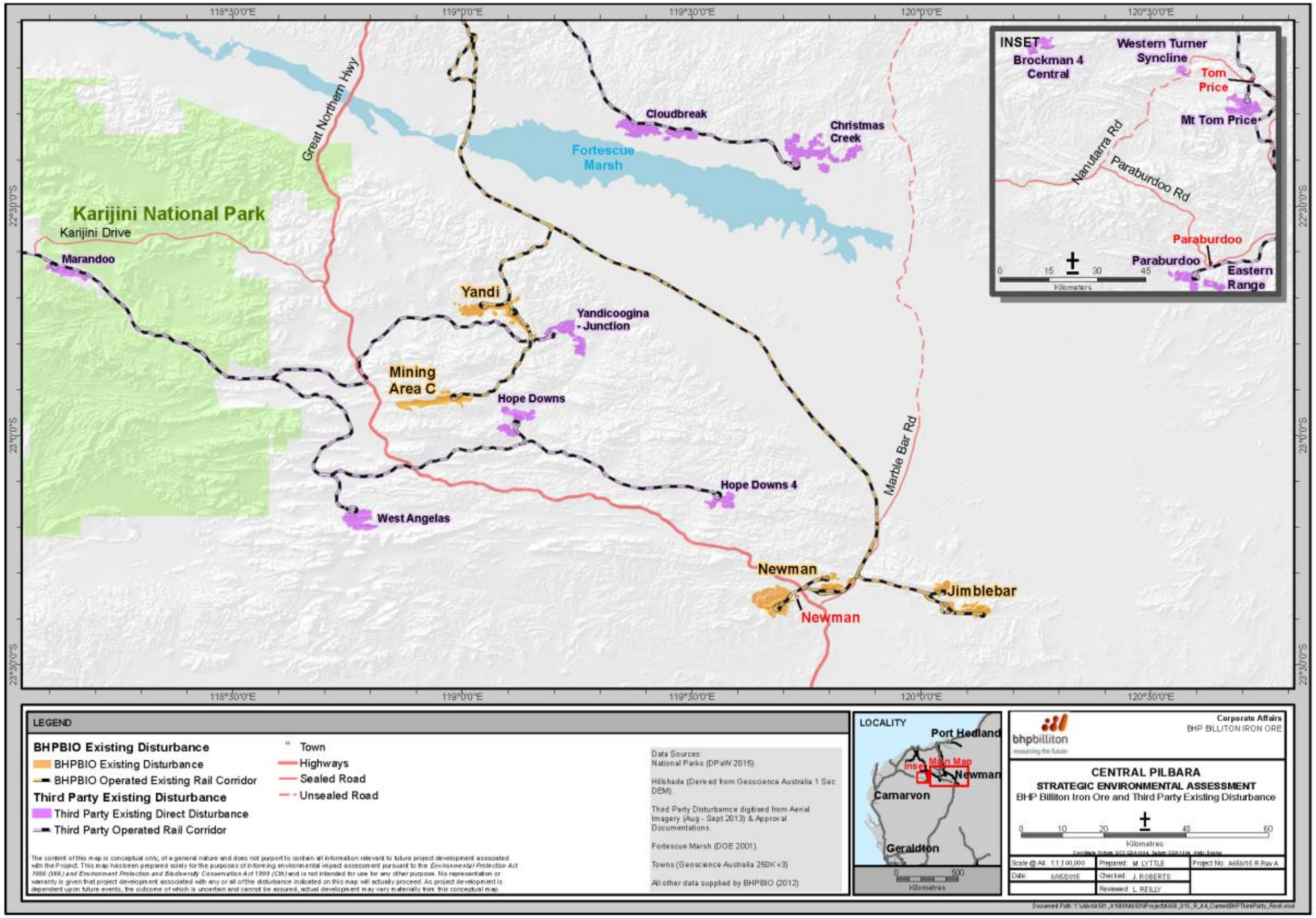

Figure 2-1: BHP Billiton Iron Ore and Third Party disturbance areas – Current operations scenario

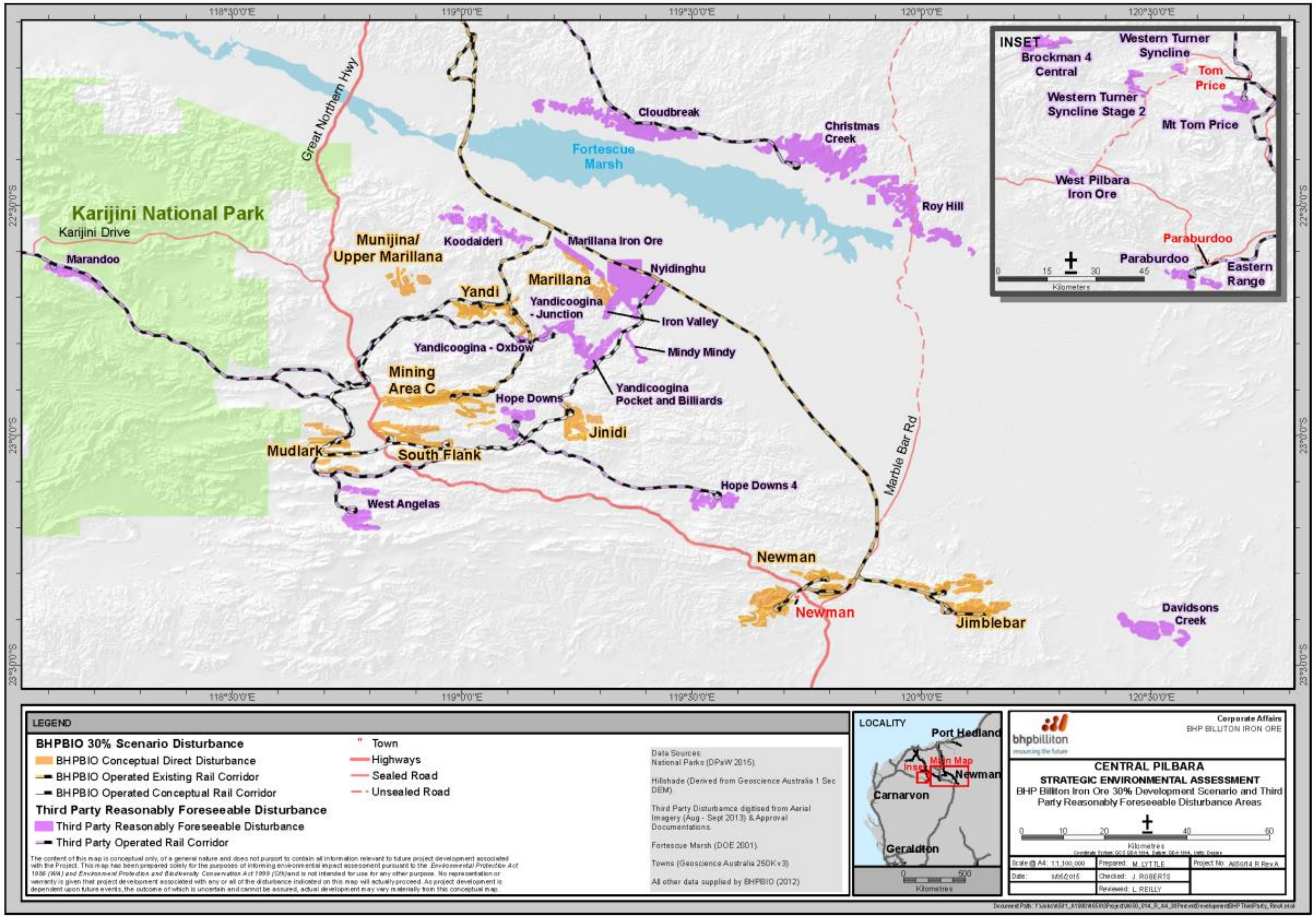

Figure 2-2: BHP Billiton Iron Ore and Third Party disturbance areas – 30% Development scenario

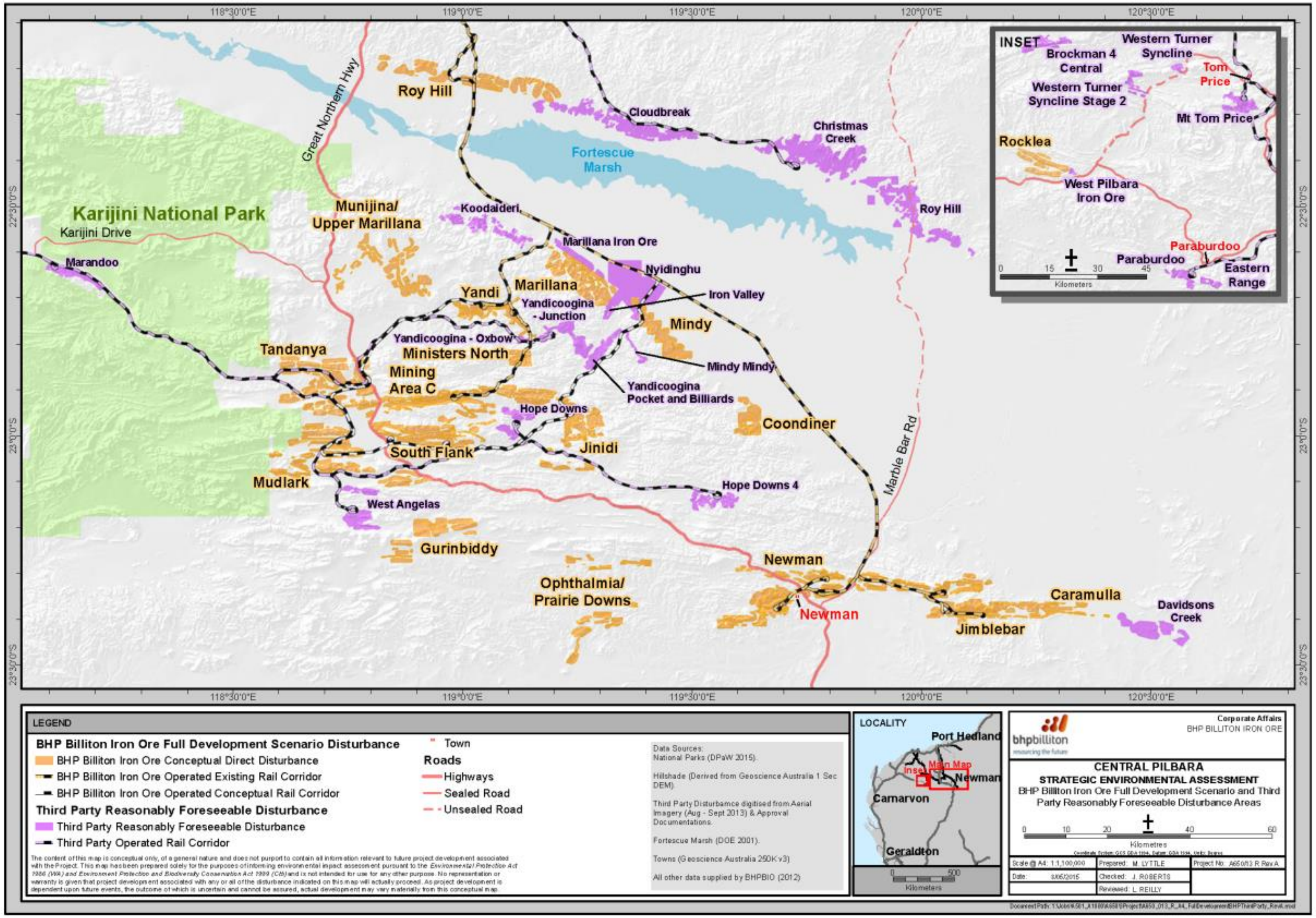

Figure 2-3: BHP Billiton Iron Ore and Third Party disturbance areas – Highest Use scenario

2.1.1 BHP Billiton Iron Ore Operations

BHP Billiton Iron Ore (related) operations identified for inclusion in the SEA are listed in Table 2-1 along with the relevant mine tonnages (ore and waste) adopted for the three scenarios.

Table 2-1: BHP Billiton Iron Ore operations included in the assessment (BHP Billiton Iron Ore, 2014)

Operational Hub	Processing Hub	Tonnage (ore and waste) (Mtpa)		
		Current	30% Development	Highest Use
Existing Operations				
Newman	Orebody 18 (OB18)	24	90	90
	Eastern Ridge (incl. Orebody 23/24/25)	35	90	90
	Whaleback (incl. Orebody 29/30/35)	104	90	90
Jimblebar	Jimblebar West		90	90
	Jimblebar East	13	90	90
Mining Area C	Mining Area C	115	90	90
Yandi	Yandi West (OHP 2 and 3)	49	90	90
	Yandi East (OHP 1)	49	90	90
Future Operations				
Roy Hill	Roy Hill			90
Tandanya	Tandanya			90
Mudlark	Mudlark		90	90
South Flank	South Flank		90	90
Ophthalmia/Prairie Downs	Ophthalmia/Prairie Downs			90
Gurinbiddy	Gurinbiddy			90
Mindy	Mindy			90
Marillana	Marillana		90	90
Coondiner	Coondiner			90
Caramulla	Caramulla			90
Minister's North	Minister's North			90
Munjina / Upper Marillana	Munjina / Upper Marillana		90	90
Packsaddle East	Packsaddle East			90
Jinidi	Jinidi		90	90

2.1.2 Third Party

Related third party operations, i.e. Rio Tinto Iron Ore (RTIO), Fortescue Metals Group Limited (FMG) and others, included in the strategic assessment are listed along with the relevant mine tonnage adopted in the study (Table 2-2).

Table 2-2: Third Party operations included in the assessment

Operation	Proponents	Tonnage (Mtpa) Current [a]	Tonnage (Mtpa) 30% Development and Highest Use [b]	Comment
Yandicoogina	RTIO	52		Commenced in 1998
▪ **SW Oxbow**			26	
▪ **SE**			16	
West Angelas	RTIO	29.5	40	Commenced in 2002
Hope Downs 4	RTIO	22	30	
Marandoo	RTIO	15	16	Commenced in 1994
Koodaideri	RTIO	-	70	Production planned for 2016 with ~30 year life of mine
Hope Downs 1	RTIO	-	30	
Christmas Creek	FMG	40	50	Commenced in May 2009
Cloudbreak	FMG	40	50	Commenced in May 2008
Mindy Mindy	FMG	-	45	
Nyidinghu	FMG	-	40	Expect to commence 2018
Davidsons Creek	Atlas Iron	-	15	
Marillana	Brockman Resources	-	19	~ 20 Mtpa with around 20 year life of mine
Iron Valley	Iron Ore Holding Ltd	-	5	
Phils Creek	Mineral Resources	-	2	7 Mt total, life of mine ~5 years
Roy Hill	Roy Hill	-	65	Expected to commence from 2015 for 20 years

Note: [a] Data for 2010
[b] Tonnage data sourced from publicly available documents

2.2 Emission Estimation for Sources

In the context of an air quality assessment the emission rates and sources for existing and future operations are defined using a 'typical' definition of the activity and application of a consistent estimation method across all sites. This will allow improved efficiency for new development in the region. To account for the regional setting, and the spatial requirements of the modelling, the emissions for each existing and proposed mine are determined using a general approach. This approach references the published National Pollutant Inventory (NPI) data for existing iron ore mines in the Pilbara region.

The emission estimation process or development of an emission inventory is described in detail in Section 6.

2.3 Meteorology

Meteorology is a critical component and input to a regional dispersion model. Meteorology of the region was characterised by analysing measurements from on-site and nearby weather data recorded by BHP Billiton Iron Ore and the Bureau of Meteorology. Recorded wind speed and direction, temperature, humidity, rainfall and evaporation data were analysed and described in detail in Section 4.

2.4 Dispersion Model – Prediction of Impacts

To better reflect the likely air quality conditions of the study area, a model for the Proposal has been created, using CAPLFUFF (California Puff model) (refer to Section 5).

To account for the regional setting, and the spatial requirements of the modelling, the emissions from individual sources for each existing and proposed mine are not calculated separately, instead being determined using a generic approach. This approach uses the published National Pollutant Inventory (NPI) data for existing iron ore mines; and is correlated with the historical site specific estimated emissions for BHP Billiton Iron Ore in the Pilbara region to project emissions for future operations. The emission sources are defined as constant-rate area sources for the whole site based on the latest disturbance area as provided by BHP Billiton Iron Ore.

2.4.1 Model Configuration

The model configurations determined through the emissions estimation process and meteorological analysis were entered into the CALPUFF dispersion model, in conjunction with terrain and land-use data for the region.

Scenarios representing various development stages were modelled, specifically:

- Existing BHP Billiton Iron Ore operations with dust control
- Existing third party operations
- Proposed 30% Development/ Highest Use BHP Billiton Iron Ore operations with no control, standard dust control and leading dust controls
- Proposed 30% Development/ Highest Use third party operations with standard controls
- Cumulative Operations (Third Parties and BHP Billiton Iron Ore operations without dust control)
- Cumulative (Third Parties and BHP Billiton Iron Ore operations with dust control)

2.4.1 Interpretation of Model Results

The model results (for each scenario) were analysed and interpreted by comparison to the pre-determined ambient air quality assessment criteria. Results are presented both in terms of statistics and as concentration contours.

3 AIR QUALITY ASSESSMENT FRAMEWORK

This assessment has considered the emissions to air in the form of particles (or dust), and greenhouse gases. To assess the relative impact or significance of the emissions, comparison is made to appropriate assessment criteria. Environmental standards, guidelines and criteria from Australia and abroad were evaluated for relevance to this assessment. Particular consideration is given to assessing the potential impact on human health, amenity and the environment.

3.1 Criteria for Assessing Impacts

Precedence was given to the criteria listed in the current National Environment Protection Measure for Ambient Air Quality (Air NEPM) (NEPC, 1997) and the Kwinana Environmental Protection Policy (EPP) (EPA WA, 1999)

3.1.1 National Environmental Protection Measure for Ambient Air Quality (Human Health and Amenity)

The National Environment Protection measure (NEPM) for Ambient Air Quality provides a set of ambient air standards that are designed to protect human health and wellbeing. In Western Australia, this criterion is applied to sensitive receptors, defined as residences, hospitals, school and other places where people may congregate including sporting and recreational venues. In addition, the Port Hedland Industries Council Taskforce guideline is reference for indication only in this assessment (DSD, 2010). These PM_{10} guidelines (shown in Table 3-1) will therefore be referenced in this assessment.

Table 3-1: Ambient PM_{10} Criteria to be used in the Assessment

Substance	Guideline (µg/m³) [a]	Averaging Period	Maximum allowable exceedances per year [b]
PM_{10}	50	24-hour	5 allowed exceedances.
PM_{10}	70[c]	24-hour	10 allowed exceedances

a. At Standard Temperature and Pressure – 0 °C, 1 atm.
b. In the airshed from all sources.
c. For reference only

3.1.2 Environmental Protection (Kwinana) (Atmospheric Wastes) Policy and Regulations (Human Health and Amenity)

In Western Australia, the main criterion used to assess TSP comes from the Environmental Protection (Kwinana) (Atmospheric Wastes) Policy and associated regulations (Kwinana EPP). The Kwinana EPP specifies three different zones; Area A, B and C. These areas represent industrial zoning (A), buffer zoning (B), and the zone outside Area A and B (C) (EPA, 1999). Typically, the Mining Area C criteria shown in Table 3-2) are applied at sensitive receptor locations. The Mining Area C criteria for TSP will therefore be referenced in this assessment.

Table 3-2: Ambient TSP Criteria to be used in the Assessment

Substance	Standard (µg/m³) [a]	Limit (µg/m³)	Averaging Period	Maximum allowable exceedances per year [b]
TSP	90	150	24-hour	

d. At Standard Temperature and Pressure – 0 °C, 1 atm.
e. In the airshed from all sources.

3.1.3 Visual Assessment (Visual Distance Lost)

The Victoria EPA has adopted a one-hour standard for visibility-reducing particles (minimum visual distance in dry air), being 20 km (EPA VIC, 1999). The New South Wales Department of Environment and Heritage (OEH) adopts visibility as a measure indicating the presence of fine particles (haze) (OEH, 2014). The method of measure is based on determining the amount of light scattering by the fine particles. The greater the concentration of particles, leads to the greater the extent of light scattering and the higher the visibility reading (in units of 10^{-4} m^{-1}). A high visibility reading indicates lower visibility in the atmosphere due to light scattering. The OEH one-hour visibility goal of 2.1 10^{-4} m^{-1}, corresponds to a visual distance of approximately 9 km.

3.2 Criteria for Assessing Greenhouse Gas Emissions

Federal parliament passed the *National Greenhouse and Energy Reporting Act 2007* (NGER Act) in September 2007. The *NGER Act* establishes a mandatory obligation on corporations which exceed the defined thresholds to report greenhouse gas emissions, energy consumption, energy production and other related information (DCCEE, 2014).

The NGER Act is one of a number of legislative instruments related to greenhouse reporting, which together form the National Greenhouse and Energy Reporting (NGER) System, this being:

- The National Greenhouse and Energy Reporting Regulations 2008 (DCC, 2008), which provides the necessary details that allow compliance with, and administration of, the NGER Act.
- The National Greenhouse and Energy Reporting System Measurement 2014 (DCCEE, 2014), which provides methods and criteria for calculating greenhouse gas emissions and energy data under the NGER Act**.**
- The National Greenhouse and Energy Reporting (Audit) Determination 2009 (DCCEE, 2009a), which sets out the requirements for preparing, conducting and reporting on greenhouse and energy audits.

The NGER Act is seen as an important first step in the establishment of a domestic emissions trading scheme. This intention is explicitly stated in the objectives for the NGER Act, as follows:

- establish a baseline of emissions for participants in a future Australian emissions trading scheme;
- inform the Australian public;
- meet international reporting obligations; and
- assist policy formulation of all Australian governments while avoiding duplication of similar reporting requirements.

The GHGs evaluated in this study are carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4). As the effects of greenhouse gases are assessed at a global scale, the use of dispersion modelling does not provide useful analysis. Greenhouse gas emissions are therefore considered in terms of total emissions produced, using the methodology consistent with the NGER System framework requirements.

The NGER framework requires the reporting of 'direct GHG emissions' (Scope 1) and 'indirect GHG emissions due to energy product use' (Scope 2). Another category of greenhouse gas emissions recognised internationally is 'other indirect GHG emissions' (Scope 3). These categories are summarised in Table 3-3. GHGs from the combustion of fuel (Scope 1) and Scope 2 emissions associated with electricity consumption have been included in this study.

Table 3-3: Scope of GHG Emission Calculations

Scope	Description	Treatment in study
Scope 1: Direct greenhouse gas emissions	GHGs emitted from sources owned or controlled by the reporting entity. Principally result from fuel combustion.	Associated with diesel combustion. Emissions calculated in study.
Scope 2: Energy product use	Indirect GHG emissions from the generation of purchased energy products by the entity. Scope 2 emissions occur at the facility that generates the electricity, rather than the facility that uses the electricity.	Associated with energy demand. Emissions calculated in study.
Scope 3: Other indirect greenhouse gas emissions	GHG emissions that are a consequence of the activities of an entity, but which arise from sources not owned or controlled by that entity (e.g. extraction and production of purchased materials, transportation of purchased fuels, and use of sold products and services).	Not calculated in this study on the basis that Scope 3 emissions were not part of the Scope of Work.

With reference to the guidance provided by EPA WA (2002), the GHGs from the combustion of fuel have been included in this assessment. This is to provide a reflective estimate of the greenhouse gas emissions from the proposed future operations in the Environmental Review Document for the Strategic Proposal. Measures to minimise greenhouse gas emissions are detailed in this report.

3.3 Summary of Emissions Assessed and Assessment Criteria

The emissions quantified, modelled and reported are summarised in Table 3-4.

Table 3-4: Summary of Substances Quantified, Modelled and Reported

Substance	Quantified	Modelled
Particulate Matter		
TSP	√	√
PM_{10}	√	√
Greenhouse Gases		
CO_{2-e}	√ (Scope 1 & 2)	No

4 CLIMATE, METEOROLOGY AND AMBIENT AIR QUALITY

This section provides a contextual summary of the existing environmental aspects relevant to the air quality assessment. It includes consideration of topography, land use (including sensitive receptors), meteorology, and existing (background) ambient air quality in the vicinity of the study area.

The climate and meteorological characteristics of the region control the dispersion, transformation and removal (or deposition) of pollutants from the atmosphere (i.e. ambient air quality). For the purposes of understanding the local climatology, an 11 year data set of meteorological parameters recorded in the region to determine the most representative model year for general conditions at the Pilbara Region (ie. meteorological conditions and background air quality). The most recent 11 years of historical (meteorological) surface observations at the Wittenoom and Newman Airport Bureau of Meteorology sites (2001 to 2012, inclusive) were reviewed. Wind speed, ambient temperature and relative humidity were compared to the long term averages for the region to determine the most representative year. The meteorological conditions indicate the most representative year in terms of wind speed, wind direction and rainfall was considered to be 2009 followed by 2010. However, based on data availability and recorded annual average concentrations, the year 2010 was selected as the most representative year for meteorological and background air quality conditions for the Pilbara region and included in the model.

4.1 Climate of the Pilbara Region

The climate in the Pilbara region is arid to tropical characterised by high temperatures, high evaporation rates, occasional intense rainfall and regular cyclonic activity. There are two major seasons: hot summers (October to April) when the majority of rainfall occurs; and mild, relatively dry winters (May to September). The weather is largely controlled by the seasonal oscillation of an anti-cyclonic belt (high-pressure system) in the sub-tropics.

The three specific weather phenomena that are of greatest importance to the Pilbara region are:

- tropical cyclones frequently accompanied by damaging winds, storm surge and flooding
- strong easterly winds in the winter caused by the development and intensification of anti-cyclones over southern Western Australia or South Australia
- major cloud bands that develop in winter and extend from the north-west coast, across the continent, bringing rain to the north-west and the interior of the continent.

The study area is approximately 300 km south of Port Hedland (Figure 1-1). With the assessment area being located in the Pilbara Region, it is likely to be affected by dispersion characteristics typical of an inland environment, including:

- Unstable (or convective) atmospheric conditions in daytime.
- Stable atmospheric conditions dominating at night and in the early morning hours.

The projections for future climate of the Pilbara region generally predict a hotter and drier climate (Loechel, Hodgkinson, & Moffat, 2011). The climate models suggest a greater degree of uncertainty for future rainfall trends in the region. The Pilbara region is already notorious for its hot conditions; the temperature trends suggest an even more difficult environment in future. In addition, increased evapotranspiration and reduced rainfall, in a context of continued industry and population growth, can be expected to put additional stress on the water resources available. In addition, it is also projected that the severity of extreme weather events or storms could increase, including an increase in the strength of tropical cyclones impacting the Pilbara region. An increase in tropical cyclone intensity not only increases the degree of destruction at the centre of the cyclone but also the geographic area over which the cyclonic winds and flooding rains impact.

The semi-arid nature of the Pilbara lends itself to being a naturally dusty environment. Wind-blown dust is expected to be a significant contributor to the ambient dust levels in the area.

4.2 Review of Meteorological Data

The data collected from the Wittenoom and Newman Airport climate monitoring stations (BOM, 2013) were used to describe the prevailing meteorological conditions in the study area.

Meteorological data obtained included average hourly wind speed, wind direction and temperature, rainfall and humidity. The analysis of the data included wind roses, diurnal temperature profiles, and atmospheric stability classifications. This data analysis provides a general description and understanding of the local climate and supports the emission estimations and dispersion model set-up. Analysis of meteorological data is also used in the analysis to identify or determine a representative year for dispersion modelling (see Appendix A).

4.2.1 Wind Speed and Wind Direction

The seasonal wind roses for Newman Airport, as recorded at the Bureau of Meteorology location (2001–2012) are presented in Figure 4-1 to Figure 4-4. Wind speed and wind direction are not available at the Wittenoom monitoring station. Collectively these figures show that the dominant annual wind directions are north-westerly during the summer months and south-easterly during the winter months. Spring also shows high north-westerly dominance, driven by land-sea temperature differences in the lead up to the summer months. The distinct seasonal pattern of westerly/north-westerly winds in summer and south-easterly winds in winter is consistent, albeit with some variations from year to year.

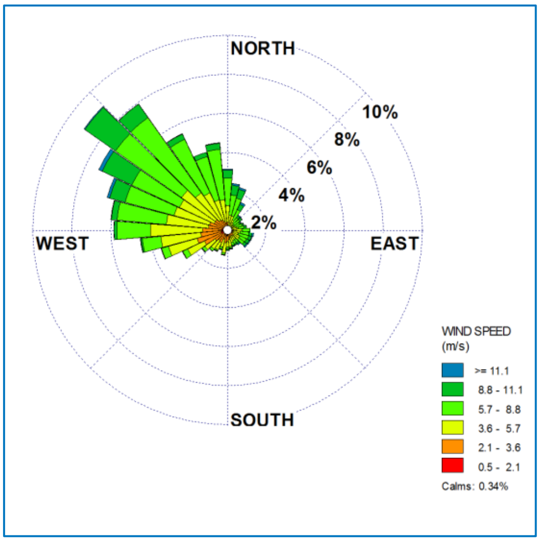

Figure 4-1: Summer wind rose (2001-2012)

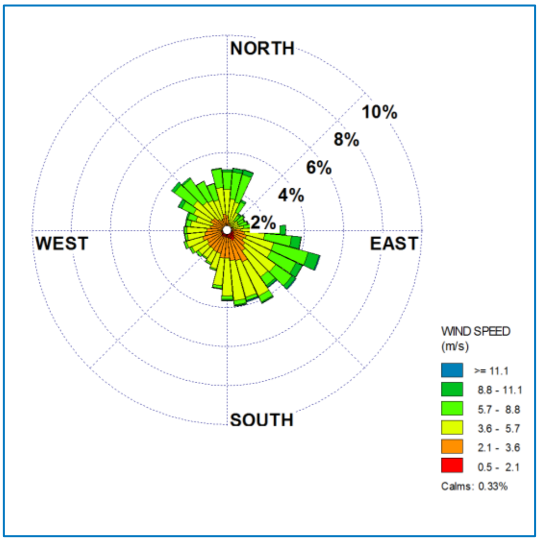

Figure 4-2: Autumn wind rose (2001-2012)

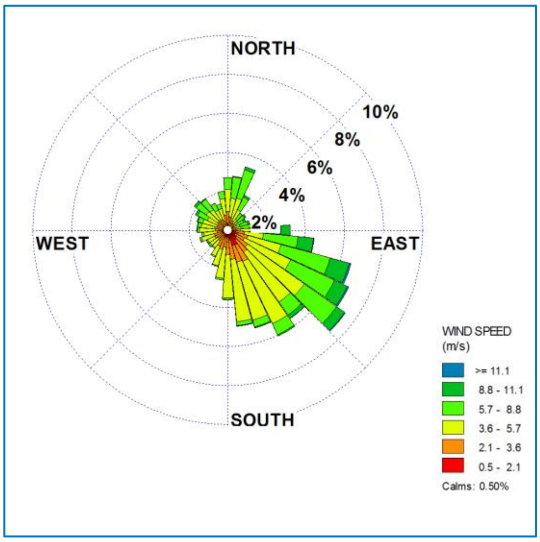

Figure 4-3: Winter wind rose (2001-2012)

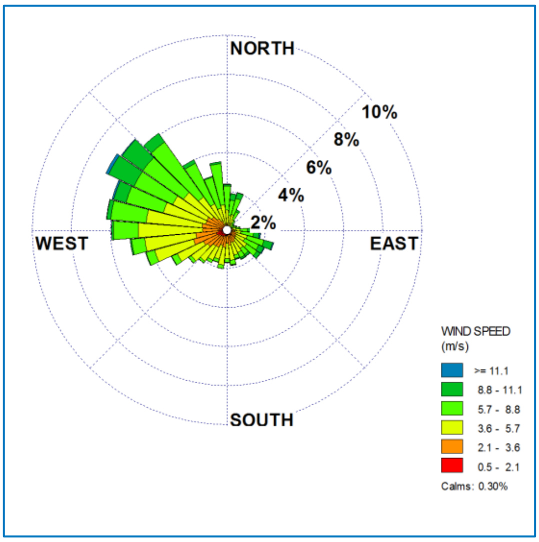

Figure 4-4: Spring wind rose (2001-2012)

Note: Date sourced from Bureau of Meteorology, Newman, (BoM, 2013).

Further analysis of wind speeds was undertaken to identify a year that is representative of the long term (15-year mean) average conditions. This analysis was undertaken using the Mann-Whitney U-test (described in detail in Appendix A). The analysis identified years 1998, 2008, 2009 and 2010 as being representative of the 15-year mean wind conditions.

4.2.2 Rainfall

Rainfall, in the context of dispersion modelling, is important for understanding the likelihood of natural dust suppression occurring.

Rainfall in the region is highly variable and predominantly limited to the summer and autumn months with very little rainfall occurring between winter and spring. Most rain occurs in the space of a few days (less than 5 days) per month, consistent with the infrequent (but climatically significant) cyclonic and storm events of the region. Rainfall statistics are illustrated in Figure 4-5 (Wittenoom) and Figure 4-6 (Newman). The figures show the mean rainfall and average days of rain per month measured between 1950 and 1971 to 2013, respectively (BoM, 2013). The significant differences between the mean rainfall and the maximum recorded rainfall in each month are due to the impact of tropical depressions in the region.

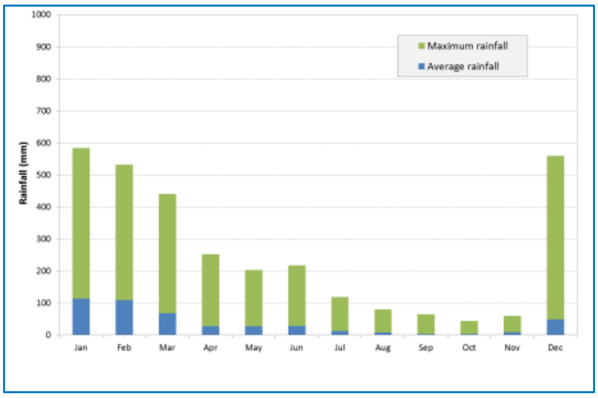

Figure 4-5: Monthly rainfall data for Wittenoom (1950-2013) (BoM, 2013)

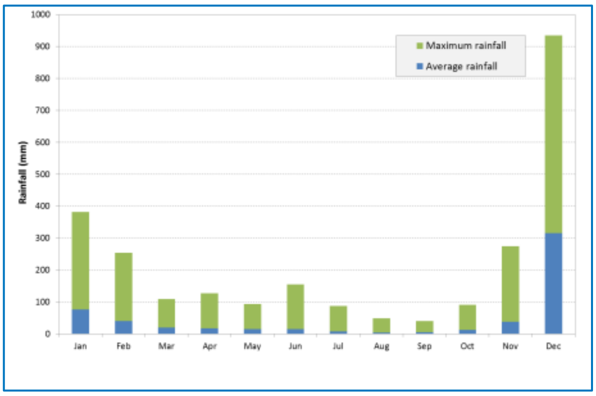

Figure 4-6: Monthly rainfall data for Newman Airport (1971-2013) (BoM, 2013)

Further analysis of the Wittenoom and Newman rainfall statistics were undertaken to identify a year that is representative of the long term (11-year mean) average conditions. This analysis was undertaken comparing total rainfall (described in detail in Appendix A). The analysis identified years 2001 and 2006 as recording rainfall higher than long term 90th percentile, therefore likely to lead to an underestimate of dust levels; with 2005 and 2007 recording rainfall in both Wittenoom and Newman close to the 10th percentile.

The BoM rainfall statistics for Newman over 32 years show only the total rainfall amounts of Year 2002, 2005, 2007, 2008, 2009 and 2010 to fall within the 10th and 90th percentile of the long term total rainfall amount (BOM, 2013).

4.2.3 Temperature

Air temperature, in the context of dispersion modelling, is important for understanding the buoyancy of the dust generated on site, and the likelihood of the development of mixing and inversion layers in the model domain.

The long term monthly temperature statistics for Wittenoom and Newman are presented in Figure 4-7 and Figure 4-8 respectively. These figures show the average monthly maxima and minima as well as the highest and lowest temperature recorded during the period 1951 to 2013 (Wittenoom) and 1996 to 2013 (Newman).

Average temperatures in Wittenoom range from 26°C to 39°C during summer, with maximum recorded temperatures of up to 48°C. During winter the temperature typically varies from 11°C to 31°C, with lowest minimum temperatures just above 1°C. Average temperature in Newman range from 24°C to 39°C during summer, with maximums of up to 47°C. During winter the temperature typically varies from 6°C to 30°C, with lowest minimum temperature of -2°C. The study area is, therefore, represented by hot summers and cold winters.

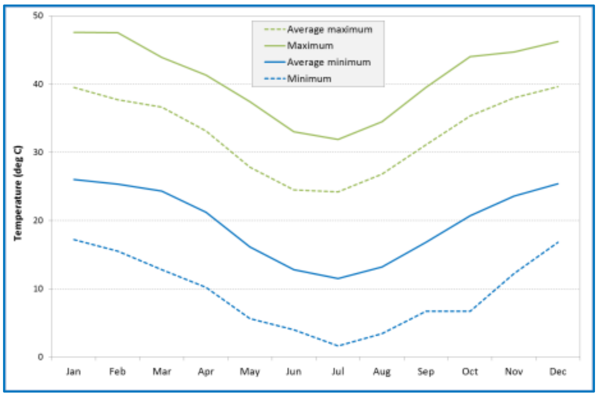

Figure 4-7: Monthly temperature data for Wittenoom (1951-2013) (BOM, 2013)

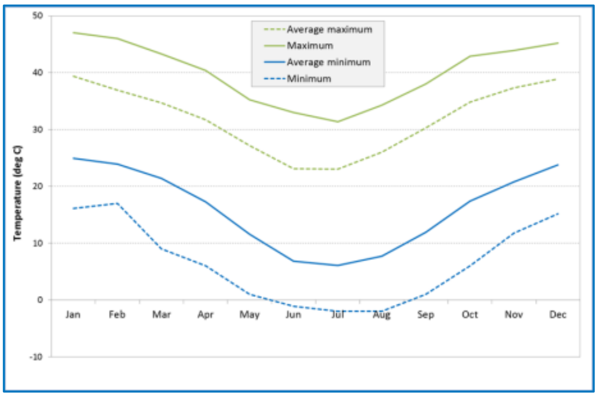

Figure 4-8: Monthly temperature data for Newman Airport (1996-2013) (BOM, 2013)

Further analysis of temperature was also undertaken to identify a year that is representative of the long term (13-year mean) average conditions. This analysis was undertaken using the Mann-Whitney U-test (described in detail in Appendix A). The analysis identified year 2009 being representative of the 15-year mean temperature conditions.

4.2.4 Relative Humidity

Relative humidity, in the context of dispersion modelling, is important to understand reduced visibility. High relative humidity can significantly increase the effect of pollution on visibility. Particles would accumulate water and grow to sizes at which they are more efficient at scattering light and reduce visibility.

The long term humidity statistics in Wittenoom and Newman at 9 am and 3 pm are presented in Figure 4-9 and Figure 4-10 respectively. Both figures have similar trends which show the humidity is typically high during the winter period and is generally low during the summer period. This is reflecting the arid nature of the region.

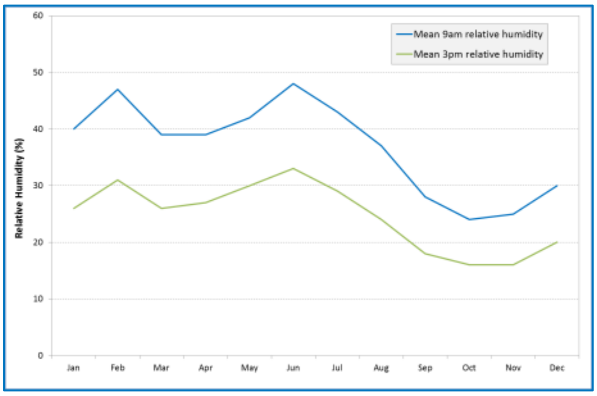

Figure 4-9: Monthly relative humidity data for Wittenoom (1951-2012) (BoM, 2013)

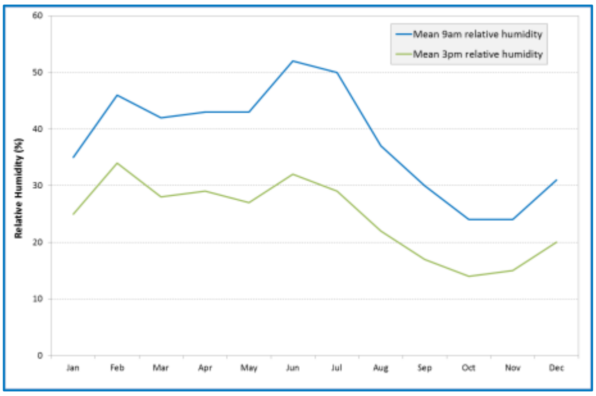

Figure 4-10: Monthly relative humidity data for Newman Airport (1994-2012) (BoM, 2013)

4.3 Review of Ambient Air Quality in the Pilbara region

The semi-arid landscape of the Pilbara makes it a naturally dusty environment with wind-blown dust a significant contributor to ambient dust levels within the region. This was highlighted by the aggregated emission study that was conducted by SKM in 2000 (SKM, 2003). This study found that the Pilbara region emitted around 170,000 tonnes of windblown particulate matter in the 1998/99 financial year. In order to determine the existing background concentration of PM_{10} to be included in the model, it is necessary to review the ambient air quality data in the region.

4.3.1 Air Quality Monitoring Network

As part of the environmental management regime, BHP Billiton Iron Ore has an ambient air quality monitoring network in place in the vicinity of the inland Pilbara operations. The current network consists of six ambient air monitoring and two meteorological stations in the region, shown in Figure 4-11. Siting of the stations was originally planned or intended to measure background dust concentrations (or regional dust concentrations) and to measure the potential impact of the operations at indicative sensitive receptor locations.

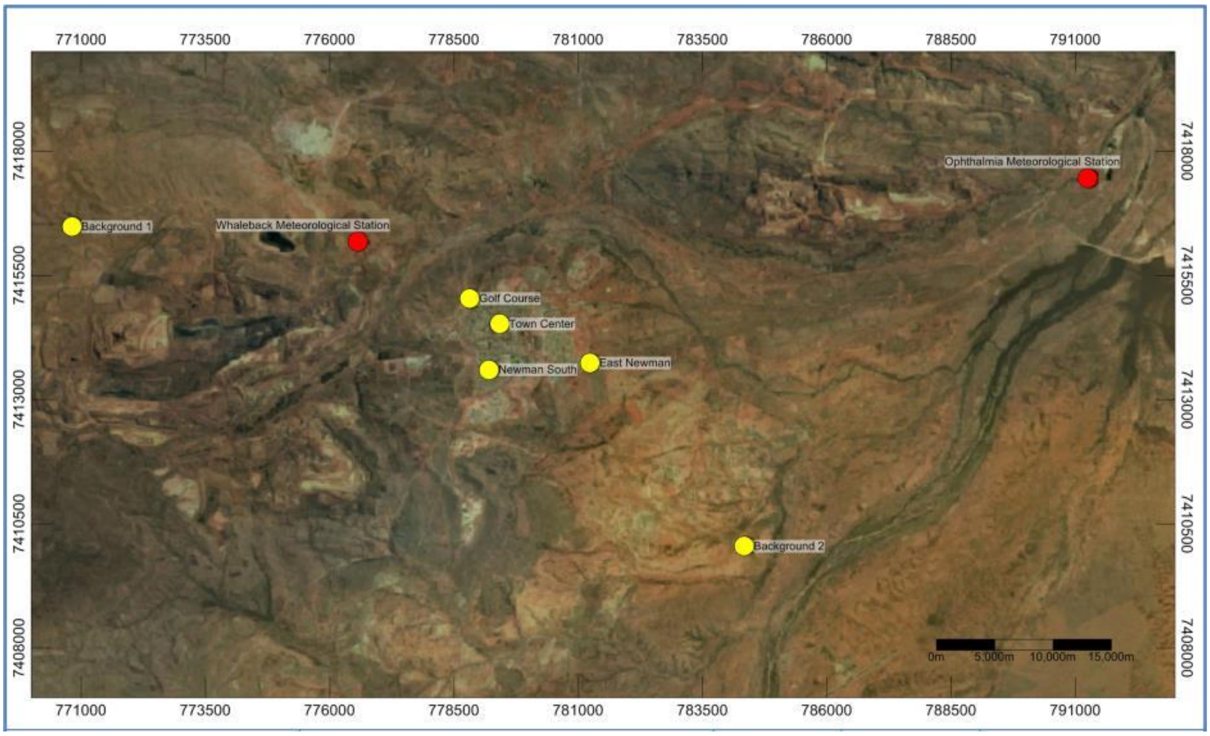

Figure 4-11: BHP Billiton Iron Ore monitoring network at Newman (2013)

Previous analysis of data from the BHP Billiton Iron Ore operations has demonstrated the impact of mining operations at each of the ambient monitoring stations, as well as the effect of local topography. Ambient monitors in the vicinity of Mining Area C have been demonstrated to be influenced by operations in the vicinity of the monitor (PEL, 2013c). This data is therefore not representative of the regional background concentrations.

Alternatively, BHP Billiton Iron Ore operates two background monitoring stations in the Newman region, identified as Background 1 (BG1) and Background 2 (BG2).

BG1 is located less than 1 km to the north west of the Mt Whaleback operation waste dumps (Figure 4-11). The prevailing wind directions in this region are easterly to south easterly (Section 4.2.1) therefore this monitoring station would be expected to be heavily influenced by emissions from the mining operations at Whaleback. The data from BG1 is therefore not considered to be representative of the regional particulate concentrations.

BG2 is located approximately 5 km south east of the Newman Township (Figure 4-11). The prevailing wind direction in this region is easterly to south easterly in autumn and winter; as well as north westerly in spring and summer (refer to Section 4.2.1). This location is not expected to be impacted by mining activities in the region due to its distance (approximately 8 km) from the mining operations and prevailing wind direction during the year. Therefore the background concentrations in this assessment have been determined solely from BG2.

4.3.2 Air Quality Monitoring Data

Monitoring data for BG2 was obtained for the period 2009 to 2012. Data obtained included both 10-minute and 24-hour average data for this ambient monitoring station. The analysis of the data included a review of the statistics. The data analysis provides a general description and understanding of the local air quality (based on current emission sources) and supports the emission estimations and dispersion model set-up. Analysis of monitored data is also used in the analysis to identify or determine a representative year for dispersion modelling.

The TSP and PM_{10} dust concentrations recorded by BHP Billiton Iron Ore at BG2 from January 2009 through to December 2012 are presented in Figure 4-12 and the concentration statistics are displayed in Table 4-1 (BHP Billiton Iron Ore, 2013a).

Particulate concentrations, especially TSP, were extremely high in 2009. One possible cause of these high annual concentrations was the contribution by wildfires or over grazing resulting in poor vegetation cover. This increases the wind erosion potential in the region. In addition, 2009 and 2012 recorded moderate data recovery (i.e. below 90%). Therefore these two years were not considered to be a representative year for background particulate concentrations.

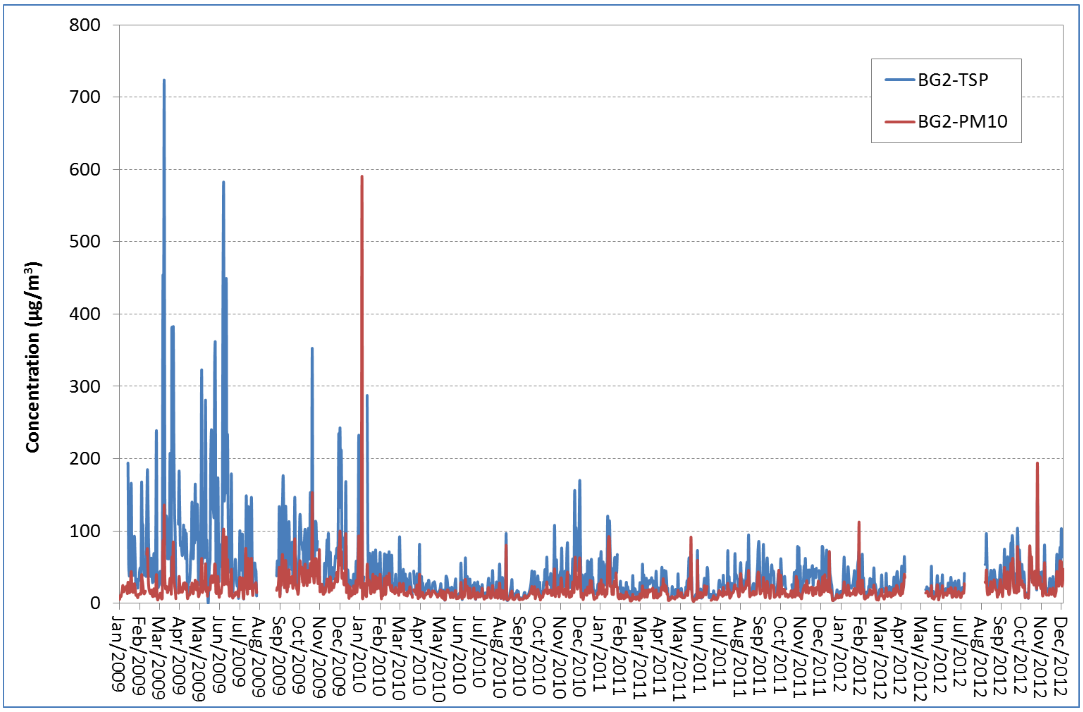

Figure 4-12: Background PM_{10} concentration at Background 2 monitoring station (2010 - 2013)

From Table 4-1 and Table 4-2, it is shown that the annual average concentrations of PM_{10} and TSP are slightly higher in 2010 than 2011. Therefore the data from 2010 was used as background concentrations for this assessment. For this assessment a background PM_{10} concentration of 18 µg/m³ and a background TSP concentration of 33 µg/m³ was considered to be reflective of the region. These were based on the 70th percentile of PM_{10} and TSP concentrations in 2010 (Table 4-1 and Table 4-2).

Table 4-1: Statistics for PM_{10} at BG2 monitoring station

	2009	2010	2011	2012
Max	153	590	92	194
99th percentile	99	63	70	77
95th percentile	67	37	34	55
90th percentile	54	30	28	35
70th percentile	31	18	19	21
Average	28.5	18.3	16.5	20.4
Data Recovery	85%	99%	95%	83%

Table 4-2: Statistical summary for TSP monitoring data in BG2 (µg/m³)

	2009	2010	2011	2012
Max	722	288	119	146
99th percentile	448	163	95	97
95th percentile	236	82	68	68
90th percentile	168	59	54	55
70th percentile	93	33	35	35
Average	90.1	31.7	29.8	29.9
Data recovery	85%	99%	96%	83%

4.4 Representative Year

The analysis of meteorological parameters (see Appendix A) indicated that a number of years were suitably representative of the long term average conditions:

- Wind - 1998, 2008, 2009 and 2010
- Rainfall - 2002, 2005, 2007, 2008, 2009 and 2010 (with 2002, 2008 and 2009 closest)
- Temperature - 2002 and 2009

The meteorological conditions highlight that the most representative year in terms of wind speed, wind direction and rainfall was considered to be 2009, with 2010 also being a reasonable option. Taking into account the availability of ambient air quality data, the year 2010 was suitable, however, 2009 was not considered suitable for further analysis due to the poor data recovery percentages.

On this analysis, the year 2010 was considered to be most representative for basing the modelling work. In making this determination is noted that 2012 has a higher proportion of northerly winds at the expense of north-westerly to westerly winds, higher maximum wind speeds and significantly higher rainfall than 2009. The increased precedence of northerly winds in 2012 was likely to influence the locations receiving concentrations of particulate matter. The higher maximum wind speeds may lead to an increase in the dispersion of particulate matter before reaching sensitive receptors however, it may also increase the degree of wind erosion occurring on exposed surfaces and increase the concentration of particulate matter blown down wind. Higher rainfall was likely to reduce the concentration of particulate matter in the air by water droplets adsorbing onto the surface of the particle and depositing on the ground below. The background air quality for the region was also higher in 2012 than 2009, which provides a more conservative estimate with the possibility of a high number of maximum ground level concentrations due to high background air quality. While 2010 presents a slightly less ideal meteorological year than 2009, the available monitoring data makes 2010 appropriate for the model year for the study area.

5 MODEL SELECTION

Modelling guidelines issued by the Department of Environment Regulation and the Environmental Protection Authority (DoE, 2006) for assessing air quality impacts through dispersion modelling allow discretion in the choice of model, model set up and emission estimation techniques.

In regulatory applications the prediction of ambient concentrations and deposition using dispersion models influences abatement strategies that may be required (e.g. emission controls). The accuracy of models (i.e being representative) is therefore important and may affect substantial levels of expenditure on emissions management.

The suites of models that are commonly used in Australia include AUSPLUME, CALPUFF and AERMOD. While AERMOD and AUSPLUME are based on an assumption of steady-state meteorology (generically known as 'plume models'), CALPUFF is based on non-steady state meteorology ('puff model').

Plume models assume instantaneous, straight-line transport of emissions between source and receptor based on hourly-averaged wind speed and direction data. For that reason they are described as steady-state models: plume calculations for one hour assume a meteorological field that is constant in time and space, and contain no memory of what happened in previous hours. Plumes can appear to travel unrealistic distances in a straight line when winds are light and variable.

Non-steady state models (including puff models) track discrete parcels of emissions as they move with the wind. They calculate variable dispersion depending on position of the puff within the model domain and the corresponding local flow conditions.

An illustration of how the formulation of the two types of models can lead to substantial differences in predicted plume behaviour is presented in Figure 5-1. The non-steady state solution evolves as the wind field changes in both time and space. The figure demonstrates an hourly sequence and shows the differences between steady-state and non-steady-state models in conditions of changing winds and terrain influences. The top sequence was generated by a steady-state model, the lower sequence by a non-steady state model. The same times and emissions source locations have been used. In the lower sequence, arrows indicate surface wind and black lines are terrain contours.

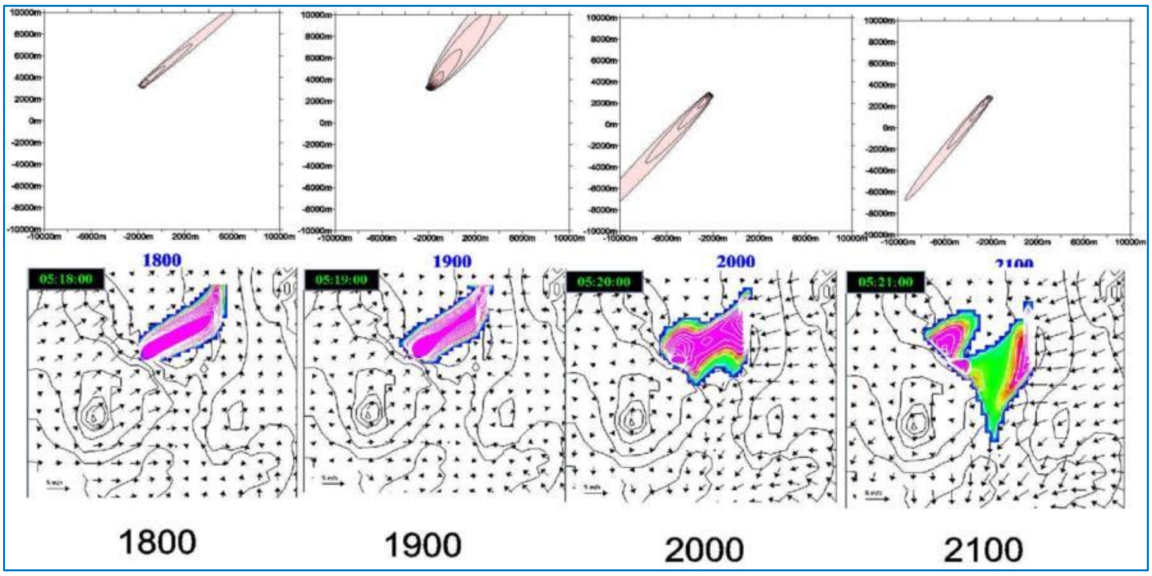

Figure 5-1: Comparison of steady-state and non-steady-state models

As outlined in Section 2.3, meteorology is a critical component and input to a regional dispersion model. Air dispersion model configuration and performance needs to be reflective of the actual setting, else the interpretation of results becomes questionable and highly caveated. Therefore, Pacific Environment applied an innovative approach to address available regional meteorological conditions into air dispersion modelling as described below.

5.1 Selection of Air Dispersion Model for the Pilbara Region

Previous dispersion modelling studies in the Pilbara have used the Commonwealth Scientific and Industry Research Organisation (CSIRO) designed model TAPM to predict the meteorology used as input into atmospheric modelling studies. Concerns have been raised about the suitability of TAPM due to its known limitations, namely over predicting the occurrence of light winds, and inability to predict high wind speeds. In the context of the Pilbara, these are critical limitations particularly for assessments where dust estimates are based on wind influences.

For the strategic assessment, Pacific Environment coupled the CALPUFF model with the Weather Research Forecast (WRF) model to improve upon historical limitation in dispersion modelling and to better reflect the likely air quality conditions of the operations and the regional setting in the Pilbara Region.

5.1.1 The Weather Research and Forecasting Model

The WRF Model is the next-generation mesoscale numerical weather prediction system replacing the MM5 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.

The model allows for simulations reflecting either real data or idealized configurations and is a computationally efficient operational forecasting tool developed to include recent advances in physics, numerics and data assimilation contributed by the research community. WRF is suitable for scales ranging from metres to thousands of kilometres. Using WRF for processing of meteorological data for dispersion modelling is a recent development and is currently becoming best practice for many applications, especially where there is a paucity of observational data.

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 Centers 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).

For the strategic assessment, the WRF model was configured for a 3 nest structure with the inner-most domain of approximately 5 km resolution. The WRF processed meteorological data, both surface and upper air, and then used as an input to CALMET for further processing down to the fine scale used in the dispersion modelling.

CALMET uses WRF modelled meteorological inputs in combination with land use and geophysical information for the modelling domain to predict gridded meteorological fields for the region of interest. CALMET 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 meteorological fields that are used in CALPUFF. In this assessment, the gridded meteorological output of CALMET is used to drive CALPUFF.

5.1.2 California Puff Model (CALPUFF)

California Puff model (CALPUFF) is a multi-layer, multi-species non-steady state puff dispersion model that can simulate the effects of time- and space-varying meteorological conditions on pollutant transport, transformation and removal (Scire et al., 2000a). CALPUFF can simulate the effects of time- and space-varying meteorological conditions on pollutant transport, transformation and removal. The model employs dispersion equations based on a Gaussian distribution of pollutants across the puff and takes into account the complex arrangement of emissions from point, area, volume and buoyant line sources.

CALPUFF contains algorithms for near-source effects such as building downwash, partial plume penetration, sub-grid scale interactions as well as effects such as pollutant removal, chemical transformation, vertical wind shear, a Probability Distribution Function for dispersion in the convective boundary layer and coastal interaction effects (e.g. sea-breeze recirculation and fumigation within the Thermal Internal Boundary Layer).

CALPUFF calculates the pollutant concentration downwind of a source or sources based on the following information:

- Pollutant emission rate
- Emission source characteristics
- Surrounding buildings
- Local topography and land-use
- Meteorology of the area and
- Receptor network.

6 EMISSION ESTIMATION

This section outlines the development of an emissions inventory for the current, proposed 30% Development and the Highest Use scenario for operations in the study area. The emissions and emission sources for existing and proposed operations in the study area are defined using a 'typical' definition of the activity and application of a consistent estimation method across all sites. This enables an evaluation of the Proposal without detailed mine planning and design data. To account for the regional setting, and the spatial requirements of the modelling, the emissions for each existing and proposed mine are determined using a general approach. This approach references the published National Pollutant Inventory (NPI) data for existing iron ore mines, published stripping ratio for individual mines as well as tonnage and disturbance footprint data provided by BHP Billiton Iron Ore for future development in the Pilbara region.

6.1 Overview

An emission estimate for all existing mines is provided through an understanding of the output for each mine (ore and waste), which when combined together provides an indication of the relationship between the total tonnes mined and a site emission rate. This relationship supports estimation of the emissions from future mines to be included in the strategic assessment.

Emission estimation is undertaken for each mine and contains the cumulative emissions from each operation including:

- Haul road
- Loading and unloading (ore and waste)
- Wind erosion
- Blasting
- Crushing / screening
- Stacking / Reclaiming
- Rail load out
- Miscellaneous transfers

This provides an emission estimate for all existing processing hubs and through an understanding of the output for each mine (ore and waste) provides an indication of the relationship between the total tonnes mined and a site emission rate. This relationship supports estimation of the emissions from future processing hubs to be included in the strategic assessment.

For modelling purposes it is imperative that all emission sources from a processing hub (existing, future and proposed) are identified and emissions calculated. Not doing this will result in an under estimation of the emissions and subsequently an under prediction of the potential impacts. Emission estimation and subsequent benchmarking with existing operations has verified the similarities between the proposed emission estimation methodology and a more detailed site specific emission estimation methodology. The benchmarking confirms this proposed methodology is acceptable (PEL, 2012, 2013 and 2014).

Source apportionment has used data from previous emission estimation and modelling studies to determine the contribution from each of the activities listed above to the total emission rate (PEL, 2012, 2013 and 2014).

The following sections outline the emission estimation process used to develop the emission inventory. A more detailed outline is provided in Appendix D.

6.2 Emission Estimation Process

To account for the regional setting, and the spatial requirements of the modelling, emissions from individual sources at each existing and proposed mines are not calculated separately, instead being determined using a generic approach.

Emissions from existing BHP Billiton Iron Ore mines have been primarily based on historic site specific data. In the absence of site specific emissions, reference has been made to the National Pollution Inventory (NPI) reporting. As for the third party operations, emissions are based on published NPI data. The emission sources are defined as constant-rate area sources for the whole site based on the indicative disturbance area provided by BHP Billiton Iron Ore.

6.2.1 NPI data

Reported NPI data is used to derive emissions for the current operations in the Pilbara Region. The emission data is treated as a constant emission rate for each mine. It is worth noting that the reported NPI emission calculations were historically conducted by different third parties and discrepancies might occur due to different choices in emission factors.

Three years of data (2010, 2011 and 2012) have been analysed in this project. It is also noted that some iron ore mines only commenced operation in 2010 and 2011. As a result emission data from 2012 were adopted to represent the current emission for this project.

Table 6-1: NPI data from Iron Ore mines in the Pilbara region (Source: NPI database)

Iron Ore Mines	NPI PM_{10} Emission (kg per year)		
	2010	2011	2012*
BHP Billiton Iron Ore			
Eastern Ridge (Orebody 23/25 Operations)	1,930,984	2,598,221	2,750,918
Jimblebar	1,362,060	1,356,128	2,278,548
Mining Area C	7,920,308	7,811,683	8,991,792
Orebody 18	1,580,971	2,021,527	2,158,939
Whaleback (incl. Orebody 29/30/35)	4,327,291	4,471,475	5,389,313
Yandi	5,415,521	9,571,115	10,863,354
Third party			
Christmas Creek Operations	3,925,458	8,169,432	16,100,032
Cloudbreak Operations	9,787,966	8,030,677	15,205,604
Hope Downs 1 Mine	3,981,094	3,922,615	3,768,086
Hope Downs 4 Mine	N/A	N/A	310,770
Marandoo Mine	1,658,407	1,633,471	1,248,612
West Angelas Mine	4,349,633	3,609,753	2,826,469
Yandicoogina Mine	2,466,327	3,717,037	2,978,011

* Note: Year 2012 was the most up to date year that NPI data available at the beginning of this project.

6.2.2 Tonnage

Mining activities involve movement of ore and waste that may lead to the generation and emission of dust. In order to obtain a representative relationship between the total tonnes mined and the emission rate, it is essential to understand the output for each mine (ore and waste). The current, conceptual 30% Development and conceptual Highest Use tonnages of BHP Billiton Iron Ore processing hubs are presented in Table 6-2, Table 6-3 and Table 6-4 respectively.

The tonnages presented in the 30% Development and Highest Use scenarios are conceptual only and are based on an average mining rate expected for a typical mine in the Pilbara. The Highest Use scenario assumes that all future BHP Billiton Iron Ore processing hubs will operate at a typical rate of 45 Mtpa for ore and 45 Mtpa of waste material, which represents a conservative case. It is unlikely that all future processing hubs would operate at these rates simultaneously. However, the Highest Use scenario was considered to be fit for purpose for this regional air quality assessment, in predicting areas of higher potential risk that will inform mitigation decisions in the future.

Table 6-2: Current tonnage (2013) of BHP Billiton Iron Ore processing hubs

Processing hub	Ore (Mtpa)	Waste (Mtpa)	Total Tonnage (Mtpa)
Orebody 18	15	9	24
Eastern Ridge (including OB24,25)	9	26	35
Jimblebar East	13		13
Whaleback	55	49	104
Mining Area C	52	63	115
Yandi West (OHP 2 and 3)	37	12	49
Yandi East (OHP 1)	37	12	49

Table 6-3: Projected conceptual tonnage of BHP Billiton Iron Ore processing hubs (30% Development scenario)

Processing hub	Tonnage (Mtpa)		
	Ore	Waste	Total
Orebody 18	45	45	90
Eastern Ridge (incl. OB24 and 25)	45	45	90
Jimblebar West	45	45	90
Jimblebar East	45	45	90
Whaleback	45	45	90
Mining Area C	45	45	90
Yandi West (OHP 2 and 3)	45	45	90
Yandi East (OHP 1)	45	45	90
Mudlark	45	45	90
South Flank	45	45	90
Marillana	45	45	90
Munjina / Upper Marillana	45	45	90
Jinidi	45	45	90

Table 6-4: Projected conceptual Highest Use tonnage of BHP Billiton Iron Ore processing hubs

Processing hub	Tonnage (Mtpa)		
	Ore	Waste	Total
Orebody 18	45	45	90
Eastern Ridge (incl. OB24 and 25)	45	45	90
Jimblebar West	45	45	90
Jimblebar East	45	45	90
Whaleback	45	45	90
Mining Area C	45	45	90
Yandi West (OHP 2 and 3)	45	45	90
Yandi East (OHP 1)	45	45	90
Roy Hill	45	45	90
Tandanya	45	45	90
Mudlark	45	45	90
South Flank	45	45	90
Ophthalmia/Prairie Downs	45	45	90
Gurinbiddy	45	45	90
Mindy	45	45	90
Marillana	45	45	90
Coondiner	45	45	90
Caramulla	45	45	90
Minister's North	45	45	90
Munjina / Upper Marillana	45	45	90
Packsaddle East	45	45	90
Jinidi	45	45	90

For third party operations in the Pilbara Region, the total tonnage (ore and waste) from each mining operation was estimated using the waste to ore ratios collected from various sources (Table 6-5). The waste to ore ratios from West Angelas, Yandicoogina and Koodaideri were not available at the time of writing, and were assumed to be identical to a nearby mine with similar ore type. It is worth noting that these values are indicative for use in this strategic assessment and might not reflect the actual amount of waste produced per year.

Table 6-5: Summary of waste to ore ratio for Third Party operations

Operation	Waste ratio	Ore ratio	Ore (MT)[a]	Waste (MT)	Estimated total tonnage (MTPA)	Waste to ore ratio references
Cloudbreak	4.2	1	50	210	260	FMG(2011)
Davidsons Creek	3	1	15	45	60	FerrAus Limited (2010)
Hope Downs 4	1.42	1	30	42.6	72.6	Hancock (2014)
West Angelas	2.3	1	40	92	132	Assumed to be similar to Mining Area C (BHP Billiton Iron Ore, 1998)
Hope Downs 1	1.19	1	30	35.7	65.7	EPA (2009)
Marandoo	4.5	1	16	72	88	RTIO (2008)
Yandicoogina SW Oxbow	0.35	1	26	9.1	35.1	Assumed to be similar to BHP's Yandi mine (BHP Billiton Iron Ore, 2005)
Yandicoogina SE	0.35	1	16	5.6	21.6	Assumed to be similar to BHP's Yandi mine (BHP Billiton Iron Ore, 2005)
Phils Creek	0.3	1	2	0.6	2.6	DEC (2012)
Iron Valley	1.8	1	5	9	14	URS (2012)
Marillana	0.8	1	19	15.2	34.2	Brockman Resources Limited (2010)
Koodaideri	0.8	1	70	56	126	Assumed to be the same as Marillana
Roy Hill	4.56	1	65	296.4	361.4	Roy Hill (2011)
Christmas Creek	4.2	1	50	210	260	FMG (2011)
Mindy Mindy	0.6	1	45	27	72	ENVIRON (2004)
Nyidinghu	2	1	40	80	120	FMG (2012)

Note: [a] Information sourced from publicly available documents

6.2.3 Dust control methods and reductions

Dusts emissions from mining operations can be controlled in various ways. Typical dust control methods used by BHP Billiton Iron Ore (Standard Controls) and recommended leading dust controls (Leading Controls) are listed in Table 6-6.

Three scenarios were developed for the air quality assessment:

- No Control – estimated emissions arising from the likely operating activities with no dust management control. Historically, BHP Billiton Iron Ore operations adopt Standard dust controls however this hypothetical scenario is intended to demonstrate the importance of implementing dust controls onsite;
- Standard Controls – estimated emissions arising from the likely operating activities with a typical suite of BHP Billiton Iron Ore operating controls;
- Leading Controls – estimated emissions arising from the likely operating activities with the leading dust controls. These controls were identified based on review of various documents including the NPI manuals and USEPA AP-42 documents.

Table 6-6: Summary of control factors for typical BHP Billiton Iron Ore operations in the Pilbara region

Operation	Dust control method and Emission Reduction
Mining	
Bulldozing	No control
Loading ore and waste	Standard: no control Leading: 50% for water sprays in specific pits
Loading ore from ROM pad to crusher	Standard: 50% for level 1 water sprays Leading: 83% for level 2 water sprays
Unloading waste	No control
Unloading ore at ROM pad	No control
Unloading ore into crusher	Standard: 50% for level 1 water sprays Leading: 83% for level 2 water sprays
Drilling	Standard: 50% for cyclone Leading: 99% for water injection
Blasting	No control
Wind Erosion in OSA and ROM pad	Standard: 50% for water sprays Leading: 90% for chemical surfactant and good housekeeping
Haul road	
Hauling	Standard: 50% for level 1 watering (2 litres/m^2/h) Leading: 90% for chemical dust suppressant
Processing facility	
Unloading ore into primary crusher	Standard: 50% for water sprays Leading : 85% for water sprays and wind shield
Primary crushing of ore	Standard: 50% for water sprays Leading: 83 % for extraction
ROM stacker	Standard: 30% for boom sprays Leading: 30% for boom sprays
Screening plant	Standard: 40% for extraction Leading: 83% for extraction with fabric filters
Transfer station	Standard: no control Leading: 50% for water sprays (including BWS)
Stackers	Standard: 30% for boom sprays Leading: 30% for boom sprays
Train load out	Standard: 30% for water sprays Leading: 30% for water sprays
Wind erosion in open area	Standard: 50% for water Leading: 90% for chemical surfactant and good housekeeping

6.3 Estimated emissions

When determining which emission estimation techniques (EETs) to use for the BHP Billiton Iron Ore operations, precedence was given to BHP Billiton Iron Ore site-specific empirical equations. These methods have been adopted in previous projects in the same region (PEL, 2012, 2013 and 2014). In the absence of BHP Billiton Iron Ore site-specific empirical equations, EETs in the relevant National Pollutant Inventory (NPI) Manuals were adopted. For activities or substances where Australian NPI data were unavailable, international emission factors were sourced from USEPA AP-42. The specific EETs, emission factors used for previous assessments in the Pilbara region are detailed in Appendix D.

PEL has undertaken assessments for various mining operations in the Pilbara region. All of these modelling assessments have followed a generic approach of assessing impact for No Control, Standard

Control and Leading Control scenario. The tonnage (ore and waste) data together with the annual emissions from various BHP Billiton Iron Ore mines are presented in Table 6-7. Due to the commercially sensitive nature of this information, the table lists generic mine names. However, the emissions and tonnages are based on site specific information and are used to generate an average emission rate. This average emission rate is used for projecting emissions for proposed BHP Billiton Iron Ore mining operations is shown in Table 6-7.

Table 6-7: Summary of tonnages and estimated PM_{10} emission at BHP Billiton Iron Ore processing hubs in the Pilbara region

	Scenario	Ore (tonnes)	Waste (tonnes)	Total tonnage (tonnes per year)	PM_{10} Emission (kg/year)
Mining Operations 1	No Control	1,261,885	7,357,395	8,619,280	2,145,171
	Standard				1,152,600
	Leading				303,036
Mining Operations 2	No Control	59,076,973	90,638,627	149,715,600	24,971,992
	Standard				13,405,983
	Leading				4,224,007
Mining Operations 3	No Control	70,000,000	52,954,987	122,954,987	20,776,303
	Standard				11,415,134
	Leading				3,692,942
Average	No Control	43,446,286	50,317,003	93,763,289	15,964,489
	Standard				8,657,906
	Leading				2,739,995

The data presented in Table 6-7 is presented in graphical format in Figure 6-1. This figure displays the relationship between the estimated PM_{10} emissions and the total tonnages of proposed BHP Billiton Iron Ore processing hubs in the Pilbara region. The lines of best fit indicate the estimated PM_{10} emissions of BHP Billiton Iron Ore mines in the Pilbara region are proportional to the total tonnage across all three scenarios.

For comparison purposes, third party current emissions extracted from the NPI database are also plotted on Figure 6-1. The majority of the third party emission data lies between the lines of best fit of Standard Controls and Leading Controls. In a conservative approach, the projected future third party PM_{10} emissions are calculated as per Standard Controls.

