APPENDIX 8

Air Quality Impact Assessment

Invincible Southern Extension Project

Shoalhaven Coal Pty Ltd

Air Quality Impact Assessment

Final | Revision 0

26 July 2016

Umwelt 3622C

JACOBS

Invincible Southern Extension Project

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Project Manager:	Shane Lakmaker
Author:	Shane Lakmaker
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Jacobs Group (Australia) Pty Limited
ABN 37 001 024 095
710 Hunter Street
Newcastle West NSW 2302 Australia
PO Box 2147 Dangar NSW 2309 Australia
T +61 2 4979 2600
F +61 2 4979 2666
www.jacobs.com

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Executive Summary

This report provides an assessment of the potential air quality impacts of the Invincible Southern Extension Project (the Project), a proposal by Shoalhaven Coal Pty Ltd (trading as Castlereagh Coal) to extend the existing approved open cut mining operations at the Invincible Colliery.

The potential air quality issues were identified as:

- Dust (that is, particulate matter in the form of TSP, PM_{10} or $PM_{2.5}$) from the general mining activities; and
- Emissions of substances from machinery exhausts, that is, diesel emissions.

A detailed review of the existing environment was carried out. The review found that air quality in the region was generally good with average concentrations of PM_{10} well below Environment Protection Authority (EPA) criteria. However, there has been an occasional exceedance of the EPA's 50 µg/m^3 24-hour criterion for PM_{10} in the past seven years (specifically, five days in the past seven years).

The computer-based dispersion model known as CALPUFF was used to predict the potential air quality impacts of the Project, including background levels. The dispersion modelling accounted for meteorological conditions, land use and terrain information and used emission estimates to predict the off-site air quality impacts. Model predictions were compared to EPA criteria.

Based on model predictions which were below EPA criteria, it was concluded that the Project will not cause adverse air quality impacts at any off-site sensitive receptor location. Emissions from diesel exhausts associated with off-road vehicles and equipment were also investigated and, again, the Project is not expected to result in any adverse air quality impacts, based on model predictions which showed compliance with air quality criteria.

The conclusions above will not change as a result of the National Clean Air Agreement which, of relevance, proposes the establishment of an annual average standard for PM_{10} of 25 µg/m^3 (as distinct from the current criterion of 30 µg/m^3) and adoption of the current $PM_{2.5}$ advisory report goals as standards.

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs is to quantify the potential air quality impacts of the Invincible Southern Extension Project in accordance with the scope of services set out in the contract between Jacobs and the Client. That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the Client (if any) and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

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1. Introduction

Shoalhaven Coal Pty Ltd (trading as Castlereagh Coal), part of the Manildra group of companies, is proposing an extension to the existing approved open cut mining operations at the Invincible Colliery. The proposal is referred to as the Invincible Southern Extension Project (the Project). A modification application has been prepared for the Project under 75W of the *Environmental Planning and Assessment Act 1979*. This report provides an assessment of the potential air quality impacts of the Project and forms part of the Environmental Assessment (EA).

The main objectives of this assessment were to:

- Identify potential air quality issues;
- Quantify potential air quality impacts; and
- Identify suitable air quality management measures, as appropriate, to minimise impacts.

The assessment was based on the use of an air dispersion model, CALPUFF, to predict concentrations of substances emitted to air due to the mining activities. Model predictions have been compared with air quality criteria referred to by the Environment Protection Authority (EPA) in order to assess the effect that the Project may have on the existing air quality environment.

In summary, the report provides information on the following:

- Existing and proposed mining activities (**Section 2**);
- Potential air quality issues (**Section 3**);
- Relevant air quality criteria (**Section 4**);
- Existing meteorological and air quality conditions (**Section 5**);
- Emissions to air from proposed mining activities (**Section 6**);
- Methods used to predict air quality impacts (**Section 7**);
- Expected air quality impacts, as determined by a comparison of model results with air quality assessment criteria (**Section 8**); and
- Management measures to be implemented, and monitoring of potential impacts (**Section 9**).

2. Project Description

Invincible Colliery (Invincible) is located approximately 25 kilometres (km) north-west of Lithgow, in the Central Tablelands of New South Wales (NSW). The existing Invincible operations include areas of previous underground and open mining and includes a coal handling and preparation plant which was originally designed to service the production from underground longwall mining. The longwall system was shut down and removed in 1988. Mining recommenced in 1989, following acquisition by Coalpac Pty Ltd, and operations were then based on bord and pillar methods. Open cut mining methods have more recently been used up to Invincible being placed on Care and Maintenance in 2013. The open cut mining was carried out by conventional methods of trucks, excavators and loaders to recover coal from the Lithgow, Lidsdale and Irondale Seams. Mining was approved to provide up to 1.2 million tonnes per annum (Mtpa) of run-of-mine (ROM) to supply local power stations and domestic thermal coal users.

The mine was acquired by Shoalhaven Coal in 2015, which has retained the trading name Castlereagh Coal, and is continuing to be maintained under Care and Maintenance. Castlereagh Coal is now proposing an extension to the existing approved open cut mining operations. This proposal is referred to as the Invincible Southern Extension Project and includes the following main components:

- Extending the period in which mining can continue for a period of 8 years from approval of the modification application.
- Extending the open cut mining area immediately south of the existing mining disturbance area.
- Extraction of coal from all seams down to, and including the Lithgow seam. No highwall mining or open cut mining in any other areas of Invincible is proposed as part of the Project.
- Continued use of existing Invincible infrastructure (including operation of, and maintenance work on, the existing Coal Preparation Plant).
- Use of existing open cut voids and former underground workings for water storage.
- No change to currently approved mining production rates.
- Rehabilitation of the proposed Southern Extension Area and all existing disturbance areas at Invincible by reshaping mining areas to remove voids and revegetating the reshaped landform with locally endemic woodland and forest communities.