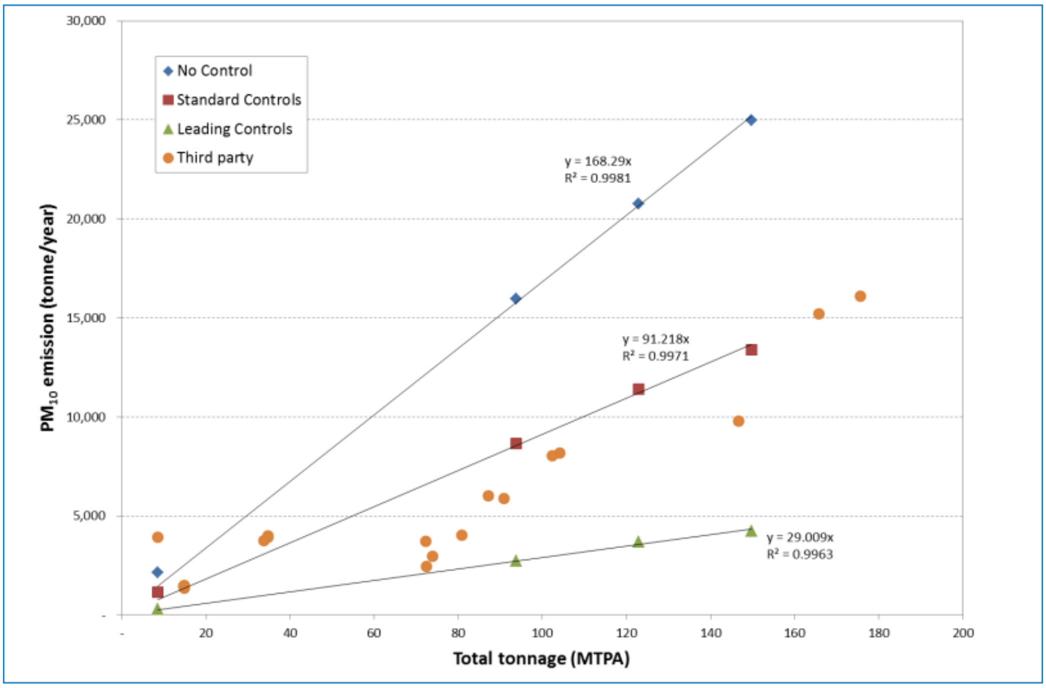

Figure 6-1: Relationship of estimated PM_{10} emission versus total tonnage

Based on the above analysis, the estimated PM_{10} emissions (No Control, Standard Controls and Leading Controls) for BHP Billiton Iron Ore processing hubs in the Pilbara region for the 30% Development scenario are summarised in Table 6-8. The projected PM_{10} emission from Third Party mining operations in the Pilbara region is presented in Table 6-9. Based on typical BHP Billiton Iron Ore particle size distribution, a scaling factor of 2.83 is applied to calculate the TSP emissions from BHP Billiton Iron Ore processing hubs as well as the third party mining operations; the total emissions are listed in Table 6-8 and Table 6-9 respectively.

The estimated PM_{10} emissions (No Control, Standard Controls and Leading Controls) for BHP Billiton Iron Ore processing hubs in the Pilbara region for the Highest Use scenario are summarised in Table 6-10. The projected PM_{10} emission from Third Party mining operations with Standard Control in the Pilbara region is presented in Table 6-9. Based on typical BHP Billiton Iron Ore particle size distribution, a scaling factor of 2.83 is applied to calculate the TSP emissions from BHP Billiton Iron Ore processing hubs as well as the third party mining operations; the total emissions are listed in Table 6-10 and Table 6-9 respectively.

In addition, a summary of the scaled TSP emissions from current operations of BHP Billiton Iron Ore and Third Party is presented in Table 6-11.

Table 6-8: Estimated emission of BHP Billiton Iron Ore processing hubs in the Pilbara region in 30% Development scenario

Processing hub	Ore and waste (MT/year)	PM_{10} emission (tonnes/year)			TSP emission (tonnes/year)		
		No control	Standard Control	Leading control	No control	Standard controls	Leading controls
Jimblebar West							
Jimblebar East							
Jinidi							
Mining Area C							
Marillana							
Mudlark Well	90	15,147	8,208	2,610	43,320	23,475	7,465
Munjina	(Identical values are assigned to all BHP Billiton Iron Ore operations in 30% Development scenario)						
Eastern Ridge (OB23 and OB25)							
OB31							
South Flank							
Whaleback							
Yandi							
Total	**1,080**	**181,764**	**98,496**	**31,320**	**519,845**	**281,699**	**89,575**

Table 6-9: Estimated emission of Third Party mining operations in the Pilbara region in 30% Development and Highest Use scenarios

Operation	Ore and waste (MT/year)	PM_{10} emission (tonnes/year)	TSP emission (tonnes/year)
Cloudbreak	260	23,712	67,816
Davidsons Creek	60	5,472	15,650
Hope Down 4	73	6,621	18,936
West Angelas	132	12,038	34,430
Hope Down 1	66	5,992	17,137
Marandoo	88	8,026	22,953
Yandicoogina SW Oxbow	36	3,324	9,507
Yandicoogina SE	32	2,955	8,451
Phils Creek	49	4,432	12,676
Iron Valley	14	1,277	3,652
Marillana	34	3,119	8,920
Koodaideri	126	11,491	32,865
Roy Hill	361	32,960	94,265
Christmas Creek	234	21,341	61,035
Mindy Mindy	72	6,566	18,780
Nyidinghu	120	10,944	31,300
Total	**1,757**	**160,270**	**458,373**

Table 6-10: Estimated emission of BHP Billiton Iron Ore processing hubs in the Pilbara region – Highest Use scenario

Facility	Ore and waste (MT/year)	PM_{10} emission (tonnes/year)			TSP emission (tonnes/year)		
		No control	Standard Control	Leading control	No control	Standard controls	Leading controls
Orebody 18							
Eastern Ridge (OB 23, 24 and 25)							
Jimblebar West							
Jimblebar East							
Whaleback							
Mining Area C							
Yandi West (OHP 2 and 3)							
Yandi East (OHP 1)							
Roy Hill							
Tandanya	90	15,147	8,208	2,610	43,320	23,475	7,465
Mudlark	(Identical values are assigned to all BHP Billiton Iron Ore operations in Highest Use scenario)						
South Flank							
Ophthalmia/Prairie Downs							
Gurinbiddy							
Mindy							
Marillana							
Coondiner							
Caramulla							
Minister's North							
Munjina / Upper Marillana							
Packsaddle East							
Jinidi							
Total	**1,980**	**333,234**	**180,576**	**57,420**	**953,049**	**516,447**	**164,221**

Table 6-11: Estimated emission of current mining operations in the Pilbara region

BHP Billiton Iron Ore	PM10 (kg per year)	TSP (kg per year)
Mining Area C	8,992	25,717
OB18	2,159	6,175
Whaleback	5,389	15,413
Eastern Ridge	2,751	7,868
Yandi	10,863	31,069
Jimblebar	2,279	6,517
Total	**32,433**	**92,758**
Third Party		
Christmas Creek Operations	16,100	46,046
Cloudbreak Operations	15,206	43,488
Hope Downs 1 Mine	3,768	10,777
Hope Downs 4 Mine	311	889
Marandoo Mine	1,249	3,571
West Angelas Mine	2,826	8,084
Yandicoogina Mine	2,978	8,517
Total	**42,438**	**121,371**
Grand total	**74,870**	**214,129**

6.4 Greenhouse gases emission

Information on greenhouse gas emissions (by fuel type) was provided by BHP Billiton Iron Ore for the following 5 operations: Mining Area C, Yandi, Orebody 24/25, Orebody 18 and Mt Whaleback mine. The data on fuel usage, together with the tonnage of material moved, was used to generate a weighted average fuel use per tonne of material moved. This was used to calculate the greenhouse gas emissions for the three scenarios, i.e. Current, 30% Development and Highest Use.

6.4.1 Greenhouse Gas Emissions

The total Greenhouse gas (GHG) emissions from BHP Billiton Iron Ore operations in the Pilbara Region for the three scenarios are presented in Table 6-12. The total GHG emissions from the current, 30% Development and Highest Use scenarios are 0.9, 2.6 and 4.4 Mt CO_2-e respectively.

Table 6-12: GHG emission from BHP Billiton Iron Ore Operations in the Pilbara Region (million tonnes CO_2-e)

Scenario	Current	30% Development	Highest Use
Scope 1 Emissions	0.6	1.8	3.0
Scope 2 Emissions	0.3	0.8	1.4
Total Emissions	0.9	2.6	4.4

6.4.2 Greenhouse Gas Contribution

The GHG contribution of BHP Billiton Iron Ore operations in the Pilbara region are presented in Table 6-13. Emission estimates from the Pilbara Region are annual estimates for the year indicated. The methodology for these calculations is described in Appendix D.

Table 6-13: Greenhouse Gas Emissions Contribution from the Pilbara Region (Current, 30% Development and Highest Use)

Geographic Coverage	Source Coverage	Timescale	Emission Mt CO_2-e	Description
Australia	Total scope 1 and Scope 2 emissions	2011-2012	554.6	(DCCEE, 2015) Including Land Use, Land Use Change and Forestry (LULUCF)
Australia	Total scope 1 and Scope 2 emissions	2011 - 2012	543.6	(DCCEE, 2015) Excluding Land Use, Land Use Change and Forestry (LULUCF)
Western Australia	Total scope 1 and Scope 2 emissions	2011 - 2012	83.2	(DCCEE, 2015) Including Land Use, Land Use Change and Forestry (LULUCF)
Western Australia	Total scope 1 and Scope 2 emissions	2011 - 2012	80.6	(DCCEE, 2015) Excluding Land Use, Land Use Change and Forestry (LULUCF)
BHP Billiton Iron Ore in Pilbara Region	Total scope 1 and Scope 2 emissions	Current	1.0%[a] 1.1%[b] 0.2%[c] 0.2%[d]	Percentage greenhouse gas contribution of current scenario
BHP Billiton Iron Ore in Pilbara Region	Total scope 1 and Scope 2 emissions	30% Development	3.1%[a] 3.2%[b] 0.5%[c] 0.5%[d]	Percentage greenhouse gas contribution of 30% Development scenario
BHP Billiton Iron Ore in Pilbara Region	Total scope 1 and Scope 2 emissions	Highest Use	5.3%[a] 5.4%[b] 0.8%[c] 0.8%[d]	Percentage greenhouse gas contribution of Highest Use scenario

a Contribution in comparison to total Western Australian GHG emissions including LULUCF.
b Contribution in comparison to total Western Australian GHG emissions excluding LULUCF.
c Contribution in comparison to total Australian GHG emissions including LULUCF.
d Contribution in comparison to total Australian GHG emissions excluding LULUCF.

6.5 Visibility

The methodology used to assess the potential risk in visibility reduction along a 230 km section of the Great Northern Highway (70 km south of Munjina Airport to 30 km south of Newman Airport) is presented in this section.

Visibility studies are often undertaken to assess the reduction in visibility caused by the formation of secondary pollutants in the atmosphere. Given that the main focus of the current study was dust, a literature review was undertaken to identify relationships between dust and observed visibility.

Reference was made to an Australian study undertaken by Baddock et.al (2014). The formula used to define the relationship between Total Suspended Dust and Visibility is presented by the equation below (Baddock M.C, 2014):

$$TSD = 4050 \times Visibility^{-1.016}$$

Where,

TSD = 5-minute total suspended dust in µg/m^3

Visibility = Visibility in km

The methodology adopted for emission estimation is using a 'typical' definition of the activity and application of a consistent estimation method across all sites (Section 6.2) which represents a high level approach. Based on the visibility calculated, the following risk ratings have been adopted in this assessment:

- High risk – visibility is up to 1 km
- Medium risk – visibility is from 1 km to 2 km
- Low risk – visibility is from 2 km to 3 km

The risk rating has been restricted to 3 km to assess visibility reduction in the vicinity of the mining operations. Given the limited information available to assess visibility, such conservative rating is considered appropriate for the SEA. It is to be noted that these visibility risk ratings are indicative.

The process undertaken to convert the model predicted 24-hour maximum TSP concentration to a 5 minute TSP concentration for use in the aforementioned equation, is outlined in Section 6.5.1 and Section 6.5.2.

6.5.1 Conversion of TSP concentration from 24-hour to 1-hour averaging period

In the first step, the 24-hour TSP concentrations are converted into a 1-hour average concentration. Reference was made to the data recorded at the background monitoring station BG2. Statistics of the ratio of 1-hour to 24-hour TSP concentrations recorded at the background station (BG2) for the period 2010 – 2013 is presented in Table 6-14. The value corresponding to the 95th percentile was used to calculate the maximum 1-hour TSP concentrations during a day. This approach is considered conservative and avoids unrealistically high concentrations.

Table 6-14: Ratio of 1-hour and 24-hour TSP concentrations at BG2 (2010-2013)

Statistic	Ratio	Statistic	Ratio
Maximum	19	**20th Percentile**	2
99th Percentile	12	**10th Percentile**	2
95th Percentile	8	**5th Percentile**	2
90th Percentile	6	**Minimum**	1
70th Percentile	4	**Average**	4
50th Percentile	3	**Standard Deviation**	2.1
40th Percentile	3	**Data Recovery**	76%
30th Percentile	2		

6.5.2 Conversion of TSP concentration from 1-hour to 5-minute averaging period

In the next step, the peak to mean concentration formula as recommended by the VicEPA (2013) was adopted to convert hourly TSP concentrations into a 5-minute average TSP concentration. Although this equation is recommended for use with AERMOD it is also applicable for use with CALPUFF in screening level assessments. The VicEPA equation is:

$$C_t = C_A \times \left(\frac{T_A}{T_t}\right)^{0.2}$$

Where,

C_t = concentrations at the required averaging period

C_A = concentration at the known averaging period

T_t = time in minutes for the required averaging period

T_A = time in minutes for the known averaging period

7 MODELLING CONFIGURATION

This section describes the model used to predict ground level concentrations from the derived emission rates and meteorological data.

CALPUFF (Scire et al., 2000a) is a multi-layer, multi-species non-steady state puff dispersion model that can simulate the effects of time and space varying meteorological conditions on pollutant transport, transformation and removal. It is an USEPA regulatory model (USEPA, 2008b) and is widely used in Australia. 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 the puff and takes into account the complex arrangement of emissions from point, area, volume, and line sources.

In addition to the three-dimensional meteorological data output from CALMET (Appendix B); CALPUFF requires the following input data:

- source locations
- emission data
- receptor information.

CALPUFF is a USEPA regulatory model for long-range transport or for modelling in regions of complex meteorology. It is the preferred dispersion model for use in coastal and complex terrain situations and is currently the best model to apply for advanced odour dispersion modelling. Detailed description of CALPUFF is provided in the user manual (TRC, 2011).

The receptor grid for the dispersion modelling was, as for the meteorological modelling, at a grid spacing of 1.3 km with additional discrete receptors representing the surrounding nearest receptors.

A sample CALPUFF input file typical of those used in this assessment is presented in Appendix E. The main model options and assumptions used are listed below:

- All individual operations were modelled as constant-rate area sources. It is noted that area sources in CALPUFF account for plume meander;
- building wake effects were excluded
- surface and upper air observations were generated for every grid point in 3D (Appendix B)
- terrain information was obtained from Shuttle Radar Topography Mission (SRTM) at 3 arc, 90 m resolution
- pollutant was modelled as a particle accounting for dry depletion. Geometric mean mass diameter and standard deviation provided in Appendix F.
- wind speed profile set to ISC rural parameters
- dispersion coefficients computed from sigma v, sigma w using micrometeorological variables (u*, w*, L, etc.)
- 12 cell faces heights defined up to 3000 m (0, 20, 40, 60, 80, 100, 150, 200, 250, 500, 1000, 2000, 3000)
- maximum travel distance of a puff (in grid units) during one sampling step set to 1
- maximum number of puffs released from one source during one time step reduced to 60
- maximum number of sampling steps for one puff during one time step reduced to 60
- minimum wind speed (m/s) allowed for non-calm conditions reduced to 0.5 m/s
- default and user defined land use categories with geophysical parameters defined for each grid point as detailed in Appendix B.

The emission source parameters for all modelled sources are presented in Appendix F.

7.1 Other Model Parameters

7.1.1 Meteorological Data

The WRF processed meteorological data was input to CALMET for further processing to finer resolution used in the dispersion modelling. The CALMET output file generated for 2010 contains three-dimensional gridded fields of U, V, W wind components and air temperature, two-dimensional fields of surface friction velocity, mixing height, Monin-Obukhov length, convective velocity scale, and precipitation rate (Appendix B).

A time series air quality meteorological data file, containing hourly values of these parameters at every grid point is input directly into CALPUFF and used to predict pollution dispersion.

7.1.2 Grid System

CALPUFF model can calculate concentrations both on a set grid (gridded receptors) and at specified locations (discrete receptors). The model was configured to predict the ground-level concentrations on a rectangular grid. The model domain was defined as 175 km in the north–south direction and 265 km in the east-west direction and has its south-west corner at 596.963 km Easting and 7389.250 km Northing (UTM Zone 50S, km). This grid approach was chosen to restrict the duration of model runs while using the particle deposition algorithms. Thirty six discrete receptors were included to give an indication of dust concentrations at specific locations (Section 7.1.3).

7.1.3 Discrete Receptors

Dust concentrations were modelled at 26 discrete receptors. The locations of these receptors are presented in Table 7-1and Figure 7-1.

Table 7-1: Selected sensitive receptor locations

Receptor ID	Easting (m)	Northing (m)	Name	Type
1	652,321	7,468,375	Juna Downs	Homestead
2	825,483	7,464,467	Ethel Creek	Homestead
3	747,479	7,495,073	Marillana	Homestead
4	651,662	7,555,182	Mulga Downs	Homestead
5	719,290	7,393,667	Prairie Downs	Homestead
6	811,750	7,388,078	Sylvania	Homestead
7	678,283	7,512,021	Munjina East Gorge	Lookout
8	676,697	7,505,825	Fig Tree Crossing	Lookout
9	662,753	7,457,807	Mt Meharry	Lookout
10	761,772	7,424,559	Mt Newman	Lookout
11	778,663	7,413,664	Tower Hill	Lookout
12	630,018	7,523,861	Karijini Eco Retreat	Recreation camp site
13	794,257	7,415,934	Ophthalmia Dam	Recreation site
14	783,071	7,404,610	Round Hill	Recreation site
15	775,106	7,449,800	Hickman Crater	Recreation site
16	726,288	7,464,069	Weeli Wolli Spring/Outfall	Recreation site
17	765,881	7,433,047	Stuarts Pool	Recreation site
18	776,023	7,433,093	Kalgan Pool	Recreation site
19	763,923	7,442,594	Eagle Rock Hole	Recreation site
20	689,526	7,450,659	Mt Robinson	Rest stop
21	671,172	7,521,766	Munjina Roadhouse	Roadhouse
22	672,582	7,524,176	Auski Village	Roadhouse
23	787,812	7,404,112	Capricorn Roadhouse	Roadhouse
24	779,758	7,414,360	Newman	Town centre
25	742,012	7,443,807	Rhodes Ridge	Town site
26	681,740	7, 546,480	Wirlu-Murra	Aboriginal community

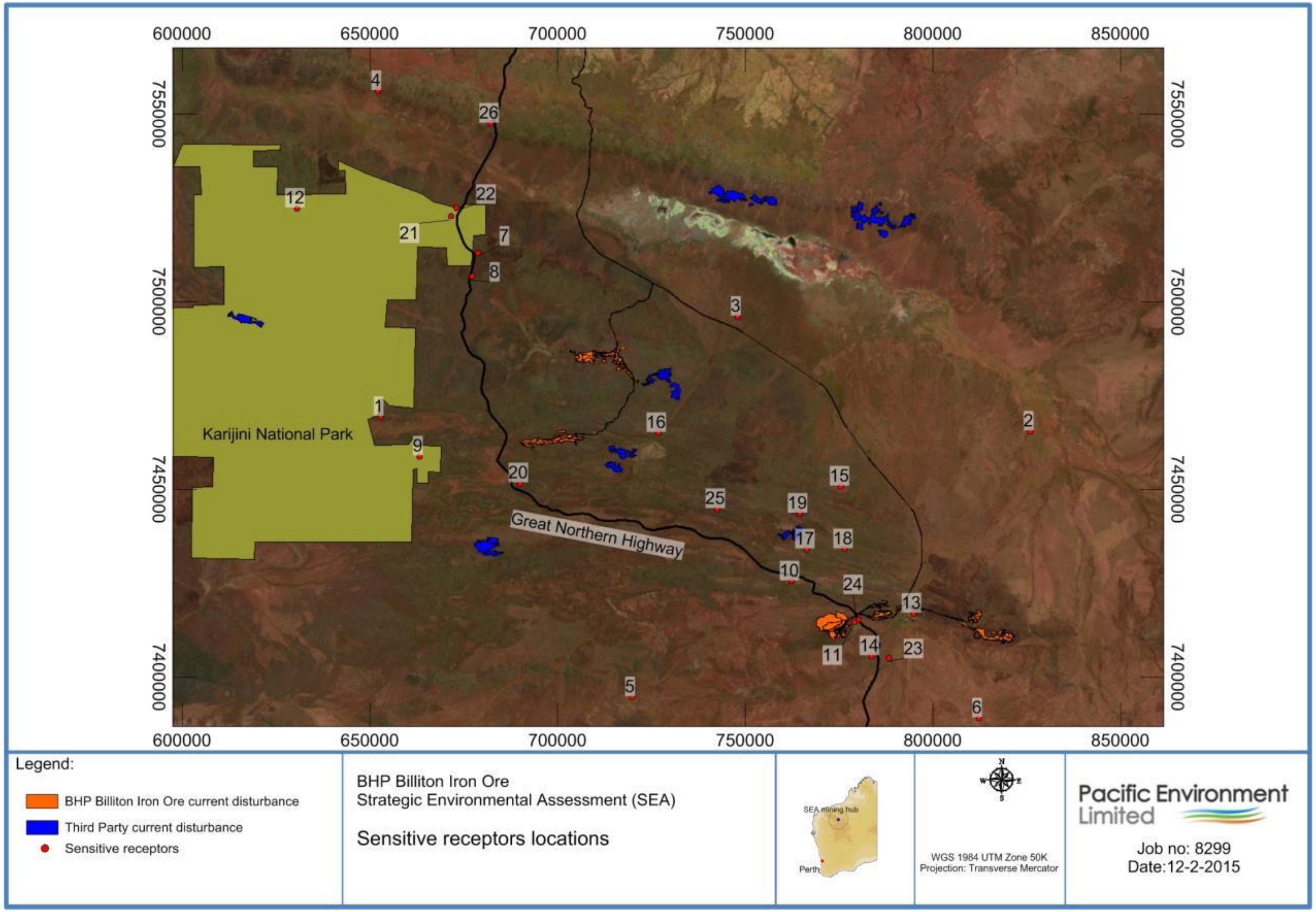

Figure 7-1: Sensitive Receptor Locations

7.1.4 Source characteristics

A total of 17 sources were used to represent current emissions, 44 sources were used to represent 30% Development scenario emissions and 60 sources were used to represent the Highest Use scenario, as shown in Figure 7-2, Figure 7-3 and Figure 7-4 respectively. The emission rates for BHP Billiton Iron Ore and Third Parties for the different scenarios are presented in Appendix F.

The effective height and sigma z for all sources in this study were derived from weighting mean of a source apportionment analysis for Mining Area C (PEL, 2014). Details of the sources including source identification, type, location and characteristics (height, horizontal and vertical spreads) are also presented in Appendix F. The source parameters listed in the tables of Appendix F are identical to those used in the modelling input files and are included in this report for transparency.

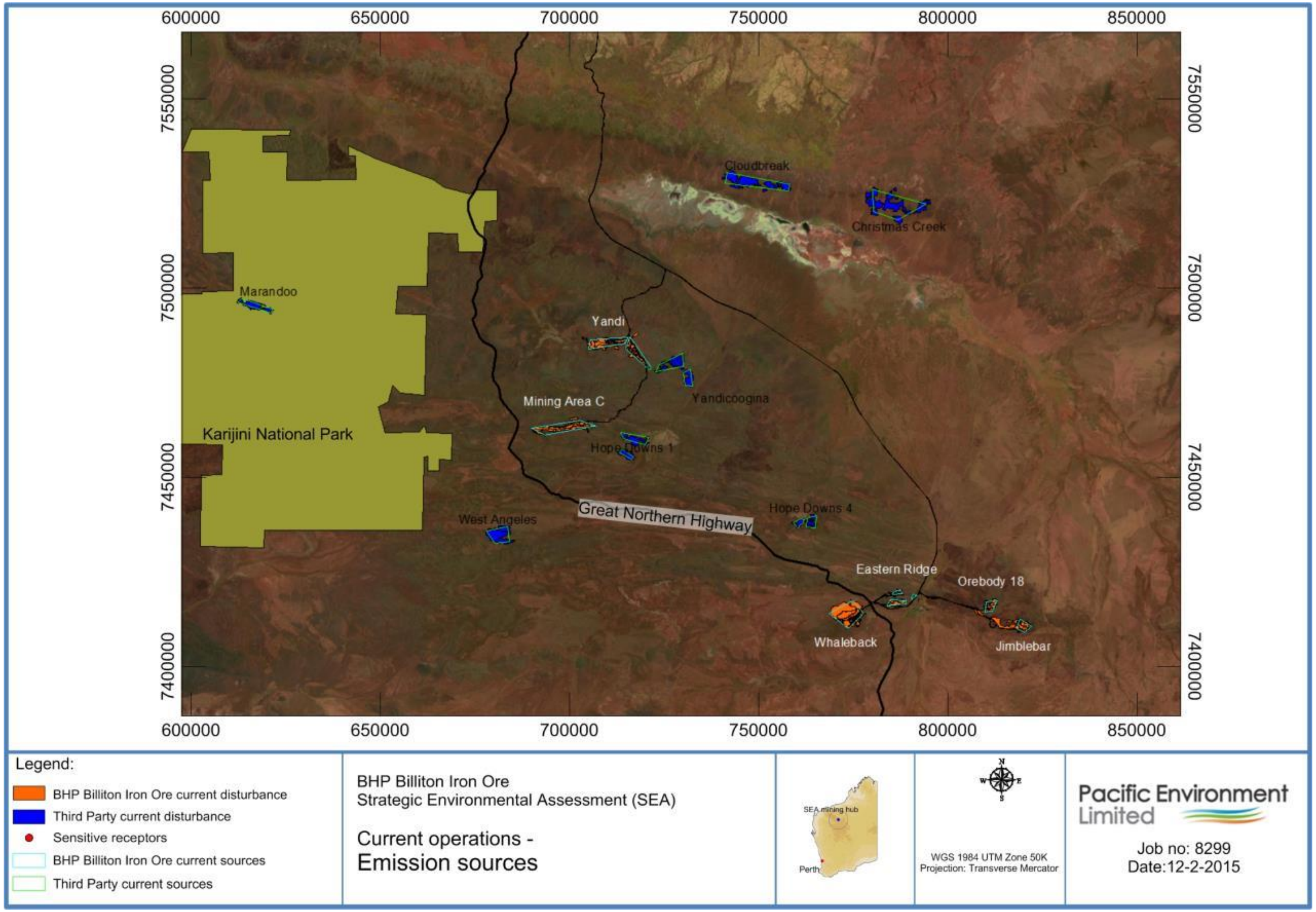

Figure 7-2: Source locations (current operations)

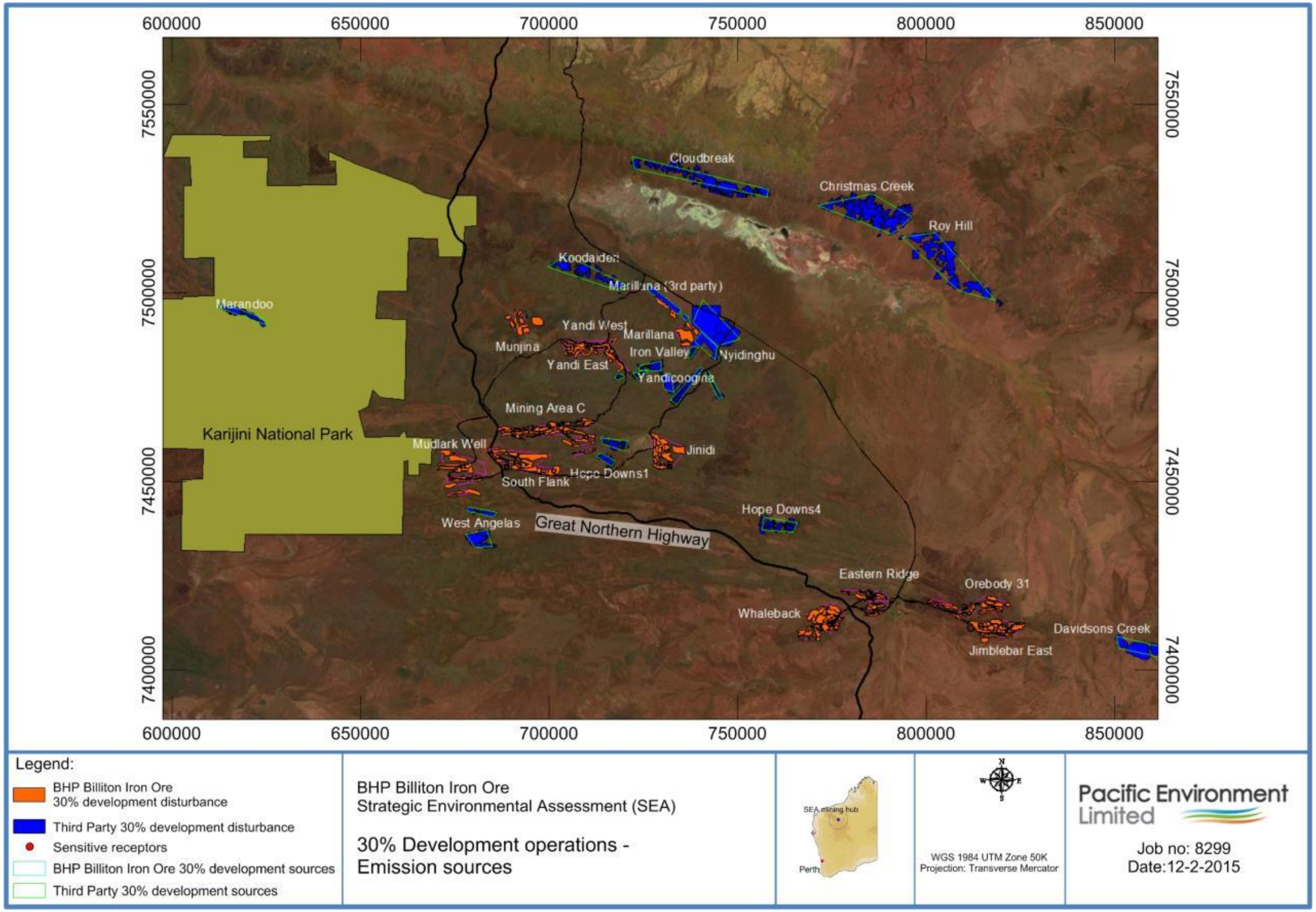

Figure 7-3: Source locations (30% Development operations)

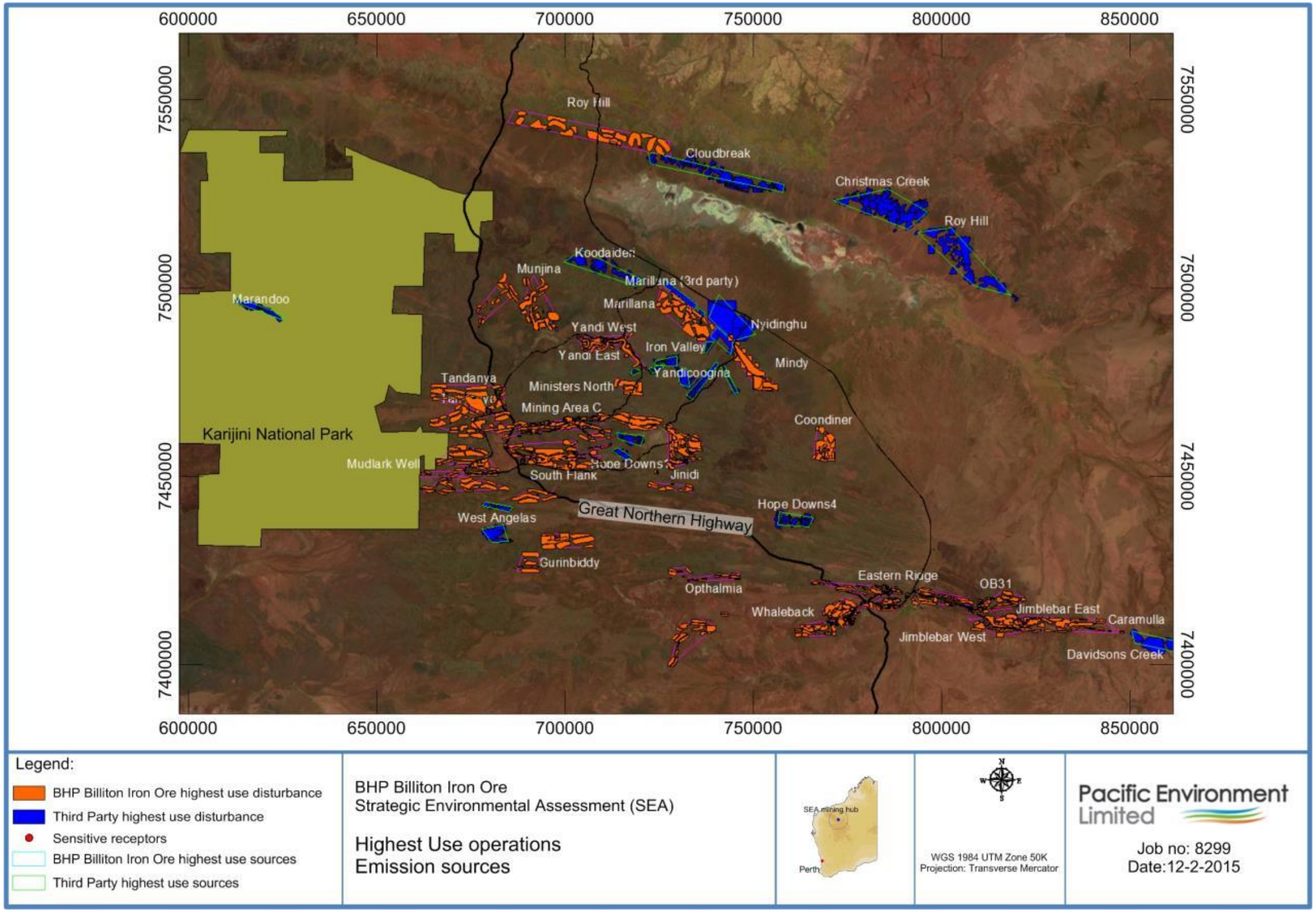

Figure 7-4: Source locations (Highest Use operations)

7.1.5 Model Uncertainty

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

Model uncertainty is composed of model chemistry/physics uncertainties, data uncertainties, and stochastic uncertainties. In addition, there is inherent uncertainty in the behaviour of the atmosphere, especially on shorter timescales due to the effects of random turbulence. The generic sources of uncertainty in dispersion models and their potential effects of this assessment are summarised in Table 7-2.

If modelling results are to be used for decision-making, it is essential to provide some indication of the model uncertainty. This information about uncertainties associated with modelling results can be as important as the modelling results in some cases.

Table 7-2: Summary of Main Sources of Modelling Uncertainty

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

8 PREDICTED AIR QUALITY IMPACTS

This section presents the results of atmospheric dispersion modelling for the strategic assessment. The modelling results are presented for the 26 sensitive receptor locations identified for the study. The modelling results are compared to the assessment criteria described in Section 3.

8.1 Overview of Modelling

Modelling was conducted (TSP and PM_{10}) and results developed for a series of scenarios to demonstrate the relative impact during the progressive development of BHP Billiton Iron Ore operations. As this development is planned to occur over a 100 year timeframe, an indicative (and consistent) approach has been applied to the definition and emission estimation of operations, both existing and future. The modelled scenarios are:

- **Scenario 1 – Existing**
  - BHP Billiton Iron Ore: Existing BHP Billiton Iron Ore operations (in isolation of other operations with background)
  - Third Party Operations: Existing third party operations (in isolation of any BHP Billiton Iron Ore Operations with background)
  - Cumulative: Cumulative current operations (i.e. BHP Billiton Iron Ore operations and third party operations with background)
- **Scenario 2 - Conceptual 30% Development**
  - BHP Billiton Iron Ore: BHP Billiton Iron Ore scenario (including current BHP Billiton Iron Ore operations) in isolation of third party operations with background. This scenario includes separate analysis of operations:
    - Without dust control applied (No Control)
    - With standard dust controls applied (Standard Controls)
    - With leading dust controls applied (Leading Controls)
  - Third Party Operations: Reasonably foreseeable third party operations (in isolation of any BHP Billiton Iron Ore Operations with background)
  - Cumulative: Cumulative 30% Development scenario (i.e. conceptual 30% Development BHP Billiton Iron Ore operations and reasonably foreseeable third party operations with background). This scenario includes separate analysis of BHP Billiton Iron Ore operations:
    - Without dust control applied (No Control)
    - With standard dust controls applied (Standard Controls)
    - With leading dust controls applied (Leading Controls)
- **Scenario 3 – Highest Use Scenario**
  - BHP Billiton Iron Ore: Highest Use Scenario of current and all reasonably foreseeable future BHP Billiton Iron Ore operations running concurrently in isolation of third party operations with background. Also includes separate analysis of operations:
    - Without dust control applied (No Control)
    - With standard dust controls applied (Standard Controls)
    - With leading dust controls applied (Leading Controls)
  - Third Party Operations: Highest Use operations (in isolation of any BHP Billiton Iron Ore Operations with background)
  - Cumulative: Cumulative Highest Use Scenario of BHP Billiton Iron Ore operations and reasonably foreseeable third party operations with background. Also includes separate analysis of BHP Billiton Iron Ore operations:
    - Without dust control applied (No Control)
    - With standard dust controls applied (Standard Controls)
    - With leading dust controls applied (Leading Controls).

8.2 Scenario 1 – Existing

Modelling results for the existing BHP Billiton Iron ore and third party operations are presented in this section. The emissions used to model this scenario are presented in Section 6. The source emission rates and parameters are presented in Appendix F.

8.2.1 Assessment of PM_{10} (potential impact on human health)

To assess the impact of modelled PM_{10}, concentrations, averaged over 24-hours, are compared to the NEPM 24-hour average of 50µg/m³ and Taskforce 24-hour average of 70µg/m³ (Section 3.1).

8.2.1.1 Existing BHP Billiton Iron Ore Operations

The key aspects of the impact assessment from existing BHP Billiton Iron Ore Operations with background are summarised below, and presented in Figure 8-1 and Table 8-1:

- The maximum 24-hour average concentration is higher than the NEPM and Taskforce criteria at 2 sensitive receptors, i.e. Tower Hill and Newman (Table 8-1).
- Out of the 2 impacted sensitive receptors, a higher number of excursions are noted at Tower Hill which is an intermittently occupied receptor.
- The excursions noted at these receptors indicate the potential for existing BHP Billiton Iron Ore operations to impact air quality in the Pilbara Region.
- At these 2 impacted receptors, there is considerable reduction from the 24-hour average maximum PM_{10} concentrations predicted (Table 8-1) when the lower 24-hour average percentiles (99th to 90th percentiles) are considered. For example at the Tower Hill receptor, a drop of 11% in concentrations is noted from the maximum to the 99th percentile (in 24-hour average) and a drop of 43% in concentration is noted from the maximum to the 95th percentile.
- The maximum predicted concentrations could therefore be regarded as a single extreme event which may occur under certain meteorological conditions.

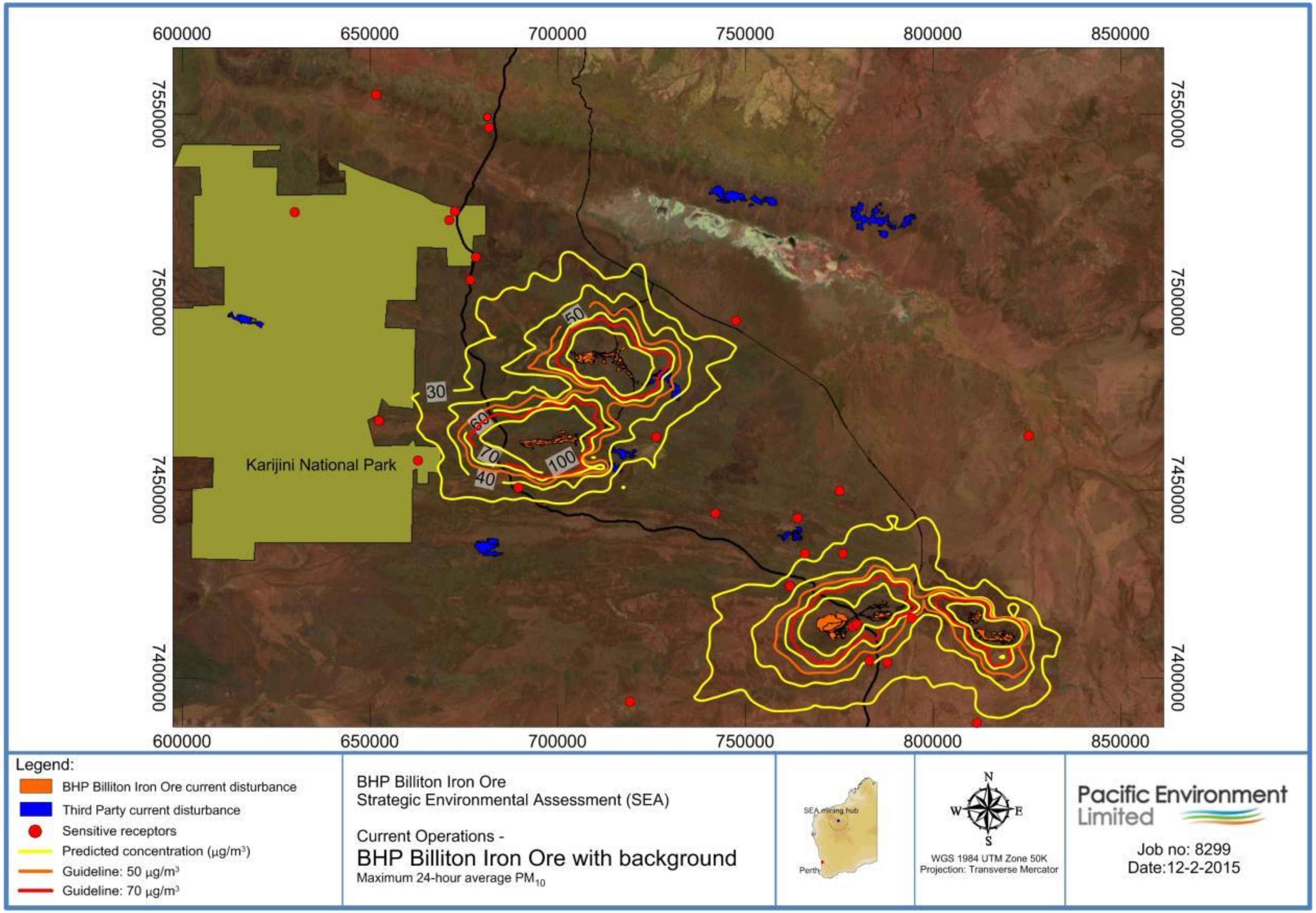

Figure 8-1: Maximum predicted 24-hour average PM_{10} concentrations for existing BHP Billiton Iron Ore operations with background

Table 8-1: Predicted 24-hour PM_{10} Concentrations at receptors including background (µg/m³): Existing BHP Billiton Iron Ore operations

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 50 µg/m³	Greater than 70 µg/m³
Juna Downs	Homestead	27	25	23	22	20	20	-	-
Ethel Creek	Homestead	22	21	20	19	18	18	-	-
Marillana	Homestead	25	22	21	20	19	19	-	-
Mulga Downs	Homestead	21	20	20	19	18	18	-	-
Prairie Downs	Homestead	23	22	21	20	19	19	-	-
Sylvania	Homestead	26	22	20	19	18	18	-	-
Munjina East Gorge	Lookout	25	24	23	22	20	20	-	-
Fig Tree Crossing	Lookout	27	26	24	23	21	20	-	-
Mt Meharry	Lookout	25	23	21	21	20	19	-	-
Mt Newman	Lookout	36	32	27	26	22	21	-	-
Tower Hill	Lookout	159	142	91	65	37	35	66	34
Karijini Eco Retreat	Recreation Camp Site	20	20	20	19	19	19	-	-
Ophthalmia Dam	Recreation Site	50	37	29	26	23	22	-	-
Round Hill	Recreation Site	46	36	32	28	21	21	-	-
Hickman Crater	Recreation Site	25	23	21	21	19	19	-	-
Weeli Wolli Spring/Outfall	Recreation Site	31	26	22	21	19	19	-	-
Stuarts Pool	Recreation Site	28	25	23	22	20	20	-	-
Kalgan Pool	Recreation Site	31	28	25	24	21	20	-	-
Eagle Rock Hole	Recreation Site	24	23	22	21	20	19	-	-
Mt Robinson	Rest Stop	34	32	26	24	19	20	-	-
Munjina Roadhouse	Roadhouse	22	21	21	20	19	19	-	-
Auski Village	Roadhouse	22	21	20	20	19	19	-	-
Capricorn Roadhouse	Roadhouse	38	36	29	25	21	21	-	-
Newman	Town centre	104	82	64	55	34	31	45	14
Rhodes Ridge	Town site	22	21	20	20	19	19	-	-
Wirlu-Murra	Aboriginal Community	22	21	20	19	18	19	-	-

8.2.1.2 Existing third party operations

The key outcomes of predicted PM_{10} impact from the existing third party operations with background are summarised below, and presented in Figure 8-2 and Table 8-2:

- No excursions of the 24-hour maximum PM_{10} criteria (NEPM and Taskforce criteria) are noted at any of the identified receptors.
- The top three maximum 24-hour PM_{10} levels are predicted to occur at the Marillana receptor (35 µg/m³) followed by Weeli Wolli Spring/ Outfall (33 µg/m³) and Eagle Rock Hole (28 µg/m³).

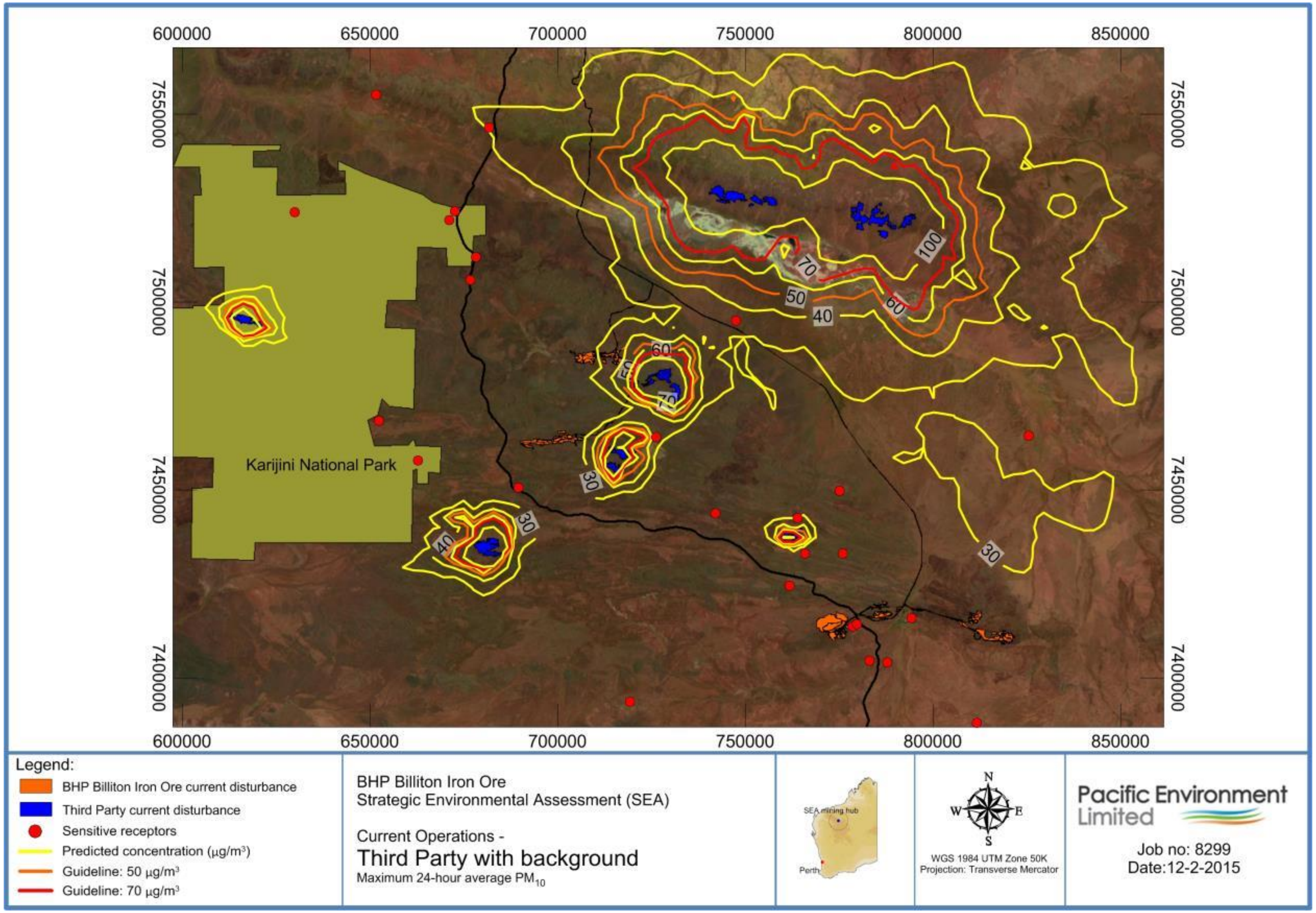

Figure 8-2: Maximum predicted 24-hour average PM_{10} concentrations for existing third party operations with background

Table 8-2: Predicted 24-hour PM_{10} Concentrations at receptors including background (µg/m³): Existing third party operations

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 50 µg/m³	Greater than 70 µg/m³
Juna Downs	Homestead	19	19	19	19	19	18	-	-
Ethel Creek	Homestead	25	24	21	19	18	19	-	-
Marillana	Homestead	35	29	25	23	20	20	-	-
Mulga Downs	Homestead	24	22	20	20	19	19	-	-
Prairie Downs	Homestead	19	19	19	18	18	18	-	-
Sylvania	Homestead	19	19	18	18	18	18	-	-
Munjina East Gorge	Lookout	21	20	20	19	19	19	-	-
Fig Tree Crossing	Lookout	21	20	20	19	19	19	-	-
Mt Meharry	Lookout	20	19	19	19	19	18	-	-
Mt Newman	Lookout	20	20	19	19	18	18	-	-
Tower Hill	Lookout	19	19	19	19	18	18	-	-
Karijini Eco Retreat	Recreation Camp Site	21	19	19	19	19	19	-	-
Ophthalmia Dam	Recreation Site	20	19	19	18	18	18	-	-
Round Hill	Recreation Site	19	19	19	18	18	18	-	-
Hickman Crater	Recreation Site	23	21	19	19	18	18	-	-
Weeli Wolli Spring/Outfall	Recreation Site	33	30	27	24	20	20	-	-
Stuarts Pool	Recreation Site	24	22	20	20	18	18	-	-
Kalgan Pool	Recreation Site	20	20	19	19	18	18	-	-
Eagle Rock Hole	Recreation Site	28	25	22	21	19	19	-	-
Mt Robinson	Rest Stop	24	23	21	20	19	19	-	-
Munjina Roadhouse	Roadhouse	23	20	20	20	19	19	-	-
Auski Village	Roadhouse	23	20	20	20	19	19	-	-
Capricorn Roadhouse	Roadhouse	19	19	19	18	18	18	-	-
Newman	Town Centre	19	19	19	19	18	18	-	-
Rhodes Ridge	Town Site	20	20	19	19	19	19	-	-
Wirlu-Murra	Aboriginal Community	31	26	23	22	20	20	-	-

8.2.1.3 Existing operations - cumulative

The key outcomes of predicted PM_{10} impacts from existing BHP Billiton Iron Ore operations, third party operations and other background sources are summarised below, and presented in Figure 8-3 and Table 8-3:

- Excursions of the both the NEPM and Taskforce criteria are noted at Tower Hill and Newman receptors.
- At the Tower Hill receptor, in comparison to the BHP Billiton Iron Ore plus background scenario (Table 8-1), no change in maximum concentration is noted for the cumulative scenario (Table 8-3).

- At the Newman receptor, in comparison to the BHP Billiton Iron Ore scenario (Table 8-1 & Table 8-3), there is
    - a slight increase in the 90th percentile PM_{10} level
    - there are 2 additional days when the 24-hour PM_{10} concentrations are greater than NEPM criteria (iel greater than 50 µg/m^3).
- At these 2 impacted receptors, there is considerable reduction from the maximum PM_{10} concentrations predicted (Table 8-3) as the lower percentiles (99th to 90th percentiles) are considered. The 99th percentile and 95th percentile at the Tower Hill receptor are lower by 11% and 43% respectively from the maximum concentrations predicted at this receptor.
- The maximum predicted concentrations could therefore be regarded as a single extreme event which may occur under certain meteorological conditions.
  Neverthless, the results indicate that the existing cumulative operations may have a potential to impact air quality in the Pilbara Region

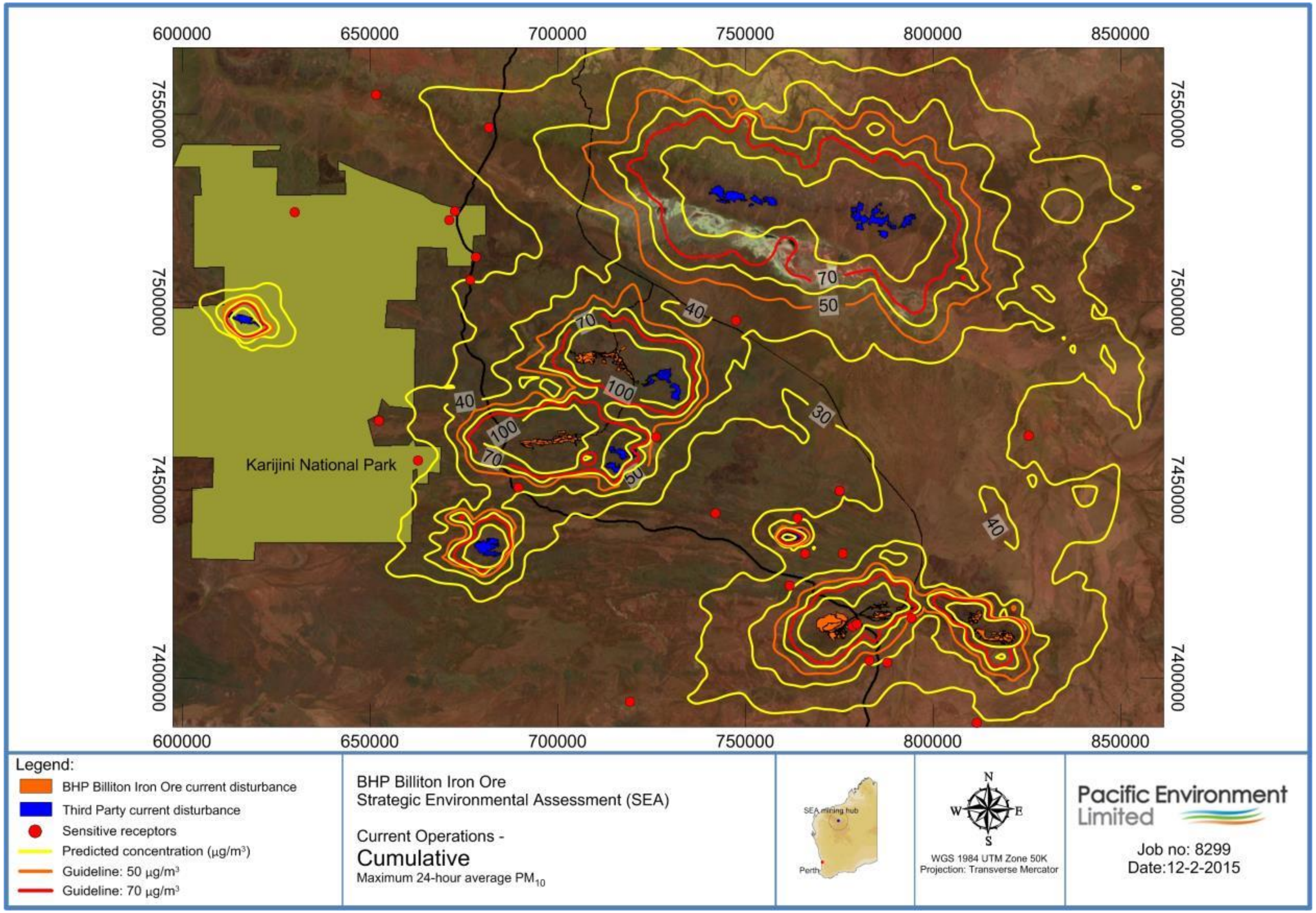

Figure 8-3: Maximum predicted 24-hour average PM_{10} concentrations for existing cumulative operations with background

Table 8-3: Predicted 24-hour PM_{10} Concentrations at receptors including background (µg/m³): Cumulative existing operations

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 50 µg/m³	Greater than 70 µg/m³
Juna Downs	Homestead	27	25	24	23	21	20	-	-
Ethel Creek	Homestead	25	25	22	20	18	19	-	-
Marillana	Homestead	35	30	27	24	20	20	-	-
Mulga Downs	Homestead	24	22	21	20	20	19	-	-
Prairie Downs	Homestead	23	22	21	20	19	19	-	-
Sylvania	Homestead	26	22	20	19	18	19	-	-
Munjina East Gorge	Lookout	26	25	23	23	21	20	-	-
Fig Tree Crossing	Lookout	29	27	25	24	22	21	-	-
Mt Meharry	Lookout	26	24	22	21	20	20	-	-
Mt Newman	Lookout	36	32	27	26	23	22	-	-
Tower Hill	Lookout	159	142	91	66	37	35	66	34
Karijini Eco Retreat	Recreation Camp Site	21	20	20	20	19	19	-	-
Ophthalmia Dam	Recreation Site	50	38	29	27	23	22	-	-
Round Hill	Recreation Site	46	36	33	28	21	21	-	-
Hickman Crater	Recreation Site	26	23	22	21	20	19	-	-
Weeli Wolli Spring/Outfall	Recreation Site	41	34	30	27	20	21	-	-
Stuarts Pool	Recreation site	28	25	24	22	21	20	-	-
Kalgan Pool	Recreation Site	32	28	25	24	21	21	-	-
Eagle Rock Hole	Recreation Site	30	28	24	23	21	20	-	-
Mt Robinson	Rest Stop	36	33	27	25	21	21	-	-
Munjina Roadhouse	Roadhouse	23	22	21	21	20	19	-	-
Auski Village	Roadhouse	23	22	21	21	20	19	-	-
Capricorn Roadhouse	Roadhouse	39	36	29	26	21	21	-	-
Newman	Town Centre	104	82	64	56	34	31	47	14
Rhodes Ridge	Town Site	23	22	21	20	20	19	-	-
Wirlu-Murra	Aboriginal Community	31	26	23	22	20	20	-	-

8.2.2 Assessment of TSP (potential impact on visual amenity)

To assess the impact to amenity the modelled TSP concentrations averaged over 24-hour are compared to the guidelines (based on Kwinana EPP 24 hour average 90 µg/m³ and 24 hour average limit 150 µg/m³) selected for this study (Section 3.1).

8.2.2.1 Existing BHP Billiton Iron Ore Operations

The key outcomes of the TSP impact from existing BHP Billiton Iron Ore operations are summarised below, and presented in Figure 8-4 and Table 8-4:

- The 24-hour maximum TSP concentration is higher than the assessment criteria at 2 sensitive receptors, i.e. Tower Hill and Newman; and higher than the Kwinana EPP limit at Tower Hill;
- For these 2 impacted sensitive receptors, a higher number of excursions is predicted at Tower Hill. The excursions predicted at these 2 receptors indicate the potential for existing BHP Billiton Iron Ore operations to impact air quality in the Pilbara Region.
- At these 2 impacted receptors, there is considerable reduction from the maximum TSP concentrations predicted (Table 8-4) in comparison to the lower percentiles (99th to 90th percentiles). For example, the 99th and 95th percentile at Tower Hill receptor are 11% and 36% lower than the maximum concentrations predicted.
- The maximum predicted concentrations could therefore be regarded as a single extreme event which may occur under certain meteorological conditions.

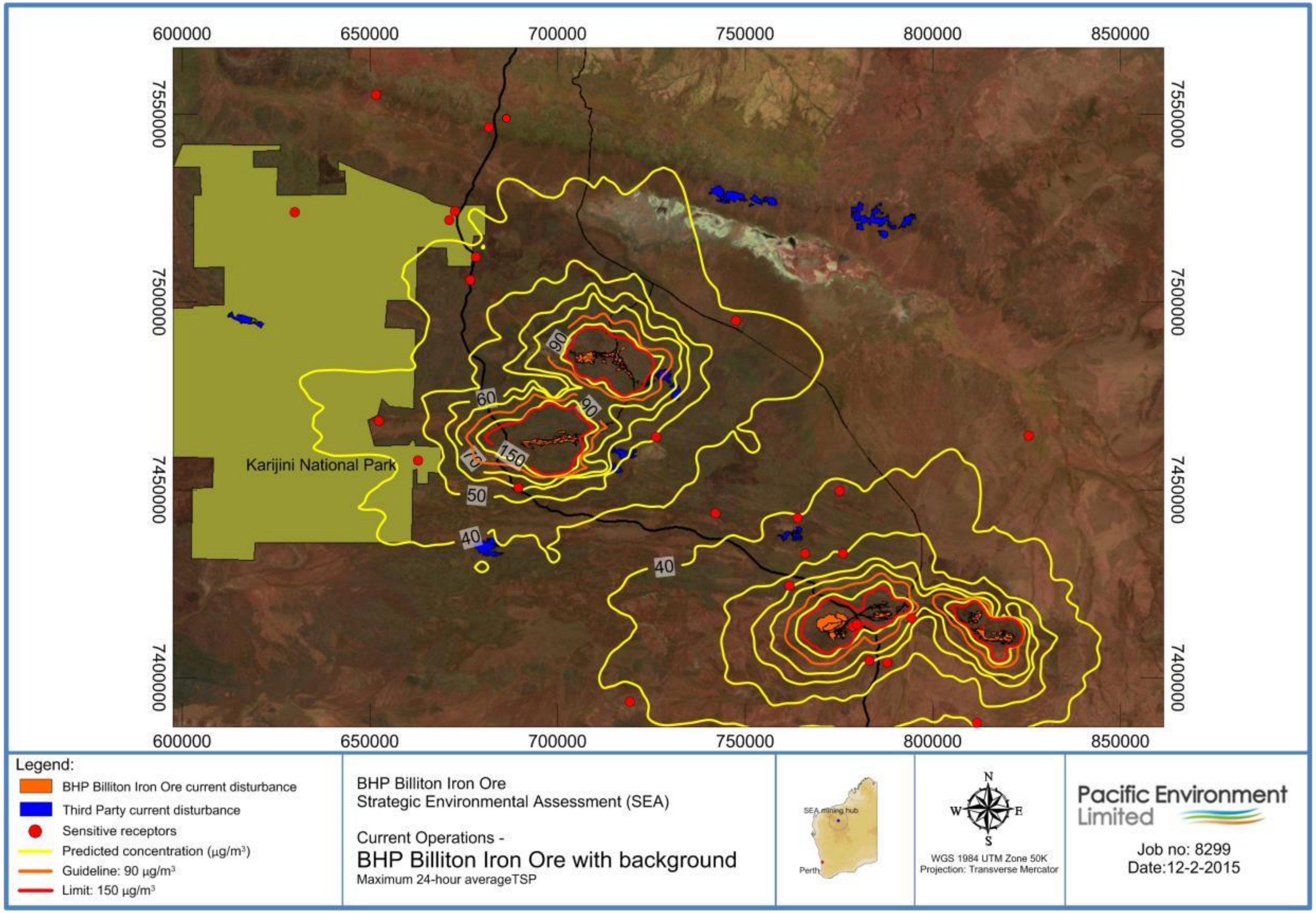

Figure 8-4: Maximum predicted 24-hour average TSP concentrations for existing BHP Billiton Iron Ore operations with background

Table 8-4: Predicted 24-hour TSP Concentrations at receptors including background (µg/m³): Existing BHP Billiton Iron Ore operations

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 90 µg/m³	Greater than 150 µg/m³
Juna Downs	Homestead	43	41	39	38	36	35	-	-
Ethel Creek	Homestead	37	36	35	34	33	33	-	-
Marillana	Homestead	41	37	36	35	34	34	-	-
Mulga Downs	Homestead	36	35	35	34	33	33	-	-
Prairie Downs	Homestead	39	37	36	35	34	34	-	-
Sylvania	Homestead	41	37	35	34	33	34	-	-
Munjina East Gorge	Lookout	40	39	38	37	35	35	-	-
Fig Tree Crossing	Lookout	43	41	40	39	37	35	-	-
Mt Meharry	Lookout	41	40	38	36	35	35	-	-
Mt Newman	Lookout	54	52	45	43	39	37	-	-
Tower Hill	Lookout	216	193	139	106	58	57	52	11
Karijini Eco Retreat	Recreation Camp Site	35	35	35	34	34	34	-	-
Ophthalmia Dam	Recreation Site	75	57	47	43	39	38	-	-
Round Hill	Recreation Site	64	54	49	45	37	37	-	-
Hickman Crater	Recreation Site	40	38	37	36	34	34	-	-
Weeli Wolli Spring/Outfall	Recreation Site	49	44	38	36	34	34	-	-
Stuarts Pool	Recreation Site	44	42	39	38	36	35	-	-
Kalgan Pool	Recreation Site	47	44	42	40	37	36	-	-
Eagle Rock Hole	Recreation Site	40	39	37	36	35	34	-	-
Mt Robinson	Rest Stop	57	49	43	40	35	35	-	-
Munjina Roadhouse	Roadhouse	37	37	36	35	34	34	-	-
Auski Village	Roadhouse	39	37	36	35	34	34	-	-
Capricorn Roadhouse	Roadhouse	55	53	46	41	37	36	-	-
Newman	Town Centre	122	108	91	82	55	50	20	-
Rhodes Ridge	Town Site	38	37	36	35	35	34	-	-
Wirlu-Murra	Aboriginal Community	37	36	35	34	33	34	-	-

8.2.2.2 Existing third party operations

The key outcomes of the predicted TSP impact from existing third party operations are summarised below, and presented in Figure 8-5 and Table 8-6:

- There are no predicted excursions of the 24-hour maximum TSP criteria (both Kwinana EPP criteria and Kwinana EPP limit).
- The top three maximum 24-hour TSP levels are predicted to occur at Marillana receptor (51µg/m³) followed by Weeli Wolli Spring/ Outfall (50µg/m³) and Eagle Rock Hole (44µg/m³).

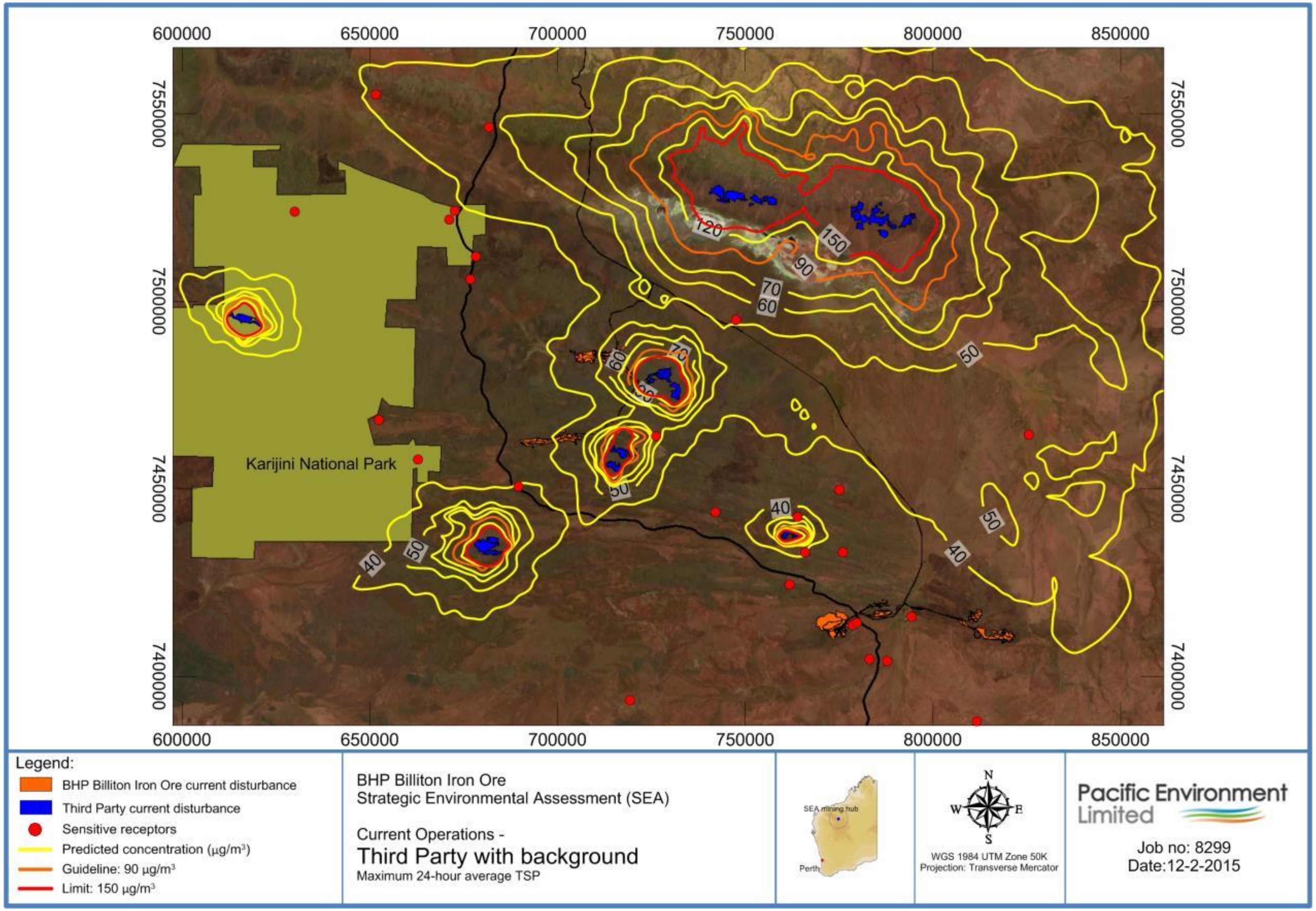

Figure 8-5: Maximum predicted 24-hour average TSP concentrations for existing third party operations with background

Table 8-5: Predicted 24-hour TSP Concentrations at receptors including background (µg/m³): existing third party operations

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 90 µg/m³	Greater than 150 µg/m³
Juna Downs	Homestead	35	34	34	34	34	34	-	-
Ethel Creek	Homestead	41	39	36	34	33	34	-	-
Marillana	Homestead	51	45	41	38	35	35	-	-
Mulga Downs	Homestead	39	37	36	35	34	34	-	-
Prairie Downs	Homestead	34	34	34	33	33	33	-	-
Sylvania	Homestead	34	34	33	33	33	33	-	-
Munjina East Gorge	Lookout	37	36	35	35	34	34	-	-
Fig Tree Crossing	Lookout	37	36	35	35	34	34	-	-
Mt Meharry	Lookout	35	35	34	34	34	34	-	-
Mt Newman	Lookout	36	35	34	34	33	33	-	-
Tower Hill	Lookout	35	34	34	34	33	33	-	-
Karijini Eco Retreat	Recreation Camp Site	36	35	34	34	34	34	-	-
Ophthalmia Dam	Recreation Site	35	34	34	33	33	33	-	-
Round Hill	Recreation Site	34	34	34	33	33	33	-	-
Hickman Crater	Recreation Site	38	36	35	34	33	33	-	-
Weeli Wolli Spring/Outfall	Recreation Site	50	46	43	41	35	35	-	-
Stuarts Pool	Recreation Site	40	37	36	35	33	34	-	-
Kalgan Pool	Recreation Site	36	35	34	34	33	33	-	-
Eagle Rock Hole	Recreation Site	44	41	39	37	35	34	-	-
Mt Robinson	Rest Stop	39	38	36	36	34	34	-	-
Munjina Roadhouse	Roadhouse	39	36	35	35	34	34	-	-
Auski Village	Roadhouse	40	36	35	35	34	34	-	-
Capricorn Roadhouse	Roadhouse	34	34	34	33	33	33	-	-
Newman	Town Centre	35	34	34	34	33	33	-	-
Rhodes Ridge	Town Site	36	35	35	34	34	34	-	-
Wirlu-Murra	Aboriginal Community	47	42	38	37	35	35	-	-

8.2.2.3 Existing operations - cumulative

The key outcomes of predicted cumulative TSP impacts from existing BHP Billiton Iron Ore operations, third party operations and background sources are summarised below, and presented in Figure 8-6 and Table 8-6:

- Excursions of the Kwinana EPP criteria are noted at Tower Hill and Newman receptors; and excursions of Kwinana EPP limit are noted at Tower Hill.
- At the Tower Hill receptor, in comparison to the BHP Billiton Iron Ore plus background scenario (Section 8.2.2.1)

  - a slight increase in the 95th percentile is noted
  - no change is noted in the other statistical variables.
- At the Newman receptor, in comparison to the levels predicted to occur for BHP Billiton Iron Ore plus background scenario (Section 8.2.2.1) no change in the statistical variables is noted.
- The results indicate that the existing cumulative operations have the potential to impact air quality in the Pilbara Region.
- At these 2 impacted receptors, there is considerable reduction from the maximum TSP concentrations predicted (Table 8-6) in comparison to the lower percentiles (99th to 90th percentiles). For example, the 99th and 95th percentile at Tower Hill receptor are 11% and 36% lower than the maximum concentrations predicted.
- The maximum predicted concentrations could therefore be regarded as a single extreme event which may occur under certain meteorological conditions.

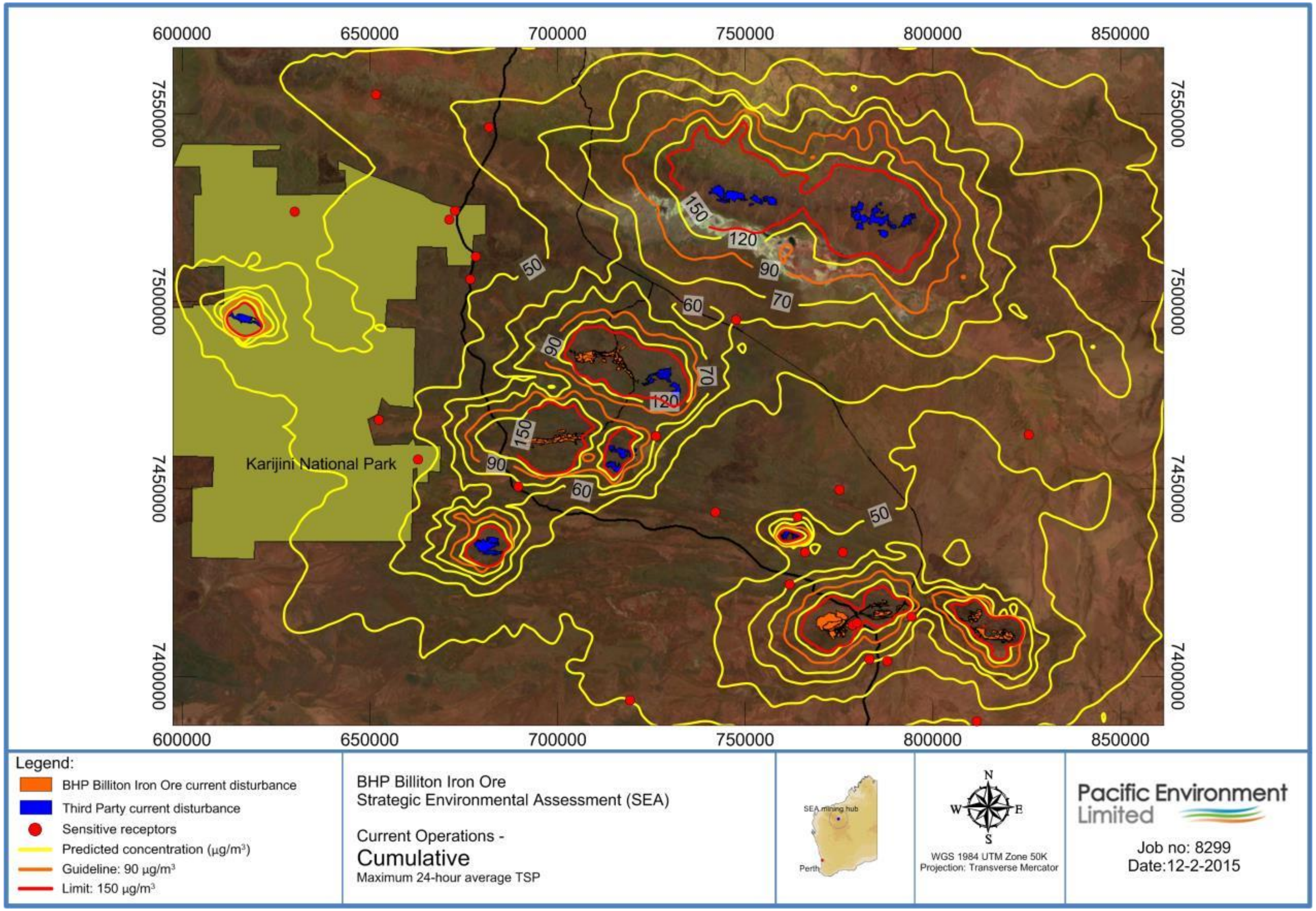

Figure 8-6: Maximum predicted 24-hour average TSP concentrations for existing cumulative operations with background

Table 8-6: Predicted 24-hour TSP Concentrations at receptors including background (µg/m³): Cumulative existing operations

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 90 µg/m³	Greater than 150 µg/m³
Juna Downs	Homestead	44	41	40	39	36	36	-	0
Ethel Creek	Homestead	41	40	37	35	33	34	-	0
Marillana	Homestead	51	46	42	40	36	35	-	0
Mulga Downs	Homestead	39	37	36	36	35	34	-	0
Prairie Downs	Homestead	39	37	36	36	34	34	-	0
Sylvania	Homestead	41	38	36	35	33	34	-	0
Munjina East Gorge	Lookout	41	40	39	38	36	35	-	0
Fig Tree Crossing	Lookout	46	43	41	40	37	36	-	0
Mt Meharry	Lookout	42	41	38	37	36	35	-	0
Mt Newman	Lookout	54	52	45	43	39	38	-	0
Tower Hill	Lookout	216	193	140	106	58	57	52	11
Karijini Eco Retreat	Recreation Camp Site	36	36	35	35	34	34	-	0
Ophthalmia Dam	Recreation Site	75	58	47	43	39	38	-	0
Round Hill	Recreation Site	64	54	49	45	37	37	-	0
Hickman Crater	Recreation Site	42	38	37	36	35	34	-	0
Weeli Wolli Spring/Outfall	Recreation Site	59	50	47	44	36	36	-	0
Stuarts Pool	Recreation Site	44	42	39	38	36	36	-	0
Kalgan Pool	Recreation Site	47	45	42	40	37	36	-	0
Eagle Rock Hole	Recreation Site	46	45	41	39	36	36	-	0
Mt Robinson	Rest Stop	58	51	44	42	36	36	-	0
Munjina Roadhouse	Roadhouse	39	38	37	36	35	35	-	0
Auski Village	Roadhouse	40	38	37	36	35	35	-	0
Capricorn Roadhouse	Roadhouse	57	54	46	42	37	36	-	0
Newman	Town centre	122	108	91	82	55	50	20	0
Rhodes Ridge	Town site	40	38	37	36	35	35	-	0
Wirlu-Murra	Aboriginal Community	47	42	39	38	36	35	-	-

8.3 Scenario 2 – 30% Development

8.3.1 Assessment of PM_{10} (potential impact on human health)

To assess the impact of modelled PM_{10}, concentrations averaged over 24-hour are compared to the NEPM 24-hour average of 50µg/m³ and Taskforce 24-hour average of 70µg/m³ (Section 3.1). It is worth-noting that there are 16 recreational sites and lookouts where people congregate only intermittently which are treated as sensitive receptors in this conceptual model. These receptors are still assessed against the NEPM and Taskforce criteria to provide an indicative dust impact. A detailed air quality assessment is required in the Derived Proposal stage to address the actual dust impact to these sensitive receptors.

8.3.1.1 BHP Billiton Iron Ore operations

The key outcomes of the impact assessment are summarised below, and presented in Figure 8-7 (No Control), Figure 8-8 (Standard Controls), Figure 8-9 (Leading Controls), Table 8-7 (No Control), Table 8-8 (Standard Controls) and Table 8-9 (Leading Controls):

- As anticipated, the highest maximum concentrations are noted for the No Control scenario with a reduction in the maximum concentrations noted for the Standard Control scenario. The lowest maximum concentration is observed for the Leading Control scenario. It is worth noting that while BHP Billiton Iron Ore historically operates with Standard dust controls, the No Control scenario is presented to emphasise the importance of dust controls.
- Across the various control scenarios, the top three maximum concentrations (in descending order) were noted at Mt Robinson, Tower Hill and Weeli Wolli Spring/ Outlet, and are all intermittently occupied receptor locations.
- For the No Control, Standard Control and Leading Control scenarios, there were (respectively) 16, 9 and 2 receptors with concentration in excess of the NEPM criteria of 50µg/m³. It is noted that the NEPM criteria is less applicable for intermittently occupied receptors.
    - Of the 16 receptors that are modelled with concentrations above the NEPM criteria for No Control scenario, only 4 receptors are expected to have continuous occupancy.
    - Of 9 receptors that exceed the NEPM criteria for the Standard Control scenario, only 2 receptors are expected to have continuous occupancy.
    - For the 2 receptors that exceed the NEPM criteria for the Leading Control scenario, no receptor is expected to have continuous occupancy.
- For the No Control and Standard Control scenarios, there were 10 and 5 receptors respectively with concentrations in excess of 70µg/m³. There were no excursions of the Taskforce criteria (70µg/m³) for the Leading Control scenario.
    - Out of the 10 receptors that exceed the Taskforce criteria for the No Control scenario, only 2 receptors are Roadhouse/town centre with expected continuous occupancy.
    - Of the 5 receptors that exceed the Taskforce criteria for Standard Control scenario, only 1 receptor is a town centre and expected to have continuous occupancy.
- From Table 8-7 to Table 8-9, it is apparent that there are significant decreases from the maximum predicted PM_{10} concentrations towards the lower statistics (99th to 95th percentiles). For example, for the Standard Control scenario, the 99th and 95th percentile at the Mt Robinson receptor are 20% and 41% lower than the maximum concentrations predicted. This indicates that the maximum predicted concentrations are single extreme events that could be managed during operations through a dust management procedure;

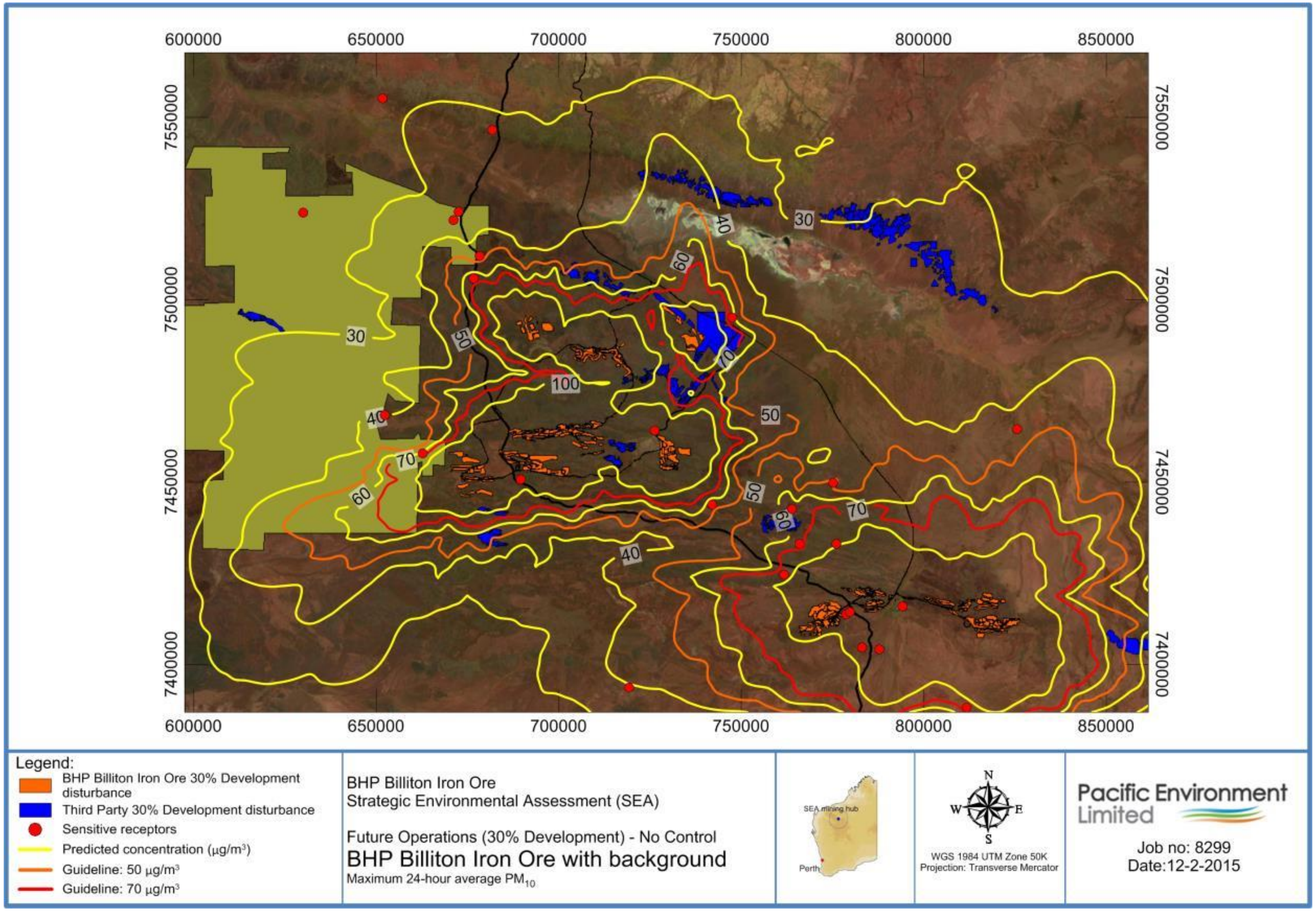

Figure 8-7: Maximum predicted 24-hour average PM_{10} concentrations for 30% Development BHP Billiton Iron Ore operations (No Control) with background

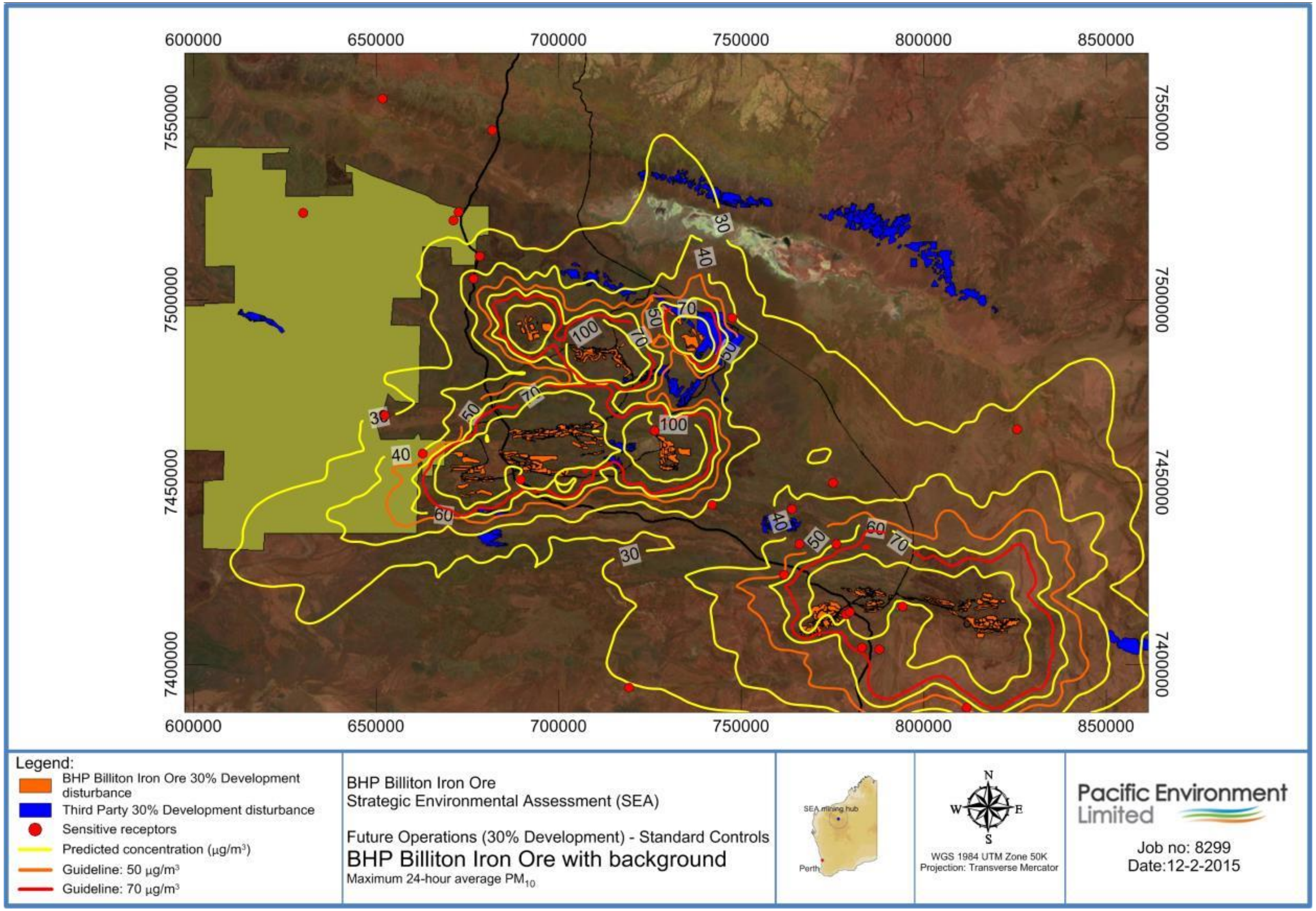

Figure 8-8: Maximum predicted 24-hour average PM_{10} concentrations for 30% Development BHP Billiton Iron Ore operations (Standard Controls) with background

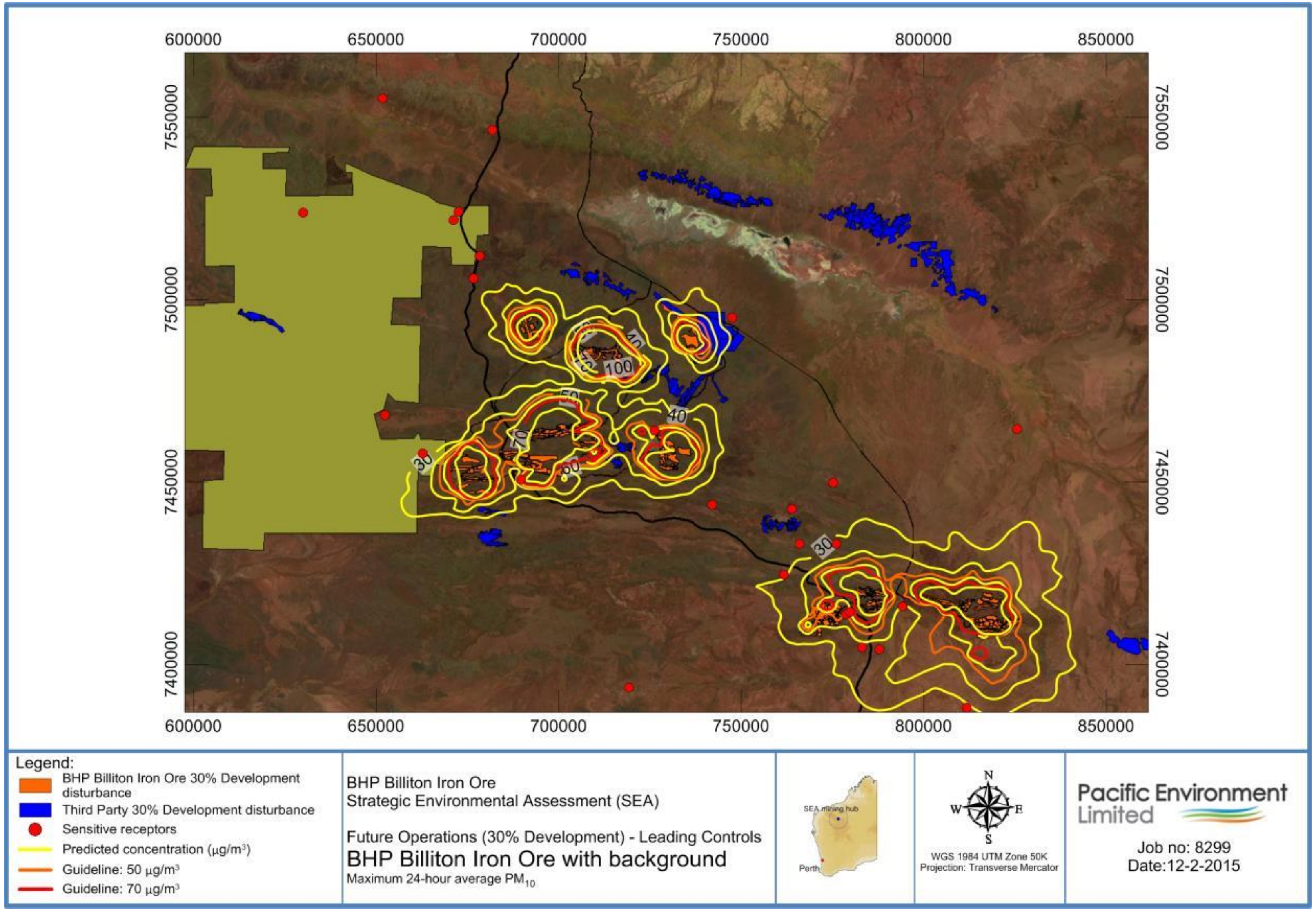

Figure 8-9: Maximum predicted 24-hour average PM_{10} concentrations for 30% Development BHP Billiton Iron Ore operations (Leading Controls) with background

Table 8-7: Predicted 24-hour PM_{10} Concentrations at receptors including background (µg/m³): BHP Billiton Iron Ore operations (30% Development) - No Control

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 50 µg/m³	Greater than 70 µg/m³
Juna Downs	Homestead	35	34	31	29	26	24	-	-
Ethel Creek	Homestead	41	35	29	26	18	20	-	-
Marillana	Homestead	70	60	45	37	24	24	14	-
Mulga Downs	Homestead	30	26	24	23	21	20	-	-
Prairie Downs	Homestead	40	36	31	27	21	21	-	-
Sylvania	Homestead	65	46	35	27	19	21	3	-
Munjina East Gorge	Lookout	55	49	42	38	28	26	3	-
Fig Tree Crossing	Lookout	97	74	61	56	44	36	73	5
Mt Meharry	Lookout	54	39	35	33	29	26	1	-
Mt Newman	Lookout	78	62	51	46	37	31	20	2
Tower Hill	Lookout	249	206	163	122	78	63	182	129
Karijini Eco Retreat	Recreation Camp Site	28	25	24	23	21	20	-	-
Ophthalmia Dam	Recreation Site	132	114	86	79	59	47	152	65
Round Hill	Recreation Site	101	87	71	62	39	33	71	21
Hickman Crater	Recreation Site	48	42	35	31	26	24	-	-
Weeli Wolli Spring/Outfall	Recreation Site	166	115	87	76	54	46	130	55
Stuarts Pool	Recreation Site	58	50	42	39	31	27	5	-
Kalgan Pool	Recreation Site	75	69	52	45	35	31	24	4
Eagle Rock Hole	Recreation Site	54	45	34	32	27	25	1	-
Mt Robinson	Rest Stop	288	227	164	132	58	57	123	96
Munjina Roadhouse	Roadhouse	40	35	31	29	23	22	-	-
Auski Village	Roadhouse	38	32	29	27	22	21	-	-
Capricorn Roadhouse	Roadhouse	110	94	74	66	38	34	76	23
Newman	Town Centre	155	135	112	100	70	54	172	108
Rhodes Ridge	Town Site	47	41	32	30	25	24	-	-
Wirlu-Murra	Aboriginal Community	34	30	27	26	23	22	-	-

Table 8-8: Predicted 24-hour PM_{10} Concentrations at receptors including background (µg/m³): BHP Billiton Iron Ore operations (30% Development) - Standard Controls

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 50 µg/m³	Greater than 70 µg/m³
Juna Downs	Homestead	27	27	25	24	23	21	-	-
Ethel Creek	Homestead	31	27	24	22	18	19	-	-
Marillana	Homestead	46	41	32	28	21	21	-	-
Mulga Downs	Homestead	24	22	21	21	20	19	-	-
Prairie Downs	Homestead	30	28	25	23	20	20	-	-
Sylvania	Homestead	44	33	27	23	18	20	-	-
Munjina East Gorge	Lookout	38	35	31	29	23	22	-	-
Fig Tree Crossing	Lookout	60	48	41	38	32	28	3	-
Mt Meharry	Lookout	38	29	27	26	24	22	-	-
Mt Newman	Lookout	50	42	36	33	28	25	1	-
Tower Hill	Lookout	143	120	96	74	51	43	113	50
Karijini Eco Retreat	Recreation Camp Site	23	22	21	21	20	19	-	-
Ophthalmia Dam	Recreation Site	80	70	55	51	40	34	43	4
Round Hill	Recreation Site	63	55	47	42	30	26	13	-
Hickman Crater	Recreation Site	34	31	28	25	22	21	-	-
Weeli Wolli Spring/Outfall	Recreation Site	98	70	55	49	38	33	34	4
Stuarts Pool	Recreation Site	40	36	31	29	25	23	-	-
Kalgan Pool	Recreation Site	49	46	36	33	27	25	-	-
Eagle Rock Hole	Recreation Site	37	33	27	25	23	22	-	-
Mt Robinson	Rest Stop	164	131	97	80	40	39	88	47
Munjina Roadhouse	Roadhouse	30	27	25	24	21	20	-	-
Auski Village	Roadhouse	29	26	24	23	20	20	-	-
Capricorn Roadhouse	Roadhouse	68	59	48	44	29	26	12	-
Newman	Town Centre	92	81	69	63	46	38	83	15
Rhodes Ridge	Town Site	34	30	26	24	22	21	-	-
Wirlu-Murra	Aboriginal Community	27	24	23	22	21	20	-	-

Table 8-9: Predicted 24-hour PM_{10} Concentrations at receptors including background (µg/m³): BHP Billiton Iron Ore operations (30% Development) - Leading Controls

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 50 µg/m³	Greater than 70 µg/m³
Juna Downs	Homestead	21	21	20	20	20	19	-	-
Ethel Creek	Homestead	22	21	20	19	18	18	-	-
Marillana	Homestead	27	25	23	21	19	19	-	-
Mulga Downs	Homestead	20	20	19	19	19	19	-	-
Prairie Downs	Homestead	22	21	20	20	19	19	-	-
Sylvania	Homestead	26	23	21	20	18	19	-	-
Munjina East Gorge	Lookout	24	23	22	22	20	19	-	-
Fig Tree Crossing	Lookout	31	28	25	25	23	21	-	-
Mt Meharry	Lookout	24	22	21	21	20	19	-	-
Mt Newman	Lookout	28	26	24	23	21	20	-	-
Tower Hill	Lookout	57	50	43	36	28	26	4	-
Karijini Eco Retreat	Recreation Camp Site	20	19	19	19	19	19	-	-
Ophthalmia Dam	Recreation Site	38	34	30	28	25	23	-	-
Round Hill	Recreation Site	32	30	27	26	22	21	-	-
Hickman Crater	Recreation Site	23	22	21	20	19	19	-	-
Weeli Wolli Spring/Outfall	Recreation Site	43	35	30	28	24	23	-	-
Stuarts Pool	Recreation Site	25	24	22	22	20	20	-	-
Kalgan Pool	Recreation Site	28	27	24	23	21	20	-	-
Eagle Rock Hole	Recreation Site	24	23	21	20	20	19	-	-
Mt Robinson	Rest Stop	64	54	43	37	25	25	7	-
Munjina Roadhouse	Roadhouse	22	21	20	20	19	19	-	-
Auski Village	Roadhouse	22	21	20	20	19	19	-	-
Capricorn Roadhouse	Roadhouse	34	31	28	26	22	21	-	-
Newman	Town Centre	41	38	34	32	27	24	-	-
Rhodes Ridge	Town Site	23	22	21	20	19	19	-	-
Wirlu-Murra	Aboriginal Community	21	20	20	19	19	19	-	-

8.3.1.2 Third party operations

The key outcomes of the impact assessment from the third party operations are summarised below, and presented in Figure 8-10 and Table 8-10:

- The 24-hour average maximum contour (NEPM criteria) occurs outside 5 sensitive receptors, i.e. Marillana, Weeli Wolli Spring/Outfall, Stuarts Pool, Eagle Rock Hole and Mt Robinson.
- The 24-hour average maximum contour (Taskforce criteria) occurs outside three sensitive receptors, i.e. Marillana, Stuarts Pool and Eagle Rock Hole.
- Table 8-10 highlights that there are considerable reductions from the maximum predicted PM_{10} concentrations towards the lower statistics (99th and 90th percentiles) at Marillana, Weeli Wolli Spring/Outfall, Stuarts Pool, Eagle Rock Hole and Mt Robinson.
- It is worth noting that the scenario modelled is highly precautionary as it is assumed all mines are developed and operating simultaneously. As a result, this scenario is unlikely to occur.
- The results clearly show that there is a potential that the current third party operations may impact the air quality in Pilbara Region. It is worth noting that the scenario modelled is highly precautionary as it is assumed all mines are developed and operating simultaneously. As a result, this scenario is unlikely to occur.

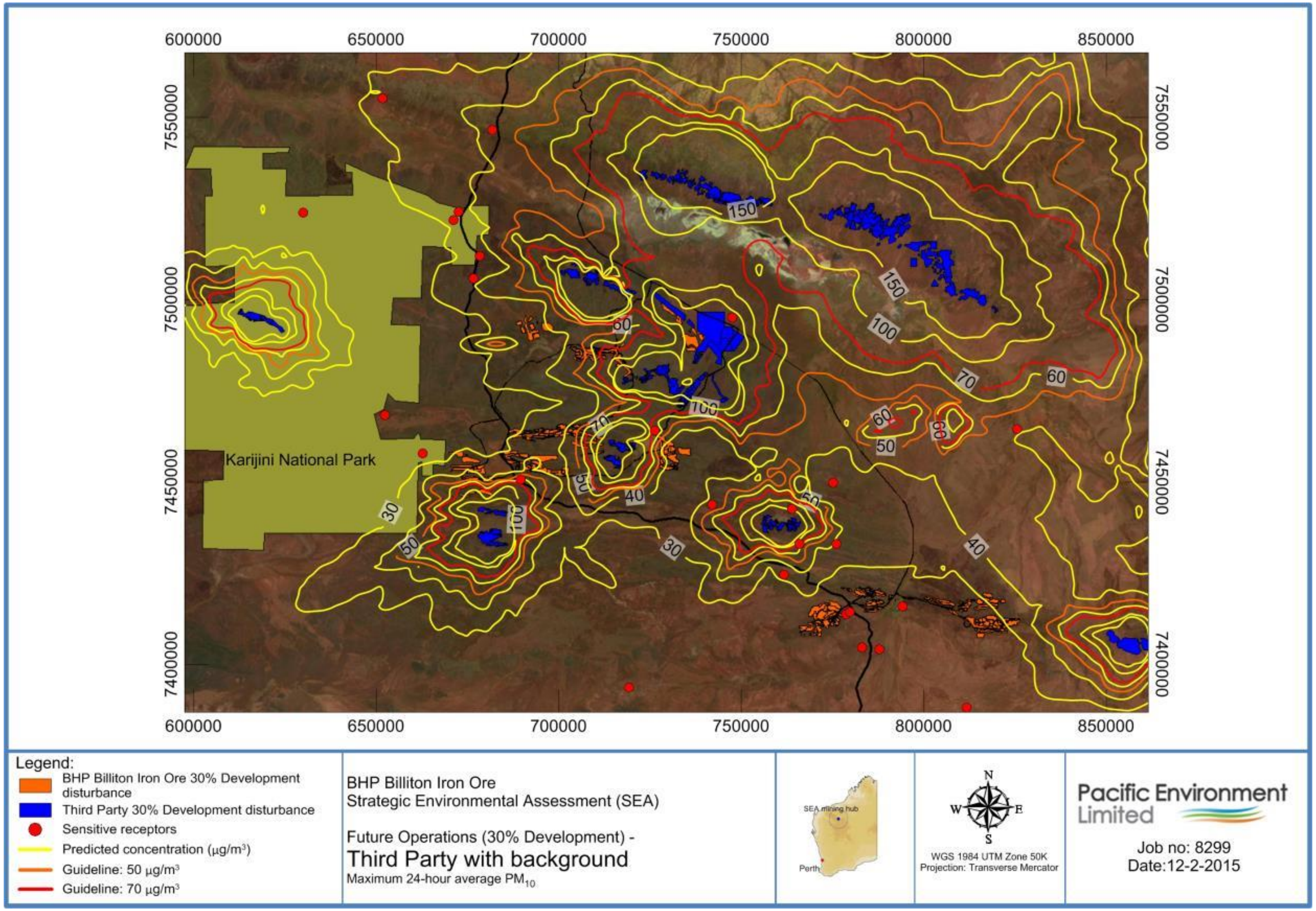

Figure 8-10: Maximum predicted 24-hour average PM_{10} concentrations for 30% Development scenario third party operations with background

Table 8-10: Predicted 24-hour PM_{10} Concentrations at receptors including background (μg/m³): third party operations (30% Development)

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 50 μg/m³	Greater than 70 μg/m³
Juna Downs	Homestead	24	23	22	21	20	20	-	-
Ethel Creek	Homestead	41	35	26	22	19	20	-	-
Marillana	Homestead	181	147	111	93	48	44	107	78
Mulga Downs	Homestead	31	30	27	26	24	22	-	-
Prairie Downs	Homestead	22	21	20	20	19	19	-	-
Sylvania	Homestead	22	21	20	19	19	19	-	-
Munjina East Gorge	Lookout	34	28	25	24	22	21	-	-
Fig Tree Crossing	Lookout	38	28	25	24	23	21	-	-
Mt Meharry	Lookout	26	23	22	21	20	20	-	-
Mt Newman	Lookout	33	30	24	22	19	19	-	-
Tower Hill	Lookout	26	25	21	20	19	19	-	-
Karijini Eco Retreat	Recreation Camp Site	25	22	21	21	20	20	-	-
Ophthalmia Dam	Recreation Site	28	24	21	20	19	19	-	-
Round Hill	Recreation Site	24	23	21	20	19	19	-	-
Hickman Crater	Recreation Site	36	32	27	24	20	20	-	-
Weeli Wolli Spring/Outfall	Recreation Site	61	57	45	39	26	25	7	-
Stuarts Pool	Recreation Site	72	59	38	29	19	21	8	1
Kalgan Pool	Recreation Site	36	29	24	22	19	19	-	-
Eagle Rock Hole	Recreation Site	107	84	60	48	29	28	34	10
Mt Robinson	Rest Stop	66	53	38	31	23	23	5	-
Munjina Roadhouse	Roadhouse	34	29	25	24	22	21	-	-
Auski Village	Roadhouse	38	30	26	25	23	22	-	-
Capricorn Roadhouse	Roadhouse	25	23	21	20	19	19	-	-
Newman	Town Centre	26	25	21	20	19	19	-	-
Rhodes Ridge	Town Site	43	38	34	30	25	23	-	-
Wirlu-Murra	Aboriginal Community	46	38	33	32	28	25	-	-

8.3.1.3 Cumulative Operations

The air quality assessment of PM_{10} for the 30% Development snapshot scenario are presented in Figure 8-11 (No Control for BHP Billiton Iron Ore operations), Figure 8-12 (Standard Controls for BHP Billiton Iron Ore operations), Figure 8-13 (Leading Controls for BHP Billiton Iron Ore operations), Table 8-11 (No Control for BHP Billiton Iron Ore operations), Table 8-12 (Standard Controls for BHP Billiton Iron Ore operations) and Table 8-13 (Leading Controls for BHP Billiton Iron Ore operations).

It is worth-noting that there are a total of 16 recreational sites and lookouts where people only congregate intermittently, however are treated as sensitive receptors in this conceptual model. These receptors are still assessed against the NEPM and Taskforce criteria to provide an indicative potential dust impact. The key outcomes of the air quality assessment are summarised below:

- There is a significant reduction in the maximum predicted PM_{10} concentrations in the Standard and Leading Control scenario when compared to the No Control scenario.
- For the No Control, Standard Control and Leading Control scenarios, there were 18, 13 and 6 receptors respectively with concentrations in excess of 50µg/m^3. It is noted that this criteria is less applicable for intermittently occupied receptors.
  - Out of the 18 receptors that exceed the criteria for the No Control scenario, only 5 receptors are expected to have continuous occupancy.
  - Of the 13 receptors that exceed the criteria for the Standard Control scenario, only 3 receptors are homestead/Roadhouse/town centre with expected continuous occupancy.
  - Out of the 6 receptors that exceed the criteria for Leading Control scenario, 1 receptor is expected to have continuous occupancy.
- For the No Control and Standard Control and Leading Control scenarios, there were 13, 8 and 4 receptors respectively with concentrations in excess of 70µg/m^3. It is noted that this criteria is less applicable for intermittently occupied receptors.
  - Out of the 13 receptors that exceed the criteria for the No Control scenario, only 3 receptors are expected to have continuous occupancy.
  - Out of the 8 receptors that exceed the criteria for the Standard Control scenario, only 2 receptors are expected to have continuous occupancy.
  - Of the 4 receptors that exceed the criteria for Leading Control scenario, 1 receptor is expected to have continuous occupancy.
- From Table 8-11 to Table 8-13, it is apparent that there are significant decreases from the maximum predicted PM_{10} concentrations at the receptors mentioned previously, with the lower statistics (99th to 95th percentiles). For example, for the Standard Control scenario, the 99th and 95th percentile at the Mt Robinson receptor are 20% and 39% lower than the maximum concentrations predicted. This indicates that the maximum predicted concentrations are single events that could be managed during operations through a dust management procedure.
- The predicted high PM_{10} concentrations at the receptors indicate there is a high potential for PM_{10} to impact the Pilbara Region at all third party mining operations (assuming Standard Controls) and in the unlikely scenario that No Control is adopted by BHP Billiton Iron Ore;
- By implementing Standard Controls at all BHP Billiton Iron Ore processing hubs in the Pilbara Region, the predicted PM_{10} concentrations have been reduced compared to the No Control scenario. However, there are still 8 receptors (i.e. 4 recreational sites, 1 lookout, 1 homestead, 1 rest stop and 1 town centre) that do not achieve the Taskforce criteria. Hence, there may still be a potential for PM_{10} impact on the Pilbara Region with Standard Controls in place at all BHP Billiton Iron Ore processing hubs.
- With Leading Controls at BHP Billiton Iron Ore in place, there are considerable reductions of PM_{10} concentrations compared to the No Control scenario. However, the predicted PM_{10} concentrations at 8 receptors (including 1 homestead, 2 recreational sites and 2 rest stops) still exceed the Taskforce criteria.
- It is worth noting that the predicted PM_{10} concentrations at Marillana are contributed to by both BHP Billiton Iron Ore and third party operations.
- For the 30% Development scenario, the Leading Controls have greatly reduced the potential impact at the sensitive receptors compared to the No Control and Standard Controls scenarios.

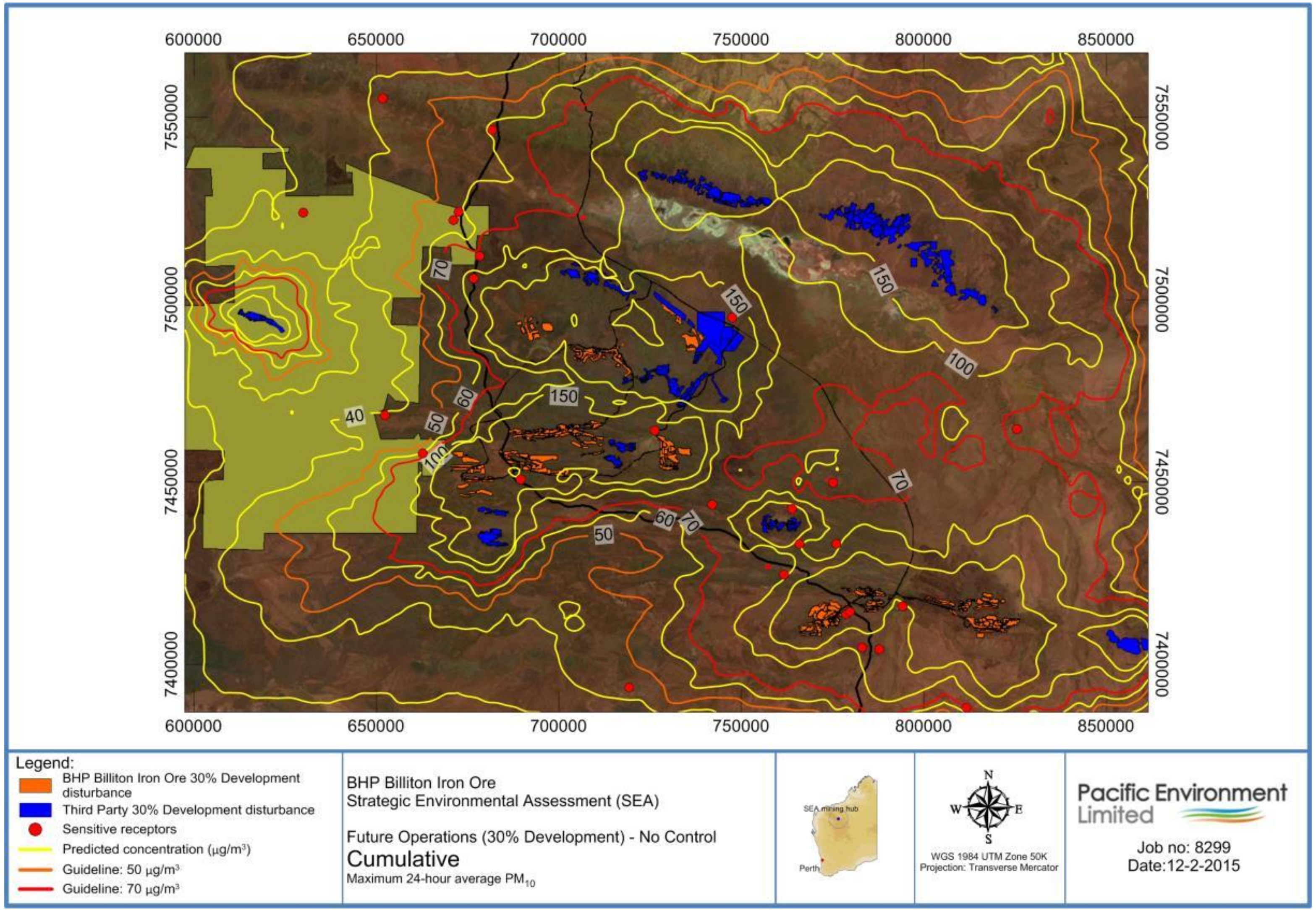

Figure 8-11: Maximum predicted 24-hour average PM_{10} concentrations for 30% Development scenario cumulative operations (No Control from BHP Billiton Iron Ore operations) with background

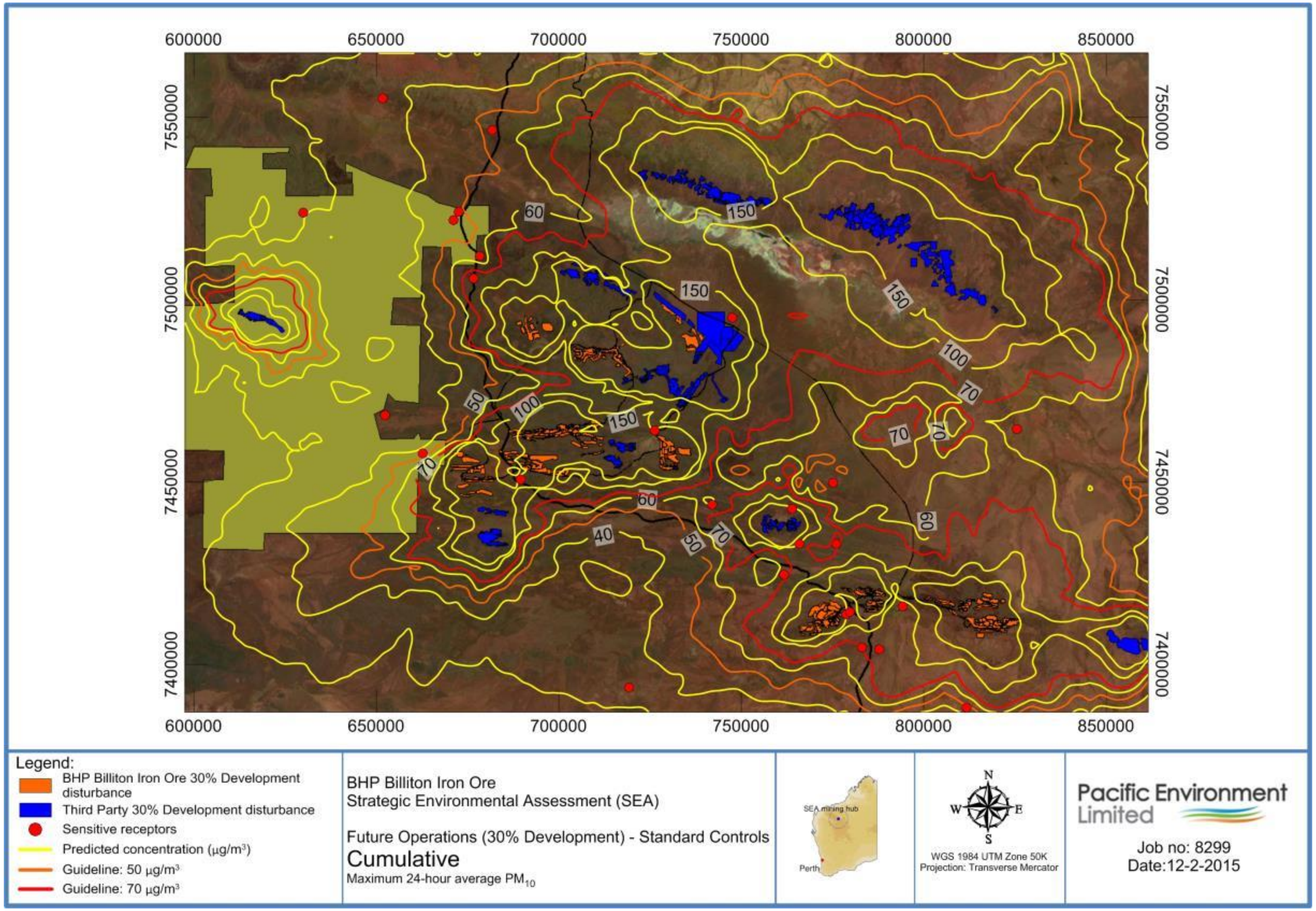

Figure 8-12: Maximum predicted 24-hour average PM_{10} concentrations for 30% Development cumulative operations (Standard Controls from BHP Billiton Iron Ore operations) with background

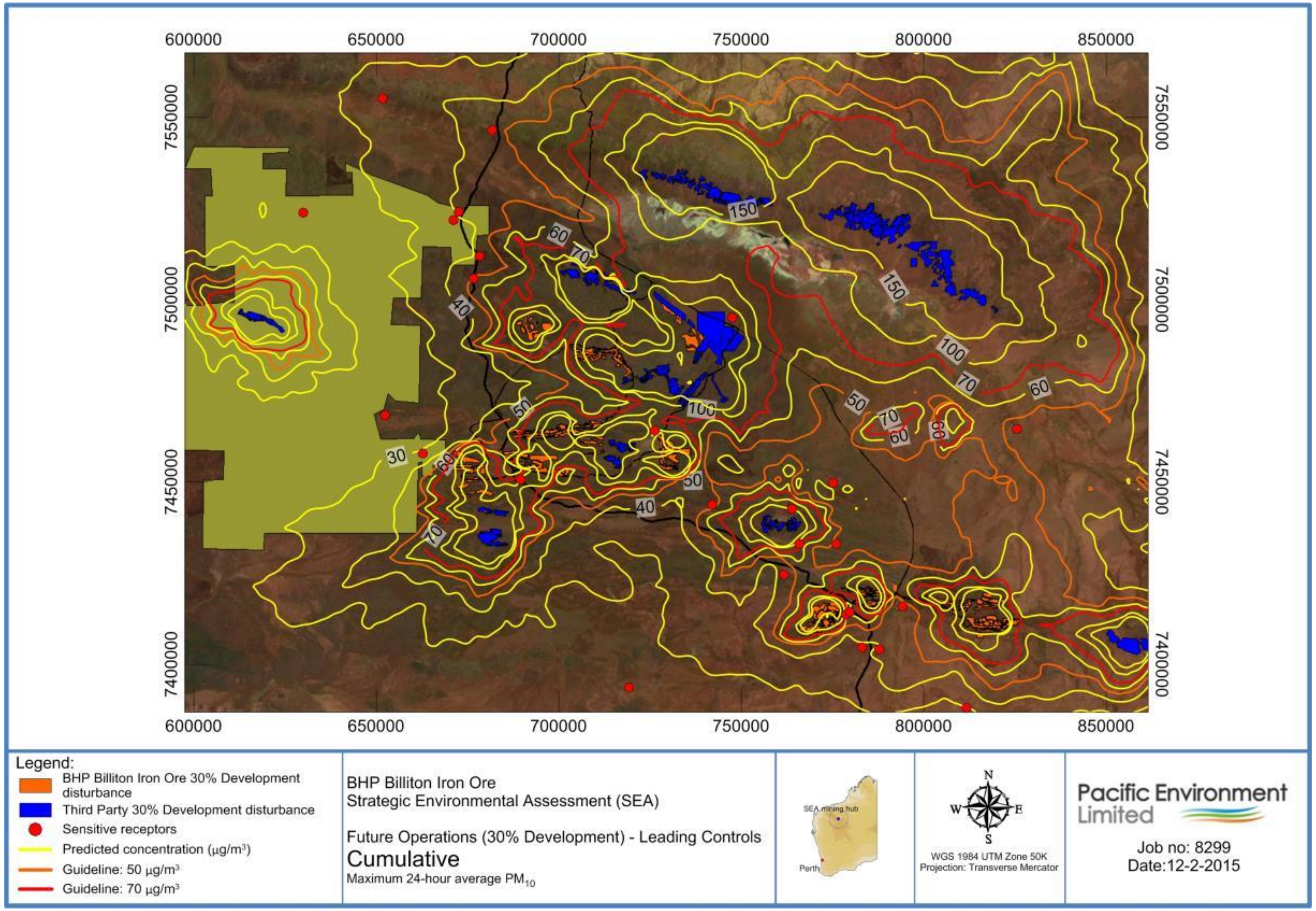

Figure 8-13: Maximum predicted 24-hour average PM_{10} concentrations for 30% Development scenario cumulative operations (Leading Controls from BHP Billiton Iron Ore operations) with background

Table 8-11: Predicted 24-hour PM_{10} Concentrations at receptors including background (µg/m³): cumulative operations (30% Development scenario) - No Control

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 50 µg/m³	Greater than 70 µg/m³
Juna Downs	Homestead	37	36	33	31	28	25	-	-
Ethel Creek	Homestead	49	41	33	30	21	21	-	-
Marillana	Homestead	222	180	134	112	53	50	120	90
Mulga Downs	Homestead	36	33	30	29	27	24	-	-
Prairie Downs	Homestead	40	37	31	28	22	22	-	-
Sylvania	Homestead	65	48	36	28	20	21	3	-
Munjina East Gorge	Lookout	62	54	45	42	32	29	9	-
Fig Tree Crossing	Lookout	104	79	66	61	48	39	94	11
Mt Meharry	Lookout	58	42	38	35	31	28	3	-
Mt Newman	Lookout	78	63	51	46	37	33	21	2
Tower Hill	Lookout	249	208	164	125	79	64	185	132
Karijini Eco Retreat	Recreation Camp Site	30	28	26	25	23	22	-	-
Ophthalmia Dam	Recreation Site	136	115	88	80	59	47	155	67
Round Hill	Recreation Site	102	89	74	64	41	34	75	26
Hickman Crater	Recreation Site	55	46	39	35	28	26	1	-
Weeli Wolli Spring/Outfall	Recreation Site	170	116	94	83	63	53	183	72
Stuarts Pool	Recreation Site	76	62	50	43	34	31	19	2
Kalgan Pool	Recreation Site	78	71	52	46	36	32	25	5
Eagle Rock Hole	Recreation Site	118	87	63	55	38	35	56	15
Mt Robinson	Rest Stop	293	231	168	138	66	62	146	103
Munjina Roadhouse	Roadhouse	48	41	35	33	28	25	-	-
Auski Village	Roadhouse	49	39	33	32	27	25	-	-
Capricorn Roadhouse	Roadhouse	112	95	76	68	39	34	78	29
Newman	Town centre	155	136	113	102	70	55	179	113
Rhodes Ridge	Town site	55	50	42	39	32	29	4	-
Wirlu-Murra	Aboriginal Community	48	44	39	37	33	28	-	-

Table 8-12: Predicted 24-hour PM_{10} Concentrations at receptors including background (µg/m³): cumulative operations (30% Development scenario) - Standard Controls

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 50 µg/m3	Greater than 70 µg/m3
Juna Downs	Homestead	30	29	27	26	25	23	-	-
Ethel Creek	Homestead	45	36	29	27	20	21	-	-
Marillana	Homestead	203	166	124	102	51	47	112	88
Mulga Downs	Homestead	33	31	29	28	25	23	-	-
Prairie Downs	Homestead	30	29	25	24	21	20	-	-
Sylvania	Homestead	44	35	28	24	19	20	-	-
Munjina East Gorge	Lookout	48	39	35	33	27	26	-	-
Fig Tree Crossing	Lookout	68	54	46	43	36	31	9	-
Mt Meharry	Lookout	42	32	30	28	26	24	-	-
Mt Newman	Lookout	51	43	36	34	29	26	2	-
Tower Hill	Lookout	143	122	97	77	51	43	114	53
Karijini Eco Retreat	Recreation Camp Site	26	25	23	23	22	21	-	-
Ophthalmia Dam	Recreation Site	83	71	56	52	41	34	49	4
Round Hill	Recreation Site	64	57	49	44	31	27	13	-
Hickman Crater	Recreation Site	42	37	31	29	24	23	-	-
Weeli Wolli Spring/Outfall	Recreation Site	102	83	64	56	46	40	83	9
Stuarts Pool	Recreation Site	74	61	41	34	28	26	10	2
Kalgan Pool	Recreation Site	53	47	37	34	29	26	1	-
Eagle Rock Hole	Recreation Site	113	86	61	52	34	32	44	14
Mt Robinson	Rest Stop	169	135	103	85	49	44	108	62
Munjina Roadhouse	Roadhouse	41	34	30	28	25	23	-	-
Auski Village	Roadhouse	43	33	29	28	25	24	-	-
Capricorn Roadhouse	Roadhouse	69	60	50	46	30	27	17	-
Newman	Town centre	92	82	70	64	47	38	86	17
Rhodes Ridge	Town site	48	42	38	34	29	26	-	-
Wirlu-Murra	Aboriginal Community	46	41	36	34	31	27	-	-

Table 8-13: Predicted 24-hour PM_{10} Concentrations at receptors including background (µg/m³): cumulative operations (30% Development scenario) - Leading Controls

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 50 µg/m³	Greater than 70 µg/m³
Juna Downs	Homestead	25	24	23	23	22	21	-	-
Ethel Creek	Homestead	42	35	27	24	19	20	-	-
Marillana	Homestead	188	153	115	96	48	45	108	80
Mulga Downs	Homestead	31	30	27	26	24	22	-	-
Prairie Downs	Homestead	22	22	21	21	19	19	-	-
Sylvania	Homestead	26	25	22	20	19	19	-	-
Munjina East Gorge	Lookout	38	31	27	26	24	23	-	-
Fig Tree Crossing	Lookout	43	36	31	30	27	24	-	-
Mt Meharry	Lookout	31	26	24	23	22	21	-	-
Mt Newman	Lookout	33	30	26	24	22	22	-	-
Tower Hill	Lookout	58	53	44	39	29	27	9	-
Karijini Eco Retreat	Recreation Camp Site	25	23	22	21	21	20	-	-
Ophthalmia Dam	Recreation Site	41	35	31	30	26	24	-	-
Round Hill	Recreation Site	34	32	29	27	23	21	-	-
Hickman Crater	Recreation Site	38	32	28	25	21	21	-	-
Weeli Wolli Spring/Outfall	Recreation Site	69	61	48	42	32	30	15	-
Stuarts Pool	Recreation Site	73	59	39	30	22	23	8	1
Kalgan Pool	Recreation Site	37	31	27	25	22	22	-	-
Eagle Rock Hole	Recreation Site	109	84	60	49	30	29	36	10
Mt Robinson	Rest Stop	70	66	51	47	34	30	24	1
Munjina Roadhouse	Roadhouse	36	30	27	25	23	22	-	-
Auski Village	Roadhouse	39	32	27	26	23	22	-	-
Capricorn Roadhouse	Roadhouse	35	33	29	28	22	21	-	-
Newman	Town centre	42	39	35	34	28	25	-	-
Rhodes Ridge	Town site	44	38	35	31	26	24	-	-
Wirlu-Murra	Aboriginal Community	46	38	34	32	29	26	-	-

8.3.2 Assessment of TSP (potential impact on amenity)

To assess the impact, modelled TSP concentrations averaged over 24-hour are compared to the assessment criteria (based on Kwinana EPP 24 hour average 90 µg/m³ and 24 hour average limit 150 µg/m³) selected for this study (Section 3.1).

8.3.2.1 BHP Billiton Iron Ore Operations

The key outcomes of the air quality assessment are summarised below, and are presented in Figure 8-14 (No Control), Figure 8-15 (Standard Controls), Figure 8-16 (Leading Controls) as well as Table 8-14 (No Control), Table 8-15 (Standard Controls) and Table 8-16 (Leading Controls):

- Similar to the assessment of PM_{10}, there is a significant reduction in the maximum predicted dust concentrations in the Standard Controls and Leading Controls dust management scenarios when compared to the No Control scenario.
- The receptors near Newman (i.e. Mt Newman, Tower Hill, Ophthalmia Dam, Round Hill, Kalgan Pool, Capricorn Roadhouse and Newman) receive the highest predicted concentrations as expected due to increased mining activities in close vicinity. The other receptors at Fig Tree Crossing, Weeli Wolli Spring/Outfall and Mt Robinson are also predicted to receive elevated TSP concentrations.
- From Table 8-14 to Table 8-16, it is apparent that there are significant decreases from the maximum predicted TSP concentrations at the receptors mentioned above with the lower statistics (99th to 95th percentiles). For example, for the Standard Control scenario, the 99^{th} and 95^{th} percentile at the Mt Robinson receptor are 18% and 36% lower than the maximum concentrations predicted. This indicates that the maximum predicted concentrations are single events that could be managed during operations through a dust management procedure.
- The predicted high TSP concentrations at the aforementioned receptors indicate there is a high potential for TSP to impact the Pilbara Region in the unlikely event that dust controls are not applied to operations.
- By implementing Standard Controls, the predicted TSP concentrations have been reduced compared to the No Control scenario. However, 1 continuous occupancy and 4 intermittently occupied receptors (Tower Hill, Newman and at Mt Robinson and Weeli Wolli Spring/ Outfall) still do not meet the criteria. Hence, there may still be a potential for TSP impact the Pilbara Region even with Standard Controls in place.
- With Leading Controls in place, there are considerable reductions of TSP concentrations compared to the No Control scenario. However, the predicted TSP concentration at Mt Robinson (an intermittently occupied receptor) exceeds the Kwinana EPP criteria but is achieved at all other receptor locations.
- Nonetheless, the Leading Controls greatly reduce the potential to impact at the sensitive receptors in the 30% Development scenario compared to No Control and Standard Controls scenarios.
- It is worth-noting that there are a total of 16 recreational sites and lookouts where people congregate only intermittently but are treated as sensitive receptors in this conceptual model. These receptors are still assessed against the Kwinana EPP to provide a conservative potential dust impact.

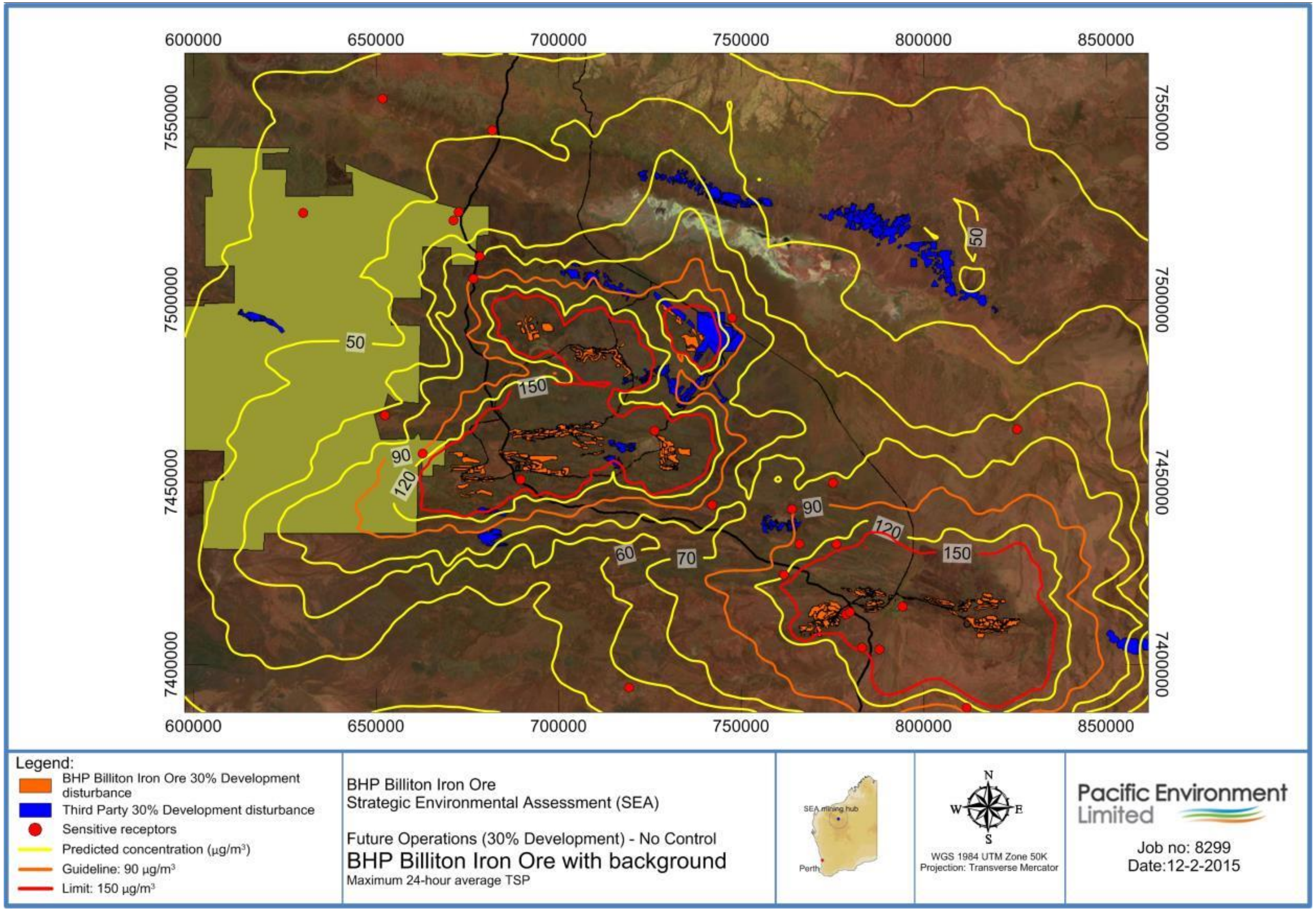

Figure 8-14: Maximum predicted 24-hour average TSP concentrations for 30% Development BHP Billiton Iron Ore operations (No Control) with background

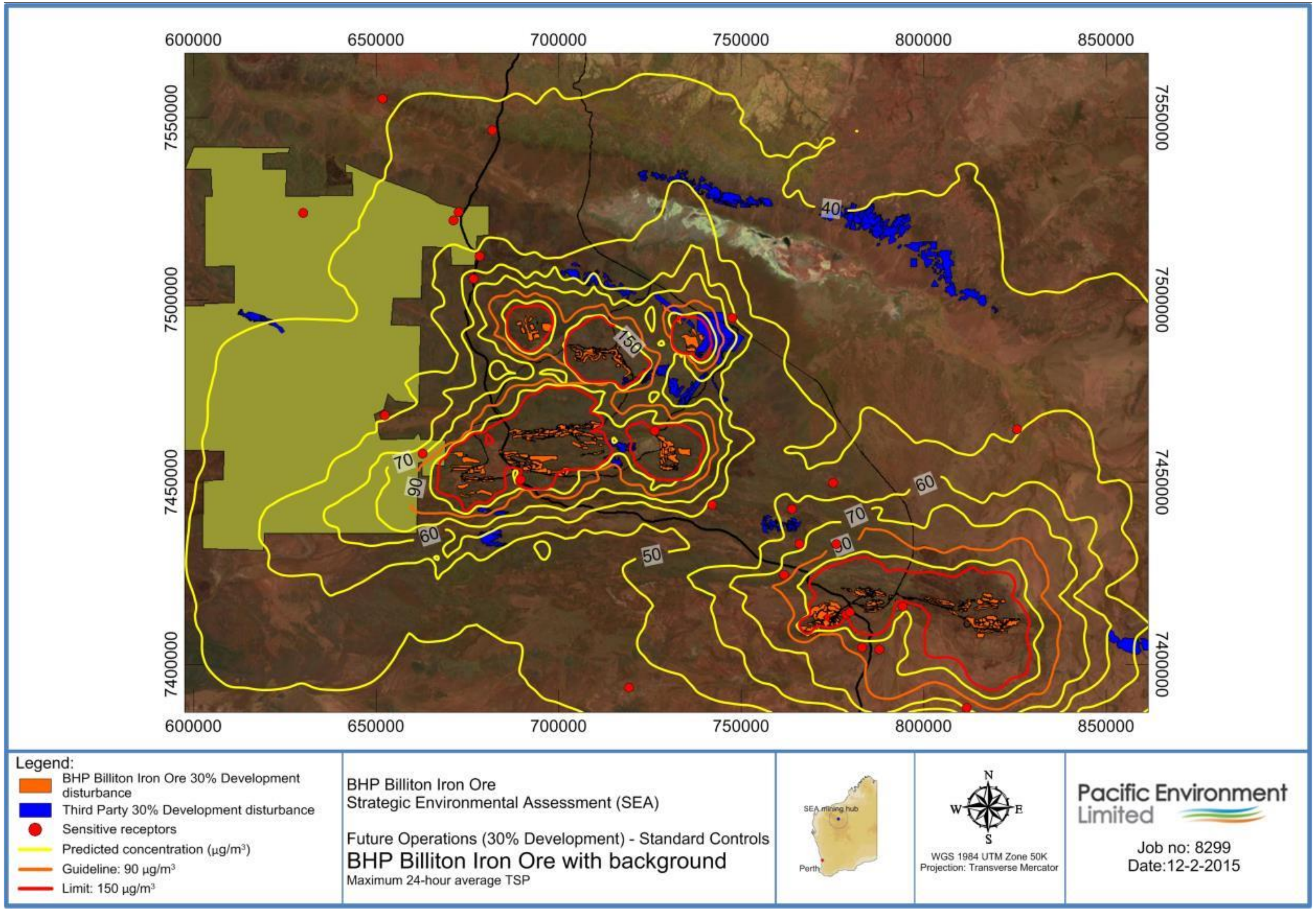

Figure 8-15: Maximum predicted 24-hour average TSP concentrations for 30% Development BHP Billiton Iron Ore operations (Standard Controls) with background

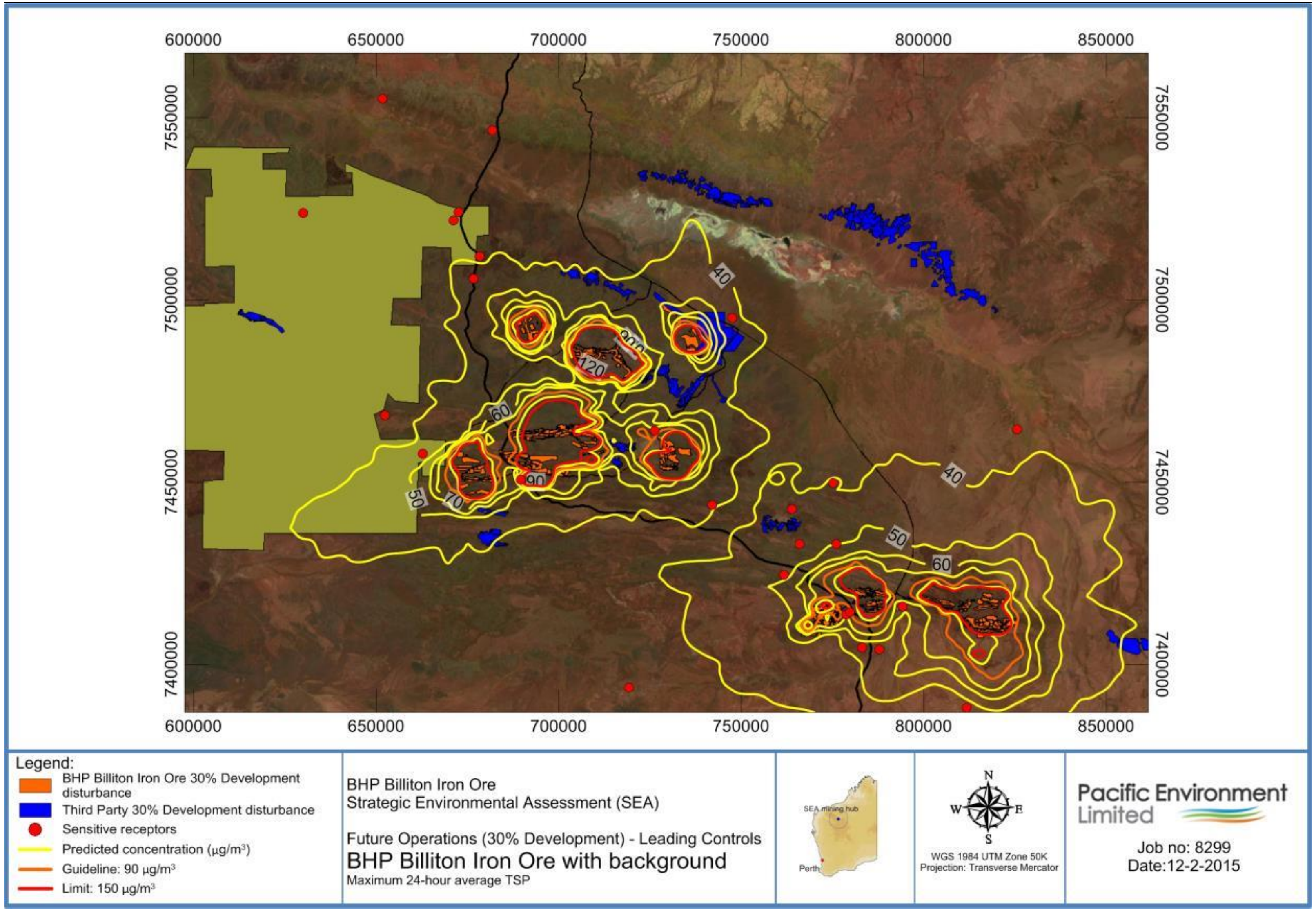

Figure 8-16: Maximum predicted 24-hour average TSP concentrations for 30% Development BHP Billiton Iron Ore operations (Leading Controls) with background

Table 8-14: Predicted 24-hour TSP Concentrations at receptors including background (µg/m³): BHP Billiton Iron Ore operations (30% Development scenario) – No Control

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 90 µg/m³	Greater than 150 µg/m³
Juna Downs	Homestead	56	53	50	48	43	40	-	-
Ethel Creek	Homestead	57	51	45	41	33	35	-	-
Marillana	Homestead	85	77	63	53	40	40	-	-
Mulga Downs	Homestead	45	42	40	38	36	35	-	-
Prairie Downs	Homestead	55	52	46	43	37	36	-	-
Sylvania	Homestead	84	62	53	44	34	36	-	-
Munjina East Gorge	Lookout	72	68	62	56	45	42	-	-
Fig Tree Crossing	Lookout	116	93	82	79	63	54	7	-
Mt Meharry	Lookout	69	63	58	56	49	44	-	-
Mt Newman	Lookout	101	84	75	68	58	50	2	-
Tower Hill	Lookout	322	293	241	207	121	101	165	79
Karijini Eco Retreat	Recreation Camp Site	44	41	40	39	37	36	-	-
Ophthalmia Dam	Recreation Site	158	139	120	111	86	71	96	2
Round Hill	Recreation Site	118	112	92	83	60	51	27	-
Hickman Crater	Recreation Site	64	58	53	48	42	40	-	-
Weeli Wolli Spring/Outfall	Recreation Site	198	153	125	115	83	71	92	5
Stuarts Pool	Recreation Site	75	70	61	58	49	45	-	-
Kalgan Pool	Recreation Site	94	87	73	67	54	49	2	-
Eagle Rock Hole	Recreation Site	69	63	53	49	43	41	-	-
Mt Robinson	Rest Stop	395	319	244	200	95	91	114	67
Munjina Roadhouse	Roadhouse	56	52	48	45	39	38	-	-
Auski Village	Roadhouse	54	50	46	43	38	37	-	-
Capricorn Roadhouse	Roadhouse	131	116	93	87	59	51	31	-
Newman	Town Centre	199	180	153	142	109	84	159	22
Rhodes Ridge	Town Site	67	61	49	47	42	40	-	-
Wirlu-Murra	Aboriginal Community	50	45	43	41	38	37	-	-

Table 8-15: Predicted 24-hour TSP Concentrations at receptors including background (µg/m³): BHP Billiton Iron Ore operations (30% Development scenario) – Standard Controls

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 90 µg/m³	Greater than 150 µg/m³
Juna Downs	Homestead	46	44	42	41	39	37	-	-
Ethel Creek	Homestead	46	43	40	38	33	34	-	-
Marillana	Homestead	61	57	49	44	37	37	-	-
Mulga Downs	Homestead	40	38	37	36	35	34	-	-
Prairie Downs	Homestead	45	43	40	39	35	35	-	-
Sylvania	Homestead	61	49	44	39	34	35	-	-
Munjina East Gorge	Lookout	54	52	49	46	39	38	-	-
Fig Tree Crossing	Lookout	78	65	60	58	49	44	-	-
Mt Meharry	Lookout	53	49	47	45	42	39	-	-
Mt Newman	Lookout	70	61	56	52	46	42	-	-
Tower Hill	Lookout	189	174	145	127	80	70	88	15
Karijini Eco Retreat	Recreation Camp Site	39	37	37	36	35	34	-	-
Ophthalmia Dam	Recreation Site	101	90	80	75	62	54	4	-
Round Hill	Recreation Site	79	76	65	60	47	43	-	-
Hickman Crater	Recreation Site	50	46	44	41	38	37	-	-
Weeli Wolli Spring/Outfall	Recreation Site	122	98	83	78	60	54	9	-
Stuarts Pool	Recreation Site	56	53	48	47	42	39	-	-
Kalgan Pool	Recreation Site	66	62	55	51	45	42	-	-
Eagle Rock Hole	Recreation Site	53	49	44	42	39	37	-	-
Mt Robinson	Rest Stop	228	187	147	123	66	64	76	17
Munjina Roadhouse	Roadhouse	45	43	41	40	36	36	-	-
Auski Village	Roadhouse	45	42	40	38	36	35	-	-
Capricorn Roadhouse	Roadhouse	86	78	66	62	47	43	-	-
Newman	Town Centre	123	112	98	92	74	61	44	-
Rhodes Ridge	Town Site	51	48	42	40	38	37	-	-
Wirlu-Murra	Aboriginal Community	42	39	38	38	36	35	-	-

Table 8-16: Predicted 24-hour TSP Concentrations at receptors including background (µg/m³): BHP Billiton Iron Ore operations (30% Development scenario) – Leading Controls

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 90 µg/m³	Greater than 150 µg/m³
Juna Downs	Homestead	37	37	36	36	35	34	-	-
Ethel Creek	Homestead	37	36	35	35	33	33	-	-
Marillana	Homestead	42	41	38	37	34	34	-	-
Mulga Downs	Homestead	35	35	34	34	34	34	-	-
Prairie Downs	Homestead	37	36	35	35	34	34	-	-
Sylvania	Homestead	42	38	37	35	33	34	-	-
Munjina East Gorge	Lookout	40	39	38	37	35	35	-	-
Fig Tree Crossing	Lookout	47	43	41	41	38	37	-	-
Mt Meharry	Lookout	39	38	37	37	36	35	-	-
Mt Newman	Lookout	45	42	40	39	37	36	-	-
Tower Hill	Lookout	82	77	68	63	48	45	-	-
Karijini Eco Retreat	Recreation Camp Site	35	34	34	34	34	34	-	-
Ophthalmia Dam	Recreation Site	54	51	48	46	42	40	-	-
Round Hill	Recreation Site	48	47	43	42	38	36	-	-
Hickman Crater	Recreation Site	38	37	37	36	35	34	-	-
Weeli Wolli Spring/Outfall	Recreation Site	61	53	49	47	42	40	-	-
Stuarts Pool	Recreation Site	40	39	38	37	36	35	-	-
Kalgan Pool	Recreation Site	43	42	40	39	37	36	-	-
Eagle Rock Hole	Recreation Site	39	38	36	36	35	34	-	-
Mt Robinson	Rest Stop	95	82	69	61	44	43	2	-
Munjina Roadhouse	Roadhouse	37	36	36	35	34	34	-	-
Auski Village	Roadhouse	37	36	35	35	34	34	-	-
Capricorn Roadhouse	Roadhouse	50	47	43	42	37	36	-	-
Newman	Town Centre	61	58	53	52	46	42	-	-
Rhodes Ridge	Town Site	39	38	36	35	35	34	-	-
Wirlu-Murra	Aboriginal Community	36	35	35	35	34	34	-	-

8.3.2.2 Third party operations

The key outcomes of the air quality assessment are summarised below, and presented in Figure 8-17 and Table 8-17:

- The 24-hour maximum contour (Kwinana EPP criteria) occurs outside three sensitive receptors, i.e. Marillana, Stuarts Pool and Eagle Rock Hole.
- The 24-hour maximum contour (Kwinana EPP limit) occurs outside 1 sensitive receptor, i.e. Marillana.
- Table 8-17 highlights that there are considerable reductions from the maximum predicted TSP concentrations towards the lower statistics (99th and 90th percentiles) at Marillana, Stuarts Pool and Eagle Rock Hole.

The results clearly show that there is a potential that the current third party operations may impact the air quality in Pilbara Region. It is worth noting that the scenario modelled is highly precautionary as it is assumed all mines are developed and operating simultaneously. As a result, this scenario is unlikely to occur.

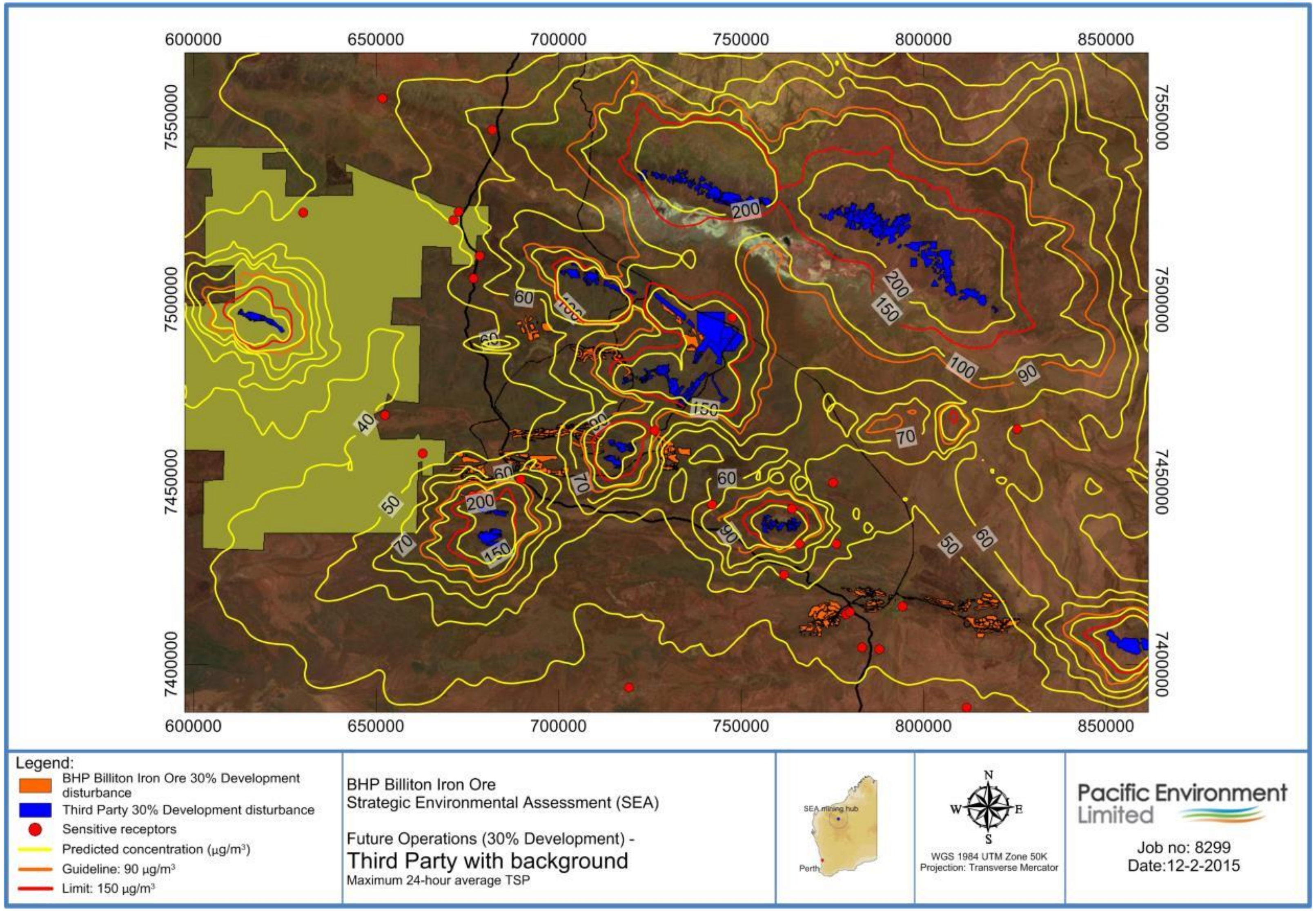

Figure 8-17: Maximum predicted 24-hour average TSP concentrations for 30% Development third party operations with background

Table 8-17: Predicted 24-hour TSP Concentrations at receptors including background (µg/m³): third party operations (30% Development scenario)

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 90 µg/m³	Greater than 150 µg/m³
Juna Downs	Homestead	39	38	37	37	36	35	-	-
Ethel Creek	Homestead	58	51	42	38	34	35	-	-
Marillana	Homestead	232	201	163	143	83	71	104	30
Mulga Downs	Homestead	46	46	43	42	39	37	-	-
Prairie Downs	Homestead	37	37	35	35	34	34	-	-
Sylvania	Homestead	37	36	35	34	34	34	-	-
Munjina East Gorge	Lookout	50	44	41	40	39	37	-	-
Fig Tree Crossing	Lookout	53	44	42	40	39	37	-	-
Mt Meharry	Lookout	42	39	38	37	36	35	-	-
Mt Newman	Lookout	50	46	41	37	34	34	-	-
Tower Hill	Lookout	42	41	37	35	34	34	-	-
Karijini Eco Retreat	Recreation Camp Site	41	38	37	36	36	35	-	-
Ophthalmia Dam	Recreation Site	43	40	36	35	34	34	-	-
Round Hill	Recreation Site	40	39	36	35	34	34	-	-
Hickman Crater	Recreation Site	52	48	43	40	35	35	-	-
Weeli Wolli Spring/Outfall	Recreation Site	84	77	65	58	43	42	-	-
Stuarts Pool	Recreation Site	91	75	58	47	34	37	1	-
Kalgan Pool	Recreation Site	53	45	40	38	34	35	-	-
Eagle Rock Hole	Recreation Site	146	125	98	84	52	49	28	-
Mt Robinson	Rest Stop	82	69	58	49	39	39	-	-
Munjina Roadhouse	Roadhouse	50	44	42	40	38	37	-	-
Auski Village	Roadhouse	54	46	43	42	39	38	-	-
Capricorn Roadhouse	Roadhouse	40	39	36	35	34	34	-	-
Newman	Town centre	42	41	37	35	34	34	-	-
Rhodes Ridge	Town site	59	54	51	48	42	40	-	-
Wirlu-Murra	Aboriginal Community	61	54	49	48	44	41	-	-

8.3.2.3 Cumulative Operations

The key outcomes of the air quality assessment are summarised below, and presented in Figure 8-18 (No Control for BHP Billiton Iron Ore), Figure 8-19 (Standard Controls for BHP Billiton Iron Ore) and Figure 8-20 (Leading Controls for BHP Billiton Iron Ore):

- Similar to the cumulative PM_{10} assessment, there is a significant reduction in the maximum predicted TSP concentrations in the Standard Controls and Leading Controls scenarios when compared to the No Control scenario.
- Receptors near Newman (i.e. Mt Newman, Tower Hill, Ophthalmia Dam, Round Hill, Stuarts Pool, Kalgan Pool, Eagle Rock Hole, Capricorn Roadhouse and Newman) receive the highest predicted concentrations as expected due to increased mining activities in the close vicinity.

Other receptors in Marillana, Fig Tree Crossing, Weeli Wolli Spring/Outfall and Mt Robinson are also predicted to receive elevated TSP concentrations.

- From Table 8-18 to Table 8-20, it is apparent that there are significant decreases from the maximum predicted TSP concentrations at the receptors mentioned above with the lower statistics (99th to 95th percentiles). For example, for the Standard Controls scenario, the 99th and 95th percentile at Mt Robinson receptor are 17% and 34% lower than the maximum concentrations predicted. This indicates that the maximum predicted concentrations are single events that could be managed during operations through a dust management procedure.
- The predicted high TSP concentrations at the receptors, as mentioned above, indicate there is a high potential for impact on air quality in the Pilbara Region when No Control is adopted by BHP Billiton Iron Ore.
- By implementing Standard Controls at all BHP Billiton Iron Ore processing hubs and all third party mining operations in the Pilbara Region, the predicted TSP concentrations have been reduced compared to the No Control scenario. However, receptors near Newman and Mt Robinson as well as receptors near third party mining operations do not meet the assessment criteria (Kwinana EPP guideline and limit). Hence, there may still be a potential impact for the Pilbara Region with Standard Controls in place at all BHP Billiton Iron Ore processing hubs and third party mines.
- With Leading Controls at BHP Billiton Iron Ore operations in place and Standard Controls from the third party operations; although the predicted TSP concentrations at Marillana, Weeli Wolli Spring/ Outlet, Stuarts Pool, Eagle Rock Hole and Mt Robinson still cannot meet the assessment criteria (Kwinana EPP guideline only), there are considerable reductions of TSP concentrations compared to the No Control scenario. It is worth noting that the predicted TSP concentrations at Marillana are contributed to by both BHP Billiton Iron Ore and third party operations.
- It is worth noting that the scenario modelled is highly precautionary as the assumption is all mines developed and operating simultaneously. Therefore, this scenario is unlikely to occur.
- In summary, compared to No Control and Standard Controls scenarios, the Leading Controls have greatly reduced the potential impact at the sensitive receptors in the 30% Development scenario to a reasonable level.

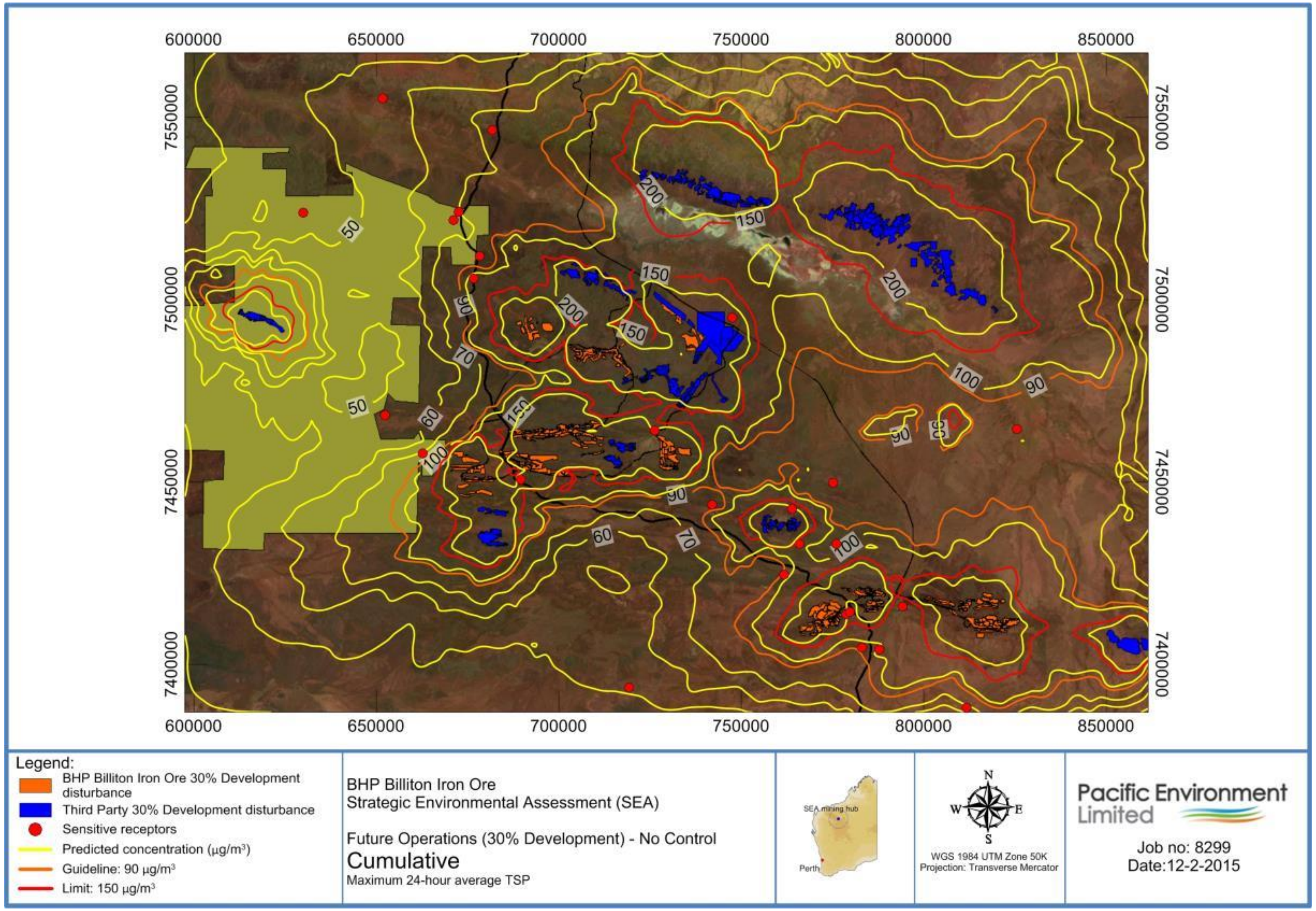

Figure 8-18: Maximum predicted 24-hour average TSP concentrations for 30% Development scenario cumulative operations (No Control from BHP Billiton Iron Ore operations) with background

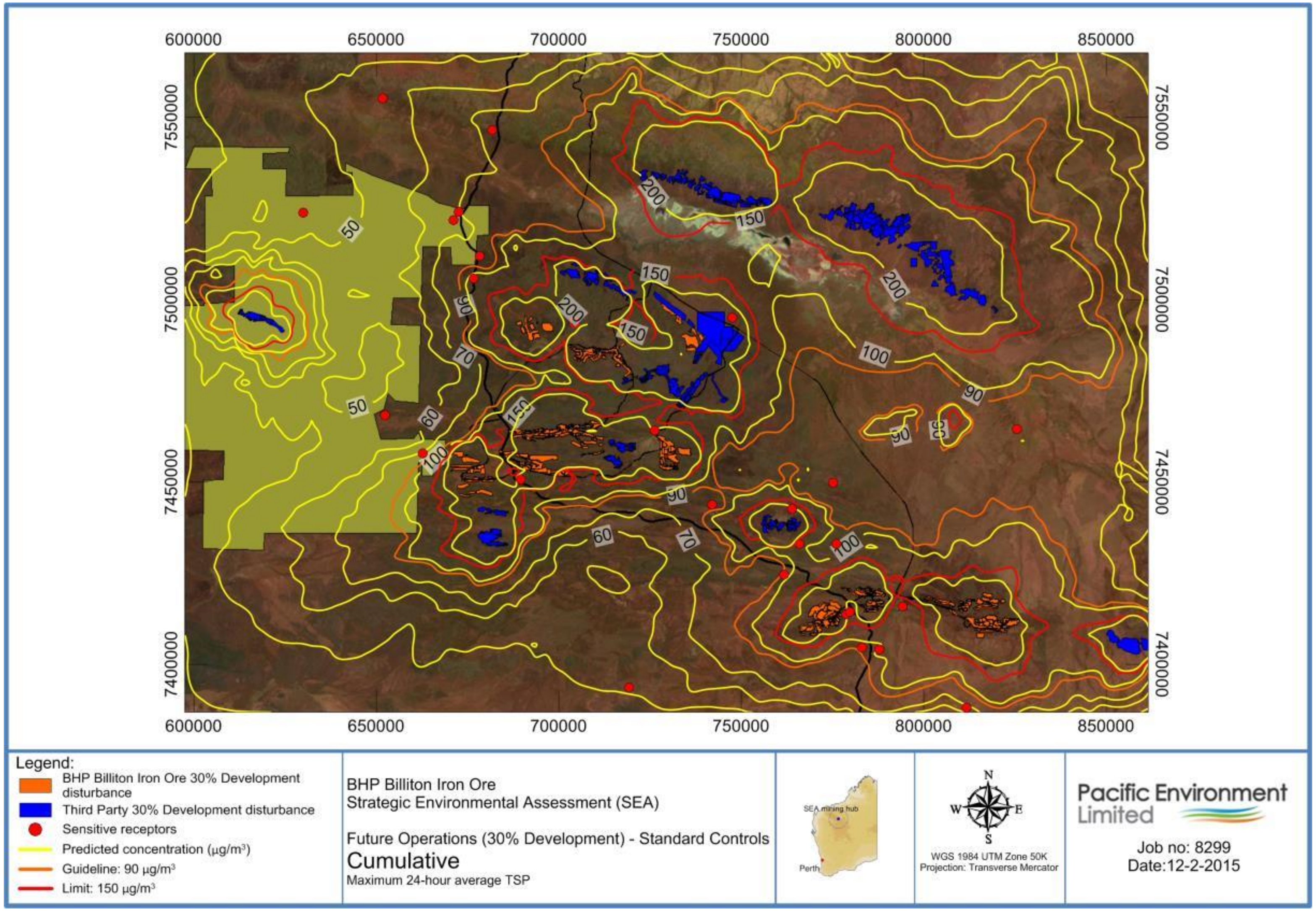

Figure 8-19: Maximum predicted 24-hour average TSP concentrations for 30% Development scenario cumulative operations (Standard Controls from BHP Billiton Iron Ore operations) with background

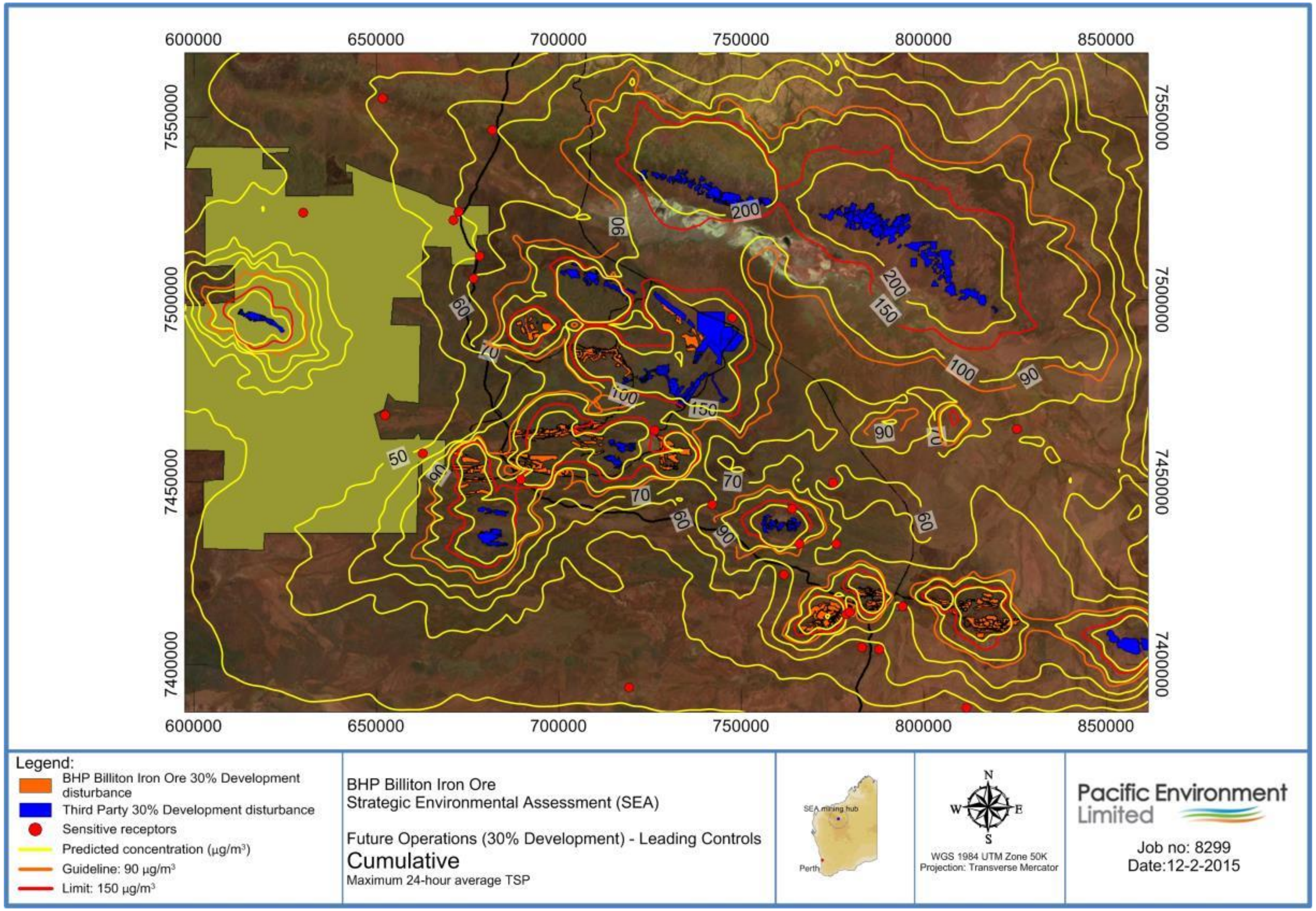

Figure 8-20: Maximum predicted 24-hour average TSP concentrations for 30% Development scenario cumulative operations (Leading Controls from BHP Billiton Iron Ore operations) with background

Table 8-18: Predicted 24-hour TSP Concentrations at receptors including background (µg/m³): cumulative operations (30% Development scenario) – No Control

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 90 µg/m³	Greater than 150 µg/m³
Juna Downs	Homestead	57	56	52	50	46	42	-	-
Ethel Creek	Homestead	65	56	50	46	36	37	-	-
Marillana	Homestead	275	234	185	162	92	77	110	52
Mulga Downs	Homestead	51	49		45	42	40	-	-
Prairie Downs	Homestead	56	53	47	44	38	37	-	-
Sylvania	Homestead	84	65	54	45	35	37	-	-
Munjina East Gorge	Lookout	80	73	66	61	50	46	-	-
Fig Tree Crossing	Lookout	124	99	89	85	70	58	15	-
Mt Meharry	Lookout	75	65	60	57	52	46	-	-
Mt Newman	Lookout	102	85	75	68	58	52	2	-
Tower Hill	Lookout	325	299	242	211	121	102	166	79
Karijini Eco Retreat	Recreation Camp Site	46	44	42	41	39	37	-	-
Ophthalmia Dam	Recreation Site	162	140	120	112	87	72	100	2
Round Hill	Recreation Site	119	113	94	84	60	52	33	-
Hickman Crater	Recreation Site	72	62	56	52	44	42	-	-
Weeli Wolli Spring/Outfall	Recreation Site	203	155	127	119	92	80	117	5
Stuarts Pool	Recreation Site	95	81	69	62	54	49	2	-
Kalgan Pool	Recreation Site	95	89	74	68	56	51	3	-
Eagle Rock Hole	Recreation Site	158	129	101	92	61	56	39	1
Mt Robinson	Rest Stop	399	324	249	207	104	97	128	71
Munjina Roadhouse	Roadhouse	64	58	52	51	44	42	-	-
Auski Village	Roadhouse	66	56	51	49	44	41	-	-
Capricorn Roadhouse	Roadhouse	133	118	96	88	60	52	33	-
Newman	Town centre	199	181	153	143	110	85	164	25
Rhodes Ridge	Town site	75	70	60	57	51	46	-	-
Wirlu-Murra	Aboriginal Community	65	60	55	53	49	44	-	-

Table 8-19: Predicted 24-hour TSP Concentrations at receptors including background (µg/m³): cumulative operations (30% Development scenario) – Standard Controls

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 90 µg/m³	Greater than 150 µg/m³
Juna Downs	Homestead	47	46	44	43	41	39	-	-
Ethel Creek	Homestead	61	52	45	43	35	36	-	-
Marillana	Homestead	255	220	175	153	89	74	109	39
Mulga Downs	Homestead	49	46	45	44	41	39	-	-
Prairie Downs	Homestead	45	44	41	39	36	35	-	-
Sylvania	Homestead	61	51	44	40	35	35	-	-
Munjina East Gorge	Lookout	64	56	53	51	44	42	-	-
Fig Tree Crossing	Lookout	86	72	66	63	56	49	-	-
Mt Meharry	Lookout	60	52	49	47	44	41	-	-
Mt Newman	Lookout	70	61	56	52	48	44	-	-
Tower Hill	Lookout	192	179	148	130	81	71	90	16
Karijini Eco Retreat	Recreation Camp Site	42	40	39	39	37	36	-	-
Ophthalmia Dam	Recreation Site	104	91	81	76	62	55	4	-
Round Hill	Receptor type	80	78	67	62	48	44	-	-
Hickman Crater	Homestead	59	54	48	46	41	39	-	-
Weeli Wolli Spring/Outfall	Homestead	127	105	88	82	71	62	17	-
Stuarts Pool	Homestead	93	78	61	53	46	43	2	-
Kalgan Pool	Homestead	70	64	56	53	46	43	-	-
Eagle Rock Hole	Homestead	152	128	99	89	56	53	35	1
Mt Robinson	Homestead	233	192	153	129	79	70	87	21
Munjina Roadhouse	Lookout	57	50	46	44	41	39	-	-
Auski Village	Lookout	60	49	46	45	42	40	-	-
Capricorn Roadhouse	Lookout	88	80	68	64	48	44	-	-
Newman	Lookout	123	113	98	93	74	62	45	-
Rhodes Ridge	Lookout	66	60	56	53	47	43	-	-
Wirlu-Murra	Aboriginal Community	61	56	52	51	47	43	-	-

Table 8-20: Predicted 24-hour TSP Concentrations at receptors including background (µg/m³): cumulative operations (30% Development scenario) – Leading Controls

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 90 µg/m³	Greater than 150 µg/m³
Juna Downs	Homestead	41	40	39	39	37	36	-	-
Ethel Creek	Homestead	59	51	43	39	34	35	-	-
Marillana	Homestead	239	206	166	146	85	72	105	35
Mulga Downs	Homestead	47	46	43	42	40	38	-	-
Prairie Downs	Homestead	38	37	37	36	35	34	-	-
Sylvania	Homestead	42	40	38	36	34	34	-	-
Munjina East Gorge	Lookout	53	47	43	42	41	39	-	-
Fig Tree Crossing	Lookout	58	53	49	47	44	41	-	-
Mt Meharry	Lookout	47	43	40	39	38	37	-	-
Mt Newman	Lookout	50	47	43	41	38	37	-	-
Tower Hill	Lookout	85	81	70	65	49	46	-	-
Karijini Eco Retreat	Recreation Camp Site	41	38	37	37	36	35	-	-
Ophthalmia Dam	Recreation Site	58	53	49	48	43	41	-	-
Round Hill	Recreation Site	51	49	46	44	38	37	-	-
Hickman Crater	Recreation Site	54	49	44	41	37	37	-	-
Weeli Wolli Spring/Outfall	Recreation Site	91	83	69	63	51	48	1	-
Stuarts Pool	Recreation Site	91	75	59	48	38	39	1	-
Kalgan Pool	Recreation Site	54	48	43	41	38	37	-	-
Eagle Rock Hole	Recreation Site	148	126	99	85	53	50	28	-
Mt Robinson	Rest Stop	99	89	77	70	54	49	4	-
Munjina Roadhouse	Roadhouse	52	45	42	41	39	38	-	-
Auski Village	Roadhouse	56	47	44	42	40	38	-	-
Capricorn Roadhouse	Roadhouse	52	49	46	44	38	37	-	-
Newman	Town centre	62	59	55	53	47	43	-	-
Rhodes Ridge	Town site	60	55	52	49	43	41	-	-
Wirlu-Murra	Aboriginal Community	61	54	50	49	45	41	-	-

8.3.3 Assessment of potential visibility risk

The potential for reduction in visibility along the Great Northern Highway due to operations at BHP Billiton Iron Ore (plus background dust levels) are presented in Figure 8-21 (No Control scenario), Figure 8-22 (Standard Controls) scenario and Figure 8-23 (Leading Control scenario). The methodology for determining the potential risk rating is discussed in Section 6.5.

- In the No Control and Standard Controls scenario, medium and low risk ratings are noted along sections of the Great Northern Highway around Mt Robinson and the town of Newman. No high risk rating is predicted for this scenario.
- In the Leading Control scenario, the potential for visibility reduction is negligible along the Great Northern Highway.

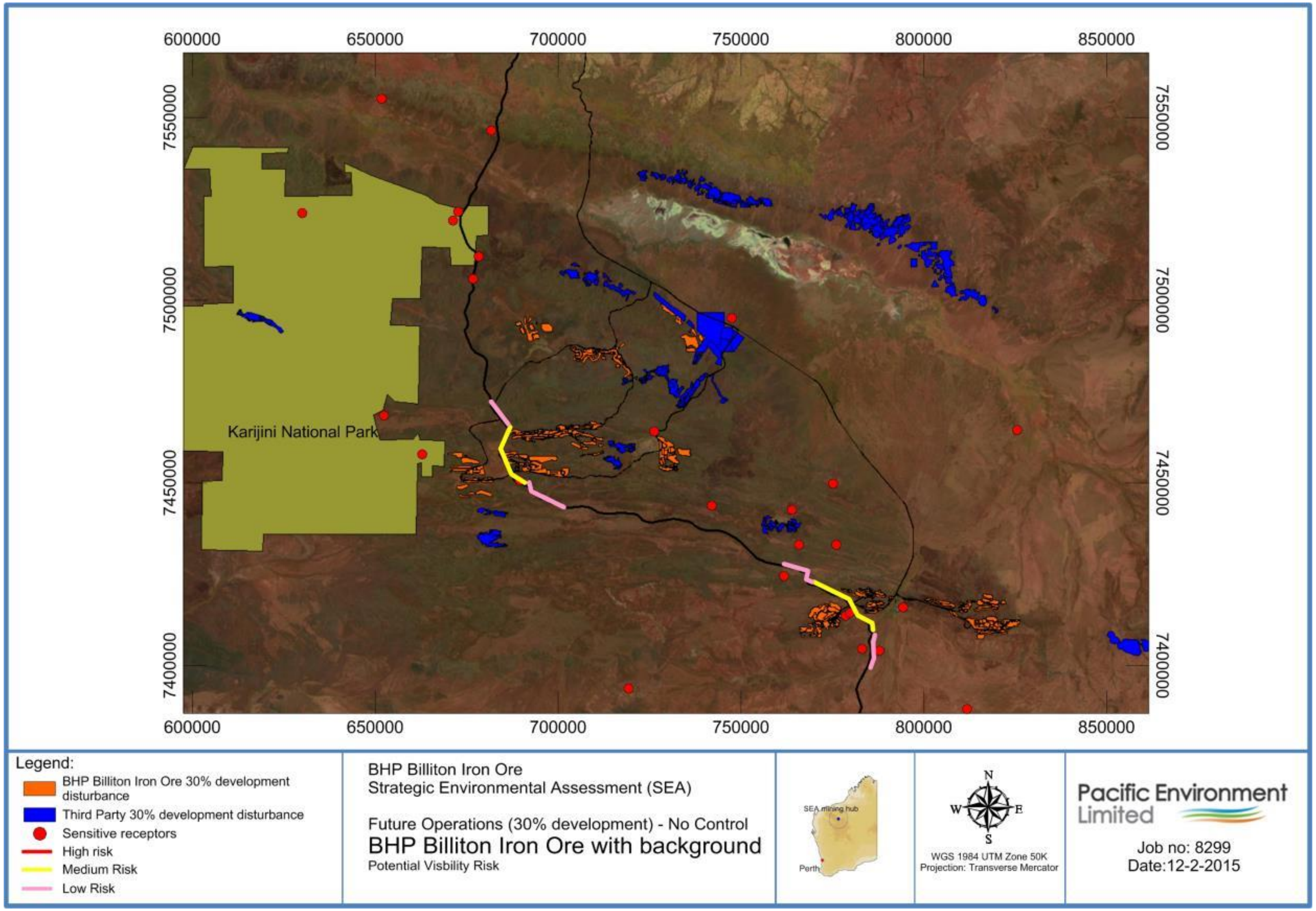

Figure 8-21: Potential Visibility Risk for 30% Development BHP Billiton Iron Ore operations (No Control)

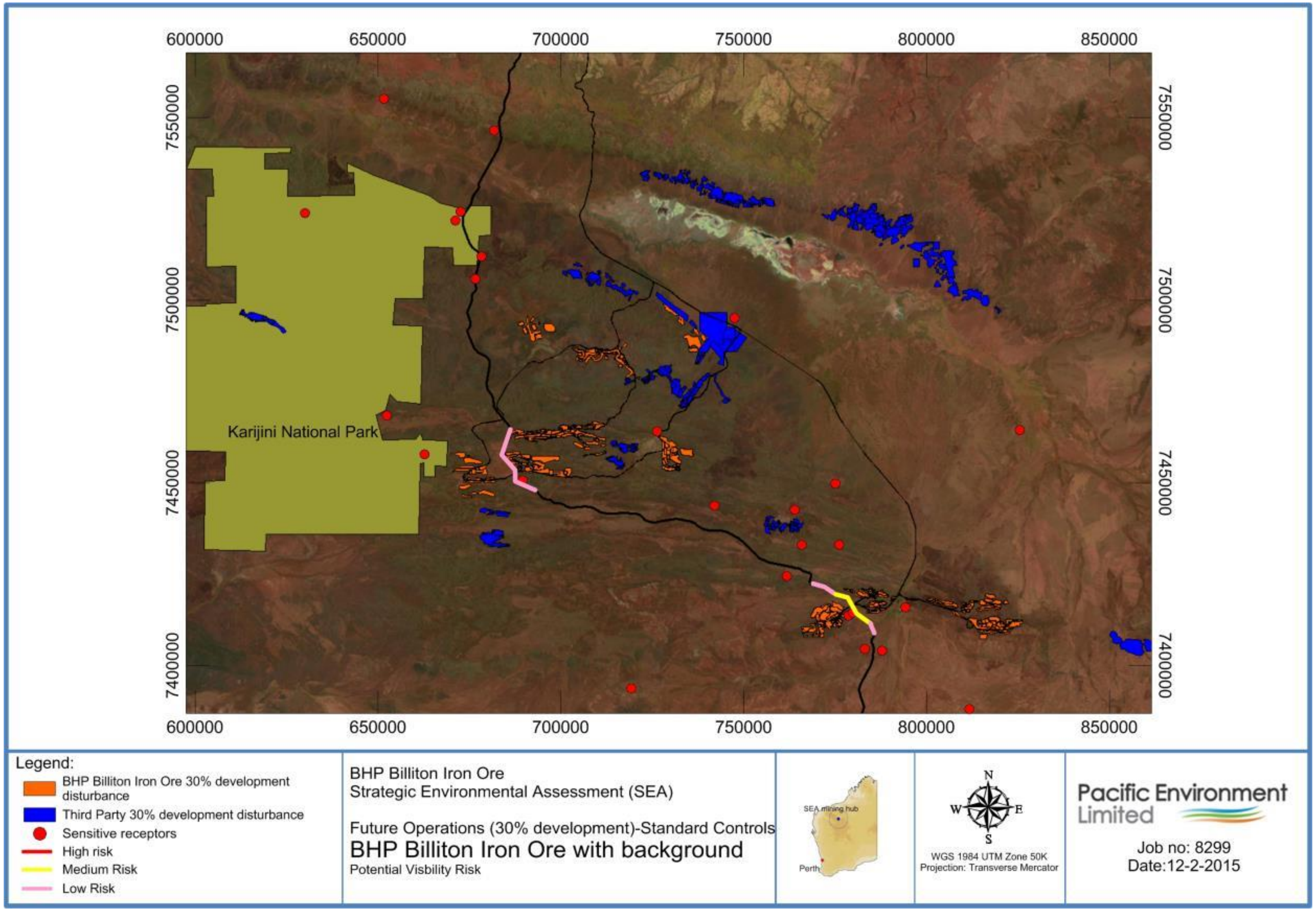

Figure 8-22: Potential Visibility Risk for 30% Development scenario BHP Billiton Iron Ore operations (Standard Controls)

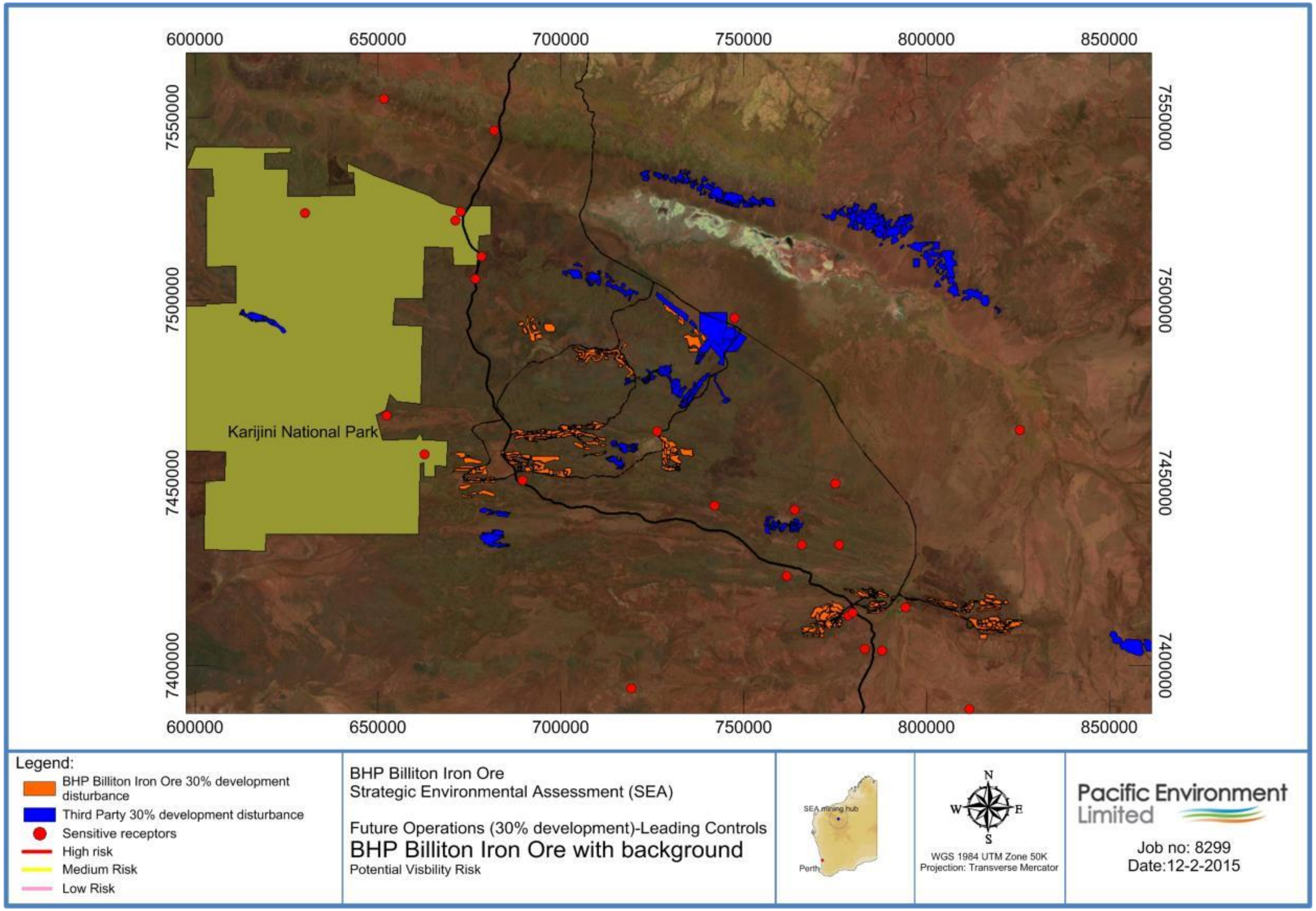

Figure 8-23: Potential Visibility Risk for 30% Development scenario BHP Billiton Iron Ore operations (Leading Controls)

8.4 Scenario 3 – Highest Use

8.4.1 Assessment of PM_{10} (potential impact on human health)

To assess the impact, modelled PM_{10} concentrations averaged over 24-hour are compared to the NEPM 24-hour average of 50µg/m³ and Taskforce 24-hour average of 70µg/m³ (Section 3.1).

8.4.1.1 BHP Billiton Iron Ore operations

The key outcomes of the impact assessment are summarised below, and presented in Figure 8-24 (No Control), Figure 8-25 (Standard Controls), Figure 8-26 (Leading Controls), Table 8-21 (No Control), Table 8-22 (Standard Controls) and Table 8-23 (Leading Controls):

- As expected, the highest maximum concentrations are noted for the No Control scenario with reduction in the maximum concentrations noted for the Standard Controls scenario. The lowest maximum concentration is observed for the Leading Controls scenario. It is worth noting that while BHP Billiton Iron Ore historically operates with Standard dust controls, the No Control scenario is presented to emphasise the importance of dust controls.
- For the No Control, Standard Controls and Leading Controls scenarios, there were 22 (receptor types include homestead, lookouts, recreational sites, rest stop, roadhouse, town centre, town site and aboriginal community), 14 (receptor types include homestead, lookouts, recreational sites, rest stop, roadhouse, and town centre) and 1 (lookout) occasions respectively that had concentration in excess of 50 µg/m³.
- For the No Control and Standard Controls scenarios, there were 15 (receptor types include homestead, lookouts, recreational sites, rest stop, roadhouse and town centre) and 6 (receptor types include lookouts, recreational sites, rest stop, roadhouse, and town centre) respectively that had concentration in excess of 70µg/m³. There were no excursions of the Taskforce criteria (70µg/m³) for the Leading Controls scenario.
- From Table 8-21 to Table 8-23, it is apparent that there are significant decreases from the maximum predicted PM_{10} concentrations towards the lower statistics (99th to 95th percentiles). For example, for the Standard Controls scenario, the 99^{th} and 95^{th} percentile at Tower Hill receptor are 22% and 38% lower than the maximum concentrations predicted.
- It is worth noting that the scenario modelled is highly precautionary as the assumption is all mines developed and operating simultaneously. Therefore, this scenario is unlikely to occur.
- In summary, the Leading Controls have greatly reduced the potential impact to the sensitive receptors compared to the No Control and Standard Controls scenarios.

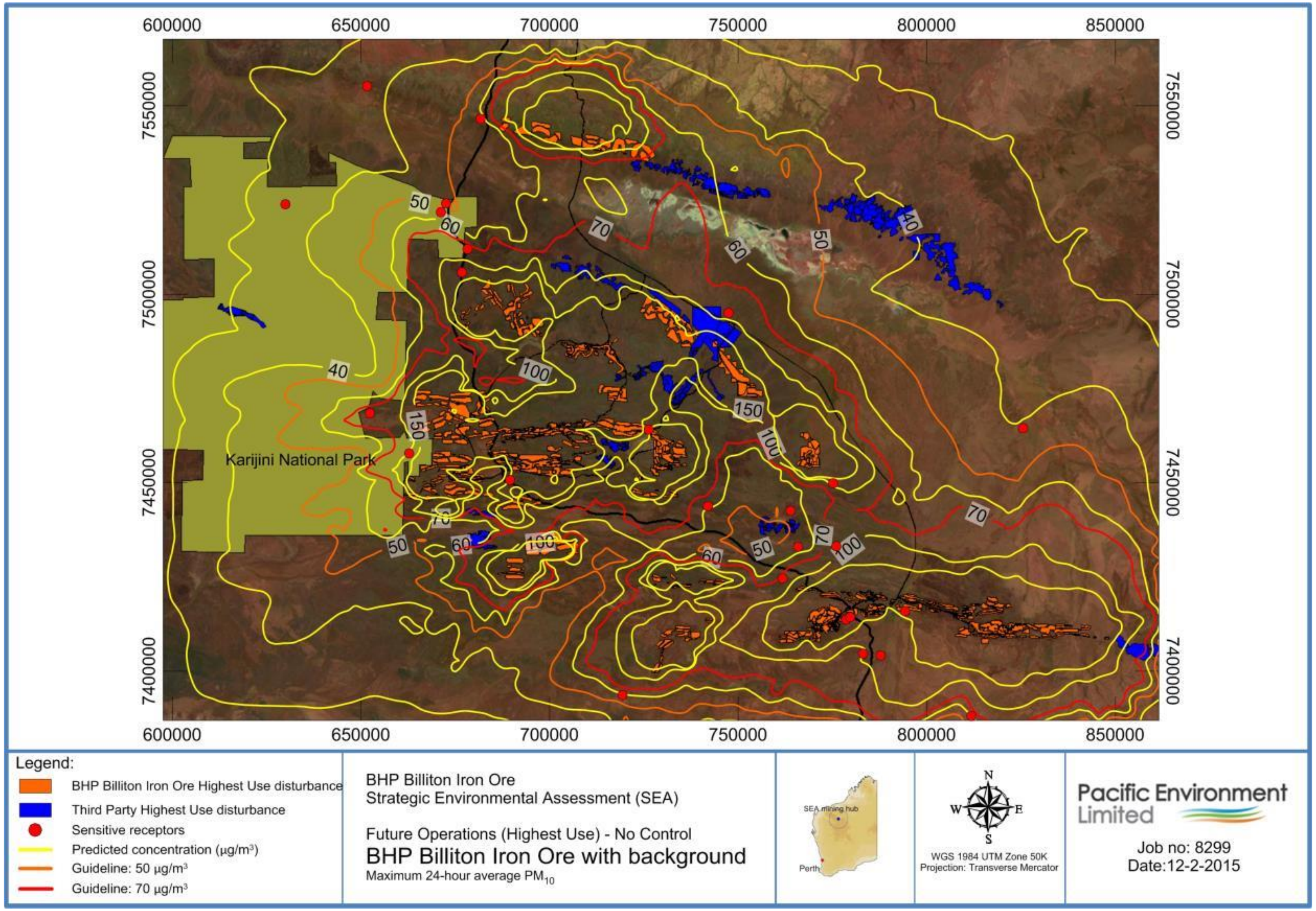

Figure 8-24: Maximum predicted 24-hour average PM_{10} concentrations for Highest Use BHP Billiton Iron Ore operations (No Control) with background

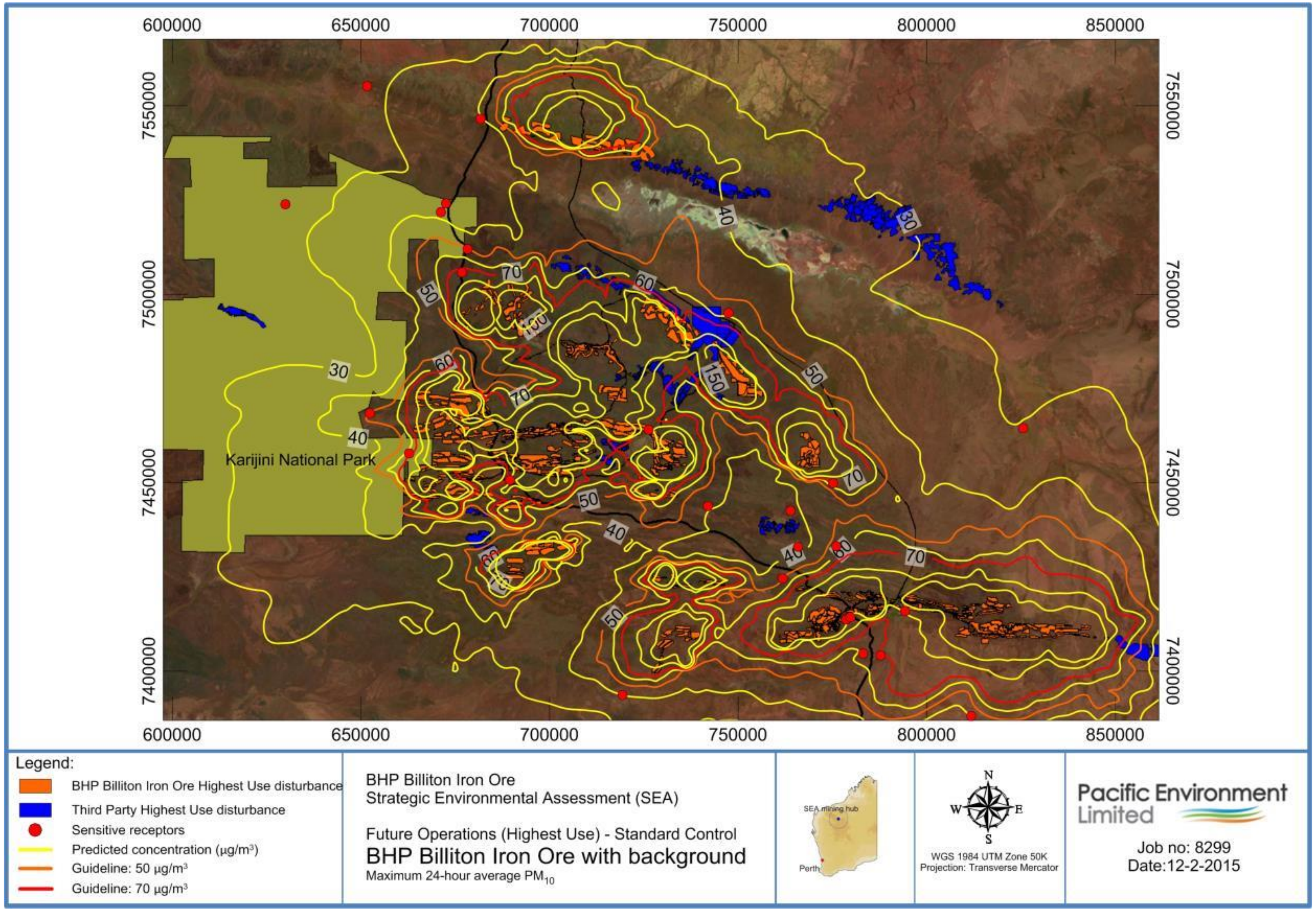

Figure 8-25: Maximum predicted 24-hour average PM_{10} concentrations for Highest Use BHP Billiton Iron Ore operations (Standard Controls) with background

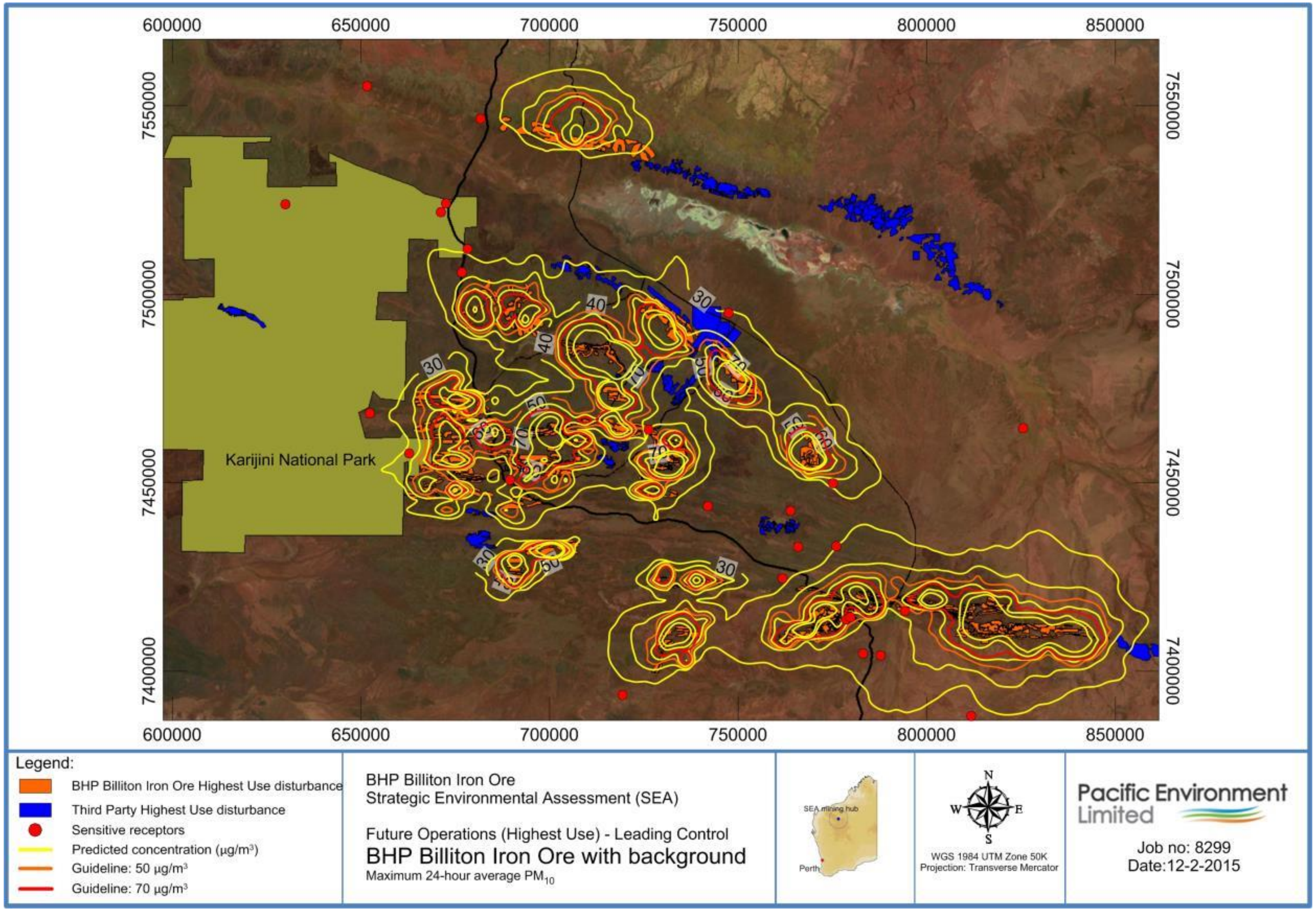

Figure 8-26: Maximum predicted 24-hour average PM_{10} concentrations for Highest Use BHP Billiton Iron Ore operations (Leading Controls) with background

Table 8-21: Predicted 24-hour PM_{10} Concentrations at receptors including background (µg/m³): BHP Billiton Iron Ore operations (Highest Use) - No Control

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 50 µg/m³	Greater than 70 µg/m³
Juna Downs	Homestead	78	65	57	52	44	36	64	2
Ethel Creek	Homestead	41	39	34	29	19	21	-	-
Marillana	Homestead	90	78	61	54	38	33	52	9
Mulga Downs	Homestead	37	34	29	27	24	23	-	-
Prairie Downs	Homestead	56	49	42	39	27	25	3	-
Sylvania	Homestead	61	44	36	31	20	22	1	-
Munjina East Gorge	Lookout	79	62	52	47	38	33	25	2
Fig Tree Crossing	Lookout	121	93	69	64	53	44	134	17
Mt Meharry	Lookout	103	76	54	46	39	35	26	5
Mt Newman	Lookout	76	62	50	45	38	33	18	1
Tower Hill	Lookout	293	224	175	148	98	81	256	181
Karijini Eco Retreat	Recreation Camp Site	33	31	28	27	24	22	-	-
Ophthalmia Dam	Recreation Site	175	153	123	106	75	59	188	121
Round Hill	Recreation Site	101	86	72	62	40	34	72	22
Hickman Crater	Recreation Site	104	89	59	44	32	31	30	11
Weeli Wolli Spring/Outfall	Recreation Site	112	93	75	66	52	46	121	31
Stuarts Pool	Recreation Site	56	44	39	37	31	29	2	-
Kalgan Pool	Recreation Site	88	64	49	43	35	32	14	2
Eagle Rock Hole	Recreation Site	54	44	36	33	29	27	1	-
Mt Robinson	Rest Stop	169	117	104	90	64	53	169	90
Munjina Roadhouse	Roadhouse	54	48	40	37	29	26	1	-
Auski Village	Roadhouse	48	43	37	33	27	25	-	-
Capricorn Roadhouse	Roadhouse	115	97	75	67	41	35	81	28
Newman	Town centre	187	161	125	103	72	59	187	118
Rhodes Ridge	Town site	64	53	41	35	27	27	6	-
Wirlu-Murra	Aboriginal Community	57	47	40	38	33	29	3	-

Table 8-22: Predicted 24-hour PM_{10} Concentrations at receptors including background (µg/m³): BHP Billiton Iron Ore operations (Highest Use) - Standard Controls

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 50 µg/m³	Greater than 70 µg/m³
Juna Downs	Homestead	50	43	39	37	32	28	1	-
Ethel Creek	Homestead	31	29	27	24	19	20	-	-
Marillana	Homestead	57	50	41	37	29	26	4	-
Mulga Downs	Homestead	28	26	24	23	22	21	-	-
Prairie Downs	Homestead	39	35	31	29	23	22	-	-
Sylvania	Homestead	41	32	28	25	19	20	-	-
Munjina East Gorge	Lookout	51	42	37	34	29	26	1	-
Fig Tree Crossing	Lookout	74	59	46	43	37	32	9	1
Mt Meharry	Lookout	64	50	37	33	29	27	4	-
Mt Newman	Lookout	49	42	35	33	29	26	-	-
Tower Hill	Lookout	167	129	103	88	61	52	160	80
Karijini Eco Retreat	Recreation Camp Site	26	25	23	23	21	20	-	-
Ophthalmia Dam	Recreation Site	103	91	75	66	49	40	99	25
Round Hill	Recreation Site	63	55	47	42	30	27	10	-
Hickman Crater	Recreation Site	65	56	40	32	26	25	6	-
Weeli Wolli Spring/Outfall	Recreation Site	69	59	49	44	37	33	15	-
Stuarts Pool	Recreation Site	38	32	30	28	25	24	-	-
Kalgan Pool	Recreation Site	56	43	35	32	27	26	2	-
Eagle Rock Hole	Recreation Site	38	32	28	26	24	23	-	-
Mt Robinson	Rest Stop	100	72	64	57	43	37	70	5
Munjina Roadhouse	Roadhouse	38	34	30	28	24	22	-	-
Auski Village	Roadhouse	34	32	28	26	23	22	-	-
Capricorn Roadhouse	Roadhouse	70	61	49	44	30	27	15	1
Newman	Town centre	109	95	76	64	47	40	98	28
Rhodes Ridge	Town site	43	37	30	27	23	23	-	-
Wirlu-Murra	Aboriginal Community	39	34	30	29	26	24	-	-

Table 8-23: Predicted 24-hour PM_{10} Concentrations at receptors including background (μg/m³): BHP Billiton Iron Ore operations (Highest Use) - Leading Controls

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 50 μg/m³	Greater than 70 μg/m³
Juna Downs	Homestead	28	26	25	24	23	21	-	-
Ethel Creek	Homestead	22	22	21	20	18	19	-	-
Marillana	Homestead	30	28	25	24	21	21	-	-
Mulga Downs	Homestead	21	21	20	20	19	19	-	-
Prairie Downs	Homestead	25	23	22	22	20	19	-	-
Sylvania	Homestead	25	22	21	20	19	19	-	-
Munjina East Gorge	Lookout	29	26	24	23	22	21	-	-
Fig Tree Crossing	Lookout	36	31	27	26	24	22	-	-
Mt Meharry	Lookout	33	28	24	23	22	21	-	-
Mt Newman	Lookout	28	26	24	23	22	21	-	-
Tower Hill	Lookout	65	53	45	40	32	29	7	-
Karijini Eco Retreat	Recreation Camp Site	21	20	20	20	19	19	-	-
Ophthalmia Dam	Recreation Site	45	41	36	33	28	25	-	-
Round Hill	Recreation Site	32	30	27	26	22	21	-	-
Hickman Crater	Recreation Site	33	30	25	23	20	20	-	-
Weeli Wolli Spring/Outfall	Recreation Site	34	31	28	26	24	23	-	-
Stuarts Pool	Recreation Site	25	23	22	21	20	20	-	-
Kalgan Pool	Recreation Site	30	26	23	22	21	21	-	-
Eagle Rock Hole	Recreation Site	24	23	21	21	20	20	-	-
Mt Robinson	Rest Stop	44	35	33	30	26	24	-	-
Munjina Roadhouse	Roadhouse	24	23	22	21	20	19	-	-
Auski Village	Roadhouse	23	22	21	21	20	19	-	-
Capricorn Roadhouse	Roadhouse	35	32	28	26	22	21	-	-
Newman	Town centre	47	42	36	33	27	25	-	-
Rhodes Ridge	Town site	26	24	22	21	20	20	-	-
Wirlu-Murra	Aboriginal Community	25	23	22	22	21	20	-	-

8.4.1.2 Third party operations

The key outcomes of the assessment are summarised below, and presented in Figure 8-27 and Table 8-24:

- The 24-hour maximum contour (NEPM criteria) occurs outside 5 sensitive receptors, i.e. Marillana, Weeli Wolli Spring/Outfall, Stuarts Pool, Eagle Rock Hole and Mt Robinson.
- The 24-hour maximum contour (Taskforce criteria) occurs outside three sensitive receptors, i.e. Marillana, Stuarts Pool and Eagle Rock Hole.
- Table 8-24 highlights that there are considerable reductions from the maximum predicted PM_{10} concentrations towards the lower statistics (99th and 90th percentiles) at Marillana, Weeli Wolli Spring/Outfall, Stuarts Pool, Eagle Rock Hole and Mt Robinson.
- It is worth noting that the scenario modelled is highly precautionary as the assumption is all mines developed and operating simultaneously. Therefore, this scenario is unlikely to occur.
- The results indicate there is a high potential that the future third party operations may impact the Pilbara Region.

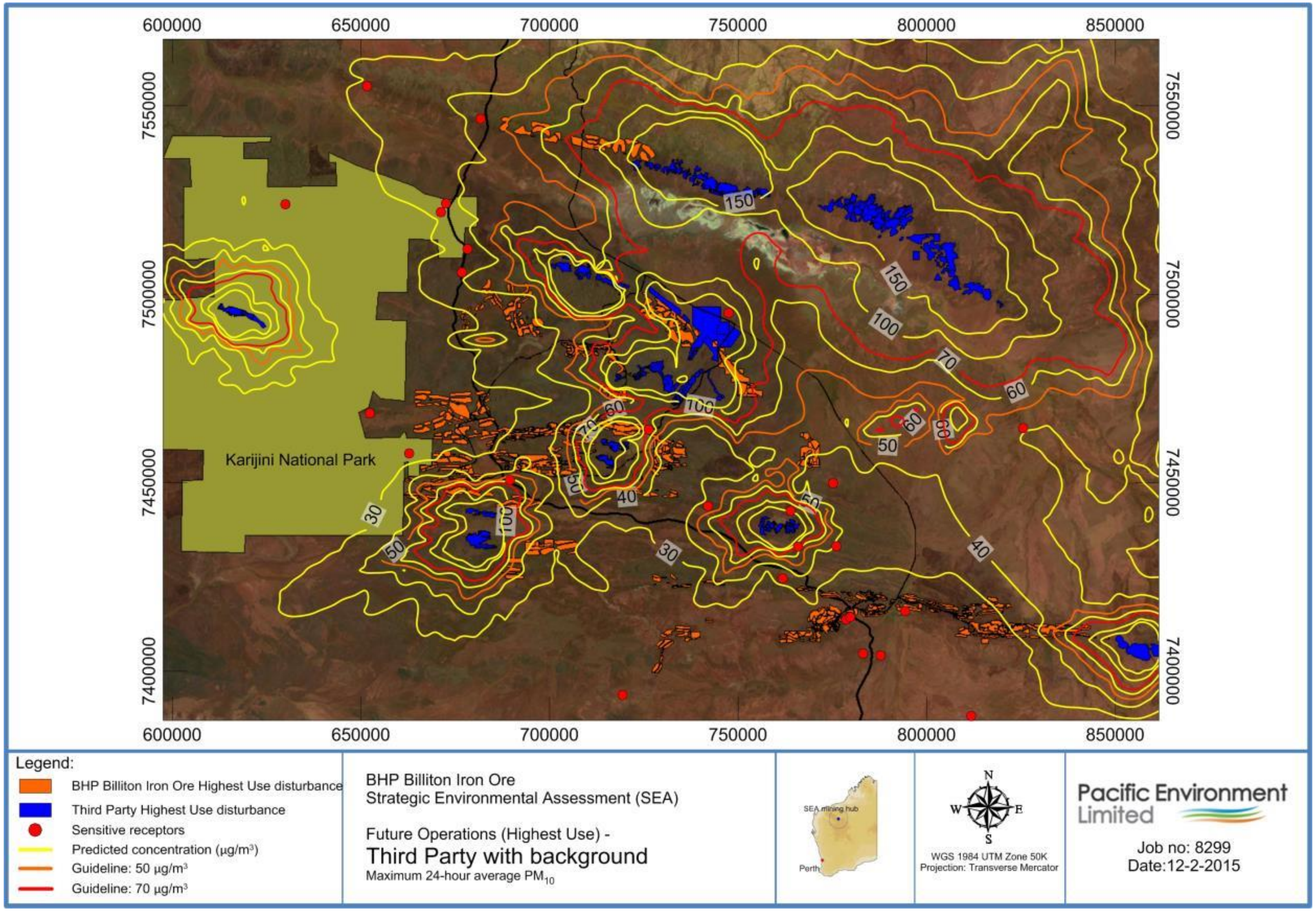

Figure 8-27: Maximum predicted 24-hour average PM_{10} concentrations for Highest Use third party operations with background

Table 8-24: Predicted 24-hour PM_{10} Concentrations at receptors including background (μg/m³): Third party operations (Highest Use)

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 50 μg/m³	Greater than 70 μg/m³
Juna Downs	Homestead	24	23	22	21	20	20	-	-
Ethel Creek	Homestead	41	35	26	22	19	20	-	-
Marillana	Homestead	181	147	111	93	48	44	107	78
Mulga Downs	Homestead	31	30	27	26	24	22	-	-
Prairie Downs	Homestead	22	21	20	20	19	19	-	-
Sylvania	Homestead	22	21	20	19	19	19	-	-
Munjina East Gorge	Lookout	34	28	25	24	22	21	-	-
Fig Tree Crossing	Lookout	38	28	25	24	23	21	-	-
Mt Meharry	Lookout	26	23	22	21	20	20	-	-
Mt Newman	Lookout	33	30	24	22	19	19	-	-
Tower Hill	Lookout	26	25	21	20	19	19	-	-
Karijini Eco Retreat	Recreation Camp Site	25	22	21	21	20	20	-	-
Ophthalmia Dam	Recreation Site	28	24	21	20	19	19	-	-
Round Hill	Recreation Site	24	23	21	20	19	19	-	-
Hickman Crater	Recreation Site	36	32	27	24	20	20	-	-
Weeli Wolli Spring/Outfall	Recreation Site	61	57	45	39	26	25	7	-
Stuarts Pool	Recreation Site	72	59	38	29	19	21	8	1
Kalgan Pool	Recreation Site	36	29	24	22	19	19	-	-
Eagle Rock Hole	Recreation Site	107	84	60	48	29	28	34	10
Mt Robinson	Rest Stop	66	53	38	31	23	23	5	-
Munjina Roadhouse	Roadhouse	34	29	25	24	22	21	-	-
Auski Village	Roadhouse	38	30	26	25	23	22	-	-
Capricorn Roadhouse	Roadhouse	25	23	21	20	19	19	-	-
Newman	Town centre	26	25	21	20	19	19	-	-
Rhodes Ridge	Town site	43	38	34	30	25	23	-	-
Wirlu-Murra	Aboriginal Community	46	38	33	32	28	25	-	-

8.4.1.3 Cumulative Impact

The key outcomes of the air quality assessment are summarised below, and presented in Figure 8-28 (No Control for BHP Billiton Iron Ore operations with Standard Controls for third party operations), Figure 8-29 (Standard Controls for BHP Billiton Iron Ore operations with Standard Controls for third party operations), Figure 8-30 (Leading Controls for BHP Billiton Iron Ore operations with Standard Controls for third party operations), Table 8-25 (No Control for BHP Billiton Iron Ore operations with Standard Controls for third party operations), Table 8-26 (Standard Controls for BHP Billiton Iron Ore operations with Standard Controls for third party operations) and Table 8-27 (Leading Controls for BHP Billiton Iron Ore operations with Standard Controls for third party operations):

- There is a significant reduction in the maximum predicted PM_{10} concentrations in the Standard Controls and Leading Controls scenarios when compared to the No Control scenario. It is worth noting that while BHP Billiton Iron Ore historically operates with Standard dust controls, the No Control scenario is presented to emphasise the importance of dust controls.
- For the No Control, Standard Controls and Leading Controls scenarios, 23, 18 and 8 receptors respectively had concentration in excess of the NEPM criteria (50µg/m^3). It is noted that NEPM criteria is less applicable for intermittently occupied receptors.
  - Out of the 23 receptors that exceed the NEPM criteria for the No Control scenario, only 9 receptors, including homestead, rest stop, roadhouse, town centre, town site and aboriginal community, are expected to have continuous occupancy.
  - Of the 18 receptors that exceed the NEPM criteria for the Standard Controls scenario, only 4 receptors, including Roadhouse/town centre, are with expected continuous occupancy.
  - Of the 8 receptors that exceed the NEPM criteria for Leading Controls scenario, only 2 receptors, including a homestead and a rest stop, are expected to have continuous occupancy.
- For the No Control and Standard Controls and Leading Controls scenarios, 19, 11 and 5 receptors respectively had concentrations in excess of 70µg/m^3. It is noted that this criteria is less applicable for intermittently occupied receptors.
  - Out of the 19 receptors that exceed the criteria for the No Control scenario, only 5 receptors are expected to have continuous occupancy.
  - Of the 11 receptors that exceed the criteria for the Standard Controls scenario, only 3 receptors are Roadhouse/town centre with expected continuous occupancy.
  - Out of the 5 receptors that exceed the criteria for Leading Controls scenario, 1 receptor is expected to have continuous occupancy.
- From Table 8-25 to Table 8-27, it is apparent that there are significant decreases from the maximum predicted PM_{10} concentrations at the receptors mentioned above towards the lower statistics (99th to 95th percentiles). For example, for the Standard Controls scenario, the 99th and 95th percentile at Marillana receptor are 19% and 38% lower than the maximum concentrations predicted. This indicates that the maximum predicted concentrations are single events that could be managed during operations through a dust management procedure.
- The predicted high PM_{10} concentrations at the receptors indicate there is a high potential for PM_{10} to impact the Pilbara Region with Standard Controls at all third party mining operations and in the unlikely event that No Control is adopted by BHP Billiton Iron Ore.
- By implementing Standard Controls at all BHP Billiton Iron Ore processing hubs in the Pilbara Region, the predicted PM_{10} concentrations have been reduced compared to the No Control scenario. However, there are 11 receptors that cannot meet both the NEPM and Taskforce criteria. Hence, there may still be a potential for a PM_{10} impact in the Pilbara Region with Standard Controls in place at all BHP Billiton Iron Ore processing hubs.
- With Leading Controls from BHP Billiton Iron Ore in place, there are considerable reductions of PM_{10} concentrations compared to the No Control scenario. However, the predicted PM_{10} concentrations at Marillana, Tower Hill, Weeli Wolli Spring/ Outfall, Stuarts Pool, Eagle Rock Hole, Hickman Crater, Mt Robinson and Wirlu-Murra still exceed the NEPM criteria. However, the scenario modelled is highly precautionary as the assumption is all mines developed and operating simultaneously. Therefore, this scenario is unlikely to occur.
- It is worth noting that the predicted PM_{10} concentrations at Marillana are contributed by both BHP Billiton Iron Ore and third party operations.
- The Leading Controls have greatly reduced the potential impact at the sensitive receptors compared to the No Control and Standard Controls scenarios.

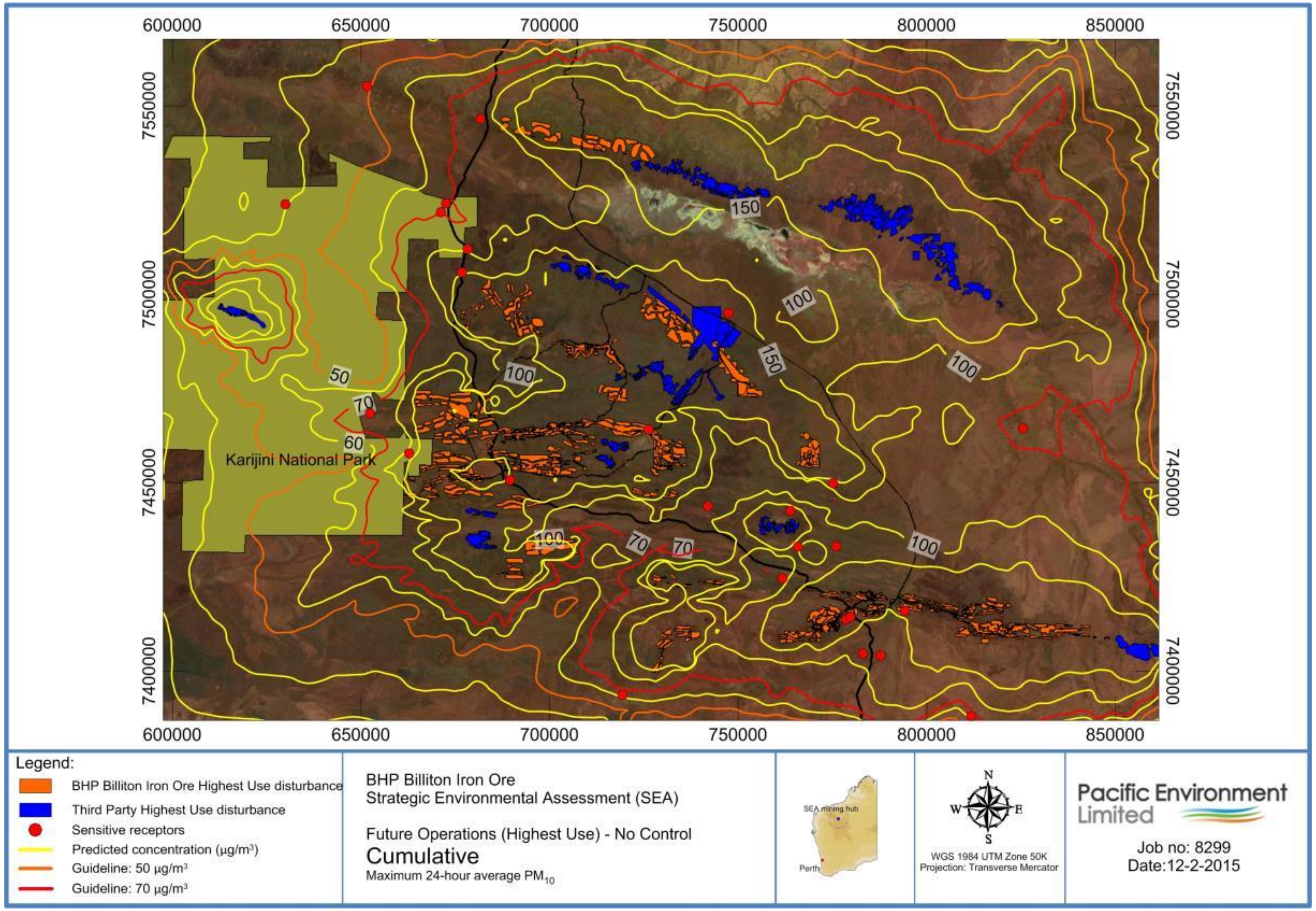

Figure 8-28: Maximum predicted 24-hour average PM_{10} concentrations for Highest Use cumulative operations (No Control from BHP Billiton Iron Ore operations) with background

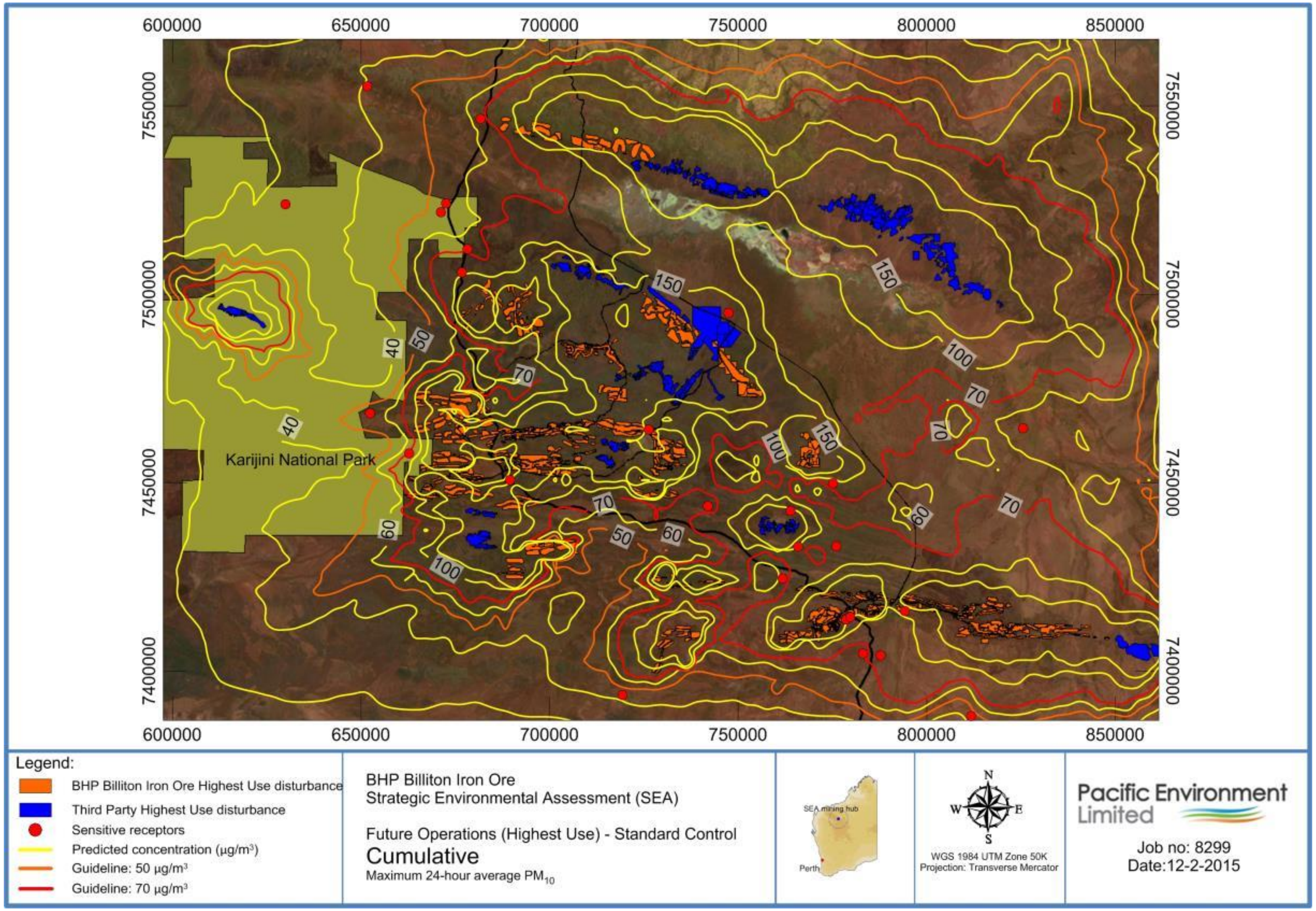

Figure 8-29: Maximum predicted 24-hour average PM_{10} concentrations for Highest Use cumulative operations (Standard Controls from BHP Billiton Iron Ore operations) with background

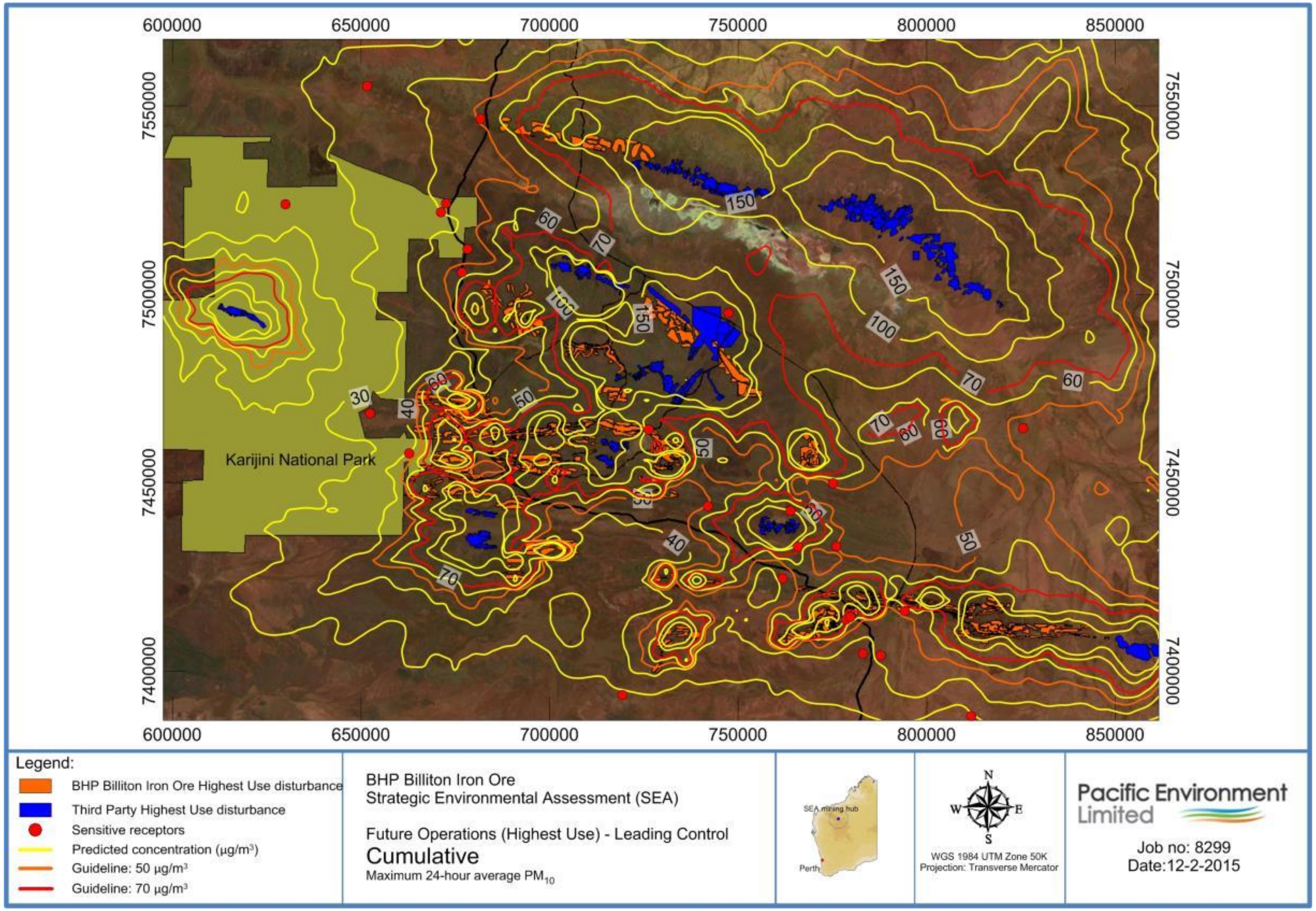

Figure 8-30: Maximum predicted 24-hour average PM_{10} concentrations for Highest Use cumulative operations (Leading Controls from BHP Billiton Iron Ore operations) with background

Table 8-25: Predicted 24-hour PM_{10} Concentrations at receptors including background (µg/m³): Cumulative operations (Highest Use) - No Control

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 50 µg/m³	Greater than 70 µg/m³
Juna Downs	Homestead	81	67	59	55	46	38	77	2
Ethel Creek	Homestead	49	45	38	34	22	22	-	-
Marillana	Homestead	246	194	147	127	71	59	142	112
Mulga Downs	Homestead	42	40	36	34	30	27	-	-
Prairie Downs	Homestead	58	51	44	40	27	25	6	-
Sylvania	Homestead	61	45	38	33	21	22	1	-
Munjina East Gorge	Lookout	86	67	56	52	42	36	40	3
Fig Tree Crossing	Lookout	129	102	73	69	57	47	162	30
Mt Meharry	Lookout	107	80	56	49	41	36	32	5
Mt Newman	Lookout	77	63	50	46	39	34	19	1
Tower Hill	Lookout	293	224	178	150	99	82	256	181
Karijini Eco Retreat	Recreation Camp Site	35	33	30	29	25	24	-	-
Ophthalmia Dam	Recreation Site	178	153	124	107	75	60	194	123
Round Hill	Recreation Site	103	87	74	64	41	35	74	25
Hickman Crater	Recreation Site	122	102	68	50	33	33	37	17
Weeli Wolli Spring/Outfall	Recreation Site	134	116	97	78	60	53	173	70
Stuarts Pool	Recreation Site	80	65	53	43	34	32	23	3
Kalgan Pool	Recreation Site	94	66	52	46	37	33	22	3
Eagle Rock Hole	Recreation Site	128	95	69	58	41	37	70	17
Mt Robinson	Rest Stop	174	122	110	99	69	58	193	108
Munjina Roadhouse	Roadhouse	62	53	44	41	32	29	8	-
Auski Village	Roadhouse	60	50	40	38	31	28	4	-
Capricorn Roadhouse	Roadhouse	117	99	77	68	41	35	83	32
Newman	Town centre	187	163	127	105	74	60	187	121
Rhodes Ridge	Town site	70	60	48	42	35	32	11	1
Wirlu-Murra	Aboriginal Community	84	65	54	50	42	36	38	1

Table 8-26: Predicted 24-hour PM_{10} Concentrations at receptors including background (µg/m³): Cumulative operations (Highest Use) - Standard Controls

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 50 µg/m³	Greater than 70 µg/m³
Juna Downs	Homestead	54	46	41	39	34	29	2	-
Ethel Creek	Homestead	46	38	31	28	21	21	-	-
Marillana	Homestead	213	173	130	112	61	52	128	97
Mulga Downs	Homestead	36	34	31	30	27	25	-	-
Prairie Downs	Homestead	40	37	32	30	23	22	-	-
Sylvania	Homestead	42	34	29	26	20	20	-	-
Munjina East Gorge	Lookout	59	47	41	38	33	29	3	-
Fig Tree Crossing	Lookout	82	67	50	47	41	35	18	1
Mt Meharry	Lookout	68	53	40	36	31	29	5	-
Mt Newman	Lookout	50	43	36	34	30	27	1	-
Tower Hill	Lookout	167	129	105	90	63	53	162	83
Karijini Eco Retreat	Recreation Camp Site	29	28	26	25	23	22	-	-
Ophthalmia Dam	Recreation Site	106	92	76	66	50	41	109	31
Round Hill	Recreation Site	65	56	49	44	31	27	16	-
Hickman Crater	Recreation Site	82	69	50	38	27	27	18	4
Weeli Wolli Spring/Outfall	Recreation Site	100	85	71	60	44	40	72	21
Stuarts Pool	Recreation Site	76	62	45	35	27	27	15	2
Kalgan Pool	Recreation Site	62	45	38	34	29	27	2	-
Eagle Rock Hole	Recreation Site	118	89	65	54	35	33	53	15
Mt Robinson	Rest Stop	104	87	70	65	49	42	105	22
Munjina Roadhouse	Roadhouse	47	41	34	32	28	26	-	-
Auski Village	Roadhouse	48	38	33	31	27	25	-	-
Capricorn Roadhouse	Roadhouse	72	62	50	46	31	28	21	1
Newman	Town centre	110	97	77	66	49	41	101	28
Rhodes Ridge	Town site	49	45	39	36	31	28	-	-
Wirlu-Murra	Aboriginal Community	67	52	45	42	36	31	5	-

Table 8-27: Predicted 24-hour PM_{10} Concentrations at receptors including background (µg/m³): Cumulative operations (Highest Use) - Leading Controls

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 50 µg/m³	Greater than 70 µg/m³
Juna Downs	Homestead	32	29	27	27	25	23	-	-
Ethel Creek	Homestead	42	35	28	24	20	20	-	-
Marillana	Homestead	187	155	116	99	51	46	113	86
Mulga Downs	Homestead	32	31	28	27	25	23	-	-
Prairie Downs	Homestead	27	25	24	23	20	20	-	-
Sylvania	Homestead	26	24	22	21	19	19	-	-
Munjina East Gorge	Lookout	41	34	29	27	25	24	-	-
Fig Tree Crossing	Lookout	44	39	32	31	28	26	-	-
Mt Meharry	Lookout	37	31	27	26	24	23	-	-
Mt Newman	Lookout	34	31	27	25	23	22	-	-
Tower Hill	Lookout	65	53	47	43	33	30	12	-
Karijini Eco Retreat	Recreation Camp Site	25	23	22	22	21	20	-	-
Ophthalmia Dam	Recreation Site	48	42	37	34	29	26	-	-
Round Hill	Recreation Site	34	32	30	27	23	21	-	-
Hickman Crater	Recreation Site	50	42	33	27	22	22	1	-
Weeli Wolli Spring/Outfall	Recreation Site	72	63	51	44	31	30	21	1
Stuarts Pool	Recreation Site	73	60	40	31	22	23	8	2
Kalgan Pool	Recreation Site	39	34	27	25	22	22	-	-
Eagle Rock Hole	Recreation Site	110	85	61	50	31	30	38	11
Mt Robinson	Rest Stop	75	58	44	39	32	29	10	1
Munjina Roadhouse	Roadhouse	38	31	28	26	24	23	-	-
Auski Village	Roadhouse	41	32	28	26	24	23	-	-
Capricorn Roadhouse	Roadhouse	37	33	30	28	23	22	-	-
Newman	Town centre	47	44	38	34	29	26	-	-
Rhodes Ridge	Town site	44	39	34	31	27	25	-	-
Wirlu-Murra	Aboriginal Community	52	41	36	35	30	27	1	-

8.4.2 Assessment of TSP (potential impact on visual amenity)

To assess the impact, modelled TSP concentrations averaged over 24-hour are compared to the assessment criteria (based on Kwinana EPP 24 hour average 90 µg/m³ and 24 hour average limit 150 µg/m³) selected for this study (Section 3.1).

8.4.2.1 BHP Billiton Iron Ore Operations

The key aspects of the air quality assessment are summarised below, and presented in Figure 8-31 (No Control), Figure 8-32 (Standard Controls), Figure 8-33 (Leading Controls) as well as Table 8-28 (No Control), Table 8-29 (Standard Controls) and Table 8-30 (Leading Controls):

- Similar to the assessment of PM_{10}, there is a significant reduction in the maximum predicted dust concentrations in the Standard Controls and Leading dust controls scenario when compared to the No Control scenario. It is worth noting that while BHP Billiton Iron Ore historically operates with Standard dust controls, the No Control scenario is presented to emphasise the importance of dust controls.
- For the No Control, Standard Controls and Leading Controls scenarios, there are 15 (receptor types include homestead, lookout, recreation site, rest stop, roadhouse and town centre), 7 (receptor types include lookout, recreation site, rest stop and town centre) and 1(lookout) receptors respectively with concentration in excess of 90µg/m^3.
- For the No Control and Standard Controls scenarios, there are 5 (receptor types include lookout, recreation site, rest stop and town centre) and 1 (lookout) receptors respectively with concentrations in excess of 150µg/m^3.
- From Table 8-28 to Table 8-30, it is apparent that there are significant decreases from the maximum predicted TSP concentrations at the receptors mentioned above with the lower statistics (99th to 95th percentiles). This indicates that the maximum predicted concentrations are single events that could be managed during operations through a dust management procedure.
- The predicted high TSP concentrations at the receptors indicate there is a high potential for TSP to impact the Pilbara Region in the unlikely event that dust controls are not applied.
- By implementing Standard Controls, the predicted TSP concentrations have been reduced compared to the No Control scenario. However, there are still 7 receptors that cannot meet the assessment criteria. Hence, there may still be a potential for TSP impact in the Pilbara Region even with Standard Controls in place.
- With Leading Controls in place, there are considerable reductions of TSP concentrations compared to the No Control scenario. However, the predicted TSP concentrations at Tower Hill exceed the Kwinana EPP criteria but comply with the Kwinana EPP limit;
- Nonetheless, the Leading Controls have greatly reduced the potential impact at the sensitive receptors compared to No Control and Standard Controls scenarios.

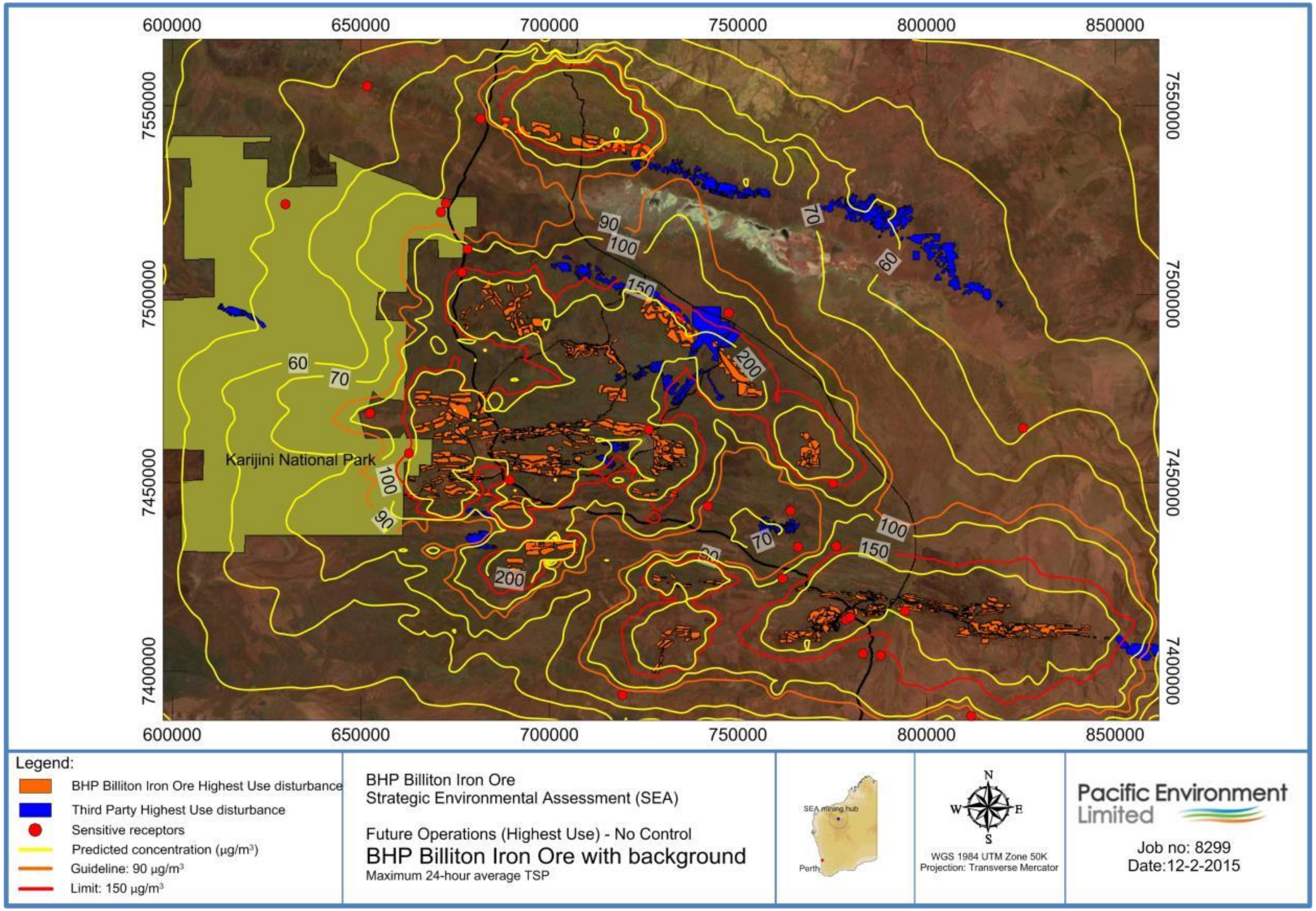

Figure 8-31: Maximum predicted 24-hour average TSP concentrations for Highest Use BHP Billiton Iron Ore operations (No Control) with background

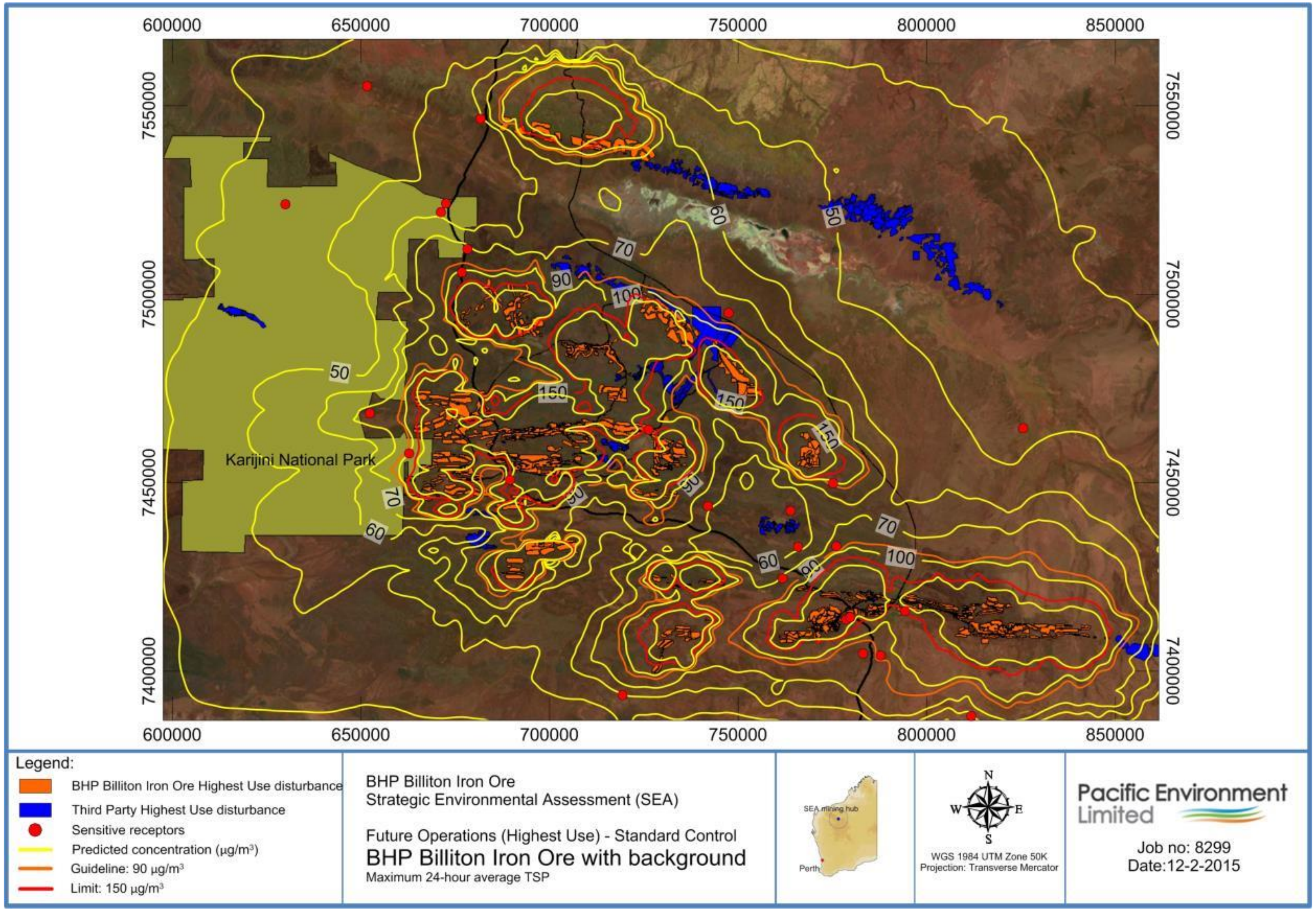

Figure 8-32: Maximum predicted 24-hour average TSP concentrations for Highest Use BHP Billiton Iron Ore operations (Standard Controls) with background

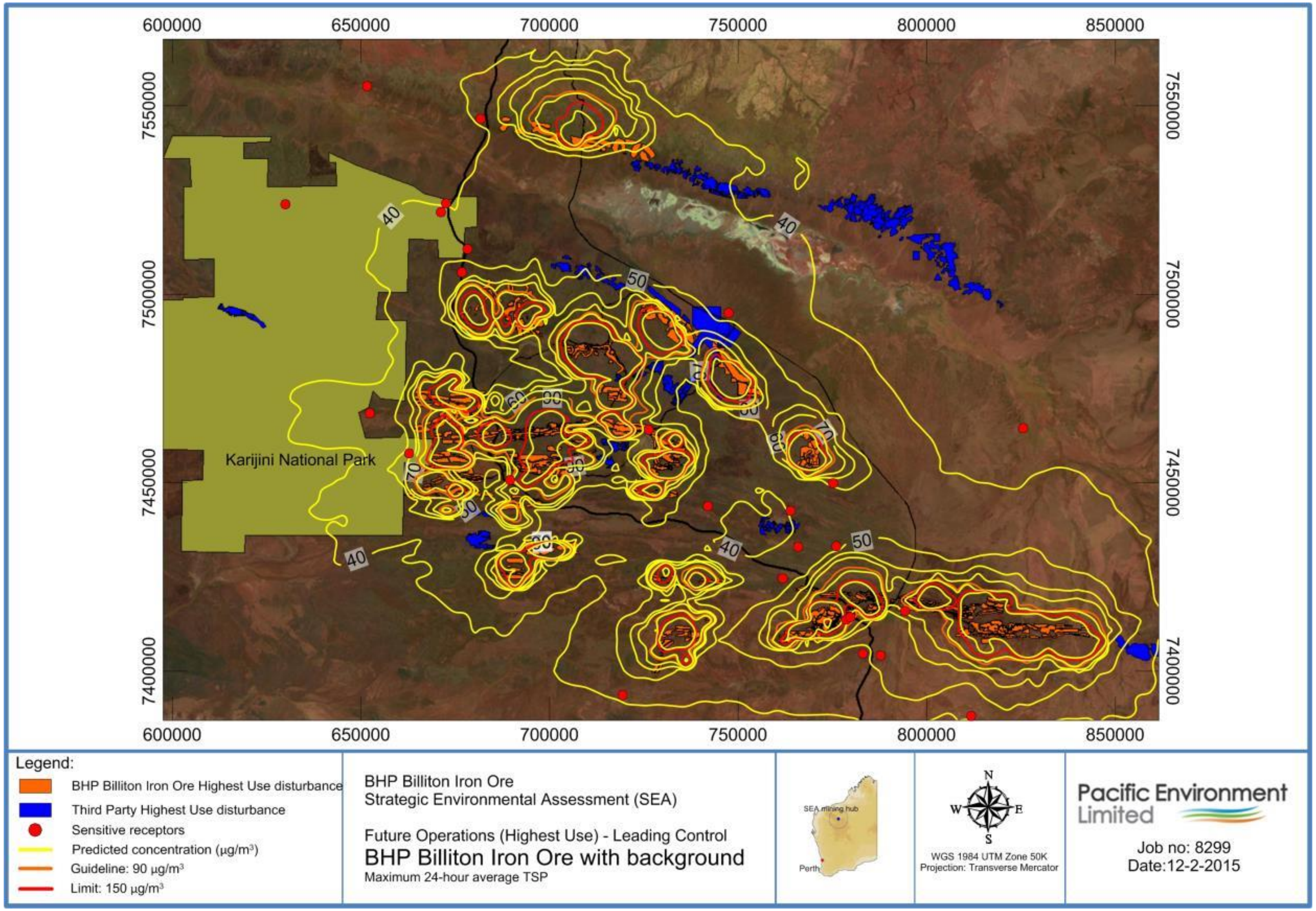

Figure 8-33: Maximum predicted 24-hour average TSP concentrations for Highest Use BHP Billiton Iron Ore operations (Leading Controls) with background

Table 8-28: Predicted 24-hour TSP Concentrations at receptors including background (µg/m³): BHP Billiton Iron Ore operations (Highest Use) – No Control

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 90 µg/m³	Greater than 150 µg/m³
Juna Downs	Homestead	102	91	83	79	68	57	5	-
Ethel Creek	Homestead	57	54	49	45	35	36	-	-
Marillana	Homestead	109	100	82	73	55	50	8	-
Mulga Downs	Homestead	52	50	45	43	40	38	-	-
Prairie Downs	Homestead	74	68	61	55	44	41	-	-
Sylvania	Homestead	77	61	54	48	36	37	-	-
Munjina East Gorge	Lookout	98	82	73	69	57	50	1	-
Fig Tree Crossing	Lookout	144	117	95	91	78	65	40	-
Mt Meharry	Lookout	136	106	78	71	62	57	8	-
Mt Newman	Lookout	98	84	73	67	59	52	2	-
Tower Hill	Lookout	494	393	324	282	187	152	263	153
Karijini Eco Retreat	Recreation Camp Site	50	47	45	43	40	38	-	-
Ophthalmia Dam	Recreation Site	219	205	175	157	115	95	168	47
Round Hill	Recreation Site	123	107	93	83	60	52	24	-
Hickman Crater	Recreation Site	138	121	81	63	49	47	13	-
Weeli Wolli Spring/Outfall	Recreation Site	175	133	108	98	82	71	73	1
Stuarts Pool	Recreation Site	72	63	59	56	50	46	-	-
Kalgan Pool	Recreation Site	106	86	68	63	55	50	2	-
Eagle Rock Hole	Recreation Site	70	61	53	51	46	43	-	-
Mt Robinson	Rest Stop	233	185	153	138	97	84	129	23
Munjina Roadhouse	Roadhouse	71	65	58	55	45	42	-	-
Auski Village	Roadhouse	65	62	55	51	43	41	-	-
Capricorn Roadhouse	Roadhouse	141	118	95	88	61	53	33	-
Newman	Town centre	246	228	180	154	115	95	169	41
Rhodes Ridge	Town site	89	74	61	53	44	44	-	-
Wirlu-Murra	Aboriginal Community	75	65	58	56	50	46	-	-

Table 8-29: Predicted 24-hour TSP Concentrations at receptors including background (µg/m³): BHP Billiton Iron Ore operations (Highest Use) – Standard Controls

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 90 µg/m³	Greater than 150 µg/m³
Juna Downs	Homestead	70	64	60	58	52	46	-	-
Ethel Creek	Homestead	46	45	42	40	34	35	-	-
Marillana	Homestead	74	69	60	54	45	42	-	-
Mulga Downs	Homestead	44	42	40	39	37	36	-	-
Prairie Downs	Homestead	55	52	48	45	39	37	-	-
Sylvania	Homestead	57	48	44	41	35	35	-	-
Munjina East Gorge	Lookout	68	60	55	52	46	42	-	-
Fig Tree Crossing	Lookout	93	78	66	64	57	50	1	-
Mt Meharry	Lookout	89	72	57	54	49	46	-	-
Mt Newman	Lookout	68	61	55	52	47	44	-	-
Tower Hill	Lookout	282	227	190	167	116	97	171	55
Karijini Eco Retreat	Recreation Camp Site	42	41	40	39	37	35	-	-
Ophthalmia Dam	Recreation Site	133	126	110	100	77	67	70	-
Round Hill	Recreation Site	82	73	66	60	48	43	-	-
Hickman Crater	Recreation Site	90	80	59	49	42	41	-	-
Weeli Wolli Spring/Outfall	Recreation Site	110	87	74	68	60	54	3	-
Stuarts Pool	Recreation Site	54	49	47	46	42	40	-	-
Kalgan Pool	Recreation Site	72	62	52	49	45	42	-	-
Eagle Rock Hole	Recreation Site	53	48	44	43	40	39	-	-
Mt Robinson	Rest Stop	141	115	98	90	68	61	36	-
Munjina Roadhouse	Roadhouse	53	50	46	45	40	38	-	-
Auski Village	Roadhouse	50	49	45	43	38	37	-	-
Capricorn Roadhouse	Roadhouse	91	79	66	63	48	44	1	-
Newman	Town centre	148	138	112	98	77	66	64	-
Rhodes Ridge	Town site	63	55	48	44	39	39	-	-
Wirlu-Murra	Aboriginal Community	56	50	47	45	42	40	-	-

Table 8-30: Predicted 24-hour TSP Concentrations at receptors including background (µg/m³): BHP Billiton Iron Ore operations (Highest Use) – Leading Controls

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 90 µg/m3	Greater than 150 µg/m3
Juna Downs	Homestead	45	43	42	41	39	37	-	-
Ethel Creek	Homestead	37	37	36	35	33	34	-	-
Marillana	Homestead	46	44	41	40	37	36	-	-
Mulga Downs	Homestead	36	36	35	35	34	34	-	-
Prairie Downs	Homestead	40	39	38	37	35	34	-	-
Sylvania	Homestead	41	38	37	36	34	34	-	-
Munjina East Gorge	Lookout	44	41	40	39	37	36	-	-
Fig Tree Crossing	Lookout	52	47	44	43	41	39	-	-
Mt Meharry	Lookout	51	45	41	40	38	37	-	-
Mt Newman	Lookout	44	42	40	39	38	36	-	-
Tower Hill	Lookout	112	94	83	75	59	53	7	-
Karijini Eco Retreat	Recreation Camp Site	36	36	35	35	34	34	-	-
Ophthalmia Dam	Recreation Site	65	62	57	54	47	44	-	-
Round Hill	Recreation Site	48	46	43	42	38	36	-	-
Hickman Crater	Recreation Site	51	48	41	38	36	36	-	-
Weeli Wolli Spring/Outfall	Recreation Site	57	50	46	44	41	40	-	-
Stuarts Pool	Recreation Site	40	38	38	37	36	35	-	-
Kalgan Pool	Recreation Site	45	42	39	38	37	36	-	-
Eagle Rock Hole	Recreation Site	39	38	37	36	35	35	-	-
Mt Robinson	Rest Stop	67	59	53	51	44	42	-	-
Munjina Roadhouse	Roadhouse	39	39	37	37	35	35	-	-
Auski Village	Roadhouse	39	38	37	36	35	34	-	-
Capricorn Roadhouse	Roadhouse	51	48	44	42	38	36	-	-
Newman	Town centre	69	66	58	54	47	44	-	-
Rhodes Ridge	Town site	43	40	38	37	35	35	-	-
Wirlu-Murra	Aboriginal Community	40	39	37	37	36	35	-	-

8.4.2.2 Third party operations

The key outcomes of the air quality assessment are summarised below, and presented in Figure 8-34 and Table 8-31:

- The 24-hour maximum contour (Kwinana EPP criteria) occurs outside three sensitive receptors, i.e. Marillana, Stuarts Pool and Eagle Rock Hole.
- The 24-hour maximum contour (Kwinana EPP limit) occurs outside 1 sensitive receptor, i.e. Marillana.
- Table 8-31 highlights that there are considerable reductions from the maximum predicted TSP concentrations towards the lower statistics (99th and 90th percentiles) at Marillana, Stuarts Pool and Eagle Rock Hole. It is worth noting that the scenario modelled is highly precautionary as the assumption is all mines developed and operating simultaneously. Therefore, this scenario is unlikely to occur.
- The results clearly show that there is a potential that the current third party operations may impact the air quality in the Pilbara Region.

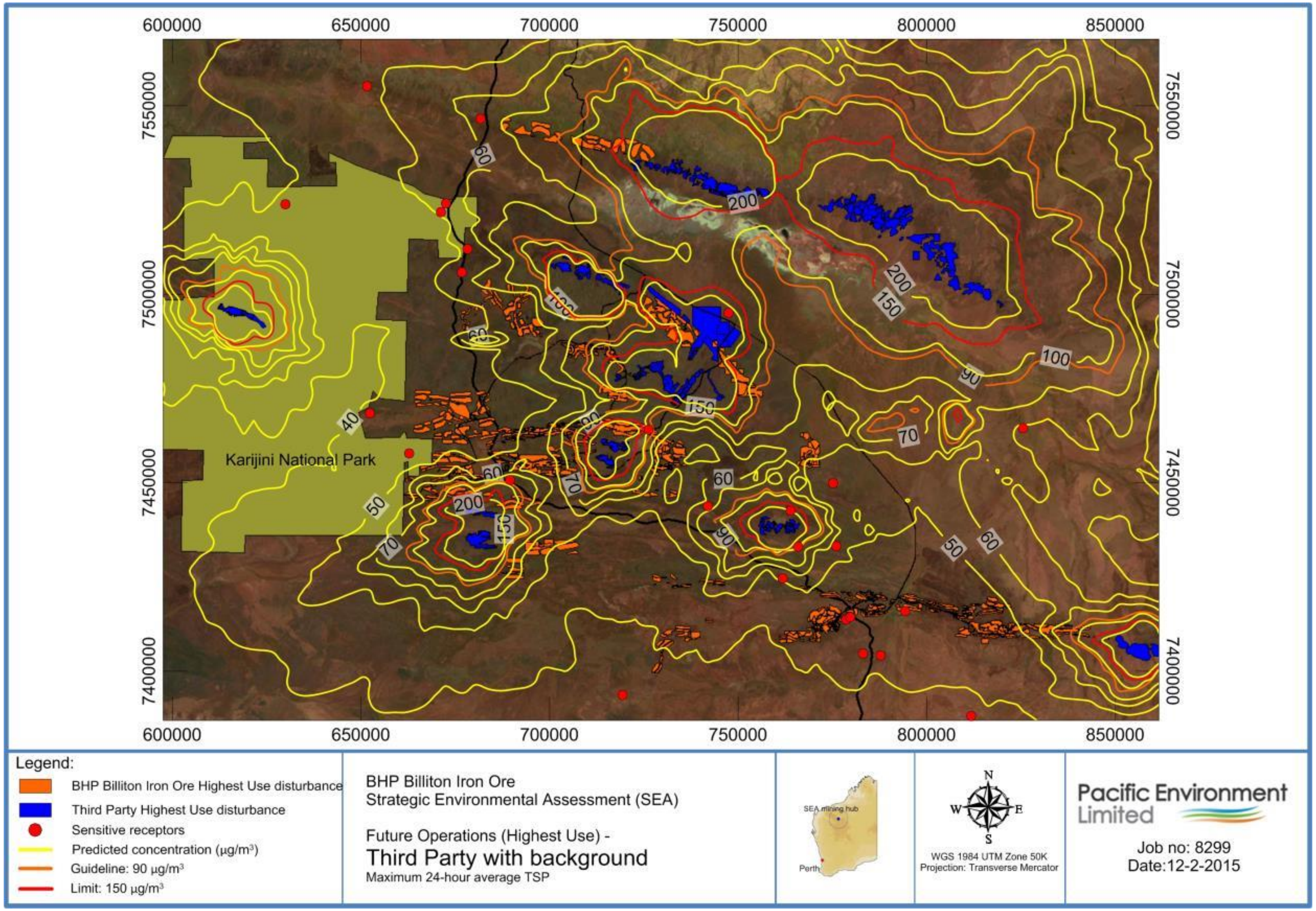

Figure 8-34: Maximum predicted 24-hour average TSP concentrations for Highest Use third party operations with background

Table 8-31: Predicted 24-hour TSP Concentrations at receptors including background (µg/m³): Third party operations (Highest Use)

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 90 µg/m³	Greater than 150 µg/m³
Juna Downs	Homestead	39	38	37	37	36	35	-	-
Ethel Creek	Homestead	58	51	42	38	34	35	-	-
Marillana	Homestead	232	201	163	143	83	71	104	30
Mulga Downs	Homestead	46	46	43	42	39	37	-	-
Prairie Downs	Homestead	37	37	35	35	34	34	-	-
Sylvania	Homestead	37	36	35	34	34	34	-	-
Munjina East Gorge	Lookout	50	44	41	40	39	37	-	-
Fig Tree Crossing	Lookout	53	44	42	40	39	37	-	-
Mt Meharry	Lookout	42	39	38	37	36	35	-	-
Mt Newman	Lookout	50	46	41	37	34	34	-	-
Tower Hill	Lookout	42	41	37	35	34	34	-	-
Karijini Eco Retreat	Recreation Camp Site	41	38	37	36	36	35	-	-
Ophthalmia Dam	Recreation Site	43	40	36	35	34	34	-	-
Round Hill	Recreation Site	40	39	36	35	34	34	-	-
Hickman Crater	Recreation Site	52	48	43	40	35	35	-	-
Weeli Wolli Spring/Outfall	Recreation Site	84	77	65	58	43	42	-	-
Stuarts Pool	Recreation Site	91	75	58	47	34	37	1	-
Kalgan Pool	Recreation Site	53	45	40	38	34	35	-	-
Eagle Rock Hole	Recreation Site	146	125	98	84	52	49	28	-
Mt Robinson	Rest Stop	82	69	58	49	39	39	-	-
Munjina Roadhouse	Roadhouse	50	44	42	40	38	37	-	-
Auski Village	Roadhouse	54	46	43	42	39	38	-	-
Capricorn Roadhouse	Roadhouse	40	39	36	35	34	34	-	-
Newman	Town centre	42	41	37	35	34	34	-	-
Rhodes Ridge	Town site	59	54	51	48	42	40	-	-
Wirlu-Murra	Aboriginal Community	61	54	49	48	44	41	-	-

8.4.2.3 Cumulative Operations

The key outcomes of the air quality assessment are summarised below, and presented in Figure 8-35 (No Control for BHP Billiton Iron Ore), Figure 8-36 (Standard Controls for BHP Billiton Iron Ore) and Figure 8-37 (Leading Controls for BHP Billiton Iron Ore):

- There is a significant reduction in the maximum predicted TSP concentrations in the Standard and Leading Controls scenarios when compared to the No Control scenario. It is worth noting that while BHP Billiton Iron Ore historically operates with Standard dust controls, the No Control scenario is presented to emphasise the importance of dust controls.
- For the No Control, Standard Controls and Leading Controls scenarios, there are 19 (receptor types including homesteads, lookouts, recreation sites, rest stops, roadhouses, town centre, town site and aboriginal communities), 12 (receptor types include homestead, lookout,

recreation site, rest stop, roadhouse and town centre) and 6 receptors (receptor types include homestead, lookout and recreation site) respectively with concentrations in excess of 90µg/m^3.

- For the No Control and Standard Controls and Leading Controls scenarios, there are 9 (receptor types include homestead, lookout, recreation site, rest stop and town centre), 3 (receptor types include homestead, lookout and recreation site) and 1 (homestead) receptors respectively with concentrations in excess of 150 µg/m^3.
- From Table 8-32 to Table 8-34, it is apparent that there are significant decreases from the maximum predicted TSP concentrations at the receptors mentioned above with the lower statistics (99th to 95th percentiles). For example, for the Standard Controls scenario, the 99th and 95th percentile at Marillana receptor are 14% and 33% lower than the maximum concentrations predicted. This indicates that the maximum predicted concentrations are single events that could be managed readily during operations.
- The predicted high TSP concentrations at the receptors, as mentioned above, indicate there is a high potential for impact on air quality in the Pilbara Region when No Control is adopted by BHP Billiton Iron Ore.
- By implementing Standard Controls at all BHP Billiton Iron Ore processing hubs and all third party mining operations in the Pilbara Region, the predicted TSP concentrations have been reduced compared to the No Control scenario. However, receptors near Marillana, Tower Hill and Eagle Rock Hole still cannot meet the Kwinana EPP limit. Hence, there might still be a potential impact on the Pilbara Region with Standard Controls in place at all BHP Billiton Iron Ore processing hubs and third party mining operations.
- With Leading Controls at BHP Billiton Iron Ore operations in place and Standard Controls at the third party operations; although the predicted TSP concentrations at Marillana still cannot meet the Kwinana EPP limit, there are considerable reductions in TSP concentrations compared to the No Control scenario. It is worth noting that the predicted TSP concentrations at Marillana are contributed to by both BHP Billiton Iron Ore and third party operations.
- However, the scenario modelled is highly precautionary as the assumption is all mines developed and operating simultaneously. Therefore, this scenario is unlikely to occur.
- In summary, compared to No Control and Standard Controls scenarios, the Leading Controls would greatly reduce the potential impact at the sensitive receptors to a reasonable level.

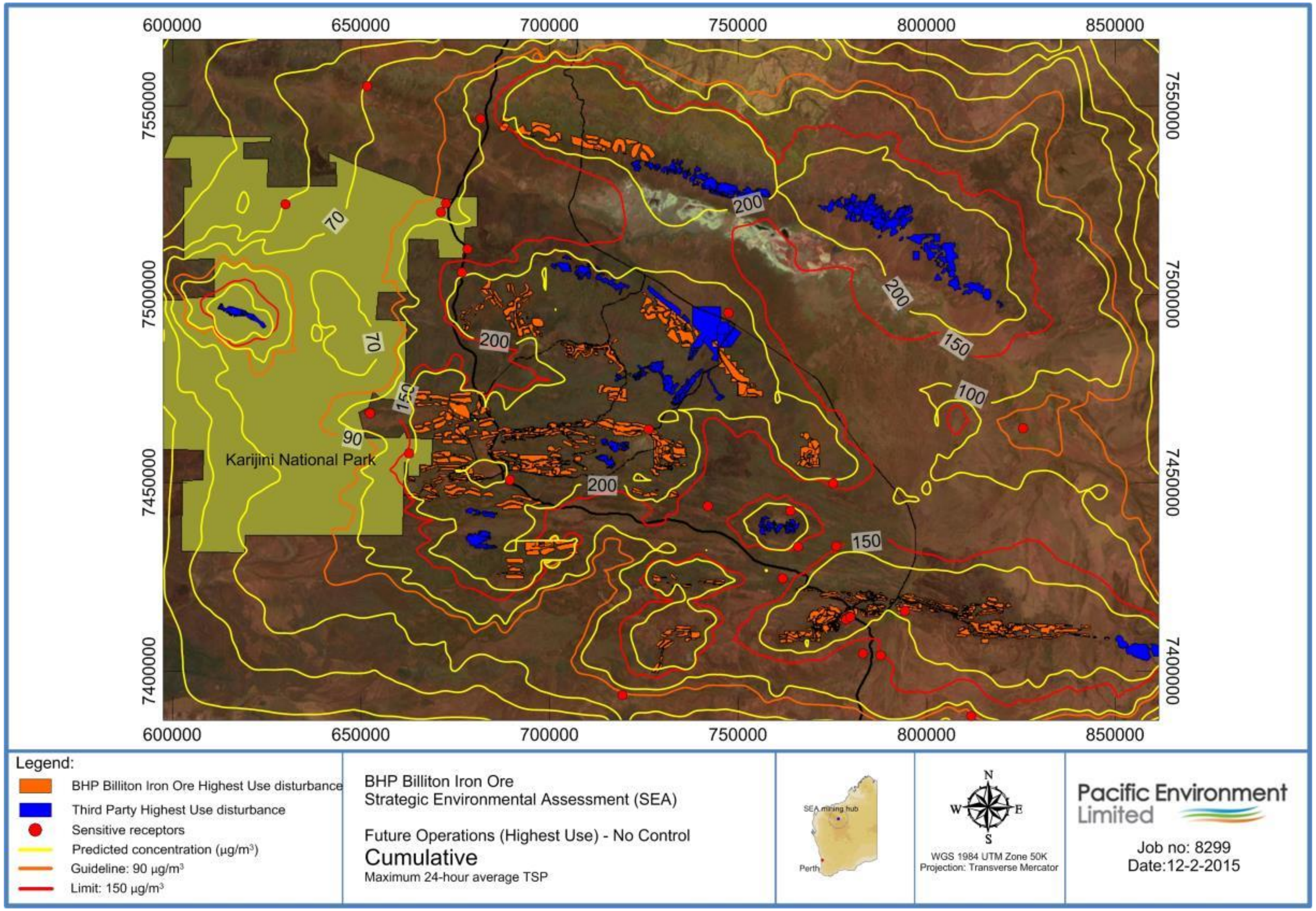

Figure 8-35: Maximum predicted 24-hour average TSP concentrations for Highest Use cumulative operations (No Control from BHP Billiton Iron Ore operations) with background

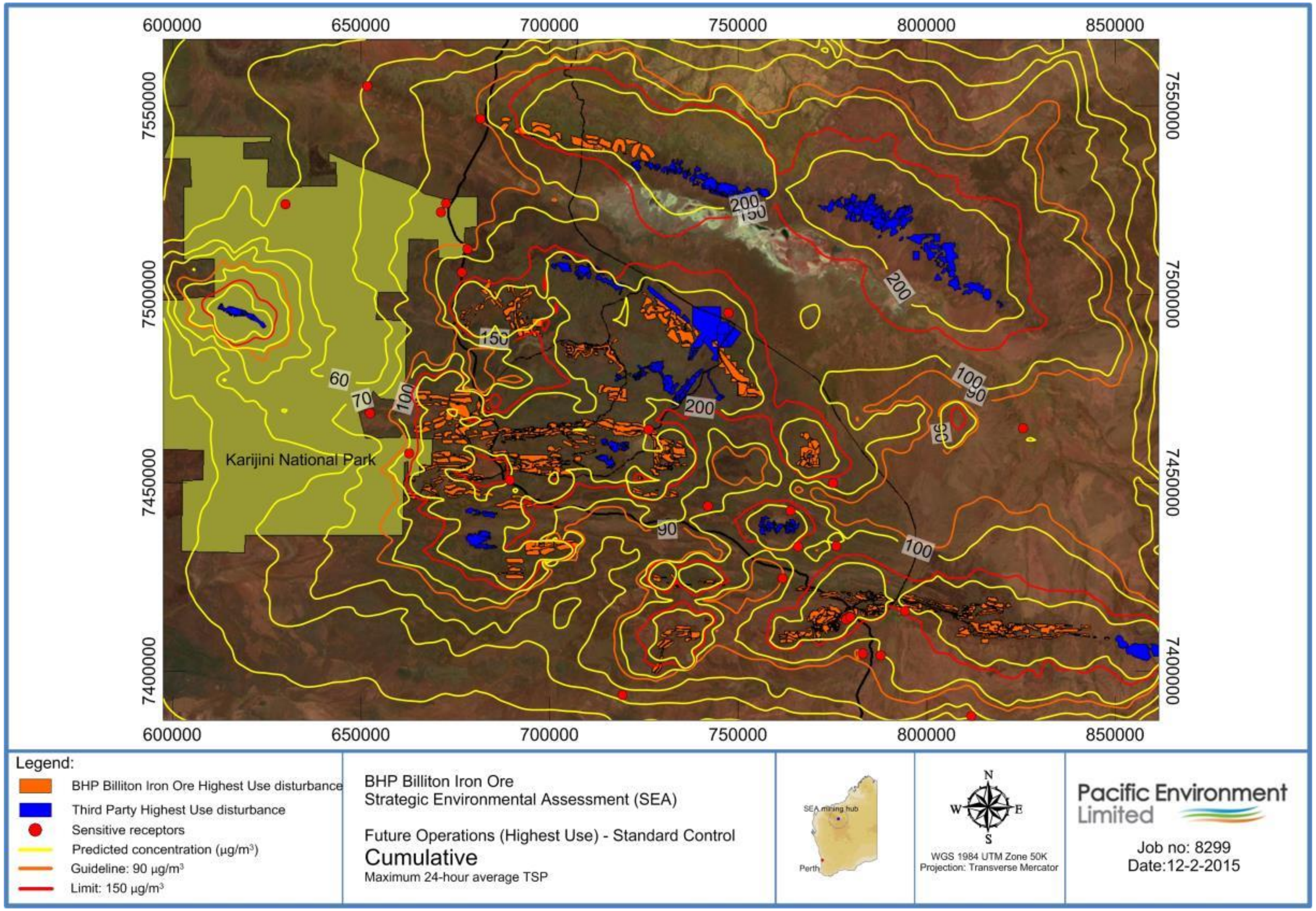

Figure 8-36: Maximum predicted 24-hour average TSP concentrations for Highest Use cumulative operations (Standard Controls from BHP Billiton Iron Ore operations) with background

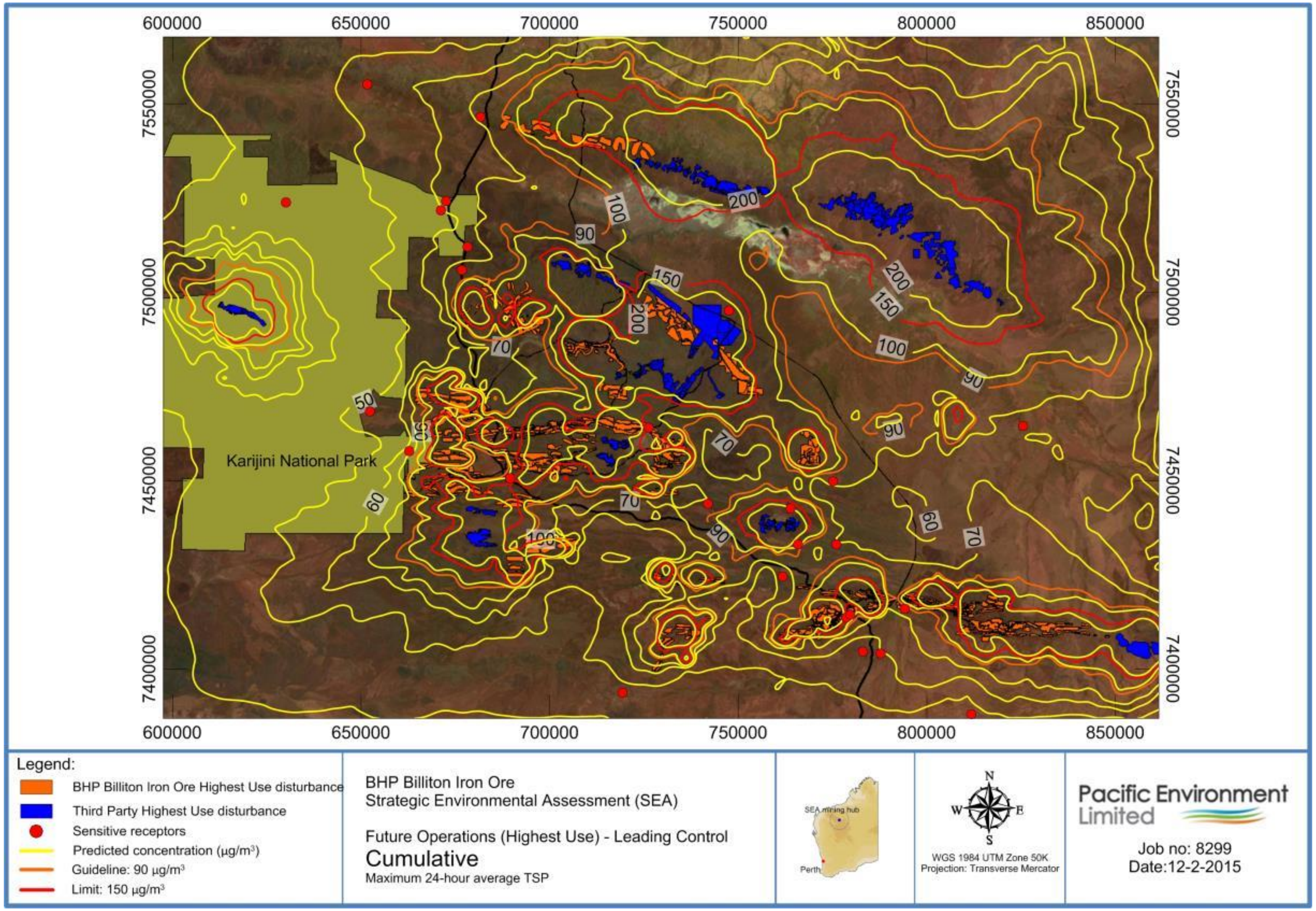

Figure 8-37: Maximum predicted 24-hour average TSP concentrations for Highest Use cumulative operations (Leading Controls from BHP Billiton Iron Ore operations) with background

Table 8-32: Predicted 24-hour TSP Concentrations at receptors including background (µg/m³): Cumulative operations (Highest Use) – No Control

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 90 µg/m³	Greater than 150 µg/m³
Juna Downs	Homestead	106	93	85	81	71	58	7	-
Ethel Creek	Homestead	66	61	54	50	38	38	-	-
Marillana	Homestead	300	254	201	177	110	87	125	66
Mulga Downs	Homestead	57	56	53	51	46	43	-	-
Prairie Downs	Homestead	75	70	62	56	44	41	-	-
Sylvania	Homestead	77	63	55	49	37	38	-	-
Munjina East Gorge	Lookout	105	87	77	73	62	54	3	-
Fig Tree Crossing	Lookout	152	124	100	96	83	69	68	1
Mt Meharry	Lookout	139	112	81	74	65	59	9	-
Mt Newman	Lookout	99	85	73	68	60	54	2	-
Tower Hill	Lookout	494	393	324	284	187	153	263	153
Karijini Eco Retreat	Recreation Camp Site	53	50	47	46	42	39	-	-
Ophthalmia Dam	Recreation Site	220	206	177	158	117	96	171	48
Round Hill	Recreation Site	125	108	95	86	60	53	27	-
Hickman Crater	Recreation Site	157	133	92	69	50	50	20	1
Weeli Wolli Spring/Outfall	Recreation Site	183	152	134	114	90	80	111	6
Stuarts Pool	Recreation Site	102	89	72	63	54	50	4	-
Kalgan Pool	Recreation Site	113	87	71	66	57	52	2	-
Eagle Rock Hole	Recreation Site	169	138	106	97	64	59	46	2
Mt Robinson	Rest Stop	238	189	159	147	105	90	154	31
Munjina Roadhouse	Roadhouse	79	71	63	59	50	46	-	-
Auski Village	Roadhouse	77	68	60	56	48	45	-	-
Capricorn Roadhouse	Roadhouse	143	119	97	89	63	53	35	-
Newman	Town centre	247	229	182	156	117	95	171	45
Rhodes Ridge	Town site	96	82	67	62	55	50	1	-
Wirlu-Murra	Aboriginal Community	103	84	73	69	61	54	1	-

Table 8-33: Predicted 24-hour TSP Concentrations at receptors including background (µg/m³): Cumulative operations (Highest Use) – Standard Controls

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 90 µg/m³	Greater than 150 µg/m³
Juna Downs	Homestead	74	67	62	61	55	48	-	-
Ethel Creek	Homestead	62	54	47	44	36	36	-	-
Marillana	Homestead	265	227	177	164	100	80	119	50
Mulga Downs	Homestead	52	50	48	46	43	40	-	-
Prairie Downs	Homestead	57	54	50	46	39	38	-	-
Sylvania	Homestead	57	50	46	42	36	36	-	-
Munjina East Gorge	Lookout	76	65	59	57	51	46	-	-
Fig Tree Crossing	Lookout	101	85	72	69	63	54	2	-
Mt Meharry	Lookout	92	79	60	57	52	48	1	-
Mt Newman	Lookout	69	61	55	53	48	45	-	-
Tower Hill	Lookout	282	228	190	169	118	98	171	57
Karijini Eco Retreat	Recreation Camp Site	45	44	42	41	39	37	-	-
Ophthalmia Dam	Recreation Site	136	127	112	101	80	67	73	-
Round Hill	Recreation Site	83	75	68	63	48	44	-	-
Hickman Crater	Recreation Site	109	93	70	55	43	43	5	-
Weeli Wolli Spring/Outfall	Recreation Site	136	116	99	89	67	62	34	-
Stuarts Pool	Recreation Site	97	82	65	54	45	44	2	-
Kalgan Pool	Recreation Site	80	64	55	52	46	44	-	-
Eagle Rock Hole	Recreation Site	158	133	103	91	58	54	40	1
Mt Robinson	Rest Stop	146	122	107	97	76	67	65	-
Munjina Roadhouse	Roadhouse	63	57	51	49	44	42	-	-
Auski Village	Roadhouse	65	54	50	49	44	42	-	-
Capricorn Roadhouse	Roadhouse	93	80	70	64	49	44	1	-
Newman	Town centre	149	139	114	100	80	67	69	-
Rhodes Ridge	Town site	71	63	57	55	49	45	-	-
Wirlu-Murra	Aboriginal Community	84	69	62	59	53	48	-	-

Table 8-34: Predicted 24-hour TSP Concentrations at receptors including background (µg/m³): Cumulative operations (Highest Use) – Leading Controls

Receptor	Receptor type	Maximum	99th Percentile	95th Percentile	90th Percentile	70th Percentile	Average	Greater than 90 µg/m³	Greater than 150 µg/m³
Juna Downs	Homestead	49	46	45	44	42	39	-	-
Ethel Creek	Homestead	59	51	43	40	35	35	-	-
Marillana	Homestead	239	208	167	151	89	73	108	38
Mulga Downs	Homestead	48	47	44	43	40	38	-	-
Prairie Downs	Homestead	43	41	39	38	36	35	-	-
Sylvania	Homestead	41	40	38	37	34	34	-	-
Munjina East Gorge	Lookout	56	50	46	44	42	40	-	-
Fig Tree Crossing	Lookout	60	56	50	49	46	43	-	-
Mt Meharry	Lookout	54	51	44	43	41	39	-	-
Mt Newman	Lookout	51	48	43	41	39	38	-	-
Tower Hill	Lookout	112	95	83	77	61	54	8	-
Karijini Eco Retreat	Recreation Camp Site	41	39	38	37	37	36	-	-
Ophthalmia Dam	Recreation Site	68	63	59	55	49	45	-	-
Round Hill	Recreation Site	51	50	45	43	39	37	-	-
Hickman Crater	Recreation Site	70	61	51	44	37	38	-	-
Weeli Wolli Spring/Outfall	Recreation Site	100	87	74	66	49	48	2	-
Stuarts Pool	Recreation Site	93	76	60	49	37	39	2	-
Kalgan Pool	Recreation Site	56	51	44	42	38	38	-	-
Eagle Rock Hole	Recreation Site	150	128	99	86	54	51	29	-
Mt Robinson	Rest Stop	94	75	66	61	53	48	1	-
Munjina Roadhouse	Roadhouse	54	47	44	42	40	39	-	-
Auski Village	Roadhouse	57	48	44	43	41	39	-	-
Capricorn Roadhouse	Roadhouse	54	49	46	44	39	37	-	-
Newman	Town centre	71	68	60	55	49	44	-	-
Rhodes Ridge	Town site	60	55	53	49	44	41	-	-
Wirlu-Murra	Aboriginal Community	68	58	53	51	47	43	-	-

8.4.3 Assessment of potential visibility risk

The potential for reduction in visibility along the Great Northern Highway due to Highest Use operations at BHP Billiton Iron Ore (plus background) are presented in Figure 8-38 (No Control scenario), Figure 8-39 (Standard Controls) scenario and Figure 8-40 (Leading Controls scenario). The methodology for determining the potential risk rating is discussed in Section 6.5.

- In the No Control and Standard Controls scenarios, a High risk potential exists along sections of the Great Northern Highway near the town of Newman and north of the Mt Robinson receptor. The potential for Low and Medium risk exists around Newman, north of Mt Robinson and south of the Fig Tree Crossing receptors along the Great Northern Highway.
- In the Leading Controls scenario, the potential for Low and Medium risk in visibility reduction exists around the north of the Mt Robinson and Newman receptors. There is no High visibility risk

predicted for this scenario. The potential for visibility reduction along the remaining sections of the Great Northern Highway (white line) is negligible.

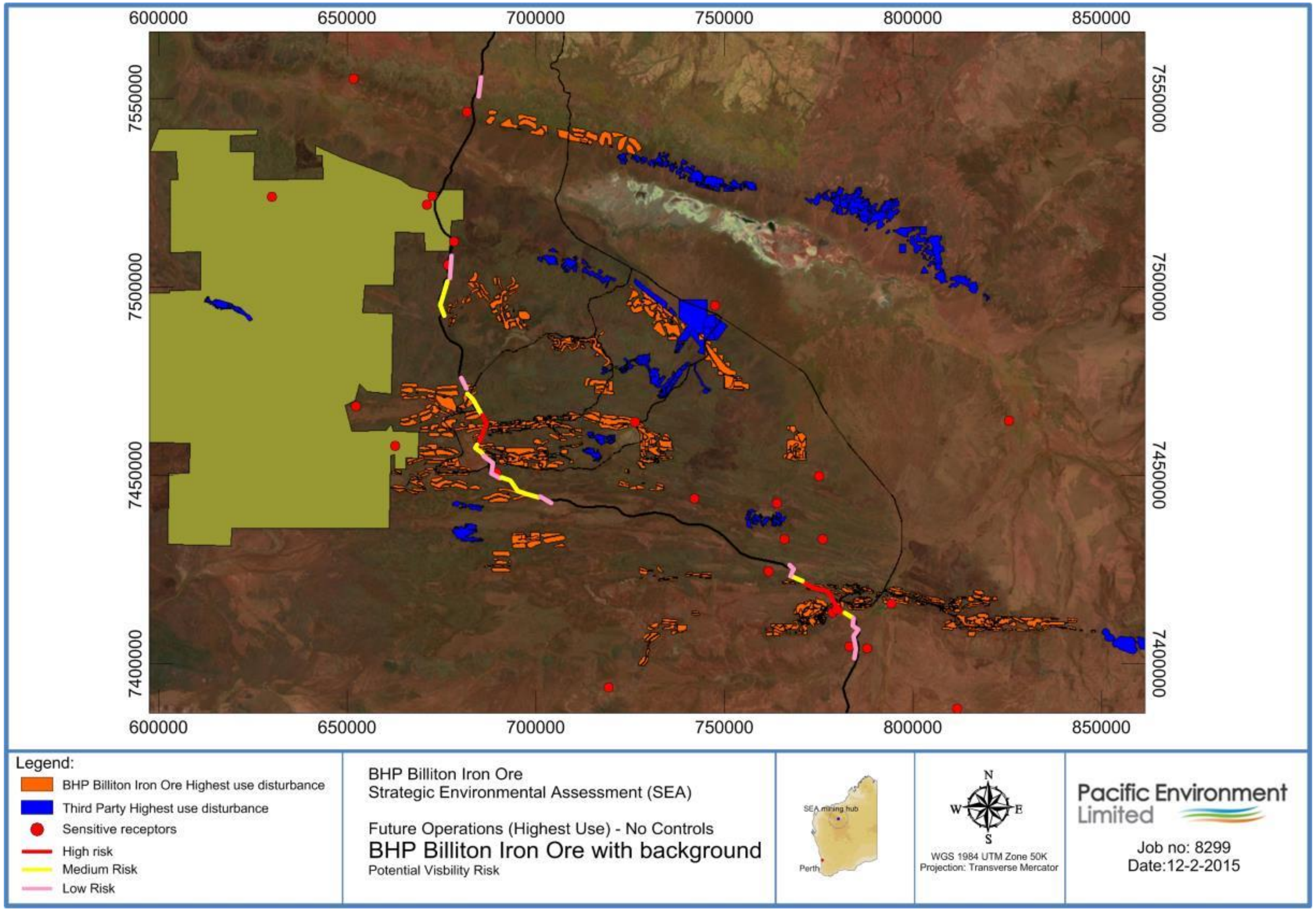

Figure 8-38: Potential Visibility Risk for Highest Use BHP Billiton Iron Ore operations (No Control)

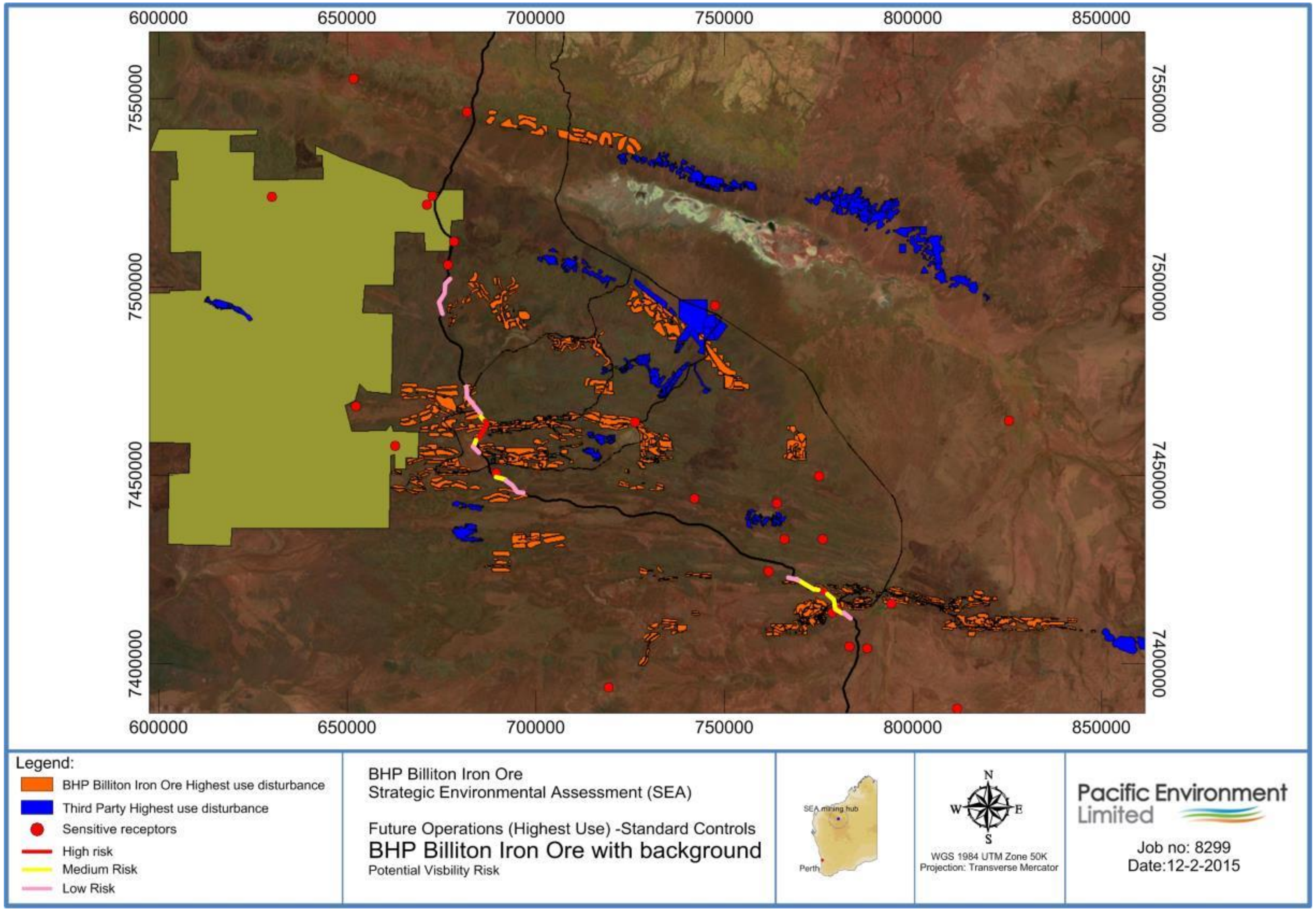

Figure 8-39: Potential Visibility Risk for Highest Use BHP Billiton Iron Ore operations (Standard Controls)

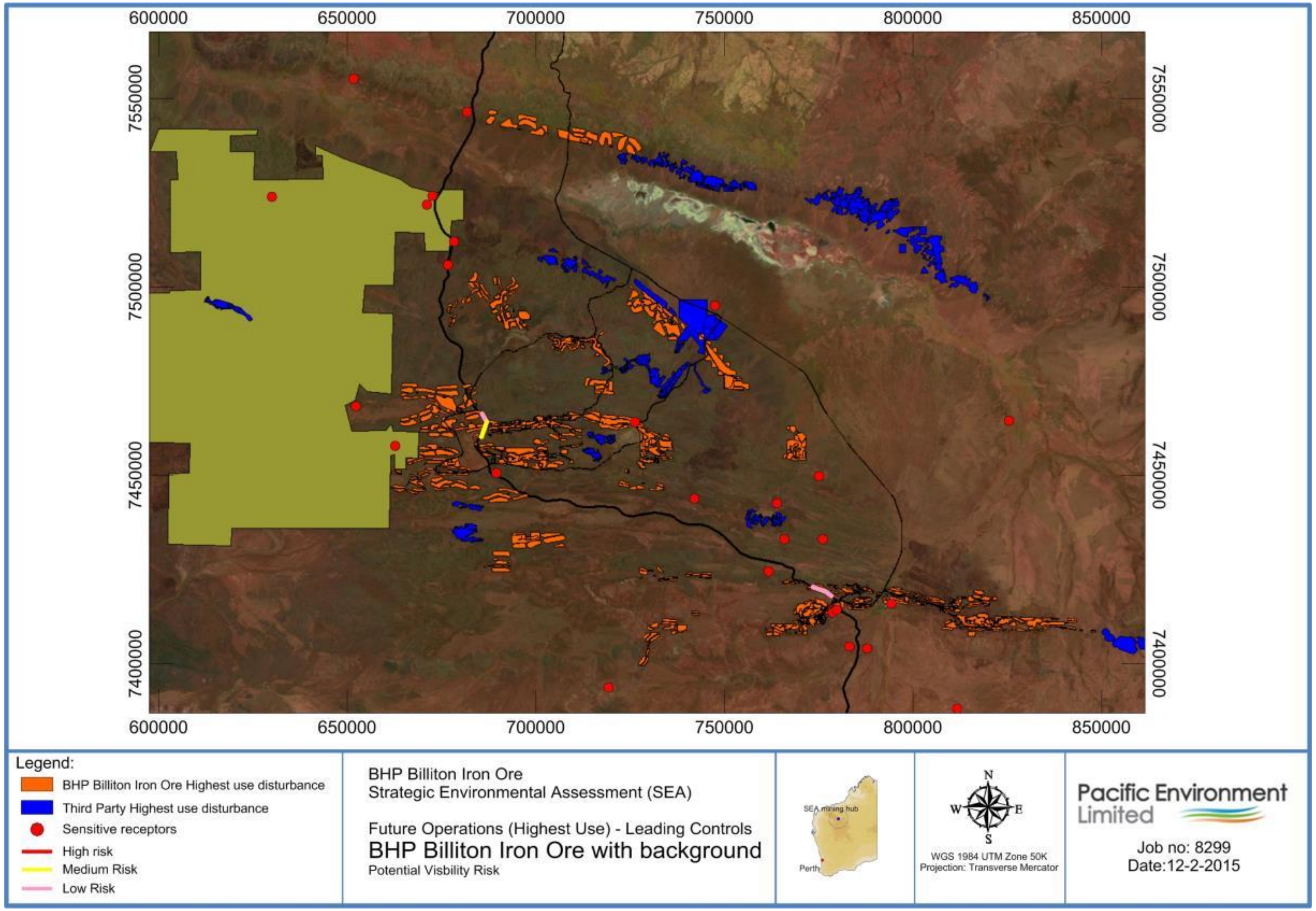

Figure 8-40: Potential Visibility Risk for Highest Use BHP Billiton Iron Ore operations (Leading Controls)

9 CONCLUSION

This assessment has evaluated the potential cumulative air quality impact in the Pilbara Region for current operations, those anticipated to be active for a 30% Development and a Highest Use scenario of BHP Billiton Iron Ore operations. The emission estimation has been based on published NPI data for existing iron ore mines, published stripping ratio for individual mines as well as tonnage and disturbance footprint data provided by BHP Billiton Iron Ore for current and future development in the Pilbara region. This air quality assessment identifies the high risk areas and establishes the most constraining factors for air quality which can be used to inform the planning and design for future developments associated with the Proposal. This assessment provides an indication of higher risk locations that may require an increased focus on dust controls in the future.

9.1 Selection of representative model year

Two key factors were considered to determine the model year that can be considered representative of general conditions at the Pilbara Region: meteorological conditions, and background air quality.

The most recent 11 years of historical (meteorological) surface observations at the Wittenoom and Newman Airport Bureau of Meteorology sites (2001 to 2012, inclusive) were reviewed. Wind speed, ambient temperature and relative humidity were compared to the long term averages for the region to determine the most representative year. The meteorological conditions indicate the most representative year in terms of wind speed, wind direction and rainfall is considered to be 2009 followed by 2010. However, based on data availability and recorded annual average concentrations, the year 2010 was selected as the representative year for meteorological and background air quality conditions for the Pilbara region. The 24-hour average background dust levels for the modelled year were estimated as 18µg/m^3 for PM_{10} and 33µg/m^3 for TSP.

9.2 Selection of assessment criteria

Modelled PM_{10} concentration has been compared to the assessment criteria selected for this study, based on:

- National Environment Protection Measure standard (NEPM) of 24-hour 50 µg/m^3
- Port Hedland Dust Management Taskforce (Taskforce) guideline of 24-hour 70 µg/m^3.

Modelled TSP concentration has been compared to the assessment criteria selected for this study, based on:

- Environmental Protection (Kwinana) (Atmospheric Wastes) Policy and Regulations of 24-hour 90 µg/m^3 and limit of 150 µg/m^3.

The selection of these criteria is considered to be a conservative approach, and appropriate given that there may be further revisions to the proposal in future. Comparison of the modelled results to the assessment criteria is intended to provide an objective evaluation of the potential impact of the operations at the nearest sensitive receptors. It is worth noting that some receptors are recreational or intermittently visited and inclusion of these in the conceptual model is considered conservative. The potential impact is defined in context of protecting human health (where people reside and amenity (visible dust leaving the premises).

9.3 Relative significance of the impacts

Air quality impacts from operations have been modelled using the CALPUFF model. CALPUFF has been configured using meteorological parameters sourced from the WRF model with the meteorological parameters validated against measured data.

This Cumulative Air Quality Assessment is conservative as it is unlikely that all BHP Billiton Iron Ore projects will be operational (mining operations) at the maximum rate at the same time. The most likely scenario is that future mining operations will slowly progress and increase as existing mining operations slowly ramp down.

9.3.1 Assessment of PM_{10}

In instances where model predictions are above the relevant assessment criteria, it suggests that the proposed development may have a high potential to increase PM_{10} concentration at the nearby sensitive receptors without appropriate mitigating controls. However, it is worth noting that some of the receptors included are used for recreational purposes and are visited intermittently with the assessment criteria less applicable at these receptors.

The modelling results for current operations predict excursions of relevant PM_{10} criteria at Tower Hill and Newman receptors.

For the 30% Development scenario, with no dust control, the maximum cumulative PM_{10} concentration is above the NEPM and Taskforce assessment criteria (see section 8.3.1.3). Also, applying the Standard Controls is not completely adequate to control the PM_{10} concentration in the Pilbara Region. Even with the Leading Controls in place, the results show that the cumulative maximum 24-hour PM_{10} concentrations at Marillana, Tower Hill, Stuarts Pool, Eagle Rock Hole, Weeli Wolli Spring/ Outfall and Mt Robinson are above the NEPM based assessment criteria. Nevertheless, there is a significant reduction in the maximum cumulative PM_{10} concentrations in the Standard Controls and Leading Controls when compared to the No Control scenario.

For the Highest Use scenario, with no dust control, the maximum cumulative PM_{10} concentration is above the NEPM and Taskforce assessment criteria (see section 8.4.1.3). Also, applying the Standard Controls is not completely adequate to control the PM_{10} concentration in the Pilbara Region. Even with the Leading Controls in place, the results show that the cumulative maximum 24-hour PM_{10} concentrations at Marillana, Tower Hill, Weeli Wolli Spring/ Outfall, Stuarts Pool, Eagle Rock Hole, Hickman Crater, Mt Robinson and Wirlu-Murra are above the NEPM based assessment criteria. It should be noted that the scenario modelled is highly precautionary as the assumption is all mines developed and operating simultaneously which is unlikely to occur in reality. Nevertheless, there is a significant reduction in the maximum cumulative PM_{10} concentrations in the Standard Controls and Leading Controls scenarios when compared to the No Control scenario.

9.3.2 Assessment of TSP

Similar to PM_{10}, in instances where model predictions are above the relevant assessment criteria, this suggests the Proposal may have a high potential to increase TSP concentration at the nearby sensitive without mitigating controls in place.

The modelling results for existing operations show the predicted TSP level at Tower Hill and Newman receptors are higher than the assessment criteria based on the Kwinana EPP criteria and Kwinana EPP limit.

For the 30% Development scenario, with no dust control, the maximum cumulative TSP concentrations at Marillana, Fig Tree Crossing, Mt Newman, Tower Hill, Ophthalmia Dam, Round Hill, Weeli Wolli Spring/Outfall, Stuarts Pool, Kalgan Pool, Eagle Rock Hole, Mt Robinson, Capricorn Roadhouse and Newman are above the Kwinana EPP assessment criteria. Also, applying the Standard Controls is not completely adequate to control the TSP concentration in the Pilbara Region as the maximum cumulative TSP concentrations at Marillana, Tower Hill, Ophthalmia Dam, Weeli Wolli Spring/Outfall, Stuarts Pool, Eagle Rock Hole, Mt Robinson and Newman are still above the Kwinana EPP assessment criteria. Even with the Leading Controls in place, the results show that the cumulative maximum 24-hour TSP concentrations at Marillana, Weeli Wolli Spring/ Outlet, Stuarts Pool, Eagle Rock Hole and Mt Robinson are above the Kwinana EPP assessment criteria. .It should be noted that the scenario modelled is highly precautionary as the assumption is all mines developed and operating simultaneously which is unlikely to occur in reality. Nevertheless, there is a significant reduction in the maximum cumulative TSP concentrations in the Standard Controls and Leading Controls scenarios when compared to the No Control scenario.

For the Highest Use operation scenario, with no dust control, the maximum cumulative TSP concentrations at Juna Downs, Marillana, Munjina East Gorge, Fig Tree Crossing, Mt Meharry, Mt Newman, Tower Hill, Ophthalmia Dam, Round Hill, Hickman Crater, Weeli Wolli Spring/Outfall, Stuarts Pool, Kalgan Pool, Eagle Rock Hole, Mt Robinson, Capricorn Roadhouse, Newman, Rhodes Ridge and Wirlu-Murra are above the assessment criteria based on the Kwinana EPP criteria. Also, applying the Standard Controls is not completely adequate to control the TSP concentration in the Pilbara Region as the maximum cumulative TSP concentrations at Marillana, Fig Tree Crossing, Mt Meharry, Tower Hill, Ophthalmia Dam, Hickman Crater, Weeli Wolli Spring/Outfall, Stuarts Pool, Eagle Rock Hole, Mt Robinson, Capricorn Roadhouse and Newman are above the Kwinana EPP criteria. Even with the Leading Controls in place, the results show that the cumulative maximum 24-hour TSP concentrations at Marillana, Tower Hill, Weeli Wolli Spring/ Outfall, Stuarts Pool, Eagle Rock Hole and Mt Robinson are above the Kwinana EPP criteria. . It should be also noted that the Highest Use scenario is highly conservative all existing and future mines are operational concurrently. . Nevertheless, there is a significant reduction in the maximum cumulative TSP concentrations in the Standard Controls and Leading Controls scenarios when compared to the No Control scenario.

9.3.3 Assessment of Visibility

For the 30% Development scenario, with No dust control, Medium and Low risk were noted along some sections of the Great Northern Highway around Mt Robinson and Newman. With Standard dust controls in place, there were still some sections of the Great Northern Highway that had Medium and Low visibility risk. With the adoption of Leading Controls, the potential for visibility reduction along the Great Northern Highway was negligible.

For the Highest Use operation scenario, with no dust control and Standard dust controls, the potential for High risk was noted along sections of the Great Northern Highway near the town of Newman and north of the Mt Robinson receptor; potential for Low and Medium risk were noted around Newman, north of Mt Robinson and south of Fig Tree Crossing receptor locations along the Great Northern Highway. With Leading Controls, the potential for Low and Medium visibility risk was noted around the north of Mt Robinson and Newman receptors, with no potential for High risk.

9.3.4 Assessment of Greenhouse Gases

Based on the total greenhouse gas emissions calculated from all BHP Billiton Iron Ore operations in the Pilbara region (Section 6.4):

- The existing scenario accounts for 0.2% of the national level (including LULUCF) and 1.2% of Western Australian levels (including LULUCF).
- The 30% Development scenario accounts for 0.5% of the national level (including LULUCF) and 3.7% of Western Australian levels (including LULUCF).
- The Highest Use scenario accounts for 0.8% of the national level (including LULUCF) and 6.2% of Western Australian levels (including LULUCF).
- The greenhouse gases intensity in all scenarios are comparable with similar developments.

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Appendix A REPRESENTATIVE MODEL YEAR

A.1 IDENTIFICATION OF REPRESENTATIVE YEAR

In dispersion modelling, one of the key considerations is the representativeness of the meteorological data used. Once emitted to atmosphere, emissions will:

- rise according to the velocity and temperature at the point of emission
- be advected from the source according to the strength and direction of the wind at the height which the plume has risen in the atmosphere
- be diluted due to mixing with the ambient air, according to the intensity of turbulence, and
- possibly be chemically transformed and/or depleted by deposition processes.

Dispersion is the combined effect of these processes. Dispersion modelling is used as a tool to simulate the air quality effects of specific emission sources, given the meteorology typical for a local area together with the expected emissions. Selection of a year when the meteorological data is atypical means that the resultant predictions may not appropriately represent air quality.

For this assessment, representative meteorological data is not the only factor influencing the appropriateness of a model year. Other factors that must also be considered include:

- Monitoring data
- Meteorology data for validation

This section sets out the analysis of these key factors to determine the representative year for modelling.

A.1.1 Existing (Background) Air Quality in Pilbara region

Background dust levels for the modelled year are required for input into the model to represent the PM_{10} entering the model domain from background sources (including dust storms, bushfires and other fugitive sources wether biogenic or anthropogenic). The concentrations of PM_{10} and TSP recorded by BHP Billiton Iron Ore at the Newman BG2 monitoring station is considered to be representative of the regional air quality.

Background levels of PM_{10} and TSP are high in the Pilbara region with the highest concentrations occurring predominately during summer periods. The likely activities contributing to these high background concentrations of PM_{10} include:

- bushfires
- low rainfall periods
- urban and transport related activities.

The statistical summary of PM_{10} concentration at BG2 for the years 2009 to 2012 is presented in Table A.1-1 and Table A.1-2 respectively. The background levels of particulates in the year 2009 presents were elevated, possibly due to some of the contributing factors mentioned above. Year 2009 would represent a conservative model year in terms of background dust levels. In 2011, the annual average concentration of PM_{10} and TSP drop below 20 µg/m^3 and 30 µg/m^3 respectively. If the model year was designated as 2011, the contribution of dust from background sources would likely be underestimated. The recorded number of 24 hour average PM_{10} concentrations in 2012 exceeded 50 µg/m^3 a total of 17 times which indicates 2012 is a high background dust level year. Note that the data recovery for 2009 is 85% while 2012 has data recovery at 83% which is significantly lower than that achieved in 2010 and 2011 and this does have the potential of affecting the annual average.

Table A.1-1: Statistical summary for PM_{10} monitoring data in BG2 (μg/m³)

	2009	2010	2011	2012
Max	153.04	590.34	92.43	193.64
99th percentile	98.59	62.82	69.93	76.91
95th percentile	67.49	37.26	34.38	54.93
90th percentile	54.40	29.61	27.62	34.69
70th percentile	31.21	18.16	18.98	21.09
Average	28.49	18.31	16.55	20.37
Data recovery	85%	99%	95%	83%
No. of times PM10 > 50 μg/m³	39	9	5	17
No. of times PM10 > 70 μg/m³	16	3	4	6

Table A.1-2: Statistical summary for TSP monitoring data in BG2 (μg/m³)

	2009	2010	2011	2012
Max	722	288	119	146
99th percentile	448	163	95	97
95th percentile	236	82	68	68
90th percentile	168	59	54	55
70th percentile	93	33	35	35
Average	90.1	31.7	29.8	29.9
Data recovery	1	1	1	1
No. of times PM10 > 90 μg/m3	96	15	5	5
No. of times PM10 > 150 μg/m3	41	6	-	-

In summary, dust levels from 2009 and 2012 would provide a conservative approach though the low level of data recovery is a concern, 2010 would represent average background dust levels, 2011 would underestimate the contribution of background sources. In terms of background PM_{10} concentration, 2010 is considered representative of the background dust concentrations. When selecting an appropriate model year the background dust levels must be considered in conjunction with the local meteorology.

A.1.2 Meteorology

In order to determine the most applicable year of meteorological data to use for the dispersion modelling 11-years of historical surface observations from BoM stations at Newman and Wittenoom (2001 to 2012 inclusive) were reviewed. Wind speed, ambient temperature and relative humidity were compared to long term averages for the region to determine the most representative year. Data collected from year 2001 to 2012 is summarised in Section A.1.2.1 and A.1.2.2.

A.1.2.1 Wind Speed and Wind Direction (Newman only)

The annual wind roses for the Newman region from 2001 to 2012 are presented Figure A-1. Wind speed and wind direction are not available at Wittenoom monitoring station. This figure shows the dominant wind directions as easterly through to south easterly. However, there is a reasonable proportion of the annual wind from the south westerly direction, but not as predominant as the easterly winds.

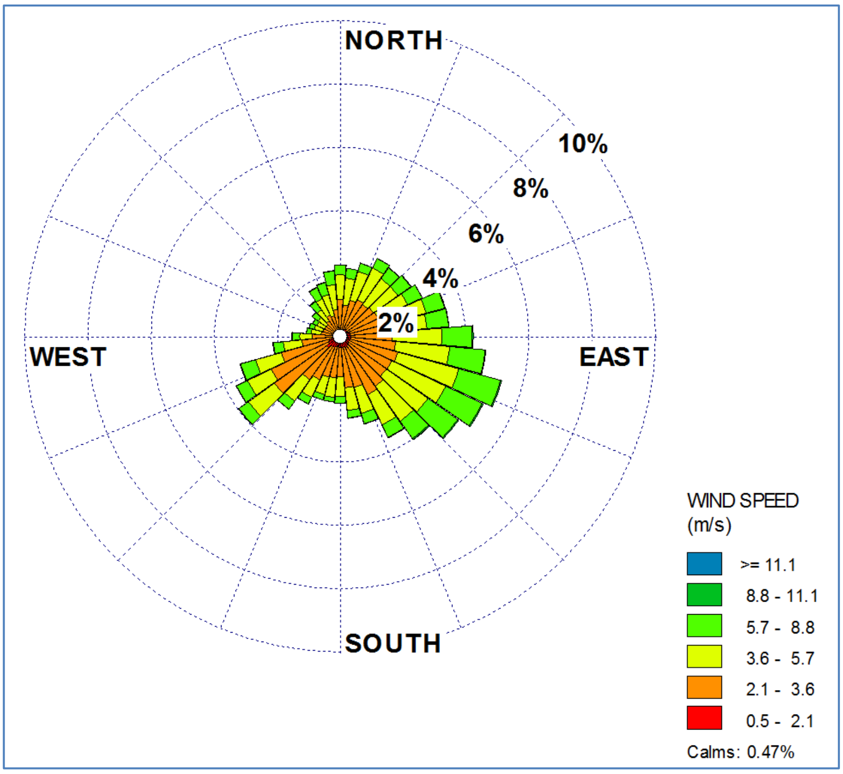

Figure A-1: Annual Wind Rose for Newman (2001 – 2012) (BoM, 2013)

The wind directions for each annual period from 2001 to 2012 at BOM Newman station are presented in Figure A-2. In 2002, there are a reasonable proportion of winds from south westerly; and in 2010, there is a reasonable proportion of winds from south-east easterly. In general, the wind direction patterns are consistent with the overall pattern of wind directions in the region from 2001 to 2012.

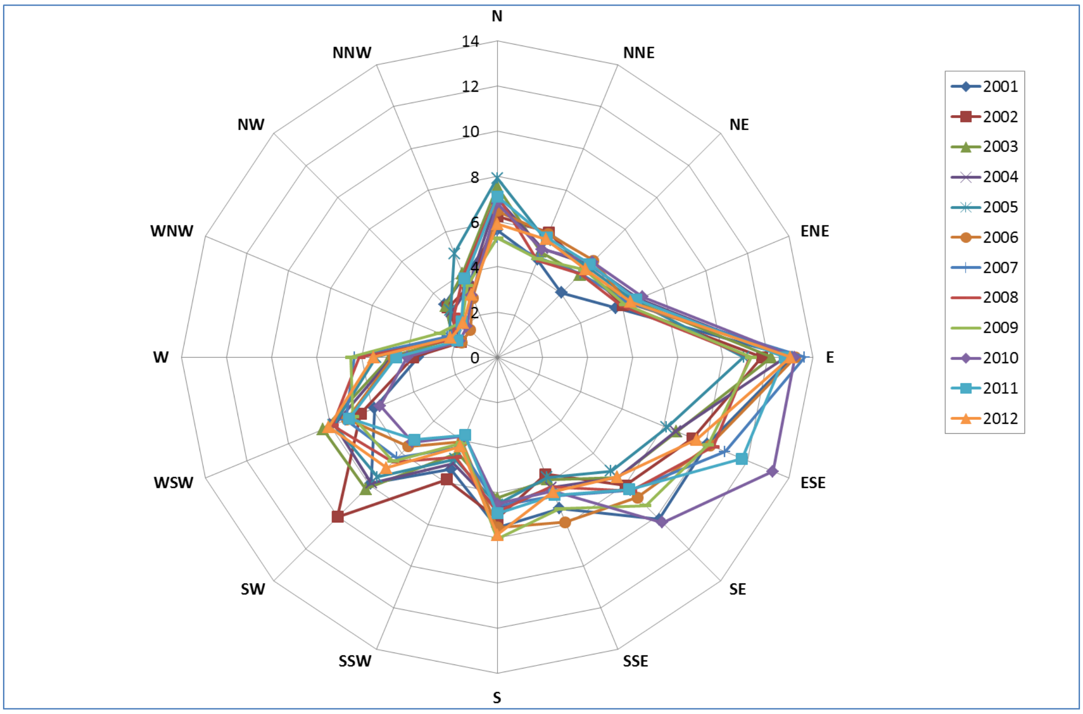

Figure A-2: Annual wind direction (%) for Newman (2001-2012) (BOM, 2013)

The statistics of annual wind speeds recorded at Newman from 2001 to 2012 is shown in Figure A-3. The recorded maximum wind speeds range from 10.8 to 15 metres per second (m/s). The average wind speeds are approximately 3.4 m/s. Year 2001, 2008, 2009, 2010, 2011 and 2012 have relatively high maximum wind speeds, suspected to be influenced by tropical cyclones in the region during those timeframes.

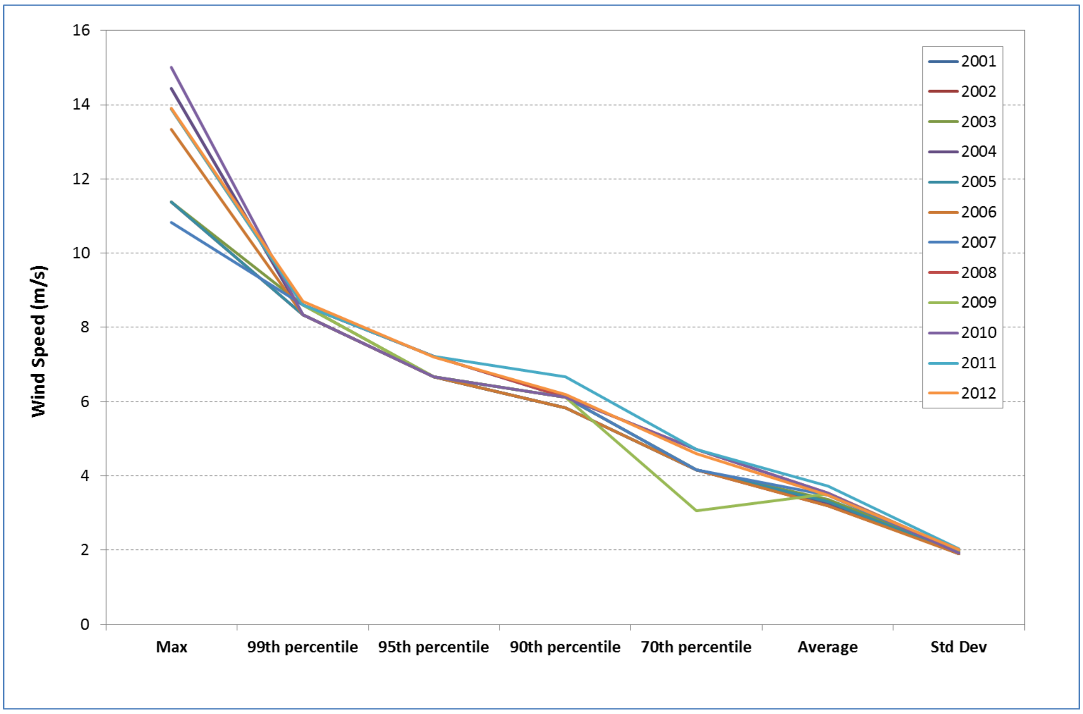

Figure A-3: Annual wind speed for Newman (2001-2012) (BOM, 2013)

A.1.2.2 Rainfall (Newman and Wittenoom)

The long term annual rainfalls in Newman Airport and Wittenoom are displayed in Figure A-4 and Figure A-5 respectively. There is a significant variation of rainfall between each year. High rainfall is likely to supress the generation of dust leading to an under-estimate of the likely emissions of dust in an average year. Conversely, years of low rainfall will cause the model to over-predict the likely emissions of dust.

In Newman, 2006 and 2007 fall outside the range of 10th percentile and 90th percentile (Figure A-4). In Wittenoom, 2006 again fall outside the 90th percentile (Figure A-5). Further analysis was conducted using BoM rainfall statistics in Newman over 32 years. It shows only the total rainfall amounts of Year 2002, 2005, 2007, 2008, 2009 and 2010 fall within the 10th and 90th percentile of long term total rainfall amount. Total rainfalls for Year 2002, 2008 and 2009 are closest to the long term median rainfall total of 322.6 mm (BOM, 2013).

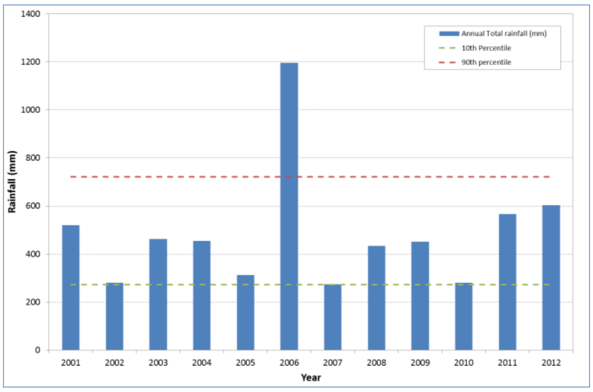

Figure A-4: Total rainfall at Newman Airport (BoM, 2013)

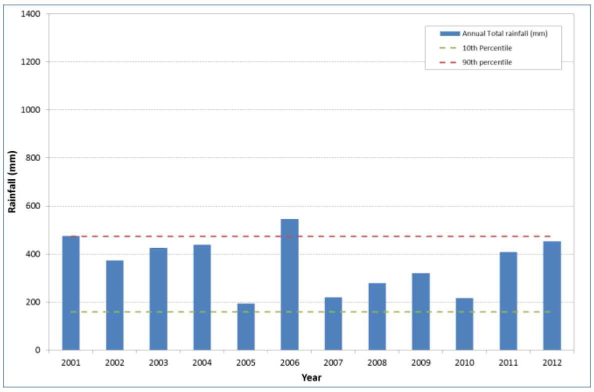

Figure A-5: Total rainfall at Wittenoom (BoM, 2013)

A.1.3 Statistical Analysis

The Mann-Whitney U test was used to statistically identify the representative modelling year based on recorded meteorological parameters including wind speed and temperature. This test was used to assess the Newman meteorological data.

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% CI, two tailed), then accept the null hypothesis (Figure A-6). It is note that only scalars were assessed (i.e. temperature and wind speed).

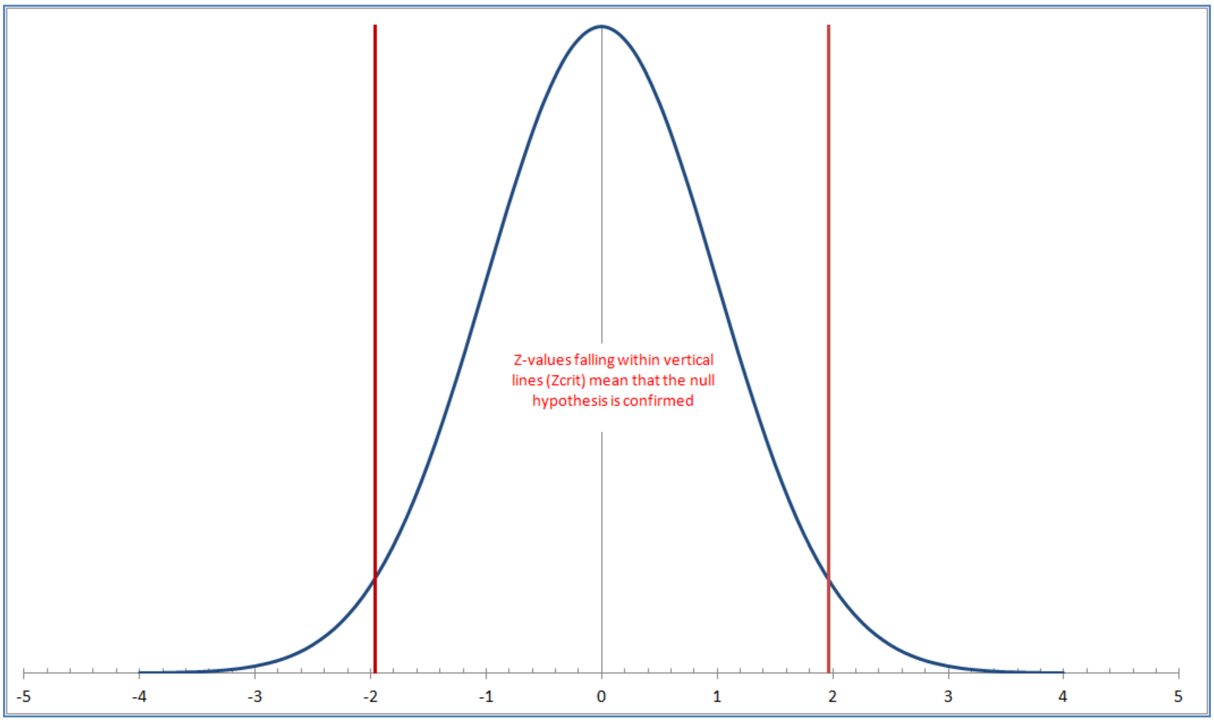

Figure A-6: Null Hypothesis for Mann-Whitney U test

A.1.3.1 Wind Speed (Newman only)

Mann-Whitney U test results for wind speed indicate that 1998, 2008, 2009 and 2010 were representative of 15 year mean conditions (Figure A-7). For meteorological data from 2009 to 2011, Year 2010 provided a better representation followed by 2009 and 2011.

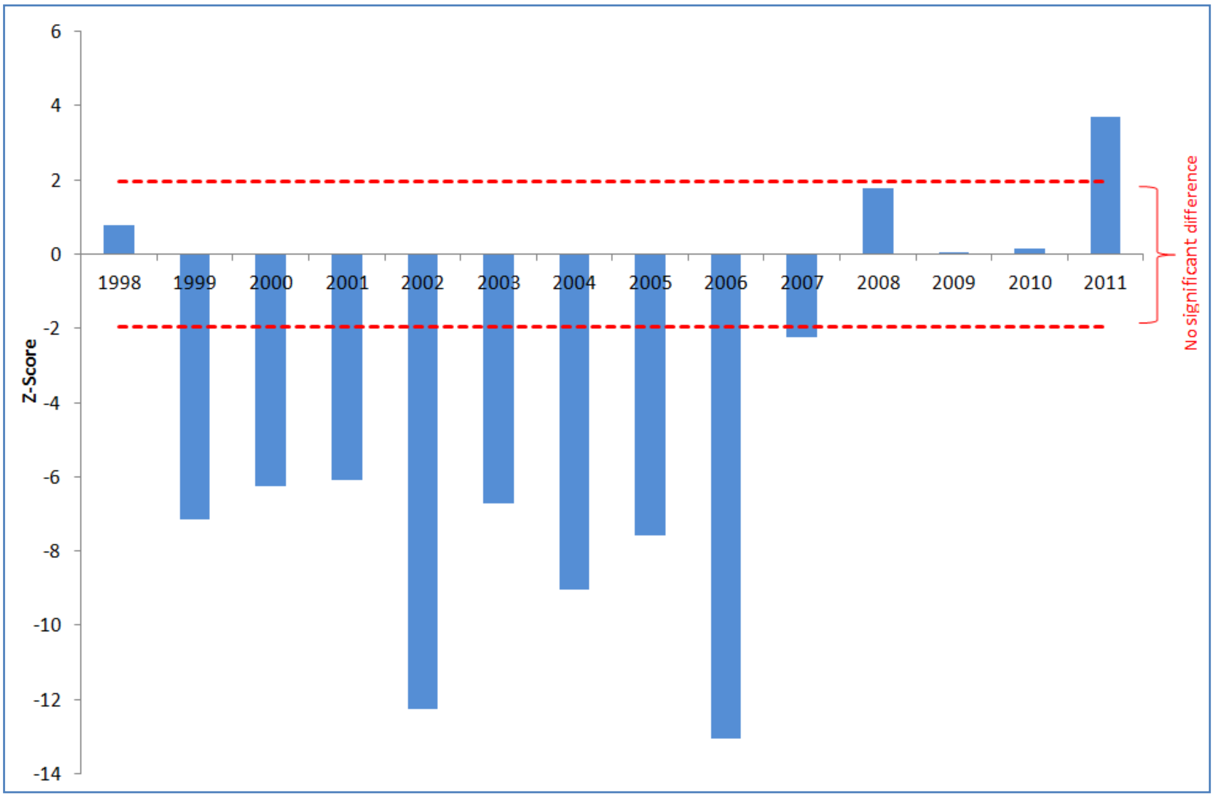

Figure A-7: Mann-Whitney U test result for wind speed

A.1.3.2 Temperature

Mann-Whitney U test results for temperature indicate that only 2009 was representative of 15 year mean conditions (Figure A-8).

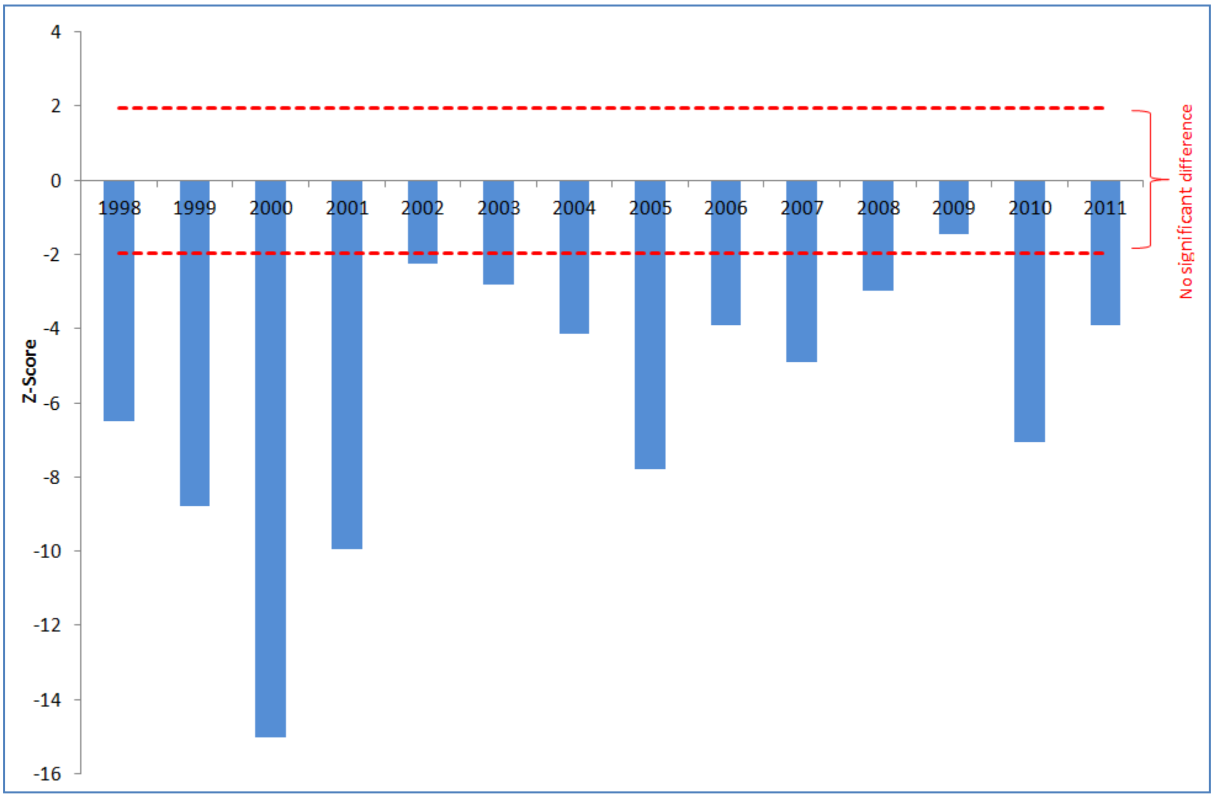

Figure A-8: Mann-Whitney U test result for temperature

A.1.4 Selected Representative Year

The selection of the most representative model year is usually determined by interrogating the meteorological data for the most conservative year, without choosing an outlying year. In this situation, the monitoring data in the study area presents a more compelling reason for the selection of the model year.

The monitoring data provides an essential service to the model validation process by providing locations where predictions of ground level concentrations of PM_{10} and TSP can be directly compared with sampled concentrations.

The meteorological conditions highlight that the most representative year in terms of wind speed, wind direction and rainfall is considered to be 2009. However, based on the analysis of the available monitoring data, year 2010 is the only practical option for the model year for Central Pilbara region

The implications for the meteorology indicate that 2010 has a higher proportion of south east easterly westerly winds, higher maximum wind speeds and relatively low rainfall. The increased precedence of southeast easterly winds in 2010 is likely to influence the locations receiving concentrations of particulate matter. The higher maximum wind speeds may lead to an increase in the dispersion of particulate matter before reaching sensitive receptors however, it may also increase the degree of wind erosion occurring on exposed surfaces and increase the concentration of particulate matter blown down wind. In addition, in terms of wind speed, the Mann Whitney U test has identified year 2010 to be an ideal year followed by 2009 and 2011 in order of preference. Low rainfall is likely to increase the concentration of particulate matter in the air as water droplets (rain) would adsorb onto the surface of the particle and deposit on the ground (wet deposition).

By taking all the factors into account, i.e. background air quality data availability and representative of meteorological parameters recorded, 2010 was identified as the most suitable year for the purpose of this assessment.

Appendix B METEOROLOGICAL MODELLING

B.1 METEOROLOGICAL MODELLING

B.1.1 WRF Meteorological Model

For this study the Weather Research and Forecast model (WRF) was run with a three nest structure (40 km, 13.3 km and 4.4 km horizontal grid space resolution) centred on 23.055°S and 119.25°E (Figure B-1). Vertical resolution consisted of 28 vertical levels.

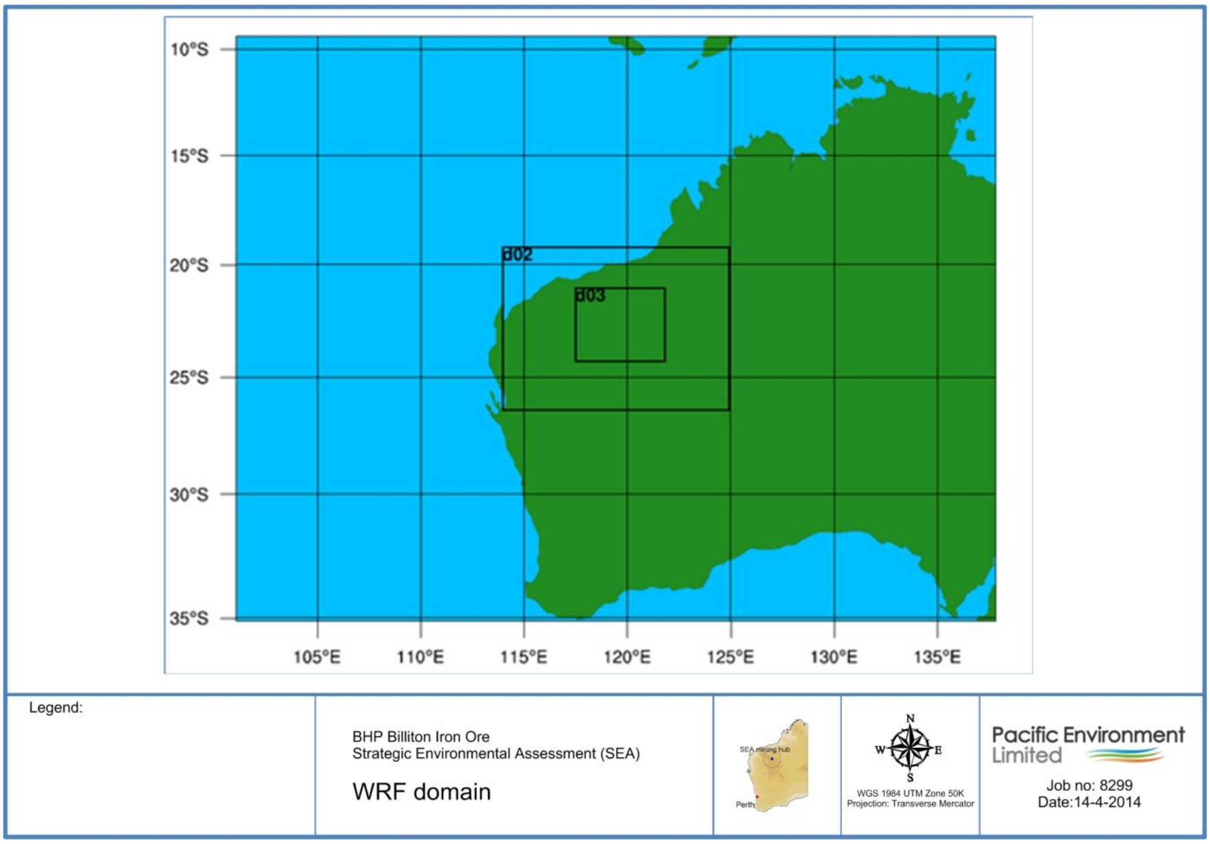

Figure B-1: WRF Domains

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 area (Figure B-2), with shrub land being the dominant vegetation type. A review of the *Landuse.tbl* revealed that they are based on North American parameterisations, with marked seasonal differences to allow for winter snow cover. These are clearly inappropriate for the Pilbara region. 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 in the Pilbara. 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 Pilbara.

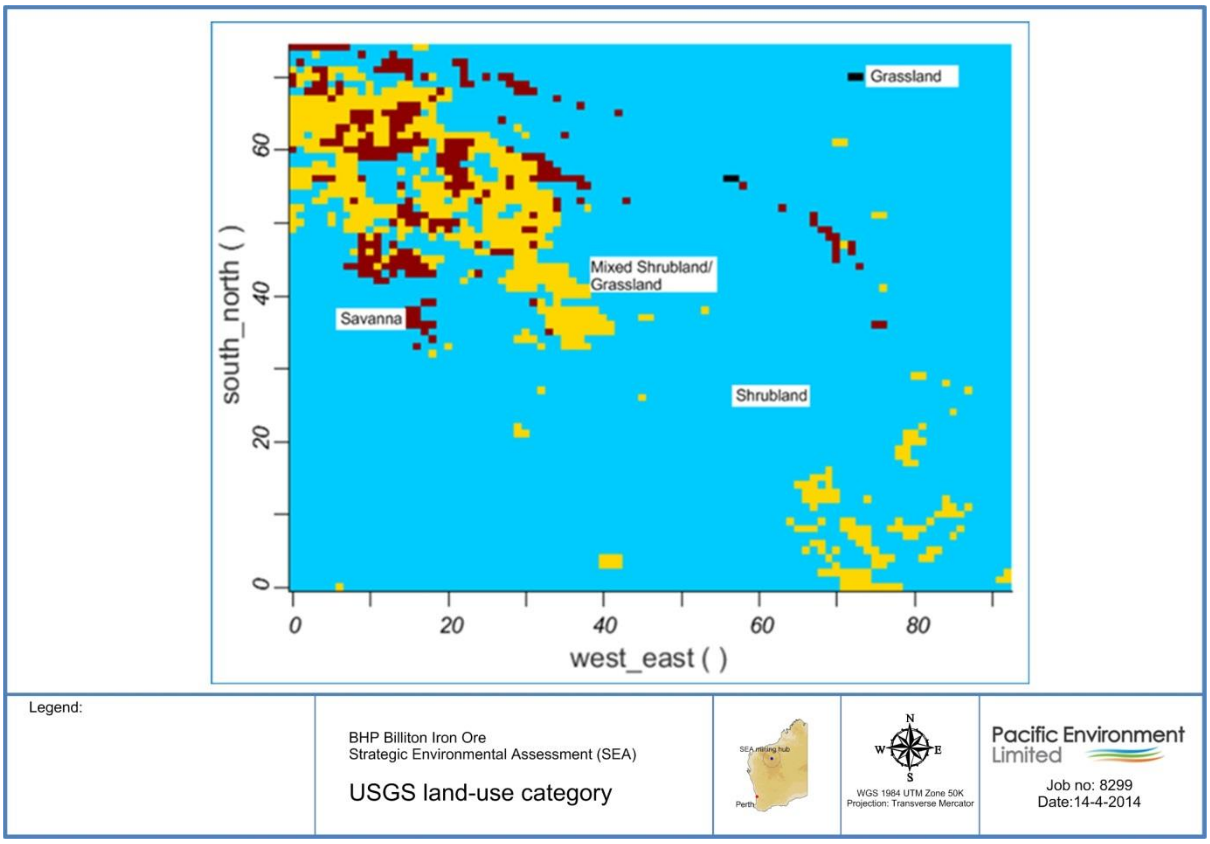

Figure B-2: Inner domain USGS land-use category

The physics options selected for the modelling are summarised in Table B-1.

Table B-1: Physics options selected for WRF

	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 (30 minute)
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	0	Kain-Fritch scheme using mass flux approach for domain 1 only.
cudt	5	5	5	Cumulus physics time step (minutes)

Six hourly global 1.0x1.0 degree grid resolution NCEP[1] FNL (Final) Operational Global Analysis data (downloaded from http://rda.ucar.edu/datasets/ds083.2/) was used to initialise the model and provide boundary conditions. The NCEP data is derived from the Global Data Assimilation System (GDAS), which continuously collects observational data from the Global Telecommunications System (GTS), and other sources. No additional observational data assimilation was undertaken.

B.1.2 CALMET Meteorology

The WRF processed meteorological data was input to CALMET for further processing to the finer resolution used in the dispersion modelling. This procedure will hereafter be referred as 'WRF-CALMET methodology'. The output from the CALMET meteorological model is input into the CALPUFF dispersion 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 temporally-varying meteorological fields that are utilised in the CALPUFF dispersion model.

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

- surface observations
    - wind speed
    - temperature
    - cloud cover amount
    - precipitation amount and type
    - base cloud height.

[1] National Centers for Environmental Prediction

- upper air observations
    - height of observation
    - wind speed and direction at each height
    - temperature at each height
    - barometric pressure at each height.
- land use data
- topographical data.

The CALMET domain covers a 37 km x 25 km area, with the origin (SW corner) at 681.8 km Easting and 7450 km Northing (UTM Zone 50S, km). This consists of 148 x 100 grid points, with a 1.3 km resolution along both the x and y axes. In the vertical, modelling consists of 12 levels extending from the surface to 3,000 m. For the purposes of modelling, a high-resolution terrain dataset was extracted from the 9-second resolution (approximately 250 m) Digital Elevation Model (DEM) from Geoscience Australia.

All surface and upper air meteorological data were generated by the WRF.

The methodology used for this project is as follows:

- The 3-dimensional hourly prognostic meteorological data produced by WRF was input to CALMET as an 'initial guess field'
- This data was then downscaled to a 1,300 m resolution to create a gridded 3-D dataset using an objective analysis procedure.
- Terrain effects (i.e. topographic blocking/deflection, acceleration and katabatic flow) were incorporated into the data to create a final hourly, three-dimensional regional meteorological field for the period January to December 2010.

B.1.2.1 Surface Air Observations

WRF provided a comprehensive data file containing surface and upper air observations at every grid point in the model domain.

B.1.2.2 Topography

Topographical data was supplied by The Shuttle Radar Topography Mission (SRTM), which obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of Earth. There are two resolution outputs available, 1 km and 90 m resolutions. SRTM data with 90 m resolution was input into the CALMET model to indicate terrain heights within the model domain, presented in Figure B-3.

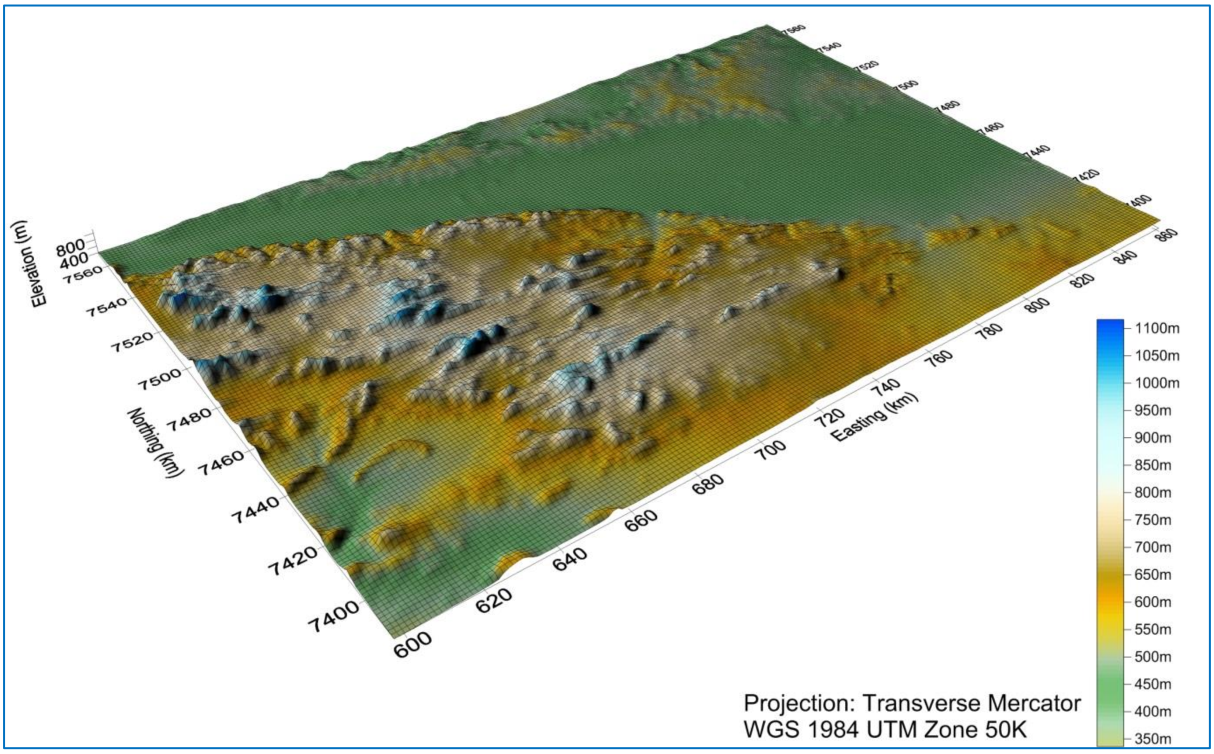

Figure B-3: 90m SRTM topography for the study area in Central Pilbara

B.1.2.3 Land Use

CALMET also requires geophysical data including gridded fields of land use categories. Gridded fields of other geophysical parameters may be input into the model if available. The optional inputs include surface roughness length, albedo, Bowen ratio, a soil heat flux parameter, anthropogenic heat flux, and vegetation leaf area index. Default values relating the optional geophysical parameters to land use categories are provided with CALMET.

The default CALMET land use scheme is based on the US Geological Survey (USGS) land use classification system (14 category system). The USGS primary land use categories defined as land use categories within the model domain are listed in Table B-2.

Table B-2: User-Defined CALMET Land Use Categories and Geophysical Parameters

CALMET Land Use Type	CALMET Description	Surface Roughness (m)	Albedo	Bowen Ratio	Soil Heat Flux Parameter	Anthropogenic Heat Flux (W/m²)	Leaf Area Index
10	Urban	0.8[1]	0.15[1]	1.5	0.25	0	0.2
30	Rangeland	0.04[2]	0.2[2]	1.0	0.15	0	0.5
60	Wetland	0.3[1]	0.12[3]	0.5	0.25	0	2.0
70	Barren Land	0.01[1]	0.25[1]	1.0	0.15	0	0.05

To account for the diverse land use that appears in the model domain, the broad categories described in Table B-2 were used to several similar land use types. The Rangeland category was used to describe the majority of the landscape, which is defined by spinifex grasses and occasional acacia trees. The deposits with minimal vegetation cover were described by the barren land category.

B.1.3 Meteorology Validation

The CALMET model output was compared against measured temperature, wind speed and direction from the Bureau of Meteorology Newman Airport weather station (inland site).

B.1.3.1 Surface Station

The hourly measured and corresponding modelled wind speed, wind direction and temperature for the period 1 January 2010 – 31 December 2010 are presented in Figure B-4 to Figure B-8.

Figure B-4 shows a comparison between hourly averages measured and modelled wind speed. Overall, the model predicts wind speed well, notwithstanding a few outlier predictions. The wind speed frequency plot (Figure B-5) shows a skewed distribution of measured wind speeds, with peak frequencies occurring at 3 m/s. By contrast, modelled wind speeds display a normal distribution with peak frequencies occurring between 4 and 5 m/s. Overall, the measured and modelled wind speed frequencies approximate each other.

The radar plot of measured and modelled wind direction is shown in Figure B-6. Through visual inspection, it appears that the model forecasts the general pattern of winds (SE-E dominant) satisfactorily. It is important to note that the 'spiky' nature of measured wind directions suggest that wind direction intervals are recorded in relatively large increments of 10°.

Time series and frequency plot of measured and corresponding modelled temperature are shown in Figure B-7 and Figure B-8 respectively. Although the model slightly over predicts the lower higher temperatures and slightly under predicts the higher temperatures on occasions, it generally performs well for this parameter.

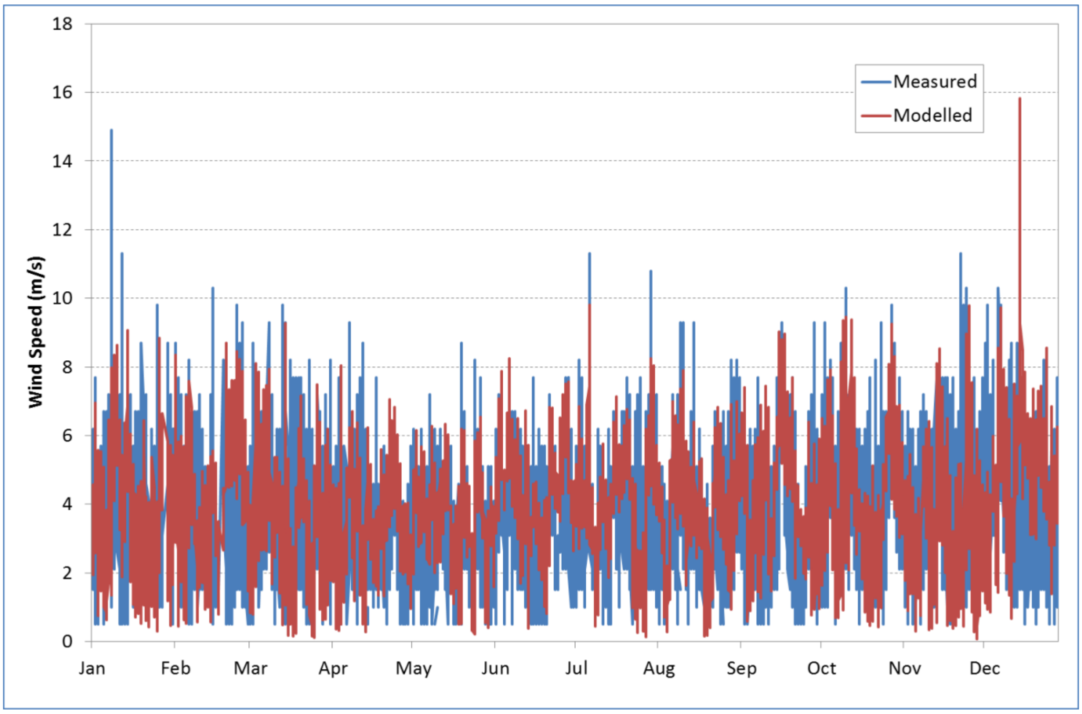

Figure B-4: CALMET Time series of hourly modelled versus measured wind speed at Newman Airport

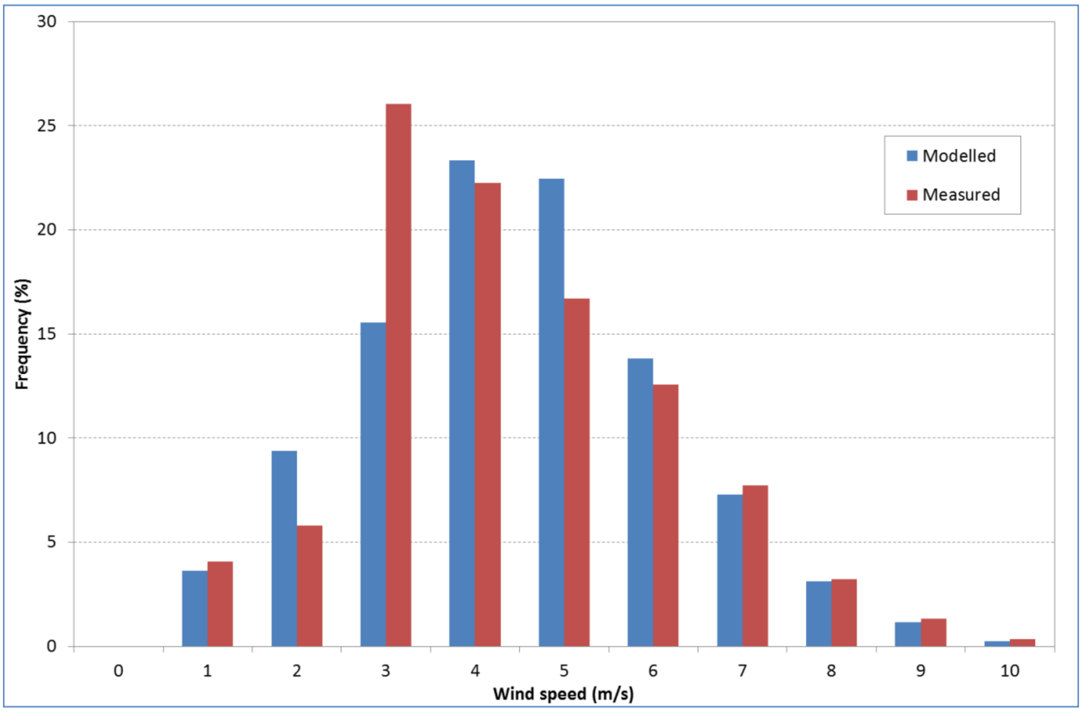

Figure B-5: Frequency plot of hourly modelled (CALMET) versus measured wind speed at Newman Airport

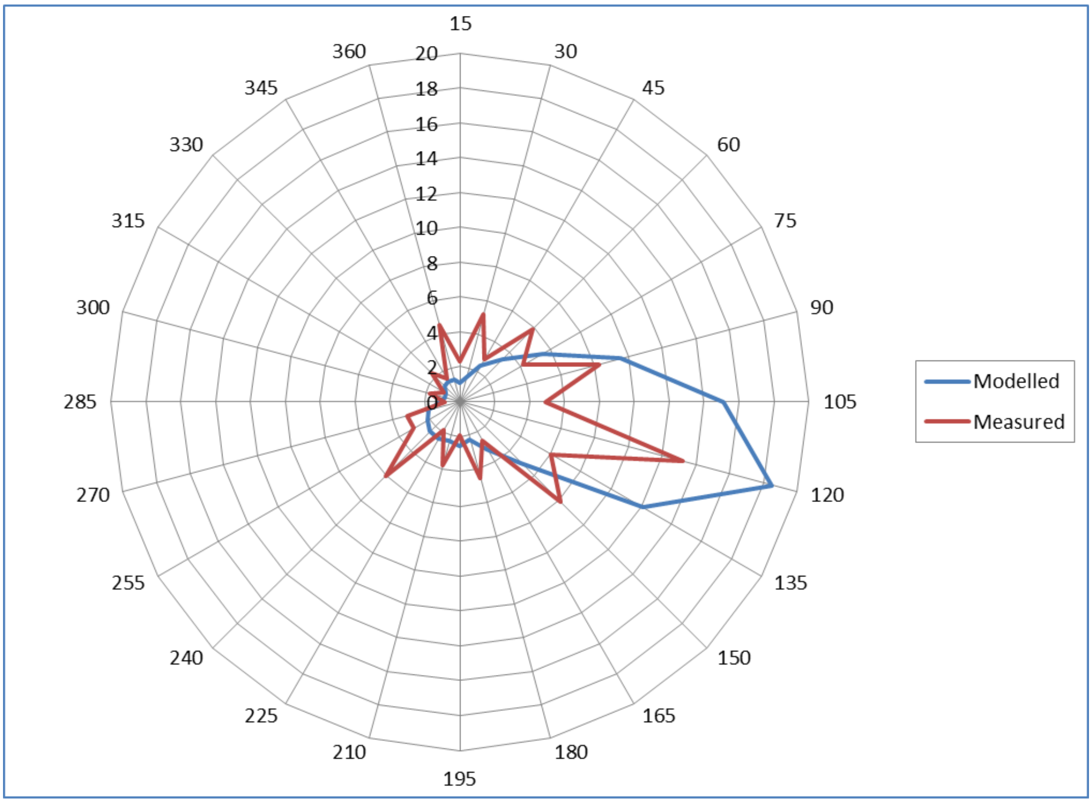

Figure B-6: Radar plot of modelled in CALMET (red) versus measured (blue) wind direction at Newman Airport

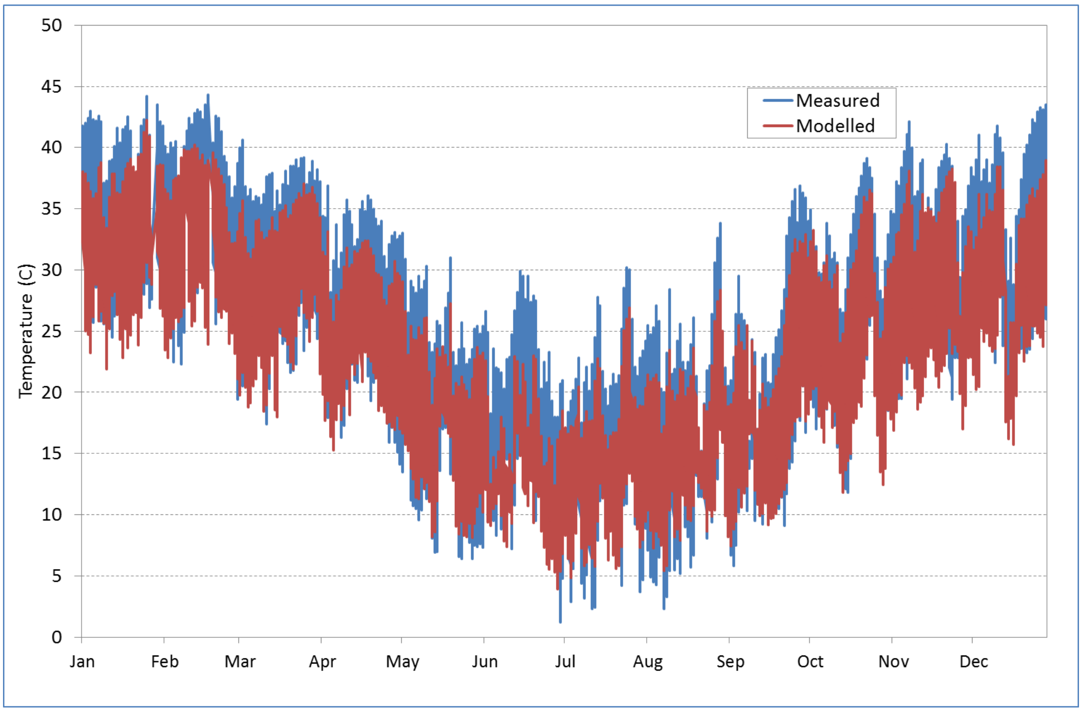

Figure B-7: Time series of hourly modelled (CALMET) versus measured temperature at Newman Airport

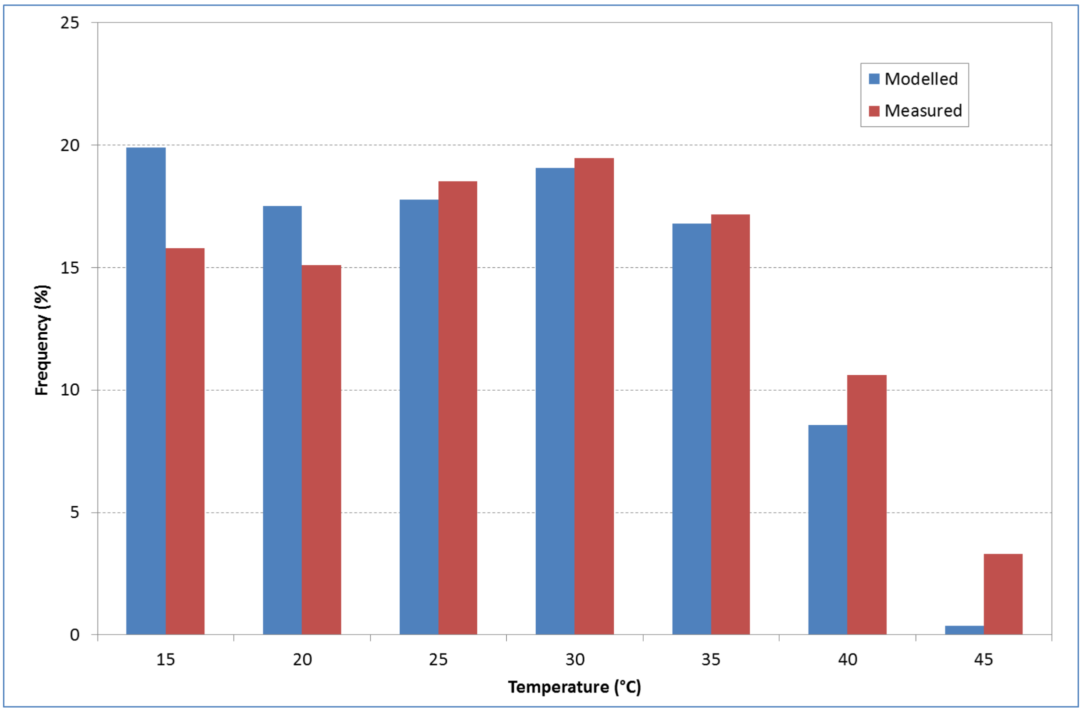

Figure B-8: Frequency plot of hourly modelled (CALMET) versus measured temperature at Newman Airport

B.1.4 Statistical Measures of Model Performance

An objective method to evaluate model performance is through the use of statistical tests that have been developed for this purpose. These tests are, *inter alia*, *geometric mean, geometric variance*, *model bias, fraction bias, gross error, root mean square error, Skill_v, Skill_r, index of agreement* and the *coefficient of correlation*. Detailed explanation of these statistical measures is provided in Appendix C.

The results of the statistical model verification are shown in Table B-3 for Newman Airport. Temperature, wind speed and wind direction meet most of the validation benchmarks or statistical criteria (Table B-3). For temperature and wind direction, the gross error values fall just outside the validation benchmark listed in Appendix C: *Mesoscale model benchmarks* (after Emery et al, 2001); Teschenke et al, (2001)). However, these values may be impacted by potential wind direction measurement issues (as stated previously).

Overall, it can be statistically concluded that the WRF-CALMET simulates surface meteorology with an acceptable degree of skill at Newman Airport.

Table B-3: Results of statistical test: Newman Airport*

	MG	GV	MB	FB	Skill_v	Skill_r	GE	r	RMSE	IOA
Ideal Score	0.7-1.3	<1.6	See Table B-1 Mesoscale model benchmarks (after Emery et al, 2001; Teschke et al, 2001)	±0.67	1.0	<1	See Table B-1 Mesoscale model benchmarks (after Emery et al, 2001; Teschke et al, 2001)	1	See Table B-1 Mesoscale model benchmarks (after Emery et al, 2001; Teschke et al, 2001)	1 and see Table B-1 Mesoscale model benchmarks (after Emery et al, 2001; Teschke et al, 2001)
Temp.	1.06	1.00	1.78	0.06	0.94	0.21	2.69	0.95	3.26	0.96
Wind Speed.	0.95	1.00	-0.27	-0.06	0.98	0.20		0.42	1.88	0.90
Wind Dir.	-	-	5.07	-	-	-	38.69	-	-	-

*Note: Shading indicates value within benchmark/criteria

Appendix C METEOROLOGY VALIDATION

C.1 STATISTICAL MEASURE OF MODEL PERFORMANCE

Statistical measure used to evaluate model performances are explained below.

C.1.1 Geometric Mean (MG)

The geometric mean is a type of mean or average, which indicates the central tendency or typical value of a set of numbers. The MG test is given by:

$$MG = exp\left[\overline{ln\left(\frac{O}{P}\right)}\right]$$

Where:

O = the average observed (measured) value

P = the average predicted (modelled) value

A model is considered to be acceptable if the geometric mean is between 0.7 and 1.3 (Chang and Hanna, 2004).

C.1.2 Geometric Variance (GV)

The geometric variance test is given by:

$$GV = exp\left[\overline{ln\left(\frac{O}{P}\right)^2}\right]$$

Where:

O = the average observed (measured) value

P = the average predicted (modelled) value

A model is considered to be acceptable if the geometric variance is less than 1.6 (Chang and Hanna, 2004).

C.1.3 Skill_r

The *Skill_r* test is the ratio of *RMSE* to observed standard deviation:

$$Skill\_r = \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}(P_i - O_i)^2}}{O_{std}}$$

Where:

N = the number of pairs of data

O_i = the observed (measured) value for the i-th hour

P_i = the predicted (modelled) value for the i-th hour

O_{std} = the standard deviation of measured data.

A model is considered to be predicting with skill if the RMSE is less than the standard deviation of the observations (Skill_r <1) (Pielke, 1984; Hurley, 2000).

C.1.4 Skill_v

$$Skill\_v = \frac{P_{std}}{O_{std}}$$

Where:

P_{std} = the standard deviation of predicted data

O_{std} = the standard deviation of observed data.

A model is considered to be predicting with skill if the standard deviations of the predictions and observations are the same (Skill_v = 1) (Pielke, 1984; Hurley, 2000).

C.1.5 Model Bias (MB)

The model bias (MB) is the mean error and is given by:

$$MB = \frac{1}{n}\sum_{i=1}^{n}(O_i - P_i)$$

Where:

n = the number of pairs of observed data

O_i = the observed value for the i-th hour

P_i = the predicted value for the i-th hour

The ideal value for the bias is zero.

C.1.6 Fraction Bias (FB)

The fraction bias (FB) is a normalised index of model performance and is expressed by:

$$FB = 2\frac{\overline{O} - \overline{P}}{\overline{O} + \overline{P}}$$

Where:

$\overline{O}$ = the average observed values

$\overline{P}$ = the average predicted values

The FB varies between +2 and –2 and has an ideal value of zero. FB values of ±0.67 correspond to a prediction within a factor of 2.

C.1.7 Gross Error (GE)

The Gross Error is given by:

$$GE = \frac{1}{N}\sum_{i-1}^{N}\left|\left(P_i - O_i\right)\right|$$

Where:

N = the number of pairs of data

O_i = the observed (measured) value for the i-th hour

P_i = the predicted (modelled) value for the i-th hour

The bias and gross error for winds are calculated from the predicted-observed residuals in speed and direction (not from vector components u and v). The direction error for a given prediction-observation pairing is limited to range from 0 to ±180° (Emery et. al (2001).

C.1.8 Root Mean Square Error (RMSE)

The Root mean Square Error is given by:

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

Where:

N = the number of pairs of data

O_i = the observed (measured) value for the i-th hour

P_i = the predicted (modelled) value for the i-th hour

While the ideal RMSE value is 0, large errors in a small section of the data may produce a large RMSE even though errors may be small elsewhere.

C.1.9 Index of Agreement (IOA)

The index of agreement (IOA) is the measure of how well the model estimates departure from the observed mean matches cases by case, the observations departure from the observed mean:

$$IOA = 1 - \left[\frac{N\left(RMSE\right)^2}{\sum_{i=1}^{n}\left\{\left|\left(P_i - \bar{O}\right)\right| + \left|\left(O_i - \bar{O}\right)\right|\right\}^2}\right]$$

Where:

n = the number of pairs of observed data

O_i = the observed value for the i-th hour

$\bar{O}_i$ = the mean observed value

The ideal value for IOA is one.

C.1.10 Model Benchmarks

A set of benchmarks were set for mesoscale model evaluation by Emery et. al (2001) and Teschke et. al (2001). These are listed in the table below:

Table C-1: Mesoscale model benchmarks (after Emery et al, 2001; Teschke et al, 2001)

Parameter	Test	Benchmark
Wind Speed	RMSE	≤2 m/s
	BIAS	≤± 0.5 m/s
	IOA	≥0.6
Temp	GE	≤2 K
	BIAS	≤± 0.5 K
	IOA	≥0.8
Wind Direction	GE	≤30 °
	BIAS	≤10 °

C.1.11 Normalised Mean Square Error (NMSE)

The Normalised Mean Square Error is given by:

$$NMSE = \frac{\overline{(O_i - P_i)^2}}{\overline{O_i}\,\overline{P_i}}$$

Where:

O_i = the observed (measured) value for the i-th hour

P_i = the predicted (modelled) value for the i-th hour

$\bar{O}$ = average over dataset

C.1.12 Fraction of predictions within a factor of two of observations (FAC2)

The Fraction of data is given by:

$$FAC2 = fraction\ of\ data\ that\ satisfy\ 0.5 \leq \frac{P_i}{O_i} \leq 2.0$$

Where:

O_i = the observed (measured) value for the i-th hour

P_i = the predicted (modelled) value for the i-th hour

The ideal FAC2 value is 1.

Appendix D ESTIMATION OF EMISSIONS

D.1 BHP BILLITON OPERATIONS

This section describes emission estimation methodology in previous projects conducted by PEL in the Central Pilbara region for BHP Billiton Iron Ore. The methodology is considered to be acceptable and would provide a representative estimated emission generated from various mining activities in the Central Pilbara region.

D.1.1 Methodology for Estimating Emission Rates

D.1.1.1 Emission Estimation

Numerous studies undertaken at BHP Billiton Iron Ore operations determined a strong relationship between product type, ore moisture, tonnage of material being handled and wind speed. As a result, two empirical equations were derived to determine the particulate emissions that could be expected to occur for a given situation (e.g. Stacking or reclaiming of various material types during different conditions).

Equation 1 determines the particulate emissions of a specific material handling operation (transferring, stacking, reclaiming or ship loading) for a given ore type and moisture content.

Equation 1

$$\mathrm{PM}_{10_i} = \frac{0.001 \times (DI + 30)}{F}$$

Where:

PM_{10_i}	=	Particulate emissions of material handling operation i	(kg/tonne)
DI	=	Dustiness Index determined from the rotating drum tests using the dust testing set up	(-)
F	=	Factor constant	(-)

The value of 30 in Equation 1 was added such that some dust would be generated even at high moistures where the rotating drum tests indicate no dust (SKM, 2002).

The calculated particulate matter value is then converted into an emission rate by incorporating the loading tonnage and the wind speed as presented in Equation 2.

Equation 2

$$\mathrm{EPM}_{10_i} = \mathrm{PM}_{10_i} \times \frac{t}{3.6} \times \left(\frac{WS}{2.2}\right)^{1.3}$$

Where:

EPM_{10_i}	=	Particulate emission rate of material handling operation i	(g/s)
PM_{10_i}	=	Particulate emissions of material handling operation i	(kg/tonne)
t	=	Loading tonnage	(t/h)
WS	=	Wind speed	(m/s)

D.1.1.2 Rotating Tumble Drum Tests

To determine the dustiness index of the ores processed at Port Hedland a series of rotating tumble drum tests were conducted based on Australian Standard AS4156.6-2000. The tumble drum method was developed to determine the dust/moisture relationship for coals and has been applied to iron ores, bauxite's and other materials. It indicates the likely response of different materials to drying or water addition during mining and handling processes. Ore samples are tumbled for a given duration at carefully controlled moisture contents, and the dust (~150 micron) is collected into a vacuum bag. The resulting dust is weighed and a measure of the dustiness calculated. A graph of the dust/moisture relationship is obtained, and the dust extinction moisture (DEM) is obtained from the graph. Figure D-1 shows the rotating tumble drum tests for a sample of MAC fines analysed during the dust management, measurement, abatement and characterisation study conducted in 2001 (SKM, 2002). A dust index of 10 corresponds to a dust yield of 0.01% at which the dust is effectively suppressed with these results showing that MAC fines have a DEM of approximately 7%.

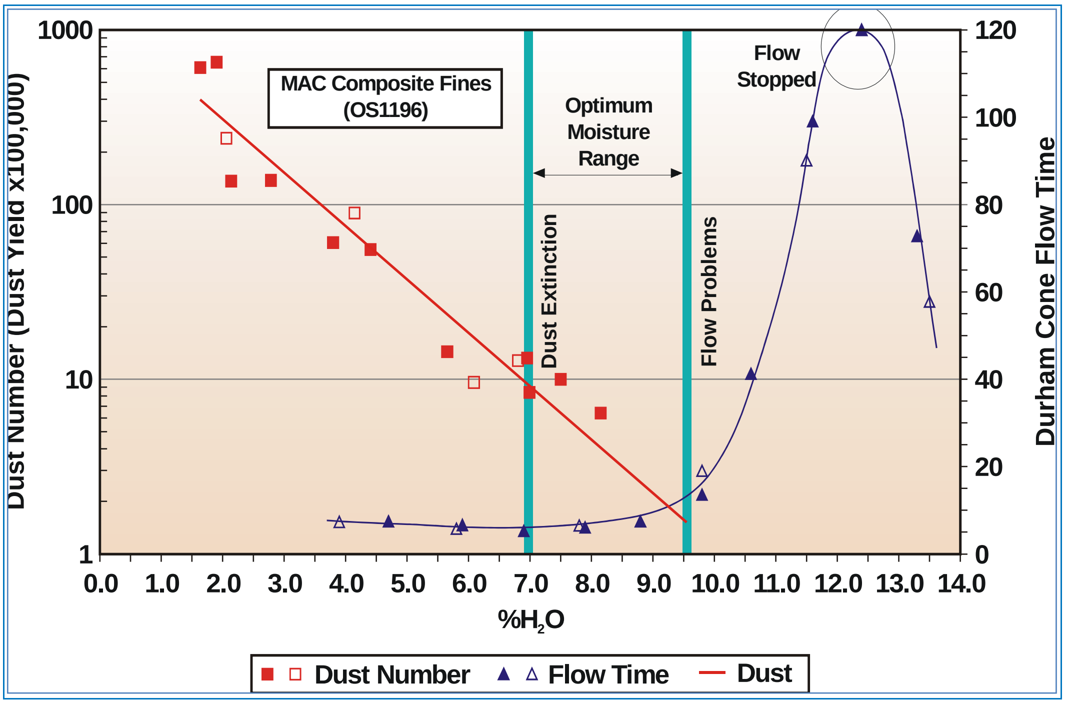

Figure D-1: Results of MAC Fines Rotating Drum and Durham Cone Test

Increasing the moisture of the ore will also have an effect on the ore handling characteristics. As can be observed in Figure D-1, the Durham cone tests on MAC fines (blue line) show that material flow problems are experienced at moisture levels higher than approximately 10%. A target optimum moisture range that suppresses dust and avoids flow problems is indicated when these dust and flow test curves are combined (Figure D-1) and for MAC fines an optimum moisture range of 7.0% to 9.5% was found.

Results from the rotating drum tests conducted on a representative section of material processed at Nelson Point is presented in Figure D-2. This data was used to determine the dustiness index of each ore over a range of ore moistures in Mining Area C. This dustiness index could then be incorporated into Equation 18. The USEPA dustiness equation has been included into this graph to highlight its inability to account for emissions from different ore types. The USEPA equation also relies on the silt loading of a material to determine its potential dustiness.

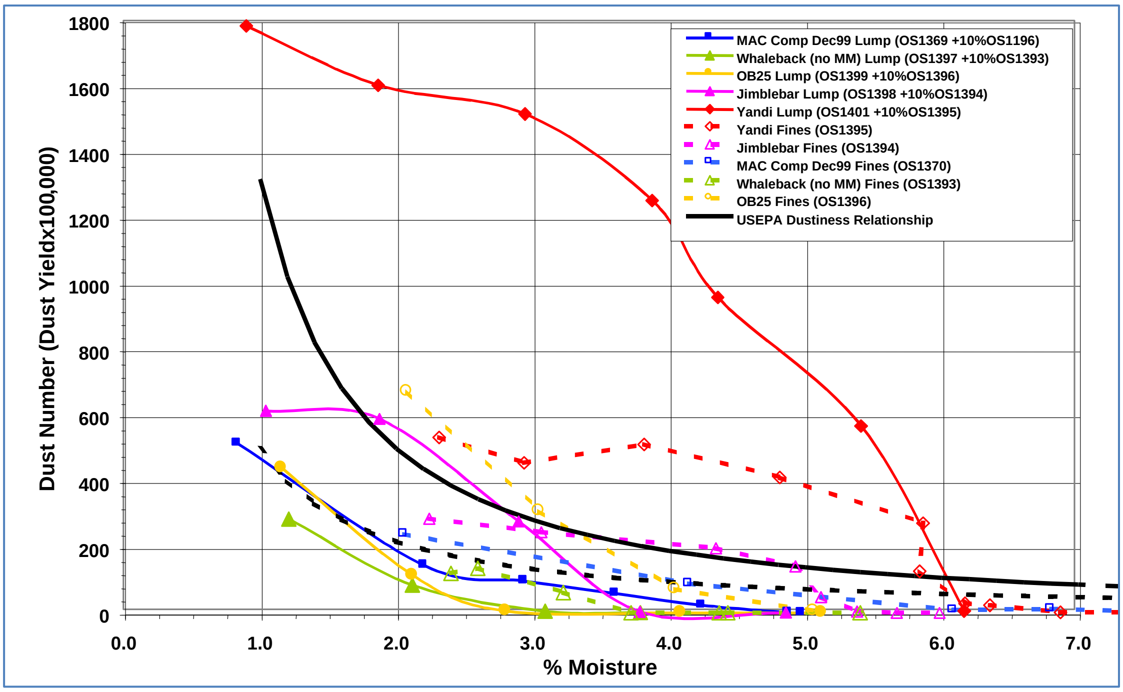

Figure D-2: Rotating Drum Testing for Nelson Point Products

D.1.1.3 Factor Constant

The factor constants used in Equation 1 are presented in Table D-1. These constants were derived by inserting emission measurements taken from various material handling processes at Nelson Point, from a variety of ore types, into Equation 2 and then rearranging to achieve Equation 3.

Equation 3

$$PM_{10_i} = EPM_{10_i} \times \frac{3.6}{\left(t \times \left(\frac{WS}{2.2}\right)^{1.3}\right)}$$

Where:

PM_{10_i}	=	Particulate emissions of material handling operation i	(kg/tonne)
EPM_{10_i}	=	Particulate emission rate of material handling operation i	(g/s)
t	=	Loading tonnage	(t/h)
WS	=	Wind speed	(m/s)

Equation 1 was then rearranged to get Equation 4 which is presented below.

Equation 4

$$F = \frac{0.001 \times (DI + 30)}{\mathrm{PM}_{10_i}}$$

Where:

PM_{10i}	=	Particulate emissions of material handling operation i	(kg/tonne)
DI	=	Dustiness Index determined from the rotating drum tests using the dust testing set up	(-)
F	=	Factor constant	(-)

Table D-1: Factor Constants for material handling process

Material Handling Process	Factor
Transfer Stations	450
Stacking	200
Reclaiming	450

Note: a. Derived from Equation 4

D.1.1.4 Transfer Stations, Reclaiming and Stacking

Emissions associated with Transfer Station, Reclaiming and Stacking were estimated using BHP Billiton Iron Ore site specific methodology. Equation 3 and Equation 4 were used to estimate the PM_{10} rate (g/s) which was the used when setting up an hourly varying CALPUFF emission source file.

D.1.1.5 Screening

Emissions associated with Screening were also estimated using BHP Billiton Iron Ore site specific methodology. The emission rates used to estimate emissions of PM_{10} from screening are listed in Table D-2. The statistic of data inputs associated with the moisture content for screening are listed in Table D-3.

Table D-2: Emission Factors for Screening

Moisture (%)	Emission Rate (g/s)
1.25	7
1.75	7
2.25	7
2.75	7
3.25	7
3.75	6.5
4.25	4
4.75	1.5
5.25	1.5
5.75	1.5
6.25	1.5
6.75	1.5
7.25	1.5
7.75	1.5
8.25	1.5
8.75	1.5

Source: PAEHolmes (2012)

Table D-3: Statistics of MAC Lump moisture content

Statistics	MAC Lump Moisture (%)
Max	5.04
Min	2.48
99th Percentile	4.57
90th Percentile	4.20
70th Percentile	3.94
Average	3.76

Source: PAEHolmes (2012)

D.1.1.6 Potential Sources of Error in Emission Estimation Methodology

While every effort is made to ensure dust sampling and emission calculations are as accurate as possible, there are sources of potential error associated with this methodology. These errors may be associated with either the physical sampling of the dust, or those associated with emission estimation calculations.

Errors associated with physical sampling of dust may include the following:

- The plume sampled may be affected by another dust sources i.e., show an elevated reading dust to another dust source;
- Wind speed is taken as an average value, which may not reflect peaks in dust concentrations associated with wind gusts;
- Calibration of DustTrak to specific ore types; and
- Distances of traverse to source were sometimes difficult to measure due to various obstacles between the source and traverse.

Errors may also be associated with source emission calculations. The main error is associated with an "idealised" method of calculating an emission rate where by an empirical equation has been used to provide an hourly average emission rate, however, in reality emissions would vary on a smaller time scale due to wind gusts, ore moisture and ore throughput.

D.2 NPI EMISSION ESTIMATION TECHNIQUES

This section describes emission estimation methodology by using NPI emission estimation techniques in the absence of site specific emission rate.

D.2.1 Bulldozing

Bulldozing emission estimation technique was sourced from the *NPI EET Manual for Mining v3.1* (Environment Australia, 2012a). The equations used to calculate the emission factor for PM_{10} and TSP are given below (Equation 5 and Equation 6). The silt and moisture contents used are provided in Table D-4 and the resulting emission factors are provided in Table D-5.

Equation 5

$$EF_{PM_{10}} = \frac{0.34 \times s^{1.5}}{M^{1.4}}$$

Equation 6

$$EF_{PM_{10}} = \frac{2.6 \times s^{1.2}}{M^{1.3}}$$

where:

$EF_{PM_{10}}$	=	Emission factor for PM_{10} due to bulldozer operations	(kg/h)
EF_{TSP}	=	Emission factor for TSP due to bulldozer operations	(kg/h)
s	=	Silt content of material bulldozed	(%)
M	=	Moisture content of material bulldozed	(%)

Table D-4: Emission Factor Equation Inputs for Bulldozing

Material	Variable	Value (%)
Ore and Waste	Silt Content[a]	10
	Moisture Content[b]	4.75

[a]Source: Environment Australia (2012a), page 55

[b]Derived from the target range (3.5%-6%) from ROM Feed (data from BHP Billiton Iron Ore)

Table D-5: Emission Factors for Bulldozing

Material	Emission Factor	Value (kg/h)
Ore and Waste	EF_{PM10}	1.21
	EF_{TSP}	5.43

Source: Environment Australia (2012a), P15

Total emissions associated with bulldozing for PM_{10} and TSP were estimated using the equation below.

Equation 7

$$E_i = OH_{total} \times EF_i \times \left(\frac{100 - CE_i}{100}\right)$$

where:

E_i	=	Emission rate for pollutant i	(kg/a)
OH_{total}	=	Total operating hours of bulldozers	(hrs/a)
EF_i	=	Uncontrolled emission factor for pollutant i	(kg/h)
CE_i	=	Overall control efficiency for pollutant i	(%)

D.2.2 Loading

Loading emission estimation technique was sourced from the *NPI EET Manual for Mining v3.1* (Environment Australia, 2012a). The default emission factor used to estimate PM_{10} and TSP emissions from drilling are provided in Table D-6.

Table D-6: Emission Factors for Loading

Material	Emission Factor	Value (kg/t)
Ore and Waste	EF_{PM10}	0.012
	EF_{TSP}	0.025

Total emissions associated with loading for PM_{10} and TSP were estimated using the equation below.

Equation 8

$$E_i = M \times EF_i \times \left(\frac{100 - CE_i}{100}\right)$$

where:

E_i	=	Emission rate for pollutant i	(kg/a)
M	=	Total amount of material loaded	(tonnes/a)
EF_i	=	Uncontrolled emission factor for pollutant i	(kg/tonne)
CE_i	=	Overall control efficiency for pollutant i	(%)

D.2.3 Unloading

Unloading emission estimation technique was sourced from the *NPI EET Manual for Mining v3.1* (Environment Australia, 2012a). The default emission factor used to estimate PM_{10} emissions from unloading are provided in Table D-7.

Table D-7: Emission Factors for Unloading

Material	Emission Factor	Value (kg/t)
Ore and Waste	EF_{PM10}	0.0043
	EF_{TSP}	0.012

Total emissions associated with unloading for PM_{10} were estimated using the equation below.

Equation 9

$$E_i = M \times EF_i \times \left(\frac{100 - CE_i}{100}\right)$$

where:

E_i	=	Emission rate for pollutant i	(kg/a)
M	=	Total amount of material unloaded	(tonnes/a)
EF_i	=	Uncontrolled emission factor for pollutant i	(kg/tonne)
CE_i	=	Overall control efficiency for pollutant i	(%)

D.2.4 Wheel Generated Dust (Unpaved Roads)

Wheel generated dust (unpaved roads) emission estimation techniques were sourced from the *NPI EET Manual for Mining v3.1* (Environment Australia, 2012a). The equations used to calculate the emission factor for PM_{10} and TSP are given below. Emission factor equation inputs and typical truck specifications used in BHP Billiton Iron Ore mine are provided in Table D-8 and the resulting emission factors are listed in Table D-9.

For heavy vehicle at industrial site:

Equation 10

$$EF_{PM_{10}} = \frac{0.4536}{1.6093} \times 1.5 \times \left(\frac{s_i}{12}\right)^{0.9} \times \left(\frac{W_i \times 1.1023}{3}\right)^{0.45}$$

Equation 11

$$EF_{TSP} = \frac{0.4536}{1.6093} \times 4.9 \times \left(\frac{s_i}{12}\right)^{0.7} \times \left(\frac{W_i \times 1.1023}{3}\right)^{0.45}$$

For light duty vehicles:

Equation 12

$$EF_{PM_{10}} = 0.51 \times \frac{\left(\frac{s_i}{12}\right)^{0.7} \times \left(\frac{S}{48}\right)^{0.5}}{\left(\frac{M_i}{0.5}\right)^{0.2}} - 0.0013$$

Equation 13

$$EF_{TSP} = 1.69 \times \frac{\left(\frac{s_i}{12}\right)^{0.7} \times \left(\frac{S}{48}\right)^{0.5}}{\left(\frac{M_i}{0.5}\right)^{0.2}} - 0.0013$$

where:

$EF_{PM_{10}}$	=	Emissions factor for PM_{10} due to travel on unpaved roads	(kg/km)
EF_{TSP}	=	Emissions factor for TSP due to travel on unpaved roads	(kg/km)
s_i	=	Silt content of material i upon which operation is occurring	(%)
M_i	=	Moisture content of material i upon which operation is occurring	(%)
W_i	=	Vehicle gross mass operating on material i	(tonnes)
S	=	Mean vehicle speed	(km/h)

Table D-8: Emission Factor Equation Inputs for Wheel Generated Dust (Unpaved Roads)

Material	Data Input	Value	Units
Ore and Waste	Silt Content[a]	10	%
	Moisture Content[b]	4.75	%
	Truck Cat 793D Capacity	218	tonnes
	Truck Cat 793D Chasis weight (empty)	117	tonnes
	Truck Cat 793D Loaded weight	335	tonnes

[a]Source: Environment Australia (2012a), page 55

[b]Derived from the target range (3.5%-6%) from ROM Feed (data from BHP Billiton Iron Ore)

Table D-9: Emission Factors for Wheel Generated Dust (Unpaved Roads)

Vehicle Type	Emission Factor	Value (kg/km)
Truck	EF_{PM10_Loaded}	3.13
	EF_{PM10_Empty}	1.95
	EF_{TSP_Loaded}	10.6
	EF_{TSP_Empty}	6.6

[a]Source: Environment Australia (2012a), page 56

Total emissions of PM_{10} and TSP associated with wheel generated dust (unpaved roads) were estimated using the equation below. Equations to calculate the total distance travelled and the number of trips for transferring ore and waste rock on unpaved roads are also listed below.

Emissions have been calculated for unpaved roads for different type of vehicles.

Equation 14

$$E_i = EF_i \times TD \times \left(\frac{100 - CE_i}{100}\right)$$

where:

E_i	=	Emission rate for pollutant i	(kg/a)
EF_i	=	Uncontrolled emission factor of pollutant i	(kg/km)
TD	=	Total distance travelled on unpaved roads by the vehicle	(km/a)
CE_i	=	Overall control efficiency for pollutant i	(%)

Equation 15

$$TD = L \times N_T$$

where:

TD	=	Total distance travelled on unpaved roads by the truck	(km/a)
L	=	Haul road length (return trip)	(km)
N_T	=	Number of trips for each truck	(-)

Equation 16

$$N_T = \frac{M}{C_T}$$

where:

N_T	=	Number of trips	(-)
M	=	Total amount of material loaded onto each truck	(tonnes/a)
C_T	=	Truck capacity	(tonnes)

Equation 17

$$M = \frac{M_T}{P}$$

where:

M	=	Total amount of material loaded onto each truck	(tonnes/a)
M_T	=	Total amount of material to be moved	(tonnes/a)
P	=	Proportion of material assigned to each truck	(tonnes)

D.2.5 Wind Erosion

Site specific wind erosion emission factors were calculated in order to estimate wind erosion emissions. The data inputs associated with wind erosion, i.e. area of stockpiles and active open areas, differ from site to site.

The site specific wind erosion emissions factor for PM_{10} was calculated using Equation 18. The wind speed threshold (WS_0) and k constant used were 5.23 m/s (SKM 2005) and 1.44×10^{-06} (SKM 2005) respectively. The constant k and wind speed threshold value is consistent with other dust studies. From Equation 18, the average PM_{10} emission rate was estimated to be 0.29kg/ha/h, which is greater than the default emission factor of 0.2kg/ha/t provided in *NPI EET Manual for Mining v3.1* (Environment Australia, 2012a). A scaling factor of 2.86 was applied to calculate the wind erosion emission rate for TSP.

All stockpiles and active open areas were assumed to be susceptible to wind erosion in this assessment. Equation 19 was used to estimate the PM_{10} rate (g/s) which was used when setting up an hourly varying CALPUFF emission file.

Equation 18

$$EF_{PM10} = k\left[WS^3 \times \left(1 - \frac{{WS_0}^2}{WS^2}\right)\right] \qquad where\ \ WS > WS_0$$

$$EF_{PM10} = 0 \qquad where\ \ WS < WS_0$$

Where:
EF_{PM10} = Emission factor for PM_{10} (g/m²/s)
WS = Wind speed (m/s)
WS_0 = Threshold for dust lift off (m/s)
k = A constant

Equation 19

$$E_{PM10(g/s)} = EF_{PM10} \times A \times \left(\frac{100 - CE_{PM10}}{100}\right)$$

$$E_{TSP(g/s)} = 2.86 \times E_{PM10(g/s)}$$

Where:
$E_{PM10\ (g/s)}$ = Emission rate for PM_{10} (g/s)

EF_{PM10} = Emission factor for PM_{10} (g/s/m²)
A = Total exposed (m²)
CE = Overall control efficiency of PM_{10} (%)

D.2.6 Blasting

Blasting emission estimation technique was sourced from the *NPI EET Manual for Mining v3.1* (Environment Australia, 2012a). The equation used to calculate the emission factors for PM_{10} and TSP are given below. Emission factor equation inputs and typical data for BHP Billiton Iron Ore mine are provided in Table D-10 and the resulting emission factors are listed in Table D-11.

Equation 20

$$EF_{PM_{10}} = 0.000114 \times A_i^{1.5}$$

Equation 21

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

where:

$EF_{PM_{10}}$	=	Emissions factor for PM_{10} due to blasting	(kg/blast)
EF_{TSP}	=	Emissions factor for TSP due to blasting	(kg/blast)
A_i	=	The area blasted of material i	(m^2)

Table D-10: Emission Factor Equation Inputs for Blasting

Material	Data Input		Units
Ore and Waste	Area per blast[a]	15,000	m^2
	Blasting frequency - every[a]	2	day
	Number of days per year	365	day
	Width of blasting area[b]	122	m
	Length of blasting area[b]	122	m
	Spacing of blasting area width[a]	6	m
	Spacing of blasting area length[a]	6	m
	Number of holes per blast[c]	458	holes
	Total number of holes	83,675	holes

[a] Assumed by PEL

[b] Calculated from taking square root of blasting area

[c] Calculated from: [(Width of blasting area/Spacing of blasting area width) + 1]x[(Length of blasting area/Spacing of blasting area length) + 1]

Table D-11: Emission Factors for Blasting

Material	Emission Factor	(kg/blast)	(g/s)
Ore and Waste	EF_{PM10}	209.43[a]	58.18[b]
	EF_{PM10}	404.17	112.27

[a] Source: Environment Australia (2012), p15

[b] For an hour every two days. Generally mid-days but could be late afternoon on occasions.

Total emissions of PM_{10} and TSP associated with blasting were estimated using the equation below. It is noted that no control measures were available for blasting.

Equation 22

$$E_i = EF_i \times NB_m \times \left(\frac{100 - CE_i}{100}\right)$$

where:

E_i	=	Emission rate for pollutant i	(kg/a)
EF_i	=	Uncontrolled emission factor for pollutant i	(kg/blast)
NB_i	=	Number of blasts per year on material i	(blasts/a)
CE_i	=	Overall control efficiency for pollutant i	(%)

D.2.7 Drilling

Drilling emission estimation techniques were sourced from the *NPI EET Manual for Mining v3.1* (Environment Australia, 2012a). The default emission factor used to estimate emissions from drilling is provided in Table D-12. Total emissions of PM_{10} and TSP associated with drilling were estimated using the equations below. No other control measures were available for drilling for PM_{10} and TSP emissions.

Table D-12: Default Emission Factor for Drilling

Material	Emission Factor	Value (kg/hole)
Ore and Waste	EF_{PM10}	0.31
	EF_{TSP}	0.59

Source: Environment Australia (2012a), p15

Equation 23

$$E_i = EF_i \times HD_i \times \left(\frac{100 - CE_i}{100}\right)$$

where:

E_i	=	Emission rate for pollutant i	(kg/a)
EF_i	=	Uncontrolled emission factor of pollutant i	(kg/hole)
HD_i	=	Holes drilled in material i	(holes/a)
CE_i	=	Overall control efficiency for pollutant i	(%)

Equation 24

$$HD_i = NB_i \times NH_i$$

where:

HD_i	=	Holes drilled in material i	(holes/a)
NB_i	=	Number of blasts per year on material i	(blasts/a)
NH_i	=	Number of holes for blast i	(holes/blast)

D.2.8 Crushing

Emissions associated with crushing were estimated using a technique from the *NPI EET Manual for Mining v3.1* (Environment Australia, 2012a). The default emission factors used to estimate emissions of PM_{10} and TSP from primary and secondary crushing are provided in Table D-13. Total emissions of PM_{10} and TSP associated with crushing were estimated using the equation below.

Table D-13: Default Emission Factors for Crushing

Material	Description	Emission Factor	Value (kg/tonne)
High Moisture Ore	Primary Crushing	EF_{PM10}	0.004
		EF_{TSP}	0.01
	Secondary Crushing	EF_{PM10}	0.012
		EF_{TSP}	0.03

Source: Environment Australia (2012), p20

Equation 25

$$E_i = EF_i \times MC_i \times \left(\frac{100 - CE_i}{100}\right)$$

where:

E_i	=	Emission rate for pollutant i	(kg/a)
EF_i	=	Uncontrolled emission factor for pollutant i	(kg/tonne)
MC_i	=	The amount of material i crushed	(tonnes/a)
CE_i	=	Overall control efficiency for pollutant i	(%)

D.3 GREENHOUSE GAS EMISSIONS

This section provides a typical calculation of scope 1 emissions for the historical greenhouse gas assessment conducted by PEL in the Central Pilbara region.

Greenhouse gases (GHGs) are gases in Earth's atmosphere that absorb and emit infrared radiation, thus contributing to the greenhouse effect. The burning of fossil fuels and deforestation have caused the GHG levels in the Earth's atmosphere to increase significantly. The major anthropogenic greenhouse gases are regulated under the Kyoto Protocol, which came into force in 2005. These gases are:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulfur hexafluoride (SF_6)

These gases vary in terms of their global warming potential (GWP). This is a measure of the total energy that a gas absorbs over a particular period of time (usually 100 years), relative to CO_2. The metric 'carbon dioxide equivalent' (CO_2-e) is commonly used to quantify GHG emissions where several of the above gases are emitted in combination. The metric takes account of the respective GWPs and emissions of the different gases.

The National Greenhouse and Energy Reporting (NGER) framework requires the reporting of 'direct GHG emissions' (scope 1) and 'indirect GHG emissions due to energy product use' (scope 2). Another category of greenhouse gas emissions recognised internationally is 'other indirect GHG emissions' (scope 3). These categories are summarised in Table D-14. GHGs from the combustion of fuel (Scope 1) and Scope 2 emissions associated with consumption of electricity have been included in this study.

Table D-14: Scope of GHG Emission Calculations

Scope	Description	Treatment in study
Scope 1: Direct greenhouse gas emissions	GHGs emitted from sources owned or controlled by the reporting entity. Principally result from fuel combustion.	Associated with diesel combustion. Emissions calculated in study.
Scope 2: Energy product use	Indirect GHG emissions from the generation of purchased energy products by the entity. Scope 2 emissions occur at the facility that generates the electricity, rather than the facility that uses the electricity.	Associated with energy demand. Emissions calculated in study.
Scope 3: Other indirect greenhouse gas emissions	GHG emissions that are a consequence of the activities of an entity, but which arise from sources not owned or controlled by that entity (*e.g.* extraction and production of purchased materials, transportation of purchased fuels, and use of sold products and services).	Not calculated in this study on the basis that Scope 3 emissions were not part of the Scope of Work.

D.3.1 Scope 1 Emissions

D.3.1.1 Diesel Consumption

Diesel is consumed by a variety of on-site stationary and transport equipment. Diesel combustion leads to emissions of CO_2, CH_4 and N_2O. Emissions are estimated using Method 1 from Part 2.4 of the *National Greenhouse and Energy Reporting System Measurement Technical Guidelines,* July 2014 (DCCEE, 2014). This method uses default emission factors and energy content factors for all emissions, together with measurements of fuel consumption.

The default emission factors for diesel combustion were sourced from Table 2.4.2A and Table 2.4.2B of the *Technical Guidelines* (DCCEE, 2014) and are presented in Table D-15. Emissions from diesel consumption were estimated using the equation below.

Table D-15: Default Diesel Combustion Greenhouse Gas Emission Factors

Emission Source	CO_2	CH_4	N_2O
	(kg CO2-e/GJ)		
Scope 1 Emission Factors for Diesel Combustion for Transport Energy Purposes	69.2	0.2	0.5
Scope 1 Emission Factors for Diesel Combustion for Stationary Energy Purposes	69.2	0.1	0.2

Source: DCCEE (2014), Table 2.4.2A and Table 2.4.2B

Equation 26

$$E_i = EF_i \times EC_i \times DC_{total}$$

where:

E_i	=	Emission rate for greenhouse gas i	(kg/a)
EF_i	=	Emission factor for greenhouse gas i	(kg/GJ)
EC_i	=	Energy content for the fuel (EC =0.0386 GJ/L)	(GJ/L)
DC_{total}	=	Total diesel consumption	(L/a)

D.3.1.2 Other Gaseous Fuel Consumption

BHP Billiton Iron Ore uses gaseous fuels in a variety of on-site equipment for both stationary energy and transportation purposes. To capture emissions from the combustion of the gaseous fuels, they are characterized as Item 27 (gaseous fossil fuels other than these mentioned in items 17 to 26) and Item 63 (natural gas – heavy duty vehicles) in Table 2.3.2A and Table 2.3.2B respectively of the *Technical Guidelines* (DCCEE, 2014) and are presented in Table D-16.

Their combustion leads to emissions of CO_2, CH_4 and N_2O. Emissions are estimated using Method 1 from Part 2.3 of the *National Greenhouse and Energy Reporting System Measurement Technical Guidelines,* July 2014 (DCCEE, 2014). This method uses default emission factors and energy content factors for all emissions, together with measurements of fuel consumption. Emissions from gaseous fuel consumption were estimated using the equation below.

Table D-16: Default Gaseous Fuel Combustion Greenhouse Gas Emission Factors

Emission Source	CO_2	CH_4	N_2O
	(kg CO2-e/GJ)		
Scope 1 Emission Factors for Other gaseous fuels combustion for Transport Energy Purposes Item 63 – natural gas – heavy duty vehicles of Table 2.3.2A	51.2	2.1	0.3
Scope 1 Emission Factors for other gaseous fuels Combustion for Stationary Energy Purposes Item 27 (gaseous fossil fuels other than these mentioned in items 17 to 26) of Table 2.3.2B	51.2	0.1	0.03

Source: DCCEE (2014), Table 2.3.2A and Table 2.3.2B

Equation 27

$$E_i = EF_i \times EC_i \times Gas_{total}$$

where:

E_i	=	Emission rate for greenhouse gas i	(kg/a)
EF_i	=	Emission factor for greenhouse gas i	(kg/GJ)
EC_i	=	Energy content for fuel (EC =0.039 GJ/m^3)	(GJ/m^3)
Gas_{total}	=	Total gaseous fuel consumption	(m^3/a)

D.3.1.3 Liquefied Petroleum Gas

Liquefied Petroleum Gas (LPG) is consumed by a variety of on-site stationary equipment. Combustion of LPG leads to emissions of CO_2, CH_4 and N_2O. Emissions are estimated using Method 1 from Part 2.4 of the *National Greenhouse and Energy Reporting System Measurement Technical Guidelines,* July 2014 (DCCEE, 2014). This method uses default emission factors and energy content factors for all emissions, together with measurements of fuel consumption.

The default emission factors were sourced from Table 2.4.2A of the *Technical Guidelines* (DCCEE, 2014) and are presented in Table D-17. Emissions from LPG consumption were estimated using the equation below.

Table D-17: Default LPG Combustion Greenhouse Gas Emission Factors

Emission Source	CO_2 (kg CO2-e/GJ)	CH_4 (kg CO2-e/GJ)	N_2O (kg CO2-e/GJ)
Scope 1 Emission Factors for LPG fuels Combustion for Stationary Energy Purposes	59.6	0.1	0.2

Source: DCCEE (2014), Table 2.4.2A

Equation 28

$$E_i = EF_{\ i} \times EC_i \times LPG_{total}$$

where:

E_i	=	Emission rate for greenhouse gas i	(kg/a)
EF_i	=	Emission factor for greenhouse gas i	(kg/GJ)
EC_i	=	Energy content for fuel (EC =0.0257 GJ/L)	(GJ/L)
LPG_{total}	=	Total gaseous fuel consumption	(L/a)

D.3.1.4 Petroleum Based Oil

Petroleum based oil is used for lubricating various on-site stationary equipment. Their combustion leads to emissions of CO_2, CH_4 and N_2O. Emissions are estimated using Method 1 from Part 2.4 of the *National Greenhouse and Energy Reporting System Measurement Technical Guidelines,* July 2014 (DCCEE, 2014). This method uses default emission factors and energy content factors for all emissions, together with measurements of fuel consumption.

The default emission factors were sourced from Table 2.4.2A of the *Technical Guidelines* (DCCEE, 2014) and are presented in Table D-18. Emissions from petroleum based oil consumption were estimated using the equation below.

Table D-18: Default Petroleum based Oils Greenhouse Gas Emission Factors

Emission Source	CO_2 (kg CO2-e/GJ)	CH_4 (kg CO2-e/GJ)	N_2O (kg CO2-e/GJ)
Scope 1 Emission Factors petroleum based oils Combustion for Stationary Energy Purposes	27.9	0	0

Source: DCCEE (2014), Table 2.4.2A

Equation 29

$$E_i = EF_i \times EC_i \times Oil_{total}$$

where:

E_i	=	Emission rate for greenhouse gas i	(kg/a)
EF_i	=	Emission factor for greenhouse gas i	(kg/GJ)
EC_i	=	Energy content for fuel (EC =0.0388 GJ/L)	(GJ/L)
Oil_{total}	=	Total oil consumption	(L/a)

D.3.2 Scope 2 Emissions

D.3.2.1 Electricity Consumption

Scope 2 emissions were associated with electricity that is consumed, but not produced at the facility. The method to estimate Scope 2 emissions can be found in Chapter 7 of the Technical Guidelines (DCCEE, 2014).

The electricity provided to the Central Pilbara region is considered purchased "from other sources" according to section 7.3 (DCCEE, 2014).

Scope 2 emissions of CO2 associated with purchased electricity were estimated using Method 1 that can be found in Division 7.2, Method 1 – purchase of electricity from main electricity grid in a State or Territory (DCCEE, 2014):

Equation 30

$$\mathrm{Y} = \mathrm{Q} \times \mathrm{EF}$$

where:

Y	=	Scope 2 GHG emissions	(kg CO2-e)
Q	=	Quantity of electricity purchased from other sources and consumed from the operation of the facility	(kWh)
EF	=	Emission factor of the electricity supplier	(kg CO2-e/kWh)

The Scope 2 emission factor used for estimating Scope 2 greenhouse gas emissions associated with electricity consumption is presented in Table D-19.

Table D-19: Indirect CO_2 Emission Factor of Electricity Purchased from Other Sources

Variable	Value (kg CO_2–e/kWh)
South West Interconnected system in Western Australia	0.76

Source: DCCEE (2013), Table 7.2

Appendix E CALPUFF INPUT FILE

E.1 CALPUFF

```
CALPUFF.INP     2.0             File version record

---------------- Run title (3 lines) ------------------------------------------

                    CALPUFF MODEL CONTROL FILE
                    --------------------------

-------------------------------------------------------------------------------

INPUT GROUP: 0 -- Input and Output File Names

--------------
Default Name  Type          File Name
------------  ----          ---------
CALMET.DAT    input    ! METDAT =D:\JOBS\8299\MET.DAT   !
    or
ISCMET.DAT    input    * ISCDAT =              *
    or
PLMMET.DAT    input    * PLMDAT =              *
    or
PROFILE.DAT   input    * PRFDAT =              *
SURFACE.DAT   input    * SFCDAT =              *
RESTARTB.DAT  input    * RSTARTB=              *
--------------------------------------------------------------------------------
CALPUFF.LST   output   ! PUFLST =BHP_EX8.LST  !
CONC.DAT      output   ! CONDAT =BHP_EX8.CON     !
DFLX.DAT      output   ! DFDAT  =BHP_EX8.FLX     !
WFLX.DAT      output   * WFDAT  =              *

VISB.DAT      output   * VISDAT =              *
TK2D.DAT      output   * T2DDAT =              *
RHO2D.DAT     output   * RHODAT =              *
RESTARTE.DAT  output   * RSTARTE=              *
--------------------------------------------------------------------------------
Emission Files
--------------
PTEMARB.DAT   input    * PTDAT  =              *
VOLEMARB.DAT  input    * VOLDAT =              *
BAEMARB.DAT   input    * ARDAT  =              *
LNEMARB.DAT   input    * LNDAT  =              *
```

```
--------------------------------------------------------------------------------
Other Files
-----------
OZONE.DAT      input    * OZDAT  =             *
VD.DAT         input    * VDDAT  =             *
CHEM.DAT       input    * CHEMDAT=             *
AUX            input    ! AUXEXT =AUX     !
(Extension added to METDAT filename(s) for files
 with auxiliary 2D and 3D data)
H2O2.DAT       input    * H2O2DAT=             *
NH3Z.DAT       input    * NH3ZDAT=             *
HILL.DAT       input    * HILDAT=             *
HILLRCT.DAT    input    * RCTDAT=             *
COASTLN.DAT    input    * CSTDAT=             *
FLUXBDY.DAT    input    * BDYDAT=             *
BCON.DAT       input    * BCNDAT=             *
DEBUG.DAT      output   * DEBUG =             *
MASSFLX.DAT    output   * FLXDAT=             *
MASSBAL.DAT    output   * BALDAT=             *
FOG.DAT        output   * FOGDAT=             *
RISE.DAT       output   * RISDAT=             *
--------------------------------------------------------------------------------
All file names will be converted to lower case if LCFILES = T
Otherwise, if LCFILES = F, file names will be converted to UPPER CASE
         T = lower case      ! LCFILES = F !
         F = UPPER CASE
NOTE: (1) file/path names can be up to 132 characters in length


Provision for multiple input files
----------------------------------

     Number of Modeling Domains (NMETDOM)
                                     Default: 1       ! NMETDOM =   1   !

     Number of CALMET.DAT files for run (NMETDAT)
                                     Default: 1       ! NMETDAT =   1   !

     Number of PTEMARB.DAT files for run (NPTDAT)
                                     Default: 0       ! NPTDAT =   0   !

     Number of BAEMARB.DAT files for run (NARDAT)
                                     Default: 0       ! NARDAT =   0   !
```

```
     Number of VOLEMARB.DAT files for run (NVOLDAT)
                                         Default: 0       ! NVOLDAT =   0   !

!END!

-------------
Subgroup (0a)
-------------

  Provide a name for each CALMET domain if NMETDOM > 1
  Enter NMETDOM lines.
                                        a,b
Default Name             Domain Name
------------             ------------
 none                  * DOMAIN1=     *   *END*
 none                  * DOMAIN2=     *   *END*
 none                  * DOMAIN3=     *   *END*


  The following CALMET.DAT filenames are processed in sequence
  if NMETDAT > 1

  Enter NMETDAT lines, 1 line for each file name.

                                         a,c,d
Default Name  Type          File Name
------------  ----          ---------
 none         input    * METDAT1=     *   *END*
 none         input    * METDAT2=     *   *END*
 none         input    * METDAT3=     *   *END*

-------------
    a
     The name for each CALMET domain and each CALMET.DAT file is treated
     as a separate input subgroup and therefore must end with an input
     group terminator.
    b
     Use DOMAIN1= to assign the name for the outermost CALMET domain.
     Use DOMAIN2= to assign the name for the next inner CALMET domain.
     Use DOMAIN3= to assign the name for the next inner CALMET domain, etc.
      --------------------------------------------------------------------
      |   When inner domains with equal resolution (grid-cell size)      |
```

```
      |   overlap, the data from the FIRST such domain in the list will  |
      |   be used if all other criteria for choosing the controlling     |
      |   grid domain are inconclusive.                                  |
      -------------------------------------------------------------------
    c
     Use METDAT1= to assign the file names for the outermost CALMET domain.
     Use METDAT2= to assign the file names for the next inner CALMET domain.
     Use METDAT3= to assign the file names for the next inner CALMET domain, etc.
    d
     The filenames for each domain must be provided in sequential order

-------------
Subgroup (0b)
-------------

  The following PTEMARB.DAT filenames are processed if NPTDAT>0
  (Each file contains a subset of the sources, for the entire simulation)

Default Name  Type          File Name
------------  ----          ---------
 none         input       * PTDAT=     *    *END*



-------------
Subgroup (0c)
-------------

  The following BAEMARB.DAT filenames are processed if NARDAT>0
  (Each file contains a subset of the sources, for the entire simulation)

Default Name  Type          File Name
------------  ----          ---------
 none         input       * ARDAT=     *    *END*



-------------
Subgroup (0d)
-------------

  The following VOLEMARB.DAT filenames are processed if NVOLDAT>0
  (Each file contains a subset of the sources, for the entire simulation)

Default Name  Type          File Name
```

```
------------  ----          ---------
 none         input       * VOLDAT=     *    *END*


--------------------------------------------------------------------------------

INPUT GROUP: 1 -- General run control parameters
--------------

    Option to run all periods found
    in the met. file      (METRUN)    Default: 0        ! METRUN =   1  !

         METRUN = 0 - Run period explicitly defined below
         METRUN = 1 - Run all periods in met. file

     Starting date:    Year   (IBYR)  --    No default   ! IBYR  =  2010  !
                       Month  (IBMO)  --    No default   ! IBMO  =  0  !
                       Day    (IBDY)  --    No default   ! IBDY  =  0  !
     Starting time:    Hour   (IBHR)  --    No default   ! IBHR  =  0  !
                       Minute (IBMIN) --    No default   ! IBMIN =  0  !
                       Second (IBSEC) --    No default   ! IBSEC =  0  !

     Ending date:      Year   (IEYR)  --    No default   ! IEYR  =  0  !
                       Month  (IEMO)  --    No default   ! IEMO  =  0  !
                       Day    (IEDY)  --    No default   ! IEDY  =  0  !
     Ending time:      Hour   (IEHR)  --    No default   ! IEHR  =  0  !
                       Minute (IEMIN) --    No default   ! IEMIN =  0  !
                       Second (IESEC) --    No default   ! IESEC =  0  !

     (These are only used if METRUN = 0)

     Base time zone:          (ABTZ)  --    No default   ! ABTZ= UTC+0800 !
      (character*8)
     The modeling domain may span multiple time zones.  ABTZ defines the
     base time zone used for the entire simulation.  This must match the
     base time zone of the meteorological data.
     Examples:
         Los Angeles, USA          = UTC-0800
         New York, USA             = UTC-0500
         Santiago, Chile           = UTC-0400
         Greenwich Mean Time (GMT) = UTC+0000
         Rome, Italy               = UTC+0100
         Cape Town, S.Africa       = UTC+0200
```

```
    Sydney, Australia         = UTC+1000

Length of modeling time-step (seconds)
Equal to update period in the primary
meteorological data files, or an
integer fraction of it (1/2, 1/3 ...)
Must be no larger than 1 hour
(NSECDT)                       Default:3600     ! NSECDT =  3600  !
                               Units: seconds

Number of chemical species (NSPEC)
                               Default: 5       ! NSPEC =  1   !

Number of chemical species
to be emitted  (NSE)           Default: 3       ! NSE =  1   !

Flag to stop run after
SETUP phase (ITEST)            Default: 2       ! ITEST =  2   !
(Used to allow checking
of the model inputs, files, etc.)
      ITEST = 1 - STOPS program after SETUP phase
      ITEST = 2 - Continues with execution of program
                  after SETUP

Restart Configuration:

   Control flag (MRESTART)     Default: 0       ! MRESTART =  0   !

      0 = Do not read or write a restart file
      1 = Read a restart file at the beginning of
          the run
      2 = Write a restart file during run
      3 = Read a restart file at beginning of run
          and write a restart file during run

   Number of periods in Restart
   output cycle (NRESPD)       Default: 0       ! NRESPD =  0   !

      0 = File written only at last period
     >0 = File updated every NRESPD periods

Meteorological Data Format (METFM)
                               Default: 1       ! METFM =  1   !
```

```
        METFM = 1 - CALMET binary file (CALMET.MET)
        METFM = 2 - ISC ASCII file (ISCMET.MET)
        METFM = 3 - AUSPLUME ASCII file (PLMMET.MET)
        METFM = 4 - CTDM plus tower file (PROFILE.DAT) and
                    surface parameters file (SURFACE.DAT)
        METFM = 5 - AERMET tower file (PROFILE.DAT) and
                    surface parameters file (SURFACE.DAT)

  Meteorological Profile Data Format (MPRFFM)
         (used only for METFM = 1, 2, 3)
                                Default: 1       ! MPRFFM =  1   !

        MPRFFM = 1 - CTDM plus tower file (PROFILE.DAT)
        MPRFFM = 2 - AERMET tower file (PROFILE.DAT)

  PG sigma-y is adjusted by the factor (AVET/PGTIME)**0.2
  Averaging Time (minutes) (AVET)
                                Default: 60.0    ! AVET = 60. !
  PG Averaging Time (minutes) (PGTIME)
                                Default: 60.0    ! PGTIME = 60. !


  Output units for binary concentration and flux files
  written in Dataset v2.2 or later formats
  (IOUTU)                       Default: 1       ! IOUTU =  1   !
      1 = mass      -  g/m3 (conc) or g/m2/s (dep)
      2 = odour     -  odour_units (conc)
      3 = radiation -  Bq/m3 (conc) or Bq/m2/s (dep)


  Output Dataset format for binary concentration
  and flux files (e.g., CONC.DAT)
  (IOVERS)                      Default: 2       ! IOVERS =  2   !
      1 = Dataset Version 2.1
      2 = Dataset Version 2.2


!END!


-------------------------------------------------------------------------------
```

```
INPUT GROUP: 2 -- Technical options
--------------


     Vertical distribution used in the
     near field (MGAUSS)                  Default: 1     ! MGAUSS =  1   !
        0 = uniform
        1 = Gaussian

     Terrain adjustment method
     (MCTADJ)                             Default: 3     ! MCTADJ =  3   !
        0 = no adjustment
        1 = ISC-type of terrain adjustment
        2 = simple, CALPUFF-type of terrain
            adjustment
        3 = partial plume path adjustment

     Subgrid-scale complex terrain
     flag (MCTSG)                         Default: 0     ! MCTSG =  0   !
        0 = not modeled
        1 = modeled

     Near-field puffs modeled as
     elongated slugs? (MSLUG)             Default: 0     ! MSLUG =  0   !
        0 = no
        1 = yes (slug model used)

     Transitional plume rise modeled?
     (MTRANS)                             Default: 1     ! MTRANS =  1   !
        0 = no  (i.e., final rise only)
        1 = yes (i.e., transitional rise computed)

     Stack tip downwash? (MTIP)           Default: 1     ! MTIP =  1  !
        0 = no  (i.e., no stack tip downwash)
        1 = yes (i.e., use stack tip downwash)

     Method used to compute plume rise for
     point sources not subject to building
     downwash? (MRISE)                    Default: 1     ! MRISE =  1  !
        1 = Briggs plume rise
        2 = Numerical plume rise

     Method used to simulate building
```

```
downwash? (MBDW)                    Default: 1      ! MBDW =   1  !
   1 = ISC method
   2 = PRIME method

Vertical wind shear modeled above
stack top (modified Briggs plume rise)?
(MSHEAR)                            Default: 0      ! MSHEAR =  0  !
   0 = no  (i.e., vertical wind shear not modeled)
   1 = yes (i.e., vertical wind shear modeled)

Puff splitting allowed? (MSPLIT)    Default: 0      ! MSPLIT =  0  !
   0 = no (i.e., puffs not split)
   1 = yes (i.e., puffs are split)

Chemical mechanism flag (MCHEM)     Default: 1      ! MCHEM =  0   !
   0 = chemical transformation not
       modeled
   1 = transformation rates computed
       internally (MESOPUFF II scheme)
   2 = user-specified transformation
       rates used
   3 = transformation rates computed
       internally (RIVAD/ARM3 scheme)
   4 = secondary organic aerosol formation
       computed (MESOPUFF II scheme for OH)
   5 = user-specified half-life with or
       without transfer to child species
   6 = transformation rates computed
       internally (Updated RIVAD scheme with
       ISORROPIA equilibrium)
   7 = transformation rates computed
       internally (Updated RIVAD scheme with
       ISORROPIA equilibrium and CalTech SOA)

Aqueous phase transformation flag (MAQCHEM)
(Used only if MCHEM = 6, or 7)      Default: 0      ! MAQCHEM =  0   !
   0 = aqueous phase transformation
       not modeled
   1 = transformation rates and wet
       scavenging coefficients adjusted
       for in-cloud aqueous phase reactions
       (adapted from RADM cloud model
        implementation in CMAQ/SCICHEM)
```

```
Liquid Water Content flag (MLWC)
(Used only if MAQCHEM = 1)            Default: 1     ! MLWC =  1   !
   0 = water content estimated from cloud cover
       and presence of precipitation
   1 = gridded cloud water data read from CALMET
       water content output files (filenames are
       the CALMET.DAT names PLUS the extension
       AUXEXT provided in Input Group 0)

Wet removal modeled ? (MWET)          Default: 1     ! MWET =  0   !
   0 = no
   1 = yes

Dry deposition modeled ? (MDRY)       Default: 1     ! MDRY =  1   !
   0 = no
   1 = yes
   (dry deposition method specified
    for each species in Input Group 3)


Gravitational settling (plume tilt)
modeled ? (MTILT)                     Default: 0     ! MTILT =  0   !
   0 = no
   1 = yes
   (puff center falls at the gravitational
    settling velocity for 1 particle species)

Restrictions:
    - MDRY  = 1
    - NSPEC = 1  (must be particle species as well)
    - sg    = 0  GEOMETRIC STANDARD DEVIATION in Group 8 is
                 set to zero for a single particle diameter

Method used to compute dispersion
coefficients (MDISP)                  Default: 3     ! MDISP =  2   !

   1 = dispersion coefficients computed from measured values
       of turbulence, sigma v, sigma w
   2 = dispersion coefficients from internally calculated
       sigma v, sigma w using micrometeorological variables
       (u*, w*, L, etc.)
   3 = PG dispersion coefficients for RURAL areas (computed using
```

```
        the ISCST multi-segment approximation) and MP coefficients in
        urban areas
    4 = same as 3 except PG coefficients computed using
        the MESOPUFF II eqns.
    5 = CTDM sigmas used for stable and neutral conditions.
        For unstable conditions, sigmas are computed as in
        MDISP = 3, described above.  MDISP = 5 assumes that
        measured values are read

 Sigma-v/sigma-theta, sigma-w measurements used? (MTURBVW)
 (Used only if MDISP = 1 or 5)         Default: 3     ! MTURBVW =  3  !
    1 = use sigma-v or sigma-theta measurements
        from PROFILE.DAT to compute sigma-y
        (valid for METFM = 1, 2, 3, 4, 5)
    2 = use sigma-w measurements
        from PROFILE.DAT to compute sigma-z
        (valid for METFM = 1, 2, 3, 4, 5)
    3 = use both sigma-(v/theta) and sigma-w
        from PROFILE.DAT to compute sigma-y and sigma-z
        (valid for METFM = 1, 2, 3, 4, 5)
    4 = use sigma-theta measurements
        from PLMMET.DAT to compute sigma-y
        (valid only if METFM = 3)

 Back-up method used to compute dispersion
 when measured turbulence data are
 missing (MDISP2)                      Default: 3     ! MDISP2 =  3  !
 (used only if MDISP = 1 or 5)
    2 = dispersion coefficients from internally calculated
        sigma v, sigma w using micrometeorological variables
        (u*, w*, L, etc.)
    3 = PG dispersion coefficients for RURAL areas (computed using
        the ISCST multi-segment approximation) and MP coefficients in
        urban areas
    4 = same as 3 except PG coefficients computed using
        the MESOPUFF II eqns.

 [DIAGNOSTIC FEATURE]
 Method used for Lagrangian timescale for Sigma-y
 (used only if MDISP=1,2 or MDISP2=1,2)
 (MTAULY)                              Default: 0     ! MTAULY =  0  !
    0 = Draxler default 617.284 (s)
    1 = Computed as Lag. Length / (.75 q) -- after SCIPUFF
```

```
  10 < Direct user input (s)             -- e.g., 306.9


 [DIAGNOSTIC FEATURE]
 Method used for Advective-Decay timescale for Turbulence
 (used only if MDISP=2 or MDISP2=2)
 (MTAUADV)                           Default: 0     ! MTAUADV =  0  !
    0 = No turbulence advection
    1 = Computed (OPTION NOT IMPLEMENTED)
  10 < Direct user input (s)   -- e.g., 800



 Method used to compute turbulence sigma-v &
 sigma-w using micrometeorological variables
 (Used only if MDISP = 2 or MDISP2 = 2)
 (MCTURB)                            Default: 1     ! MCTURB =  1  !
    1 = Standard CALPUFF subroutines
    2 = AERMOD subroutines

 PG sigma-y,z adj. for roughness?      Default: 0     ! MROUGH =  0  !
 (MROUGH)
    0 = no
    1 = yes

 Partial plume penetration of          Default: 1     ! MPARTL =  1  !
 elevated inversion modeled for
 point sources?
 (MPARTL)
    0 = no
    1 = yes

 Partial plume penetration of          Default: 1     ! MPARTLBA =  1  !
 elevated inversion modeled for
 buoyant area sources?
 (MPARTLBA)
    0 = no
    1 = yes

 Strength of temperature inversion     Default: 0     ! MTINV =  0  !
 provided in PROFILE.DAT extended records?
 (MTINV)
    0 = no (computed from measured/default gradients)
    1 = yes
```

```
PDF used for dispersion under convective conditions?
                                      Default: 0     ! MPDF =  0  !
(MPDF)
   0 = no
   1 = yes

Sub-Grid TIBL module used for shore line?
                                      Default: 0     ! MSGTIBL = 0  !
(MSGTIBL)
   0 = no
   1 = yes

Boundary conditions (concentration) modeled?
                                      Default: 0     ! MBCON = 0  !
(MBCON)
   0 = no
   1 = yes, using formatted BCON.DAT file
   2 = yes, using unformatted CONC.DAT file

Note:  MBCON > 0 requires that the last species modeled
       be 'BCON'.  Mass is placed in species BCON when
       generating boundary condition puffs so that clean
       air entering the modeling domain can be simulated
       in the same way as polluted air.  Specify zero
       emission of species BCON for all regular sources.

Individual source contributions saved?
                                      Default: 0     ! MSOURCE = 1  !
(MSOURCE)
   0 = no
   1 = yes


Analyses of fogging and icing impacts due to emissions from
arrays of mechanically-forced cooling towers can be performed
using CALPUFF in conjunction with a cooling tower emissions
processor (CTEMISS) and its associated postprocessors.  Hourly
emissions of water vapor and temperature from each cooling tower
cell are computed for the current cell configuration and ambient
conditions by CTEMISS. CALPUFF models the dispersion of these
emissions and provides cloud information in a specialized format
for further analysis. Output to FOG.DAT is provided in either
```

```
     'plume mode' or 'receptor mode' format.

     Configure for FOG Model output?
                                          Default: 0     ! MFOG =  0   !
     (MFOG)
        0 = no
        1 = yes  - report results in PLUME Mode format
        2 = yes  - report results in RECEPTOR Mode format


     Test options specified to see if
     they conform to regulatory
     values? (MREG)                       Default: 1     ! MREG =  0   !

        0 = NO checks are made
        1 = Technical options must conform to USEPA
            Long Range Transport (LRT) guidance
                       METFM    1 or 2
                       AVET     60. (min)
                       PGTIME   60. (min)
                       MGAUSS   1
                       MCTADJ   3
                       MTRANS   1
                       MTIP     1
                       MRISE    1
                       MCHEM    1 or 3 (if modeling SOx, NOx)
                       MWET     1
                       MDRY     1
                       MDISP    2 or 3
                       MPDF     0 if MDISP=3
                                1 if MDISP=2
                       MROUGH   0
                       MPARTL   1
                       MPARTLBA 0
                       SYTDEP   550. (m)
                       MHFTSZ   0
                       SVMIN    0.5 (m/s)


!END!


-------------------------------------------------------------------------------
```

```
INPUT GROUP: 3a, 3b -- Species list
-------------------

------------
Subgroup (3a)
------------

  The following species are modeled:

! CSPEC =          PM10 !         !END!

                                                                     Dry                  OUTPUT
GROUP
    SPECIES          MODELED           EMITTED        DEPOSITED               NUMBER
     NAME         (0=NO, 1=YES)    (0=NO, 1=YES)    (0=NO,                 (0=NONE,
   (Limit: 12                                           1=COMPUTED-GAS          1=1st
CGRUP,
    Characters                                          2=COMPUTED-PARTICLE    2=2nd
CGRUP,
    in length)                                       3=USER-SPECIFIED)      3= etc.)

!         PM10   =         1,              1,           2,                 0   !

!END!

  Note:  The last species in (3a) must be 'BCON' when using the
         boundary condition option (MBCON > 0).  Species BCON should
         typically be modeled as inert (no chem transformation or
         removal).


-------------
Subgroup (3b)
-------------
  The following names are used for Species-Groups in which results
  for certain species are combined (added) prior to output.  The
  CGRUP name will be used as the species name in output files.
  Use this feature to model specific particle-size distributions
  by treating each size-range as a separate species.
  Order must be consistent with 3(a) above.
```

```
-------------------------------------------------------------------------------


INPUT GROUP: 4 -- Map Projection and Grid control parameters
--------------

     Projection for all (X,Y):
     -------------------------

     Map projection
     (PMAP)                     Default: UTM    ! PMAP = UTM  !

         UTM :  Universal Transverse Mercator
         TTM :  Tangential Transverse Mercator
         LCC :  Lambert Conformal Conic
          PS :  Polar Stereographic
          EM :  Equatorial Mercator
        LAZA :  Lambert Azimuthal Equal Area

     False Easting and Northing (km) at the projection origin
     (Used only if PMAP= TTM, LCC, or LAZA)
     (FEAST)                    Default=0.0     ! FEAST  = 0.000  !
     (FNORTH)                   Default=0.0     ! FNORTH = 0.000  !

     UTM zone (1 to 60)
     (Used only if PMAP=UTM)
     (IUTMZN)                   No Default      ! IUTMZN =  50   !

     Hemisphere for UTM projection?
     (Used only if PMAP=UTM)
     (UTMHEM)                   Default: N      ! UTMHEM = S  !
         N   :  Northern hemisphere projection
         S   :  Southern hemisphere projection

     Latitude and Longitude (decimal degrees) of projection origin
     (Used only if PMAP= TTM, LCC, PS, EM, or LAZA)
     (RLAT0)                    No Default      ! RLAT0 = 0N  !
     (RLON0)                    No Default      ! RLON0 = 0E  !

         TTM :  RLON0 identifies central (true N/S) meridian of projection
                RLAT0 selected for convenience
         LCC :  RLON0 identifies central (true N/S) meridian of projection
                RLAT0 selected for convenience
```

```
    PS  :  RLON0 identifies central (grid N/S) meridian of projection
           RLAT0 selected for convenience
    EM  :  RLON0 identifies central meridian of projection
           RLAT0 is REPLACED by 0.0N (Equator)
    LAZA:  RLON0 identifies longitude of tangent-point of mapping plane
           RLAT0 identifies latitude of tangent-point of mapping plane

Matching parallel(s) of latitude (decimal degrees) for projection
(Used only if PMAP= LCC or PS)
(XLAT1)                     No Default      ! XLAT1 = 30N  !
(XLAT2)                     No Default      ! XLAT2 = 60N  !

    LCC :  Projection cone slices through Earth's surface at XLAT1 and XLAT2
    PS  :  Projection plane slices through Earth at XLAT1
           (XLAT2 is not used)

----------
Note:  Latitudes and longitudes should be positive, and include a
       letter N,S,E, or W indicating north or south latitude, and
       east or west longitude.  For example,
       35.9  N Latitude  =  35.9N
       118.7 E Longitude = 118.7E


Datum-region
------------

The Datum-Region for the coordinates is identified by a character
string.  Many mapping products currently available use the model of the
Earth known as the World Geodetic System 1984 (WGS-84).  Other local
models may be in use, and their selection in CALMET will make its output
consistent with local mapping products.  The list of Datum-Regions with
official transformation parameters is provided by the National Imagery and
Mapping Agency (NIMA).

NIMA Datum - Regions(Examples)
------------------------------------------------------------------------------
WGS-84    WGS-84 Reference Ellipsoid and Geoid, Global coverage (WGS84)
NAS-C     NORTH AMERICAN 1927 Clarke 1866 Spheroid, MEAN FOR CONUS (NAD27)
NAR-C     NORTH AMERICAN 1983 GRS 80 Spheroid, MEAN FOR CONUS (NAD83)
NWS-84    NWS 6370KM Radius, Sphere
ESR-S     ESRI REFERENCE 6371KM Radius, Sphere
```

```
     Datum-region for output coordinates
     (DATUM)                    Default: WGS-84    ! DATUM = WGS-84  !


METEOROLOGICAL Grid:

     Rectangular grid defined for projection PMAP,
     with X the Easting and Y the Northing coordinate

            No. X grid cells (NX)      No default     ! NX =  204   !
            No. Y grid cells (NY)      No default     ! NY =  140   !
         No. vertical layers (NZ)      No default     ! NZ =  12   !

           Grid spacing (DGRIDKM)      No default     ! DGRIDKM = 1.3 !
                                       Units: km

                Cell face heights
                    (ZFACE(nz+1))      No defaults
                                       Units: m
   ! ZFACE = .0, 20.0, 40.0, 60.0, 80.0, 100.0, 150.0, 200.0, 250.0, 500.0,
              1000.0, 2000.0, 3000.0 !

            Reference Coordinates
           of SOUTHWEST corner of
                 grid cell(1, 1):

            X coordinate (XORIGKM)     No default     ! XORIGKM = 596.963 !
            Y coordinate (YORIGKM)     No default     ! YORIGKM = 7386.25 !
                                      Units: km


COMPUTATIONAL Grid:

     The computational grid is identical to or a subset of the MET. grid.
     The lower left (LL) corner of the computational grid is at grid point
     (IBCOMP, JBCOMP) of the MET. grid.  The upper right (UR) corner of the
     computational grid is at grid point (IECOMP, JECOMP) of the MET. grid.
     The grid spacing of the computational grid is the same as the MET. grid.

        X index of LL corner (IBCOMP)      No default     ! IBCOMP =  1   !
                  (1 <= IBCOMP <= NX)

        Y index of LL corner (JBCOMP)      No default     ! JBCOMP =  1   !
```

```
                  (1 <= JBCOMP <= NY)


        X index of UR corner (IECOMP)      No default     ! IECOMP =  204   !
                  (1 <= IECOMP <= NX)

        Y index of UR corner (JECOMP)      No default     ! JECOMP =  140   !
                  (1 <= JECOMP <= NY)



SAMPLING Grid (GRIDDED RECEPTORS):

     The lower left (LL) corner of the sampling grid is at grid point
     (IBSAMP, JBSAMP) of the MET. grid.  The upper right (UR) corner of the
     sampling grid is at grid point (IESAMP, JESAMP) of the MET. grid.
     The sampling grid must be identical to or a subset of the computational
     grid.  It may be a nested grid inside the computational grid.
     The grid spacing of the sampling grid is DGRIDKM/MESHDN.

        Logical flag indicating if gridded
        receptors are used (LSAMP)         Default: T     ! LSAMP = F !
        (T=yes, F=no)

        X index of LL corner (IBSAMP)      No default     ! IBSAMP =  1   !
         (IBCOMP <= IBSAMP <= IECOMP)

        Y index of LL corner (JBSAMP)      No default     ! JBSAMP =  1   !
         (JBCOMP <= JBSAMP <= JECOMP)


        X index of UR corner (IESAMP)      No default     ! IESAMP =  204   !
         (IBCOMP <= IESAMP <= IECOMP)

        Y index of UR corner (JESAMP)      No default     ! JESAMP =  140   !
         (JBCOMP <= JESAMP <= JECOMP)


       Nesting factor of the sampling
        grid (MESHDN)                      Default: 1     ! MESHDN =  1  !
        (MESHDN is an integer >= 1)

!END!
```

```
--------------------------------------------------------------------------------

INPUT GROUP: 5 -- Output Options
--------------
                                             *                           *
     FILE                           DEFAULT VALUE             VALUE THIS RUN
     ----                           -------------             --------------

   Concentrations (ICON)                  1                   !  ICON =  1   !
   Dry Fluxes (IDRY)                      1                   !  IDRY =  1   !
   Wet Fluxes (IWET)                      1                   !  IWET =  0   !
   2D Temperature (IT2D)                  0                   !  IT2D =  0   !
   2D Density (IRHO)                      0                   !  IRHO =  0   !
   Relative Humidity (IVIS)               1                   !  IVIS =  0   !
    (relative humidity file is
     required for visibility
     analysis)
   Use data compression option in output file?
   (LCOMPRS)                               Default: T         ! LCOMPRS = T !

   *
    0 = Do not create file, 1 = create file


    QA PLOT FILE OUTPUT OPTION:

       Create a standard series of output files (e.g.
       locations of sources, receptors, grids ...)
       suitable for plotting?
       (IQAPLOT)                           Default: 1         !  IQAPLOT =  1   !
         0 = no
         1 = yes

    DIAGNOSTIC MASS FLUX OUTPUT OPTIONS:

       Mass flux across specified boundaries
       for selected species reported?
       (IMFLX)                             Default: 0         ! IMFLX =  0  !
         0 = no
         1 = yes (FLUXBDY.DAT and MASSFLX.DAT filenames
```

```
             are specified in Input Group 0)

    Mass balance for each species
    reported?
    (IMBAL)                         Default: 0         ! IMBAL =  0  !
      0 = no
      1 = yes (MASSBAL.DAT filename is
           specified in Input Group 0)


NUMERICAL RISE OUTPUT OPTION:

    Create a file with plume properties for each rise
    increment, for each model timestep?
    This applies to sources modeled with numerical rise
    and is limited to ONE source in the run.
    (INRISE)                        Default: 0         ! INRISE =  0  !
      0 = no
      1 = yes (RISE.DAT filename is
               specified in Input Group 0)


LINE PRINTER OUTPUT OPTIONS:

    Print concentrations (ICPRT)    Default: 0         ! ICPRT =  1   !
    Print dry fluxes (IDPRT)        Default: 0         ! IDPRT =  1   !
    Print wet fluxes (IWPRT)        Default: 0         ! IWPRT =  0   !
    (0 = Do not print, 1 = Print)

    Concentration print interval
    (ICFRQ) in timesteps            Default: 1         ! ICFRQ =  1   !
    Dry flux print interval
    (IDFRQ) in timesteps            Default: 1         ! IDFRQ =  1   !
    Wet flux print interval
    (IWFRQ) in timesteps            Default: 1         ! IWFRQ =  1   !

    Units for Line Printer Output
    (IPRTU)                         Default: 1         ! IPRTU =  3   !
                     for            for
               Concentration    Deposition
        1 =        g/m**3          g/m**2/s
        2 =       mg/m**3         mg/m**2/s
        3 =       ug/m**3         ug/m**2/s
```

```
          4 =      ng/m**3        ng/m**2/s
          5 =     Odour Units


      Messages tracking progress of run
      written to the screen ?
      (IMESG)                        Default: 2         ! IMESG =  2   !
        0 = no
        1 = yes (advection step, puff ID)
        2 = yes (YYYYJJJHH, # old puffs, # emitted puffs)



    SPECIES (or GROUP for combined species) LIST FOR OUTPUT OPTIONS


                ---- CONCENTRATIONS ----    ------ DRY FLUXES ------    ------ WET
FLUXES ------   -- MASS FLUX --
   SPECIES
   /GROUP          PRINTED?  SAVED ON DISK?    PRINTED?  SAVED ON DISK?    PRINTED?
SAVED ON DISK?   SAVED ON DISK?
   -------       ------------------------    ------------------------    ------------
------------   ---------------
!          PM10 =      1,             1,             1,             1,             0,
0,           0   !

  Note:  Species BCON (for MBCON > 0) does not need to be saved on disk.


    OPTIONS FOR PRINTING "DEBUG" QUANTITIES (much output)

      Logical for debug output
      (LDEBUG)                                Default: F     ! LDEBUG = F !

      First puff to track
      (IPFDEB)                                Default: 1     ! IPFDEB =  1  !

      Number of puffs to track
      (NPFDEB)                                Default: 1     ! NPFDEB =  1  !

      Met. period to start output
      (NN1)                                   Default: 1     ! NN1 =  1   !

      Met. period to end output
      (NN2)                                   Default: 10    ! NN2 =  10  !

!END!
```

```
--------------------------------------------------------------------------------

INPUT GROUP: 6a, 6b, & 6c -- Subgrid scale complex terrain inputs
-------------------------

---------------
Subgroup (6a)
---------------
       Number of terrain features (NHILL)       Default: 0     ! NHILL =  0   !

       Number of special complex terrain
       receptors  (NCTREC)                      Default: 0     ! NCTREC =  0   !

       Terrain and CTSG Receptor data for
       CTSG hills input in CTDM format ?
       (MHILL)                                  No Default     ! MHILL =  2   !
       1 = Hill and Receptor data created
           by CTDM processors & read from
           HILL.DAT and HILLRCT.DAT files
       2 = Hill data created by OPTHILL &
           input below in Subgroup (6b);
           Receptor data in Subgroup (6c)

       Factor to convert horizontal dimensions  Default: 1.0   ! XHILL2M = 1.0 !
       to meters (MHILL=1)

       Factor to convert vertical dimensions    Default: 1.0   ! ZHILL2M = 1.0 !
       to meters (MHILL=1)

       X-origin of CTDM system relative to      No Default     ! XCTDMKM = 0 !
       CALPUFF coordinate system, in Kilometers (MHILL=1)

       Y-origin of CTDM system relative to      No Default     ! YCTDMKM = 0 !
       CALPUFF coordinate system, in Kilometers (MHILL=1)

! END !

---------------
Subgroup (6b)
---------------
```

```
                 1 **
     HILL information



HILL           XC         YC        THETAH  ZGRID  RELIEF    EXPO 1    EXPO 2    SCALE
1    SCALE 2    AMAX1      AMAX2
 NO.          (km)       (km)       (deg.)    (m)      (m)       (m)       (m)       (m)
(m)        (m)        (m)
----          ----       ----       ------ ----- ------    ------    ------    -----
--    -------    -----     -----


---------------
Subgroup (6c)
---------------


    COMPLEX TERRAIN RECEPTOR INFORMATION

                   XRCT          YRCT        ZRCT           XHH
                   (km)          (km)         (m)
                  ------        -----      ------          ----



-------------------
1
     Description of Complex Terrain Variables:
          XC, YC  = Coordinates of center of hill
          THETAH  = Orientation of major axis of hill (clockwise from
                    North)
          ZGRID   = Height of the  0  of the grid above mean sea
                    level
          RELIEF  = Height of the crest of the hill above the grid elevation
          EXPO 1  = Hill-shape exponent for the major axis
          EXPO 2  = Hill-shape exponent for the major axis
          SCALE 1 = Horizontal length scale along the major axis
          SCALE 2 = Horizontal length scale along the minor axis
          AMAX    = Maximum allowed axis length for the major axis
          BMAX    = Maximum allowed axis length for the major axis

          XRCT, YRCT = Coordinates of the complex terrain receptors
          ZRCT    = Height of the ground (MSL) at the complex terrain
                    Receptor
          XHH     = Hill number associated with each complex terrain receptor
                    (NOTE: MUST BE ENTERED AS A REAL NUMBER)
```

```
   **
     NOTE: DATA for each hill and CTSG receptor are treated as a separate
           input subgroup and therefore must end with an input group terminator.

-------------------------------------------------------------------------------


INPUT GROUP: 7 -- Chemical parameters for dry deposition of gases
--------------

      SPECIES       DIFFUSIVITY        ALPHA STAR        REACTIVITY      MESOPHYLL
RESISTANCE     HENRY'S LAW COEFFICIENT
       NAME         (cm**2/s)                                                  (s/cm)
(dimensionless)
      -------     -----------      ----------      ----------    ------------------
--     -----------------------


!END!


-------------------------------------------------------------------------------


INPUT GROUP: 8 -- Size parameters for dry deposition of particles
--------------

     For SINGLE SPECIES, the mean and standard deviation are used to
     compute a deposition velocity for NINT (see group 9) size-ranges,
     and these are then averaged to obtain a mean deposition velocity.

     For GROUPED SPECIES, the size distribution should be explicitly
     specified (by the 'species' in the group), and the standard deviation
     for each should be entered as 0.  The model will then use the
     deposition velocity for the stated mean diameter.

      SPECIES      GEOMETRIC MASS MEAN        GEOMETRIC STANDARD
       NAME             DIAMETER                   DEVIATION
                        (microns)                  (microns)
      -------      -------------------        ------------------
!         PM10 =          3.98,                    2.34   !

!END!
```

```
--------------------------------------------------------------------------------


INPUT GROUP: 9 -- Miscellaneous dry deposition parameters
--------------

     Reference cuticle resistance (s/cm)
     (RCUTR)                          Default: 30    !  RCUTR = 30.0 !
     Reference ground resistance  (s/cm)
     (RGR)                            Default: 10    !    RGR = 10.0 !
     Reference pollutant reactivity
     (REACTR)                         Default: 8     ! REACTR = 8.0 !

     Number of particle-size intervals used to
     evaluate effective particle deposition velocity
     (NINT)                           Default: 9     !   NINT =  9  !

     Vegetation state in unirrigated areas
     (IVEG)                           Default: 1     !   IVEG =  1   !
        IVEG=1 for active and unstressed vegetation
        IVEG=2 for active and stressed vegetation
        IVEG=3 for inactive vegetation

!END!


--------------------------------------------------------------------------------


INPUT GROUP: 10 -- Wet Deposition Parameters
---------------


                      Scavenging Coefficient -- Units: (sec)**(-1)

       Pollutant      Liquid Precip.       Frozen Precip.
       ---------      --------------       --------------

!END!
```

```
--------------------------------------------------------------------------------

INPUT GROUP: 11a, 11b -- Chemistry Parameters
---------------------

---------------
Subgroup (11a)
---------------

     Several parameters are needed for one or more of the chemical transformation
     mechanisms.  Those used for each mechanism are:
                                             M                 B
                                             A  B  R  R  R     C  B        N
                                       B     V  C  N  N  N  M  K  C  O     D
                                       C  M  G  K  I  I  I  H  H  K  F  V  E
                                    M  K  N  N  N  T  T  T  2  2  P  R  C  C
                                    O  O  H  H  H  E  E  E  O  O  M  A  N  A
     Mechanism (MCHEM)              Z  3  3  3  3  1  2  3  2  2  F  C  X  Y
     --------------------   --------------------------------------------
     0 None                         .  .  .  .  .  .  .  .  .  .  .  .  .  .
     1 MESOPUFF II                  X  X  .  .  X  X  X  X  .  .  .  .  .  .
     2 User Rates                   .  .  .  .  .  .  .  .  .  .  .  .  .  .
     3 RIVAD                        X  X  .  .  X  .  .  .  .  .  .  .  .  .
     4 SOA                          X  X  .  .  .  .  .  .  .  .  X  X  X  .
     5 Radioactive Decay            .  .  .  .  .  .  .  .  .  .  .  .  .  X
     6 RIVAD/ISORRPIA               X  X  X  X  X  X  .  .  X  X  .  .  .  .
     7 RIVAD/ISORRPIA/SOA           X  X  X  X  X  X  .  .  X  X  X  X  .  .


     Ozone data input option (MOZ)     Default: 1            ! MOZ =  0   !
     (Used only if MCHEM = 1, 3, 4, 6, or 7)
        0 = use a monthly background ozone value
        1 = read hourly ozone concentrations from
            the OZONE.DAT data file

     Monthly ozone concentrations in ppb (BCKO3)
     (Used only if MCHEM = 1,3,4,6, or 7 and either
        MOZ = 0, or
        MOZ = 1 and all hourly O3 data missing)
                                       Default: 12*80.
     !   BCKO3  =  80.00,  80.00,  80.00,  80.00,  80.00,  80.00,  80.00,  80.00,  80.00,
80.00, 80.00, 80.00 !
```

```
Ammonia data option (MNH3)         Default: 0            ! MNH3 =  0   !
(Used only if MCHEM = 6 or 7)
   0 = use monthly background ammonia values (BCKNH3) - no vertical variation
   1 = read monthly background ammonia values for each layer from
       the NH3Z.DAT data file

Ammonia vertical averaging option (MAVGNH3)
(Used only if MCHEM = 6 or 7, and MNH3 = 1)
   0 = use NH3 at puff center height (no averaging is done)
   1 = average NH3 values over vertical extent of puff
                                   Default: 1            ! MAVGNH3 =  1   !

Monthly ammonia concentrations in ppb (BCKNH3)
(Used only if MCHEM = 1 or 3, or
           if MCHEM = 6 or 7, and MNH3 = 0)
                                   Default: 12*10.
!  BCKNH3 = 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00,
10.00, 10.00, 10.00 !

Nighttime SO2 loss rate in %/hour (RNITE1)
(Used only if MCHEM = 1, 6 or 7)
This rate is used only at night for MCHEM=1
and is added to the computed rate both day
and night for MCHEM=6,7 (heterogeneous reactions)
                                   Default: 0.2          ! RNITE1 = .2 !

Nighttime NOx loss rate in %/hour (RNITE2)
(Used only if MCHEM = 1)
                                   Default: 2.0          ! RNITE2 = 2.0 !

Nighttime HNO3 formation rate in %/hour (RNITE3)
(Used only if MCHEM = 1)
                                   Default: 2.0          ! RNITE3 = 2.0 !

H2O2 data input option (MH2O2)     Default: 1            ! MH2O2 =  1   !
(Used only if MCHEM = 6 or 7, and MAQCHEM = 1)
   0 = use a monthly background H2O2 value
   1 = read hourly H2O2 concentrations from
       the H2O2.DAT data file

Monthly H2O2 concentrations in ppb (BCKH2O2)
(Used only if MQACHEM = 1 and either
```

```
        MH2O2 = 0 or
        MH2O2 = 1 and all hourly H2O2 data missing)
                                     Default: 12*1.
     !  BCKH2O2 = 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00,
1.00 !


 --- Data for SECONDARY ORGANIC AEROSOL (SOA) Options
     (used only if MCHEM = 4 or 7)

     The MCHEM = 4 SOA module uses monthly values of:
          Fine particulate concentration in ug/m^3 (BCKPMF)
          Organic fraction of fine particulate     (OFRAC)
          VOC / NOX ratio (after reaction)         (VCNX)

     The MCHEM = 7 SOA module uses monthly values of:
          Fine particulate concentration in ug/m^3 (BCKPMF)
          Organic fraction of fine particulate     (OFRAC)

     These characterize the air mass when computing
     the formation of SOA from VOC emissions.
     Typical values for several distinct air mass types are:

        Month    1    2    3    4    5    6    7    8    9   10   11   12
                Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec

     Clean Continental
        BCKPMF   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
        OFRAC  .15  .15  .20  .20  .20  .20  .20  .20  .20  .20  .20  .15
        VCNX    50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.

     Clean Marine (surface)
        BCKPMF  .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5
        OFRAC  .25  .25  .30  .30  .30  .30  .30  .30  .30  .30  .30  .25
        VCNX    50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.

     Urban - low biogenic (controls present)
        BCKPMF  30.  30.  30.  30.  30.  30.  30.  30.  30.  30.  30.  30.
        OFRAC  .20  .20  .25  .25  .25  .25  .25  .25  .20  .20  .20  .20
        VCNX     4.   4.   4.   4.   4.   4.   4.   4.   4.   4.   4.   4.

     Urban - high biogenic (controls present)
        BCKPMF  60.  60.  60.  60.  60.  60.  60.  60.  60.  60.  60.  60.
```

```
      OFRAC  .25  .25  .30  .30  .30  .55  .55  .55  .35  .35  .35  .25
      VCNX    15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.

   Regional Plume
      BCKPMF  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
      OFRAC  .20  .20  .25  .35  .25  .40  .40  .40  .30  .30  .30  .20
      VCNX    15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.

   Urban - no controls present
      BCKPMF 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
      OFRAC  .30  .30  .35  .35  .35  .55  .55  .55  .35  .35  .35  .30
      VCNX     2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.

   Default: Clean Continental
   !  BCKPMF = 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00,
1.00 !
   !  OFRAC  = 0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20,
0.15 !
   !  VCNX    = 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00,
50.00, 50.00, 50.00 !

 --- End Data for SECONDARY ORGANIC AEROSOL (SOA) Option


   Number of half-life decay specification blocks provided in Subgroup 11b
   (Used only if MCHEM = 5)
   (NDECAY)                                Default: 0      ! NDECAY =  0   !

!END!


--------------
Subgroup (11b)
--------------

   Each species modeled may be assigned a decay half-life (sec), and the
associated
   mass lost may be assigned to one or more other modeled species using a mass
yield
   factor. This information is used only for MCHEM=5.

   Provide NDECAY blocks assigning the half-life for a parent species and mass
yield
   factors for each child species (if any) produced by the decay.
   Set HALF_LIFE=0.0 for NO decay (infinite half-life).
```

```
                          a             b
        SPECIES      Half-Life   Mass Yield
         NAME          (sec)       Factor
        -------      ---------   ----------

     *   SPEC1   =    3600.,        -1.0   *    (Parent)
     *   SPEC2   =     -1.0,         0.0   *    (Child)
   *END*

--------
    a
     Specify a half life that is greater than or equal to zero for 1 parent species
     in each block, and set the yield factor for this species to -1
    b
     Specify a yield factor that is greater than or equal to zero for 1 or more
child
     species in each block, and set the half-life for each of these species to -1

     NOTE: Assignments in each block are treated as a separate input
           subgroup and therefore must end with an input group terminator.
           If NDECAY=0, no assignments and input group terminators should appear.

--------------------------------------------------------------------------------


INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters
---------------

     Horizontal size of puff (m) beyond which
     time-dependent dispersion equations (Heffter)
     are used to determine sigma-y and
     sigma-z (SYTDEP)                           Default: 550.   ! SYTDEP = 5.5E02 !

     Switch for using Heffter equation for sigma z
     as above (0 = Not use Heffter; 1 = use Heffter
     (MHFTSZ)                                   Default: 0      ! MHFTSZ =  0   !

     Stability class used to determine plume
     growth rates for puffs above the boundary
     layer (JSUP)                               Default: 5      ! JSUP =  5   !
```

```
Vertical dispersion constant for stable
conditions (k1 in Eqn. 2.7-3)  (CONK1)      Default: 0.01    ! CONK1 = .01 !

Vertical dispersion constant for neutral/
unstable conditions (k2 in Eqn. 2.7-4)
(CONK2)                                     Default: 0.1     ! CONK2 = .1 !

Factor for determining Transition-point from
Schulman-Scire to Huber-Snyder Building Downwash
scheme (SS used for Hs < Hb + TBD * HL)
(TBD)                                       Default: 0.5     ! TBD = .5 !
   TBD < 0   ==> always use Huber-Snyder
   TBD = 1.5 ==> always use Schulman-Scire
   TBD = 0.5 ==> ISC Transition-point

Range of land use categories for which
urban dispersion is assumed
(IURB1, IURB2)                              Default: 10      ! IURB1 =  10  !
                                                     19      ! IURB2 =  19  !

Site characterization parameters for single-point Met data files ---------
(needed for METFM = 2,3,4,5)

   Land use category for modeling domain
   (ILANDUIN)                               Default: 20      ! ILANDUIN =  20  !

   Roughness length (m) for modeling domain
   (Z0IN)                                   Default: 0.25    ! Z0IN = .25 !

   Leaf area index for modeling domain
   (XLAIIN)                                 Default: 3.0     ! XLAIIN = 3.0 !

   Elevation above sea level (m)
   (ELEVIN)                                 Default: 0.0     ! ELEVIN = .0 !

   Latitude (degrees) for met location
   (XLATIN)                                 Default: -999.   ! XLATIN = -999.0 !

   Longitude (degrees) for met location
   (XLONIN)                                 Default: -999.   ! XLONIN = -999.0 !

Specialized information for interpreting single-point Met data files -----
```

```
   Anemometer height (m) (Used only if METFM = 2,3)
   (ANEMHT)                                  Default: 10.    ! ANEMHT = 10.0 !

   Form of lateral turbulance data in PROFILE.DAT file
   (Used only if METFM = 4,5 or MTURBVW = 1 or 3)
   (ISIGMAV)                                 Default: 1      ! ISIGMAV =  1  !
       0 = read sigma-theta
       1 = read sigma-v

   Choice of mixing heights (Used only if METFM = 4)
   (IMIXCTDM)                                Default: 0      ! IMIXCTDM =  0  !
       0 = read PREDICTED mixing heights
       1 = read OBSERVED mixing heights

Maximum length of a slug (met. grid units)
(XMXLEN)                                     Default: 1.0    ! XMXLEN = 1.0 !

Maximum travel distance of a puff/slug (in
grid units) during one sampling step
(XSAMLEN)                                    Default: 1.0    ! XSAMLEN = 1.0 !

Maximum Number of slugs/puffs release from
one source during one time step
(MXNEW)                                      Default: 99     ! MXNEW =  60   !

Maximum Number of sampling steps for
one puff/slug during one time step
(MXSAM)                                      Default: 99     ! MXSAM =  60   !

Number of iterations used when computing
the transport wind for a sampling step
that includes gradual rise (for CALMET
and PROFILE winds)
(NCOUNT)                                     Default: 2      ! NCOUNT =  2   !

Minimum sigma y for a new puff/slug (m)
(SYMIN)                                      Default: 1.0    ! SYMIN = 1.0  !

Minimum sigma z for a new puff/slug (m)
(SZMIN)                                      Default: 1.0    ! SZMIN = 1.0  !

Maximum sigma z (m) allowed to avoid
numerical problem in calculating virtual
```

```
     time or distance.  Cap should be large
     enough to have no influence on normal events.
     Enter a negative cap to disable.
     (SZCAP_M)                                   Default: 5.0e06 ! SZCAP_M = 5.0E06
!

     Default minimum turbulence velocities sigma-v and sigma-w
     for each stability class over land and over water (m/s)
     (SVMIN(12) and SWMIN(12))

                     ----------  LAND  ----------       ---------  WATER  ---------
-
        Stab Class :  A    B    C    D    E    F        A    B    C    D    E    F
                     ---  ---  ---  ---  ---  ---      ---  ---  ---  ---  ---  --
-
     Default SVMIN : .50, .50, .50, .50, .50, .50,       .37, .37, .37, .37, .37,
.37
     Default SWMIN : .20, .12, .08, .06, .03, .016,      .20, .12, .08, .06, .03,
.016

           ! SVMIN = 0.500, 0.500, 0.500, 0.500, 0.500, 0.500, 0.370, 0.370, 0.370,
0.370, 0.370, 0.370!
           ! SWMIN = 0.200, 0.120, 0.080, 0.060, 0.030, 0.016, 0.200, 0.120, 0.080,
0.060, 0.030, 0.016!

     Divergence criterion for dw/dz across puff
     used to initiate adjustment for horizontal
     convergence (1/s)
     Partial adjustment starts at CDIV(1), and
     full adjustment is reached at CDIV(2)
     (CDIV(2))                                  Default: 0.0,0.0  ! CDIV = .0, .0 !

     Search radius (number of cells) for nearest
     land and water cells used in the subgrid
     TIBL module
     (NLUTIBL)                                  Default: 4      ! NLUTIBL =  4  !

     Minimum wind speed (m/s) allowed for
     non-calm conditions. Also used as minimum
     speed returned when using power-law
     extrapolation toward surface
     (WSCALM)                                   Default: 0.5    ! WSCALM = .5 !

     Maximum mixing height (m)
     (XMAXZI)                                   Default: 3000.  ! XMAXZI = 3000.0 !
```

```
     Minimum mixing height (m)
     (XMINZI)                                  Default: 50.    ! XMINZI = 50.0 !

     Default wind speed classes --
     5 upper bounds (m/s) are entered;
     the 6th class has no upper limit
     (WSCAT(5))                     Default   :
                                    ISC  RURAL  :  1.54,  3.09,  5.14,  8.23,  10.8
(10.8+)

                          Wind Speed Class :  1     2     3     4     5
                                              ---   ---   ---   ---   ---
                                    ! WSCAT = 1.54, 3.09, 5.14, 8.23, 10.80 !

     Default wind speed profile power-law
     exponents for stabilities 1-6
     (PLX0(6))                      Default   : ISC RURAL values
                                    ISC RURAL : .07, .07, .10, .15, .35, .55
                                    ISC URBAN : .15, .15, .20, .25, .30, .30

                          Stability Class :  A     B     C     D     E     F
                                             ---   ---   ---   ---   ---   ---
                                    ! PLX0 = 0.07, 0.07, 0.10, 0.15, 0.35, 0.55
!

     Default potential temperature gradient
     for stable classes E, F (degK/m)
     (PTG0(2))                      Default: 0.020, 0.035
                                    ! PTG0 = 0.020,   0.035 !

     Default plume path coefficients for
     each stability class (used when option
     for partial plume height terrain adjustment
     is selected -- MCTADJ=3)
     (PPC(6))             Stability Class :  A     B     C     D     E     F
                              Default  PPC : .50,  .50,  .50,  .50,  .35,  .35
                                             ---   ---   ---   ---   ---   ---
                                    !  PPC = 0.50, 0.50, 0.50, 0.50, 0.35, 0.35
!

     Slug-to-puff transition criterion factor
     equal to sigma-y/length of slug
     (SL2PF)                              Default: 10.       ! SL2PF = 10.0 !
```

```
Puff-splitting control variables ------------------------

  VERTICAL SPLIT
  --------------

  Number of puffs that result every time a puff
  is split - nsplit=2 means that 1 puff splits
  into 2
  (NSPLIT)                           Default:   3        ! NSPLIT =  3  !

  Time(s) of a day when split puffs are eligible to
  be split once again; this is typically set once
  per day, around sunset before nocturnal shear develops.
  24 values: 0 is midnight (00:00) and 23 is 11 PM (23:00)
  0=do not re-split    1=eligible for re-split
  (IRESPLIT(24))                     Default:  Hour 17 = 1
  !  IRESPLIT = 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0 !

  Split is allowed only if last hour's mixing
  height (m) exceeds a minimum value
  (ZISPLIT)                          Default: 100.       ! ZISPLIT = 100.0 !

  Split is allowed only if ratio of last hour's
  mixing ht to the maximum mixing ht experienced
  by the puff is less than a maximum value (this
  postpones a split until a nocturnal layer develops)
  (ROLDMAX)                          Default: 0.25       ! ROLDMAX = 0.25 !


  HORIZONTAL SPLIT
  ----------------

  Number of puffs that result every time a puff
  is split - nsplith=5 means that 1 puff splits
  into 5
  (NSPLITH)                          Default:   5        ! NSPLITH =  5  !

  Minimum sigma-y (Grid Cells Units) of puff
  before it may be split
  (SYSPLITH)                         Default:  1.0       ! SYSPLITH = 1.0 !

  Minimum puff elongation rate (SYSPLITH/hr) due to
  wind shear, before it may be split
```

```
      (SHSPLITH)                          Default:  2.       ! SHSPLITH = 2.0 !

      Minimum concentration (g/m^3) of each
      species in puff before it may be split
      Enter array of NSPEC values; if a single value is
      entered, it will be used for ALL species
      (CNSPLITH)                          Default:  1.0E-07   ! CNSPLITH = 1.0E-07
!

    Integration control variables ------------------------

      Fractional convergence criterion for numerical SLUG
      sampling integration
      (EPSSLUG)                           Default:   1.0e-04  ! EPSSLUG = 1.0E-04
!

      Fractional convergence criterion for numerical AREA
      source integration
      (EPSAREA)                           Default:   1.0e-06  ! EPSAREA = 1.0E-06
!

      Trajectory step-length (m) used for numerical rise
      integration
      (DSRISE)                            Default:   1.0      ! DSRISE = 1.0 !

      Boundary Condition (BC) Puff control variables ------------------------

      Minimum height (m) to which BC puffs are mixed as they are emitted
      (MBCON=2 ONLY).  Actual height is reset to the current mixing height
      at the release point if greater than this minimum.
      (HTMINBC)                           Default:   500.     ! HTMINBC = 500.0 !

      Search radius (km) about a receptor for sampling nearest BC puff.
      BC puffs are typically emitted with a spacing of one grid cell
      length, so the search radius should be greater than DGRIDKM.
      (RSAMPBC)                           Default:   10.      ! RSAMPBC = 10.0 !

      Near-Surface depletion adjustment to concentration profile used when
      sampling BC puffs?
      (MDEPBC)                            Default:   1        ! MDEPBC =  1  !
         0 = Concentration is NOT adjusted for depletion
         1 = Adjust Concentration for depletion

!END!
```

```
--------------------------------------------------------------------------------

INPUT GROUPS: 13a, 13b, 13c, 13d -- Point source parameters
--------------------------------

---------------
Subgroup (13a)
---------------

     Number of point sources with
     parameters provided below      (NPT1)  No default  !  NPT1 =  0  !

     Units used for point source
     emissions below                (IPTU)  Default: 1  !  IPTU =   1  !
           1 =        g/s
           2 =       kg/hr
           3 =       lb/hr
           4 =     tons/yr
           5 =     Odour Unit * m**3/s  (vol. flux of odour compound)
           6 =     Odour Unit * m**3/min
           7 =     metric tons/yr
           8 =     Bq/s  (Bq = becquerel = disintegrations/s)
           9 =     GBq/yr

     Number of source-species
     combinations with variable
     emissions scaling factors
     provided below in (13d)        (NSPT1) Default: 0  !  NSPT1 =  0  !

     Number of point sources with
     variable emission parameters
     provided in external file      (NPT2)  No default  !  NPT2 =  0  !

     (If NPT2 > 0, these point
     source emissions are read from
     the file: PTEMARB.DAT)

!END!

---------------
```

```
Subgroup (13b)
---------------
                                      a
          POINT SOURCE: CONSTANT DATA
          -----------------------------
                                                                              b
c
  Source        X          Y         Stack     Base      Stack     Exit   Exit     Bldg.
Emission
   No.      Coordinate Coordinate Height  Elevation Diameter   Vel.   Temp.    Dwash
Rates
               (km)       (km)       (m)       (m)        (m)   (m/s)  (deg. K)
  ------    ---------- ---------- ------  ------   -------- ----- -------- ----- ---
-----


--------


    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.

     SRCNAM  is a 12-character name for a source
             (No default)
     X       is an array holding the source data listed by the column headings
             (No default)
     SIGYZI  is an array holding the initial sigma-y and sigma-z (m)
             (Default: 0.,0.)
     FMFAC   is a vertical momentum flux factor (0. or 1.0) used to represent
             the effect of rain-caps or other physical configurations that
             reduce momentum rise associated with the actual exit velocity.
             (Default: 1.0  -- full momentum used)
     ZPLTFM  is the platform height (m) for sources influenced by an isolated
             structure that has a significant open area between the surface
             and the bulk of the structure, such as an offshore oil platform.
             The Base Elevation is that of the surface (ground or ocean),
             and the Stack Height is the release height above the Base (not
             above the platform).  Building heights entered in Subgroup 13c
             must be those of the buildings on the platform, measured from
             the platform deck.  ZPLTFM is used only with MBDW=1 (ISC
             downwash method) for sources with building downwash.
             (Default: 0.0)

    b
     0. = No building downwash modeled
```

```
     1. = Downwash modeled for buildings resting on the surface
     2. = Downwash modeled for buildings raised above the surface (ZPLTFM > 0.)
     NOTE: must be entered as a REAL number (i.e., with decimal point)

    c
     An emission rate must be entered for every pollutant modeled.
     Enter emission rate of zero for secondary pollutants that are
     modeled, but not emitted.  Units are specified by IPTU
     (e.g. 1 for g/s).

---------------
Subgroup (13c)
---------------

           BUILDING DIMENSION DATA FOR SOURCES SUBJECT TO DOWNWASH
           -------------------------------------------------------
Source                                                                    a
 No.       Effective building height, width, length and X/Y offset (in meters)
           every 10 degrees.  LENGTH, XBADJ, and YBADJ are only needed for
           MBDW=2 (PRIME downwash option)
------     --------------------------------------------------------------------



--------

    a
     Building height, width, length, and X/Y offset from the source are treated
     as a separate input subgroup for each source and therefore must end with
     an input group terminator.  The X/Y offset is the position, relative to the
     stack, of the center of the upwind face of the projected building, with the
     x-axis pointing along the flow direction.

---------------
Subgroup (13d)
---------------
                                                      a
          POINT SOURCE: VARIABLE EMISSIONS DATA
          ---------------------------------------

     Use this subgroup to describe temporal variations in the emission
     rates given in 13b.  Factors entered multiply the rates in 13b.
     Skip sources here that have constant emissions.  For more elaborate
     variation in source parameters, use PTEMARB.DAT and NPT2 > 0.
```

```
     IVARY determines the type of variation, and is source-specific:
     (IVARY)                                Default: 0
           0 =       Constant
           1 =       Diurnal cycle (24 scaling factors: hours 1-24)
           2 =       Monthly cycle (12 scaling factors: months 1-12)
           3 =       Hour & Season (4 groups of 24 hourly scaling factors,
                                    where first group is DEC-JAN-FEB)
           4 =       Speed & Stab. (6 groups of 6 scaling factors, where
                                    first group is Stability Class A,
                                    and the speed classes have upper
                                    bounds (m/s) defined in Group 12
           5 =       Temperature   (12 scaling factors, where temperature
                                    classes have upper bounds (C) of:
                                    0, 5, 10, 15, 20, 25, 30, 35, 40,
                                    45, 50, 50+)



--------
    a
     Data for each species are treated as a separate input subgroup
     and therefore must end with an input group terminator.


--------------------------------------------------------------------------------



INPUT GROUPS: 14a, 14b, 14c, 14d -- Area source parameters
--------------------------------


---------------
Subgroup (14a)
---------------

     Number of polygon area sources with
     parameters specified below (NAR1)       No default  !  NAR1 =  9   !

     Units used for area source
     emissions below            (IARU)       Default: 1  !  IARU =   1  !
           1 =        g/m**2/s
           2 =       kg/m**2/hr
           3 =       lb/m**2/hr
```

```
          4 =     tons/m**2/yr
          5 =     Odour Unit * m/s  (vol. flux/m**2 of odour compound)
          6 =     Odour Unit * m/min
          7 =     metric tons/m**2/yr
          8 =     Bq/m**2/s  (Bq = becquerel = disintegrations/s)
          9 =     GBq/m**2/yr

     Number of source-species
     combinations with variable
     emissions scaling factors
     provided below in (14d)        (NSAR1) Default: 0  !  NSAR1 =  0  !

     Number of buoyant polygon area sources
     with variable location and emission
     parameters (NAR2)                      No default  !  NAR2 =  0   !
     (If NAR2 > 0, ALL parameter data for
     these sources are read from the file: BAEMARB.DAT)

!END!

---------------
Subgroup (14b)
---------------
                                     a
          AREA SOURCE: CONSTANT DATA
          ----------------------------
                                                         b
Source           Effect.    Base      Initial    Emission
 No.             Height   Elevation   Sigma z     Rates
                   (m)       (m)        (m)
-------          ------    ------     --------   ---------


   1! SRCNAM = ER_A !
   1! X =          3.1,    580.48,         1.4,    1.08E-05! !END!
   2! SRCNAM = ER_C !
   2! X =          3.1,    523.45,         1.4,    1.08E-05! !END!
   3! SRCNAM = ER_B !
   3! X =          3.1,    553.48,         1.4,    1.08E-05! !END!
   4! SRCNAM = JIM !
   4! X =          3.1,    565.89,         1.4,    5.45E-06! !END!
   5! SRCNAM = MAC !
   5! X =          3.1,    713.76,         1.4,    9.32E-06! !END!
   6! SRCNAM = OB18 !
```

```
   6! X =          3.1,    594.88,         1.4,    1.12E-05! !END!
   7! SRCNAM = WHB !
   7! X =          3.1,    569.35,         1.4,    4.94E-06! !END!
   8! SRCNAM = YND2 !
   8! X =          3.1,    561.42,         1.4,    1.02E-05! !END!
   9! SRCNAM = YND1 !
   9! X =          3.1,    578.99,         1.4,    1.02E-05! !END!

--------
    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.
    b
     An emission rate must be entered for every pollutant modeled.
     Enter emission rate of zero for secondary pollutants that are
     modeled, but not emitted.  Units are specified by IARU
     (e.g. 1 for g/m**2/s).

---------------
Subgroup (14c)
---------------

           COORDINATES (km) FOR EACH VERTEX(4) OF EACH POLYGON
           --------------------------------------------------------
Source                                                              a
 No.       Ordered list of X followed by list of Y, grouped by source
------     ------------------------------------------------------------

 1    ! SRCNAM  =   ER_A !
 1      !  XVERT = 785.72,  785.41,  788.06,  787.48!
 1      !  YVERT = 7419.80,  7419.14,  7419.29,  7420.35!
!END!
 2    ! SRCNAM  =   ER_C !
 2      !  XVERT = 790.53,  791.91,  790.96,  790.50!
 2      !  YVERT = 7417.69,  7418.93,  7419.10,  7418.61!
!END!
 3    ! SRCNAM  =   ER_B !
 3      !  XVERT = 784.88,  784.14,  789.08,  789.08!
 3      !  YVERT = 7417.77,  7416.17,  7416.79,  7417.51!
!END!
 4    ! SRCNAM  =   JIM !
 4      !  XVERT = 813.76,  820.85,  822.12,  818.25!
 4      !  YVERT = 7410.20,  7409.38,  7410.73,  7412.38!
```

```
!END!
 5    ! SRCNAM  =   MAC !
 5      !  XVERT = 690.13,  693.47,  707.34,  702.90!
 5      !  YVERT = 7463.01,  7461.20,  7463.70,  7465.14!
!END!
 6    ! SRCNAM  =   OB18 !
 6      !  XVERT = 810.37,  809.96,  811.87,  813.18!
 6      !  YVERT = 7417.19,  7414.56,  7414.80,  7417.59!
!END!
 7    ! SRCNAM  =   WHB !
 7      !  XVERT = 773.75,  777.87,  775.08,  768.70!
 7      !  YVERT = 7410.02,  7414.19,  7417.56,  7414.19!
!END!
 8    ! SRCNAM  =   YND2 !
 8      !  XVERT = 714.94,  721.42,  721.71,  716.03!
 8      !  YVERT = 7484.16,  7478.39,  7478.95,  7487.26!
!END!
 9    ! SRCNAM  =   YND1 !
 9      !  XVERT = 705.67,  705.30,  714.96,  715.66!
 9      !  YVERT = 7486.44,  7484.13,  7485.56,  7487.00!
!END!

--------
    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.



---------------
Subgroup (14d)
---------------
                                                a
          AREA SOURCE: VARIABLE EMISSIONS DATA
          ---------------------------------------

     Use this subgroup to describe temporal variations in the emission
     rates given in 14b.  Factors entered multiply the rates in 14b.
     Skip sources here that have constant emissions.  For more elaborate
     variation in source parameters, use BAEMARB.DAT and NAR2 > 0.

     IVARY determines the type of variation, and is source-specific:
     (IVARY)                                Default: 0
           0 =       Constant
```

```
          1 =        Diurnal cycle (24 scaling factors: hours 1-24)
          2 =        Monthly cycle (12 scaling factors: months 1-12)
          3 =        Hour & Season (4 groups of 24 hourly scaling factors,
                                   where first group is DEC-JAN-FEB)
          4 =        Speed & Stab. (6 groups of 6 scaling factors, where
                                   first group is Stability Class A,
                                   and the speed classes have upper
                                   bounds (m/s) defined in Group 12
          5 =        Temperature   (12 scaling factors, where temperature
                                   classes have upper bounds (C) of:
                                   0, 5, 10, 15, 20, 25, 30, 35, 40,
                                   45, 50, 50+)



--------
    a
     Data for each species are treated as a separate input subgroup
     and therefore must end with an input group terminator.



-------------------------------------------------------------------------------

INPUT GROUPS: 15a, 15b, 15c -- Line source parameters
---------------------------

---------------
Subgroup (15a)
---------------

     Number of buoyant line sources
     with variable location and emission
     parameters (NLN2)                          No default  !  NLN2 =  0   !

     (If NLN2 > 0, ALL parameter data for
      these sources are read from the file: LNEMARB.DAT)

     Number of buoyant line sources (NLINES)     No default   ! NLINES =  0  !

     Units used for line source
     emissions below                (ILNU)      Default: 1  !  ILNU =   1  !
          1 =         g/s
          2 =        kg/hr
```

```
          3 =       lb/hr
          4 =     tons/yr
          5 =     Odour Unit * m**3/s  (vol. flux of odour compound)
          6 =     Odour Unit * m**3/min
          7 =     metric tons/yr
          8 =     Bq/s  (Bq = becquerel = disintegrations/s)
          9 =     GBq/yr

     Number of source-species
     combinations with variable
     emissions scaling factors
     provided below in (15c)        (NSLN1) Default: 0  !  NSLN1 =  0  !

     Maximum number of segments used to model
     each line (MXNSEG)                             Default: 7   ! MXNSEG =  7  !

     The following variables are required only if NLINES > 0.  They are
     used in the buoyant line source plume rise calculations.

        Number of distances at which                Default: 6   ! NLRISE =  6  !
        transitional rise is computed

        Average building length (XL)                No default   ! XL = .0 !
                                                    (in meters)

        Average building height (HBL)               No default   ! HBL = .0 !
                                                    (in meters)

        Average building width (WBL)                No default   ! WBL = .0 !
                                                    (in meters)

        Average line source width (WML)             No default   ! WML = .0 !
                                                    (in meters)

        Average separation between buildings (DXL)  No default   ! DXL = .0 !
                                                    (in meters)

        Average buoyancy parameter (FPRIMEL)        No default   ! FPRIMEL = .0 !
                                                    (in m**4/s**3)

!END!

---------------
```

```
Subgroup (15b)
---------------

          BUOYANT LINE SOURCE: CONSTANT DATA
          ----------------------------------

a
Source       Beg.  X        Beg.  Y        End.  X     End.  Y       Release      Base
Emission
 No.        Coordinate   Coordinate   Coordinate  Coordinate   Height      Elevation
Rates
            (km)         (km)         (km)        (km)        (m)        (m)
------   ----------  ----------  ---------  ----------  -------   ---------    ----
-----

--------

    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.

    b
     An emission rate must be entered for every pollutant modeled.
     Enter emission rate of zero for secondary pollutants that are
     modeled, but not emitted.  Units are specified by ILNTU
     (e.g. 1 for g/s).

---------------
Subgroup (15c)
---------------
                                                       a
          BUOYANT LINE SOURCE: VARIABLE EMISSIONS DATA
          ----------------------------------------------

     Use this subgroup to describe temporal variations in the emission
     rates given in 15b.  Factors entered multiply the rates in 15b.
     Skip sources here that have constant emissions.

     IVARY determines the type of variation, and is source-specific:
     (IVARY)                                Default: 0
           0 =       Constant
           1 =       Diurnal cycle (24 scaling factors: hours 1-24)
           2 =       Monthly cycle (12 scaling factors: months 1-12)
           3 =       Hour & Season (4 groups of 24 hourly scaling factors,
```

```
                              where first group is DEC-JAN-FEB)
         4 =       Speed & Stab. (6 groups of 6 scaling factors, where
                              first group is Stability Class A,
                              and the speed classes have upper
                              bounds (m/s) defined in Group 12
         5 =       Temperature   (12 scaling factors, where temperature
                              classes have upper bounds (C) of:
                              0, 5, 10, 15, 20, 25, 30, 35, 40,
                              45, 50, 50+)



--------
   a
    Data for each species are treated as a separate input subgroup
    and therefore must end with an input group terminator.


-------------------------------------------------------------------------------


INPUT GROUPS: 16a, 16b, 16c -- Volume source parameters
---------------------------


---------------
Subgroup (16a)
---------------

    Number of volume sources with
    parameters provided in 16b,c (NVL1)     No default  !  NVL1 =  0   !

    Units used for volume source
    emissions below in 16b       (IVLU)     Default: 1  !  IVLU =   1  !
         1 =        g/s
         2 =       kg/hr
         3 =       lb/hr
         4 =     tons/yr
         5 =     Odour Unit * m**3/s  (vol. flux of odour compound)
         6 =     Odour Unit * m**3/min
         7 =     metric tons/yr
         8 =     Bq/s  (Bq = becquerel = disintegrations/s)
         9 =     GBq/yr
```

```
     Number of source-species
     combinations with variable
     emissions scaling factors
     provided below in (16c)      (NSVL1)    Default: 0  !  NSVL1 =  0  !

     Number of volume sources with
     variable location and emission
     parameters                   (NVL2)     No default  !  NVL2 =   0   !

     (If NVL2 > 0, ALL parameter data for
      these sources are read from the VOLEMARB.DAT file(s) )

!END!

---------------
Subgroup (16b)
---------------
                                        a
           VOLUME SOURCE: CONSTANT DATA
           ------------------------------
                                                                              b
         X           Y          Effect.    Base      Initial    Initial    Emission
     Coordinate  Coordinate    Height   Elevation   Sigma y    Sigma z     Rates
        (km)        (km)        (m)       (m)        (m)        (m)
     ----------  ----------    ------    ------    --------   --------   --------



--------
    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.

    b
     An emission rate must be entered for every pollutant modeled.
     Enter emission rate of zero for secondary pollutants that are
     modeled, but not emitted.  Units are specified by IVLU
     (e.g. 1 for g/s).

---------------
Subgroup (16c)
---------------
                                                 a
          VOLUME SOURCE: VARIABLE EMISSIONS DATA
```

```
          ----------------------------------------

     Use this subgroup to describe temporal variations in the emission
     rates given in 16b.  Factors entered multiply the rates in 16b.
     Skip sources here that have constant emissions.  For more elaborate
     variation in source parameters, use VOLEMARB.DAT and NVL2 > 0.

     IVARY determines the type of variation, and is source-specific:
     (IVARY)                                Default: 0
           0 =       Constant
           1 =       Diurnal cycle (24 scaling factors: hours 1-24)
           2 =       Monthly cycle (12 scaling factors: months 1-12)
           3 =       Hour & Season (4 groups of 24 hourly scaling factors,
                                    where first group is DEC-JAN-FEB)
           4 =       Speed & Stab. (6 groups of 6 scaling factors, where
                                    first group is Stability Class A,
                                    and the speed classes have upper
                                    bounds (m/s) defined in Group 12
           5 =       Temperature   (12 scaling factors, where temperature
                                    classes have upper bounds (C) of:
                                    0, 5, 10, 15, 20, 25, 30, 35, 40,
                                    45, 50, 50+)



--------
    a
     Data for each species are treated as a separate input subgroup
     and therefore must end with an input group terminator.


-------------------------------------------------------------------------------

INPUT GROUPS: 17a & 17b -- Non-gridded (discrete) receptor information
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Subgroup (17a)
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     Number of non-gridded receptors (NREC)  No default  !  NREC =  36   !

!END!
```

Subgroup (17b)

----

a

NON-GRIDDED (DISCRETE) RECEPTOR DATA

Receptor No.		X Coordinate (km)	Y Coordinate (km)	Ground Elevation (m)	Height b Above Ground (m)	
1	! X =	625.03,	7496.54,	708.481,	0.000!	!END!
2	! X =	667.87,	7530.94,	439.131,	0.000!	!END!
3	! X =	667.71,	7514.67,	590.955,	0.000!	!END!
4	! X =	746.87,	7518.92,	409.183,	0.000!	!END!
5	! X =	660.28,	7546.76,	406.535,	0.000!	!END!
6	! X =	630.19,	7485.33,	700.926,	0.000!	!END!
7	! X =	783.52,	7414.67,	527.890,	0.000!	!END!
8	! X =	794.6,	7418.35,	516.546,	0.000!	!END!
9	! X =	652.11,	7470.53,	783.324,	0.000!	!END!
10	! X =	769.24,	7453.36,	544.002,	0.000!	!END!
11	! X =	717.93,	7442.71,	673.726,	0.000!	!END!
12	! X =	652.32,	7468.35,	781.191,	0.000!	!END!
13	! X =	825.49,	7464.44,	432.345,	0.000!	!END!
14	! X =	747.48,	7495.05,	434.200,	0.000!	!END!
15	! X =	651.66,	7555.16,	416.089,	0.000!	!END!
16	! X =	719.29,	7393.64,	623.068,	0.000!	!END!
17	! X =	811.75,	7388.05,	598.533,	0.000!	!END!
18	! X =	678.28,	7512.0,	686.727,	0.000!	!END!
19	! X =	676.7,	7505.8,	668.970,	0.000!	!END!
20	! X =	662.75,	7457.78,	1061.523,	0.000!	!END!
21	! X =	761.77,	7424.54,	860.663,	0.000!	!END!
22	! X =	778.66,	7413.64,	563.680,	0.000!	!END!
23	! X =	660.66,	7513.58,	672.259,	0.000!	!END!
24	! X =	794.26,	7415.91,	511.480,	0.000!	!END!
25	! X =	783.07,	7404.59,	532.482,	0.000!	!END!
26	! X =	775.11,	7449.78,	546.410,	0.000!	!END!
27	! X =	726.29,	7464.05,	571.658,	0.000!	!END!
28	! X =	765.88,	7433.02,	652.573,	0.000!	!END!
29	! X =	776.02,	7433.07,	591.506,	0.000!	!END!
30	! X =	763.92,	7442.57,	634.745,	0.000!	!END!
31	! X =	689.53,	7450.64,	788.925,	0.000!	!END!

```
32 ! X =       671.17,     7521.74,     645.721,        0.000!    !END!
33 ! X =       672.58,     7524.15,     498.612,        0.000!    !END!
34 ! X =       787.81,     7404.09,     527.822,        0.000!    !END!
35 ! X =       779.76,     7414.34,     543.534,        0.000!    !END!
36 ! X =       742.01,     7443.78,     696.764,        0.000!    !END!


-------------
    a
     Data for each receptor are treated as a separate input subgroup
     and therefore must end with an input group terminator.

    b
     Receptor height above ground is optional.  If no value is entered,
     the receptor is placed on the ground.
```

Appendix F SOURCE CHARACTERISTICS

F.1 EXISTING SCENARIO

Table F-1: Source parameters for current BHP Billiton Iron Ore operations

Facility	CALPUFF ID	Easting(m)				Northing (m)				Area (m^2)	Base Elevation (m)	Effective Height (m)	Sigma Z (m)
Eastern Ridge	ER_A	785,718	785,412	788,055	787,484	7,419,805	7,419,141	7,419,287	7,420,349	1,949,391	580.5	3.1	1.4
Eastern Ridge	ER_B	784,881	784,137	789,078	789,078	7,417,773	7,416,166	7,416,790	7,417,507	5,243,211	553.5	3.1	1.4
Eastern Ridge	ER_C	790,526	791,907	790,964	790,499	7,417,693	7,418,928	7,419,101	7,418,610	921,211	523.4	3.1	1.4
Jimblebar	JIM	813,756	820,848	822,124	818,245	7,410,202	7,409,379	7,410,733	7,412,380	13,250,125	565.9	3.1	1.4
MAC	MAC	690,128	693,475	707,341	702,905	7,463,011	7,461,205	7,463,702	7,465,136	30,580,241	713.8	3.1	1.4
OB18	OB18	810,369	809,957	811,870	813,185	7,417,188	7,414,559	7,414,798	7,417,587	6,130,594	594.9	3.1	1.4
Whaleback	WHB	773,751	777,868	775,079	768,704	7,410,016	7,414,187	7,417,560	7,414,187	34,569,558	569.4	3.1	1.4
Yandi	YND1	705,667	705,296	714,965	715,655	7,486,440	7,484,129	7,485,564	7,486,998	17,877,553	579.0	3.1	1.4
Yandi	YND2	714,938	721,420	721,712	716,027	7,484,156	7,478,392	7,478,949	7,487,264	16,011,972	561.4	3.1	1.4

Table F-2: Emission rates for current BHP Billiton Iron Ore operations

Facility	CALPUFF ID	PM10 Emission rate ($g/m^2/s$)	TSP Emission rate ($g/m^2/s$)
Eastern Ridge	ER_A	1.08E-05	3.07E-05
Eastern Ridge	ER_B	1.08E-05	3.07E-05
Eastern Ridge	ER_C	1.08E-05	3.07E-05
Jimblebar	JIM	5.45E-06	1.56E-05
MAC	MAC	9.32E-06	2.67E-05
OB18	OB18	1.12E-05	3.19E-05
Whaleback	WHB	4.94E-06	1.41E-05
Yandi	YND1	1.02E-05	2.91E-05
Yandi	YND2	1.02E-05	2.91E-05

Table F-3: Source parameters for current third party operations

Facility	CALPUFF ID	Easting(m)				Northing (m)				Area (m²)	Base Elevation (m)	Effective Height (m)	Sigma Z (m)
Christmas Creek	XMAS	780,471	786,847	794,285	780,259	7,520,442	7,518,211	7,522,461	7,526,180	61,690,075	446.6	3.1	1.4
Cloudbreak	CLDB	758,051	758,264	741,794	741,263	7,525,861	7,527,561	7,530,536	7,527,880	37,150,524	438.7	3.1	1.4
HopeDown1a	HPD1A	714,434	720,189	721,112	713,796	7,460,248	7,458,568	7,460,677	7,461,789	12,127,421	622.9	3.1	1.4
HopeDown1b	HPD1B	716,432	717,140	714,125	713,235	7,454,843	7,455,470	7,457,365	7,456,706	3,498,154	644.8	3.1	1.4
HopeDown4a	HPD4A	762,222	761,332	759,353	760,522	7,438,931	7,439,130	7,438,041	7,436,593	3,278,500	668.4	3.1	1.4
HopeDown4b	HPD4B	762,793	765,117	765,264	762,992	7,436,792	7,436,713	7,439,954	7,439,329	6,590,818	671.6	3.1	1.4
Marandoo	MARD	621,805	613,411	612,375	621,061	7,494,489	7,497,358	7,496,402	7,493,506	10,845,364	735.6	3.1	1.4
West Angeles	WANG	678,147	680,379	684,257	683,938	7,435,810	7,432,755	7,433,127	7,437,058	17,921,315	758.1	3.1	1.4
Yandicoogina	YNDC1	723,837	722,881	730,212	730,106	7,479,746	7,477,940	7,479,428	7,482,828	16,732,055	526.7	3.1	1.4
Yandicoogina	YNDC2	730,637	732,683	732,072	730,319	7,474,434	7,474,088	7,478,657	7,477,860	7,839,008	528.4	3.1	1.4

Table F-4: Emission rate for current third party operations

Facility	CALPUFF ID	PM_{10} Emission rate (g/m²/s)	TSP Emission rate (g/m²/s)
Christmas Creek	XMAS	8.28E-06	2.37E-05
Cloudbreak	CLDB	1.30E-05	3.71E-05
HopeDown1a	HPD1A	3.45E-06	9.86E-06
HopeDown1b	HPD1B	3.45E-06	9.86E-06
HopeDown4a	HPD4A	1.45E-06	4.16E-06
HopeDown4b	HPD4B	1.45E-06	4.16E-06
Marandoo	MARD	3.65E-06	1.04E-05
West Angeles	WANG	5.00E-06	1.43E-05
Yandicoogina	YNDC1	5.05E-06	1.45E-05
Yandicoogina	YNDC2	5.05E-06	1.45E-05

F.2 2030 SCENARIO

Table F-5: Source parameters for future BHP Billiton Iron Ore operations

Facility	CALPUFF ID	Easting(m)				Northing (m)				Area (m^2)	Base Elevation (m)	Effective Height (m)	Sigma Z (m)
Jimblebar West	JIMW	811,301	815,197	818,707	817,557	7,412,675	7,407,187	7,409,062	7,413,419	27,343,785	562.99	3.1	1.4
Jimblebar East	JIME	817,497	818,768	822,822	826,514	7,413,419	7,408,820	7,408,881	7,412,209	26,599,928	581.81	3.1	1.4
Jinidi	JINI	728,087	732,497	736,535	727,131	7,453,926	7,453,554	7,458,655	7,463,064	52,852,235	638.61	3.1	1.4
Mining Area C	MAC1	692,455	708,712	711,847	686,505	7,461,659	7,463,040	7,466,228	7,463,624	56,398,630	694.31	3.1	1.4
Mining Area C	MAC2	706,268	712,591	712,325	706,162	7,456,983	7,458,205	7,458,737	7,457,568	3,704,385	685.04	3.1	1.4
Mining Area C	MAC3	707,118	711,687	710,837	703,825	7,459,427	7,460,277	7,462,615	7,460,596	13,124,842	663.60	3.1	1.4
Marillana	MARL1	736,126	739,951	736,710	733,416	7,485,194	7,489,497	7,492,473	7,489,922	23,905,428	473.89	3.1	1.4
Marillana	MARL2	733,646	733,225	727,949	728,229	7,494,748	7,493,232	7,498,733	7,499,014	6,514,840	474.70	3.1	1.4
Mudlark Well	MUDW1	671,762	683,025	682,760	671,550	7,453,636	7,451,936	7,454,938	7,458,099	41,355,374	715.85	3.1	1.4
Mudlark Well	MUDW2	681,973	681,802	673,170	672,904	7,450,276	7,451,348	7,451,724	7,448,403	19,400,423	701.12	3.1	1.4
Mudlark Well	MUDW3	678,855	672,972	673,958	681,245	7,448,005	7,446,633	7,446,033	7,447,288	6,554,803	759.90	3.1	1.4
Munjina	MUNJ1	688,683	692,243	694,793	692,296	7,493,748	7,488,860	7,489,657	7,495,288	19,746,401	660.31	3.1	1.4
Munjina	MUNJ2	696,235	698,199	697,301	695,336	7,491,576	7,491,913	7,493,541	7,493,541	3,680,019	663.38	3.1	1.4
OB23 (Newman Joint Venture)	OB23	799,959	808,645	807,317	801,207	7,417,722	7,415,810	7,417,377	7,418,785	9,661,491	580.16	3.1	1.4
OB25_A (Newman Joint Venture)	OB25_A	776,875	782,612	791,219	787,925	7,421,229	7,418,679	7,418,307	7,420,751	22,622,597	583.26	3.1	1.4
OB25_B (Newman Joint Venture)	OB25_B	783,978	788,972	788,919	784,828	7,414,452	7,415,409	7,417,640	7,417,799	12,511,068	541.49	3.1	1.4
OB31 (Newman Joint Venture)	OB31	815,870	808,964	818,898	821,927	7,419,741	7,415,438	7,415,225	7,417,563	32,487,439	531.02	3.1	1.4
South Flank	SF1	683,559	686,346	695,882	700,319	7,458,764	7,455,163	7,453,968	7,457,220	46,180,052	803.63	3.1	1.4
South Frank	SF2	690,065	691,127	702,271	703,028	7,454,327	7,452,800	7,451,737	7,453,504	19,706,921	731.81	3.1	1.4
Whaleback	WHB1	774,696	778,203	774,431	768,109	7,409,806	7,415,491	7,417,722	7,414,747	40,051,390	582.15	3.1	1.4
Whaleback	WHB2	766,993	771,881	771,509	765,984	7,408,053	7,407,894	7,412,144	7,410,391	17,700,160	635.34	3.1	1.4
Yandi East	YNDE	714,769	720,985	721,516	716,097	7,484,078	7,478,022	7,478,819	7,486,044	14,209,797	555.64	3.1	1.4
Yandi West	YNDW	705,737	715,672	717,850	703,134	7,483,016	7,485,513	7,487,585	7,486,841	36,687,499	576.72	3.1	1.4

Table F-6: Emission rates for future BHP Billiton Iron Ore operations

Facility	CALPUFF ID	PM10 Emission rate (g/m²/s)			TSP Emission rate (g/m²/s)		
		No Control	Standard Controls	Leading Controls	No Control	Standard Controls	Leading Controls
Jimblebar West	JIMW	1.76E-05	9.52E-06	3.03E-06	5.02E-05	2.72E-05	8.66E-06
Jimblebar East	JIME	1.81E-05	9.78E-06	3.11E-06	5.16E-05	2.80E-05	8.90E-06
Jinidi	JINI	9.09E-06	4.92E-06	1.57E-06	2.60E-05	1.41E-05	4.48E-06
Mining Area C	MAC1	6.56E-06	3.55E-06	1.13E-06	1.88E-05	1.02E-05	3.23E-06
Mining Area C	MAC2	6.56E-06	3.55E-06	1.13E-06	1.88E-05	1.02E-05	3.23E-06
Mining Area C	MAC3	6.56E-06	3.55E-06	1.13E-06	1.88E-05	1.02E-05	3.23E-06
Marillana	MARL1	1.58E-05	8.56E-06	2.72E-06	4.52E-05	2.45E-05	7.78E-06
Marillana	MARL2	1.58E-05	8.56E-06	2.72E-06	4.52E-05	2.45E-05	7.78E-06
Mudlark Well	MUDW1	7.14E-06	3.87E-06	1.23E-06	2.04E-05	1.11E-05	3.52E-06
Mudlark Well	MUDW2	7.14E-06	3.87E-06	1.23E-06	2.04E-05	1.11E-05	3.52E-06
Mudlark Well	MUDW3	7.14E-06	3.87E-06	1.23E-06	2.04E-05	1.11E-05	3.52E-06
Munjina	MUNJ1	2.05E-05	1.11E-05	3.53E-06	5.86E-05	3.18E-05	1.01E-05
Munjina	MUNJ2	2.05E-05	1.11E-05	3.53E-06	5.86E-05	3.18E-05	1.01E-05
OB23 (Newman Joint Venture)	OB23	1.07E-05	5.81E-06	1.85E-06	3.07E-05	1.66E-05	5.28E-06
OB25_A (Newman Joint Venture)	OB25_A	1.07E-05	5.81E-06	1.85E-06	3.07E-05	1.66E-05	5.28E-06
OB25_B (Newman Joint Venture)	OB25_B	1.07E-05	5.81E-06	1.85E-06	3.07E-05	1.66E-05	5.28E-06
OB31 (Newman Joint Venture)	OB31	1.48E-05	8.01E-06	2.55E-06	4.23E-05	2.29E-05	7.29E-06
South Flank	SF1	7.29E-06	3.95E-06	1.26E-06	2.08E-05	1.13E-05	3.59E-06
South Frank	SF2	7.29E-06	3.95E-06	1.26E-06	2.08E-05	1.13E-05	3.59E-06
Whaleback	WHB1	8.32E-06	4.51E-06	1.43E-06	2.38E-05	1.29E-05	4.10E-06
Whaleback	WHB2	8.32E-06	4.51E-06	1.43E-06	2.38E-05	1.29E-05	4.10E-06
Yandi East	YNDE	9.44E-06	5.11E-06	1.63E-06	2.70E-05	1.46E-05	4.65E-06
Yandi West	YNDW	9.44E-06	5.11E-06	1.63E-06	2.70E-05	1.46E-05	4.65E-06

Table F-7: Source parameters for future third party operations

Facility	CALPUFF ID	Easting(m)				Northing (m)				Area (m²)	Base Elevation (m)	Effective Height (m)	Sigma Z (m)
Cloudbreak	CLDB	722,098	722,582	757,943	758,185	7,536,138	7,532,989	7,525,360	7,527,419	92,018,410	432.56	3.1	1.4
Iron Valley	IVIO	737,583	736,811	737,598	739,596	7,485,762	7,482,704	7,482,629	7,485,701	4,386,157	494.52	3.1	1.4
Davidsons Creek	DAVC	861,692	850,551	851,338	861,722	7,406,232	7,408,987	7,405,748	7,403,417	31,542,611	529.08	3.1	1.4
Marandoo	MARD	612,143	624,828	625,312	612,869	7,496,146	7,491,635	7,492,907	7,497,448	18,905,614	739.54	3.1	1.4
West Angelas	WANG2	680,502	685,012	683,499	677,777	7,432,601	7,432,813	7,437,081	7,435,870	20,791,687	759.14	3.1	1.4
West Angelas	WANG1	678,776	677,822	685,209	686,148	7,443,151	7,442,167	7,440,684	7,441,849	9,248,028	761.82	3.1	1.4
Hope Downs 4	HPD4	756,429	764,815	766,026	756,822	7,437,202	7,436,597	7,438,898	7,440,654	26,240,598	666.08	3.1	1.4
Hope Downs 1	HPD1B	714,045	712,289	716,497	717,648	7,457,516	7,456,759	7,454,004	7,455,397	7,738,570	650.27	3.1	1.4
Hope Downs 1	HPD1A	714,227	719,918	721,099	713,833	7,459,968	7,458,213	7,460,725	7,461,603	13,953,443	629.96	3.1	1.4
Yandicoogina SE	YNDC_SE	730,575	733,088	732,391	729,818	7,474,470	7,473,713	7,478,496	7,478,103	10,569,326	527.05	3.1	1.4
Yandicoogina OX	YNDC_OX	718,087	720,342	717,845	717,527	7,476,937	7,477,921	7,478,799	7,477,073	2,723,682	559.04	3.1	1.4
Yandicoogina SE	YNDC_SW	723,249	726,185	725,050	722,174	7,477,209	7,479,086	7,479,450	7,478,602	4,057,060	538.64	3.1	1.4
Yandicoogina C	YNDC_C	723,763	729,757	729,757	723,945	7,479,495	7,479,344	7,481,917	7,480,676	11,031,191	525.22	3.1	1.4
Mindy Mindy	MIND	741,262	744,955	745,772	742,230	7,479,404	7,471,806	7,472,229	7,479,798	8,251,236	518.50	3.1	1.4
Nyidinghu	NYDH1	740,356	738,575	744,026	744,607	7,489,594	7,487,166	7,482,254	7,485,807	19,645,464	469.48	3.1	1.4
Nyidinghu	NYDH2	740,842	738,143	744,592	750,719	7,498,230	7,492,131	7,485,883	7,487,813	69,539,626	446.24	3.1	1.4
Marillana	MARB	737,114	736,932	735,540	735,055	7,492,074	7,493,542	7,494,632	7,493,724	2,257,887	444.15	3.1	1.4
Marillana	MARA	734,510	734,843	726,064	726,548	7,494,148	7,495,571	7,502,443	7,500,445	13,819,518	442.62	3.1	1.4
Koodaideri	KDR	704,539	699,574	718,707	720,766	7,509,860	7,506,833	7,500,414	7,502,110	66,627,468	587.22	3.1	1.4
Roy Hill	ROYH	808,682	818,491	802,506	793,666	7,500,536	7,497,993	7,515,915	7,514,825	138,915,216	436.41	3.1	1.4
Christmas Creek	XMAS	785,795	771,263	791,002	796,330	7,526,329	7,523,302	7,515,552	7,520,153	126,882,241	443.45	3.1	1.4
Yandicoogina S	YNDC_S	732,044	733,933	740,788	740,194	7,471,622	7,470,326	7,479,987	7,480,311	17,272,678	507.31	3.1	1.4

Table F-8: Emission rate for future third party operations

Facility	CALPUFF ID	PM_{10} Emission rate ($g/m^2/s$)	TSP Emission rate ($g/m^2/s$)
Cloudbreak	CLDB	8.17E-06	2.34E-05
Iron Valley	IVIO	9.23E-06	2.64E-05
Davidsons Creek	DAVC	5.50E-06	1.57E-05
Marandoo	MARD	1.35E-05	3.85E-05
West Angelas	WANG2	1.27E-05	3.63E-05
West Angelas	WANG1	1.27E-05	3.63E-05
Hope Downs 4	HPD4	8.00E-06	2.29E-05
Hope Downs 1	HPD1B	8.76E-06	2.51E-05
Hope Downs 1	HPD1A	8.76E-06	2.51E-05
Yandicoogina SE	YNDC_SE	1.68E-06	4.81E-06
Yandicoogina OX	YNDC_OX	1.55E-05	4.45E-05
Yandicoogina SE	YNDC_SW	1.55E-05	4.45E-05
Yandicoogina C	YNDC_C	1.27E-05	3.64E-05
Mindy Mindy	MIND	2.52E-05	7.22E-05
Nyidinghu	NYDH1	3.89E-06	1.11E-05
Nyidinghu	NYDH2	3.89E-06	1.11E-05
Marillana	MARB	6.15E-06	1.76E-05
Marillana	MARA	6.15E-06	1.76E-05
Koodaideri	KDR	5.47E-06	1.56E-05
Roy Hill	ROYH	7.52E-06	2.15E-05
Christmas Creek	XMAS	5.33E-06	1.53E-05
Yandicoogina S	YNDC_S	1.68E-06	4.81E-06

F.3 HIGHEST USE SCENARIO

Table F-9: Source parameters for Highest Use BHP Billiton Iron Ore operations

Facility	CALPUFF ID	Easting(m)				Northing (m)				Area (m²)	Base Elevation (m)	Effective Height (m)	Sigma Z (m)
Caramulla	CAMU	834,544	831,509	847,833	842,173	7,412,407	7,408,798	7,408,634	7,411,915	40,830,242	518.07	3.1	1.4
Coondiner	CODN	771,450	771,394	767,016	766,006	7,454,193	7,460,143	7,463,005	7,454,923	35,317,854	468.29	3.1	1.4
Eastern Ridge OB23	OB23	792,163	808,645	807,317	794,184	7,416,192	7,415,810	7,417,377	7,420,514	44,212,602	554.37	3.1	1.4
Eastern Ridge OB25A	OB25_A	765,332	780,937	789,525	787,841	7,422,310	7,417,932	7,418,999	7,420,514	42,665,979	551.08	3.1	1.4
Eastern Ridge OB25B	OB25_B	778,074	787,223	789,188	785,146	7,415,574	7,414,452	7,417,034	7,417,595	18,983,065	550.09	3.1	1.4
Gurinbiddy1	GUBY1	707,405	706,563	693,765	694,158	7,431,235	7,434,603	7,434,715	7,430,842	47,233,802	866.19	3.1	1.4
Gurinbiddy2	GUBY2	693,091	692,979	688,881	687,141	7,424,387	7,429,832	7,429,776	7,424,948	26,007,467	779.33	3.1	1.4
Jimblebar East	JIMW	807,038	814,559	819,943	821,911	7,412,263	7,407,997	7,408,552	7,412,817	44,746,191	554.12	3.1	1.4
Jimblebar East	JIME	821,911	820,189	831,427	834,462	7,412,899	7,408,798	7,408,880	7,412,161	44,685,940	517.60	3.1	1.4
Jinidi1	JINI1	727,612	732,497	736,535	727,131	7,452,284	7,453,554	7,458,655	7,463,064	59,517,768	645.03	3.1	1.4
Jinidi2	JINI2	734,011	733,618	721,999	722,897	7,445,829	7,447,513	7,448,355	7,446,952	16,911,660	733.37	3.1	1.4
Marillana	MARL	736,593	740,185	725,703	724,020	7,484,897	7,489,836	7,500,501	7,495,337	96,179,066	553.94	3.1	1.4
Mindy	MINDY	745,125	751,299	755,902	744,227	7,481,192	7,473,221	7,473,783	7,487,030	48,206,336	490.44	3.1	1.4
Mining Area C1	MAC1	692,455	708,712	711,847	686,505	7,461,659	7,463,040	7,466,228	7,463,624	56,398,630	694.31	3.1	1.4
Mining Area C2	MAC2	706,268	712,591	712,325	706,162	7,456,983	7,458,205	7,458,737	7,457,568	3,704,385	685.04	3.1	1.4
Mining Area C3	MAC3	707,118	711,687	710,837	703,825	7,459,427	7,460,277	7,462,615	7,460,596	13,124,842	663.60	3.1	1.4
Mining Area C4	MAC4	684,222	690,958	684,952	679,564	7,460,423	7,461,883	7,463,679	7,462,332	18,712,060	700.02	3.1	1.4
Ministers North	MINN	715,937	720,315	720,090	713,186	7,471,930	7,471,594	7,474,793	7,475,860	19,063,335	652.10	3.1	1.4
Mudlark Well1	MUDW1	666,204	681,753	678,104	670,358	7,453,744	7,451,835	7,456,943	7,458,403	57,303,495	768.38	3.1	1.4
Mudlark Well2	MUDW2	681,973	681,802	662,668	661,602	7,450,276	7,451,348	7,451,274	7,449,927	23,794,044	703.09	3.1	1.4
Mudlark Well3	MUDW3	679,732	667,608	662,331	685,008	7,448,692	7,449,534	7,445,829	7,446,615	50,301,789	787.97	3.1	1.4
Mudlark Well4	MUDW4	688,264	697,750	691,295	686,075	7,442,910	7,444,538	7,446,671	7,443,921	21,018,379	772.03	3.1	1.4
Munjina_1	MUJA1	677,936	686,187	683,773	677,094	7,491,015	7,497,975	7,502,746	7,494,607	43,508,212	673.81	3.1	1.4
Munjina_2	MUJA2	688,264	692,530	697,975	691,632	7,495,505	7,489,050	7,491,913	7,503,252	67,338,939	671.42	3.1	1.4

Facility	CALPUFF ID	Easting(m)				Northing (m)				Area (m²)	Base Elevation (m)	Effective Height (m)	Sigma Z (m)
OB31	OB31	816,355	806,982	819,555	822,081	7,419,560	7,413,834	7,415,182	7,417,764	39,340,149	532.95	3.1	1.4
Opthalmia1	OPMA1	732,720	746,416	746,472	732,664	7,422,086	7,422,759	7,424,443	7,422,815	16,596,170	693.40	3.1	1.4
Opthalmia2	OPMA2	728,061	733,562	732,439	727,444	7,423,714	7,424,499	7,425,847	7,425,510	8,737,083	700.57	3.1	1.4
Opthalmia3	OPMA3	727,893	739,849	736,481	730,587	7,399,521	7,410,298	7,411,870	7,410,467	57,908,408	664.38	3.1	1.4
Opthalmia4	OPMA4	743,216	743,160	741,476	741,589	7,412,992	7,414,003	7,413,947	7,412,992	1,628,928	644.94	3.1	1.4
Packsaddle East	PACE	712,400	723,290	725,816	714,197	7,464,914	7,462,051	7,465,138	7,466,879	33,400,691	734.03	3.1	1.4
Roy Hill	ROYH	686,438	684,656	728,061	727,724	7,547,399	7,543,999	7,534,854	7,539,007	166,270,569	463.25	3.1	1.4
South Frank1	SF1	683,942	686,346	703,307	703,026	7,458,290	7,455,163	7,455,428	7,459,245	63,397,020	847.60	3.1	1.4
South Frank2	SF2	689,948	690,790	705,665	709,482	7,454,754	7,453,014	7,452,004	7,455,596	45,995,597	704.34	3.1	1.4
Tandanya_1	TDYA1	665,250	684,391	683,549	664,689	7,470,752	7,465,363	7,474,063	7,474,232	113,768,233	766.94	3.1	1.4
Tandanya_2	TDYA2	664,801	675,073	683,998	671,930	7,463,623	7,460,536	7,465,363	7,468,731	81,396,054	738.53	3.1	1.4
Whaleback1	WHB1	774,696	778,203	774,431	768,109	7,409,806	7,415,491	7,417,722	7,414,747	40,051,390	582.15	3.1	1.4
Whaleback2	WHB2	760,898	771,881	771,509	762,301	7,407,604	7,407,894	7,412,144	7,410,410	35,098,764	653.02	3.1	1.4
Yandi East	YNDE	714,769	720,985	721,516	716,097	7,484,078	7,478,022	7,478,819	7,486,044	14,209,797	555.64	3.1	1.4
Yandi West	YNDW	705,737	715,672	717,850	703,134	7,483,016	7,485,513	7,487,585	7,486,841	36,687,499	576.72	3.1	1.4

Table F-10: Emission rates for Highest Use BHP Billiton Iron Ore operations

Facility	CALPUFF ID	PM$_{10}$ Emission rate (g/m^2/s)			TSP Emission rate (g/m^2/s)		
		No Control	Standard Controls	Leading Controls	No Control	Standard Controls	Leading Controls
Caramulla	CAMU	1.18E-05	6.37E-06	2.03E-06	3.36E-05	1.82E-05	5.80E-06
Coondiner	CODN	1.36E-05	7.37E-06	2.34E-06	3.89E-05	2.11E-05	6.70E-06
Eastern Ridge OB23	OB23	4.54E-06	2.46E-06	7.82E-07	1.30E-05	7.03E-06	2.24E-06
Eastern Ridge OB25A	OB25_A	4.54E-06	2.46E-06	7.82E-07	1.30E-05	7.03E-06	2.24E-06
Eastern Ridge OB25B	OB25_B	4.54E-06	2.46E-06	7.82E-07	1.30E-05	7.03E-06	2.24E-06
Gurinbiddy1	GUBY1	6.56E-06	3.55E-06	1.13E-06	1.88E-05	1.02E-05	3.23E-06
Gurinbiddy2	GUBY2	6.56E-06	3.55E-06	1.13E-06	1.88E-05	1.02E-05	3.23E-06
Jimblebar East	JIMW	1.07E-05	5.82E-06	1.85E-06	3.07E-05	1.66E-05	5.29E-06
Jimblebar East	JIME	1.07E-05	5.82E-06	1.85E-06	3.07E-05	1.67E-05	5.30E-06
Jinidi1	JINI1	6.28E-06	3.41E-06	1.08E-06	1.80E-05	9.74E-06	3.10E-06
Jinidi2	JINI2	6.28E-06	3.41E-06	1.08E-06	1.80E-05	9.74E-06	3.10E-06
Marillana	MARL	4.99E-06	2.71E-06	8.61E-07	1.43E-05	7.74E-06	2.46E-06
Mindy	MINDY	9.96E-06	5.40E-06	1.72E-06	2.85E-05	1.54E-05	4.91E-06
Mining Area C1	MAC1	5.22E-06	2.83E-06	9.00E-07	1.49E-05	8.10E-06	2.57E-06
Mining Area C2	MAC2	5.22E-06	2.83E-06	9.00E-07	1.49E-05	8.10E-06	2.57E-06
Mining Area C3	MAC3	5.22E-06	2.83E-06	9.00E-07	1.49E-05	8.10E-06	2.57E-06
Mining Area C4	MAC4	5.22E-06	2.83E-06	9.00E-07	1.49E-05	8.10E-06	2.57E-06
Ministers North	MINN	2.52E-05	1.37E-05	4.34E-06	7.21E-05	3.90E-05	1.24E-05
Mudlark Well1	MUDW1	3.15E-06	1.71E-06	5.43E-07	9.01E-06	4.88E-06	1.55E-06
Mudlark Well2	MUDW2	3.15E-06	1.71E-06	5.43E-07	9.01E-06	4.88E-06	1.55E-06
Mudlark Well3	MUDW3	3.15E-06	1.71E-06	5.43E-07	9.01E-06	4.88E-06	1.55E-06
Mudlark Well4	MUDW4	3.15E-06	1.71E-06	5.43E-07	9.01E-06	4.88E-06	1.55E-06
Munjina_1	MUJA1	4.33E-06	2.35E-06	7.47E-07	1.24E-05	6.72E-06	2.14E-06
Munjina_2	MUJA2	4.33E-06	2.35E-06	7.47E-07	1.24E-05	6.72E-06	2.14E-06
OB31	OB31	1.22E-05	6.62E-06	2.10E-06	3.49E-05	1.89E-05	6.02E-06

Facility	CALPUFF ID	PM10 Emission rate (g/m²/s)			TSP Emission rate (g/m²/s)		
		No Control	Standard Controls	Leading Controls	No Control	Standard Controls	Leading Controls
Opthalmia1	OPMA1	5.66E-06	3.07E-06	9.75E-07	1.62E-05	8.77E-06	2.79E-06
Opthalmia2	OPMA2	5.66E-06	3.07E-06	9.75E-07	1.62E-05	8.77E-06	2.79E-06
Opthalmia3	OPMA3	5.66E-06	3.07E-06	9.75E-07	1.62E-05	8.77E-06	2.79E-06
Opthalmia4	OPMA4	5.66E-06	3.07E-06	9.75E-07	1.62E-05	8.77E-06	2.79E-06
Packsaddle East	PACE	1.44E-05	7.79E-06	2.48E-06	4.11E-05	2.23E-05	7.09E-06
Roy Hill	ROYH	2.89E-06	1.57E-06	4.98E-07	8.262E-06	4.48E-06	1.42E-06
South Frank1	SF1	4.39E-06	2.38E-06	7.57E-07	1.26E-05	6.80E-06	2.16E-06
South Frank2	SF2	4.39E-06	2.38E-06	7.57E-07	1.26E-05	6.80E-06	2.16E-06
Tandanya_1	TDYA1	2.46E-06	1.33E-06	4.24E-07	7.04E-06	3.81E-06	1.21E-06
Tandanya_2	TDYA2	2.46E-06	1.33E-06	4.24E-07	7.04E-06	3.81E-06	1.21E-06
Whaleback1	WHB1	6.39E-06	3.46E-06	1.10E-06	1.83E-05	9.91E-06	3.15E-06
Whaleback2	WHB2	6.39E-06	3.46E-06	1.10E-06	1.83E-05	9.91E-06	3.15E-06
Yandi East	YNDE	3.38E-05	1.83E-05	5.82E-06	9.67E-05	5.24E-05	1.67E-05
Yandi West	YNDW	1.31E-05	7.09E-06	2.26E-06	3.74E-05	2.03E-05	6.45E-06