There will be no change to the existing approved transport of coal operations or hours of operation. Specifically, coal would be processed at the CPP and transported off-site by truck to either Mount Piper Power Station or to Manildra’s Shoalhaven Starches plant at Bomaderry. Mining operations will be carried out between the hours of 7 am and 6 pm, Monday to Saturday. Coal loading operations will be carried out between 7am and 10 pm Monday to Saturday.

The purpose of the Southern Extension Project is to provide Manildra’s Shoalhaven Starches with a reliable and cost effect source of specialty nut coal for its Bomaderry operations on the NSW South Coast. The proposed modification will provide access to an additional approximately 300 kt of nut coal from the Lithgow seam for use at the Shoalhaven Starches plant. Coal from the Lidsdale and Irondale seams which is unsuitable for use in Shoalhaven Starches plant will be sold to the Mount Piper Power Station.

The 8 year extension to the life of mining operations is to provide Shoalhaven Starches with flexibility of accessing nut coal from Invincble along with other suppliers or source nut coal solely from Invincible. The eight year extension of mine life will also enable Castlereagh Coal and Shoalhaven Starches to fully investigate options of using coal from the Lidsdale and Irondale seams at the Shoalhaven Starches Plant. This assessment has assumed a conservative mining scenario of up to maximum limits of production to provide a conservative assessment of impacts over the life of the Project.

Figure 1 shows the location of the Southern Extension Area as well as the location of nearest private and mine-owned dwellings.

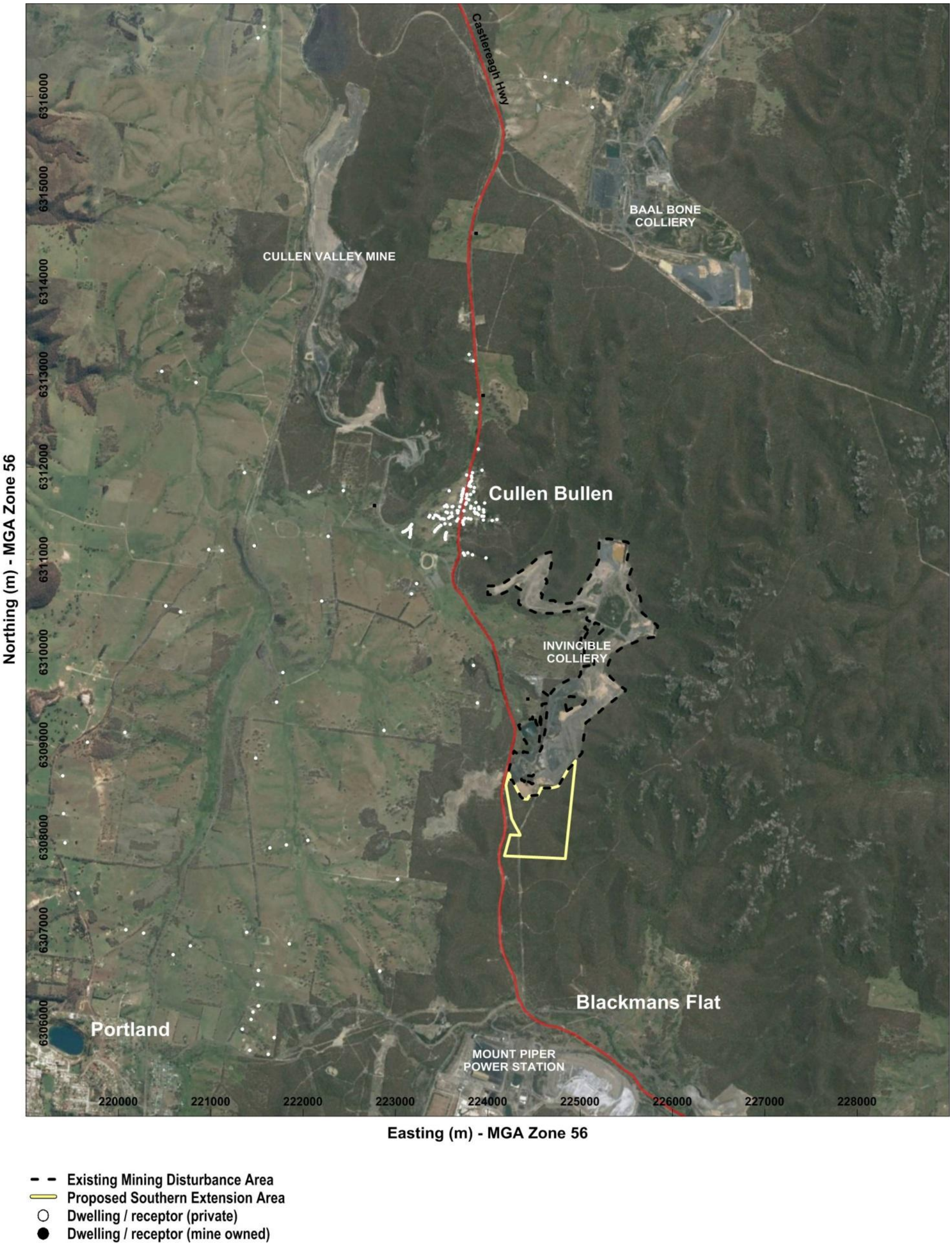

Figure 1 The Project

Figure 2 shows a three-dimensional representation of the local terrain. A key feature of the area is the Ben Bullen State Forest, which bounds Invincible to the north, east and south. The terrain in this area rises to over 1,000 metres above sea-level. These topographical features are important for influencing the local meteorological conditions which are discussed in more detail in **Section 5.1**.

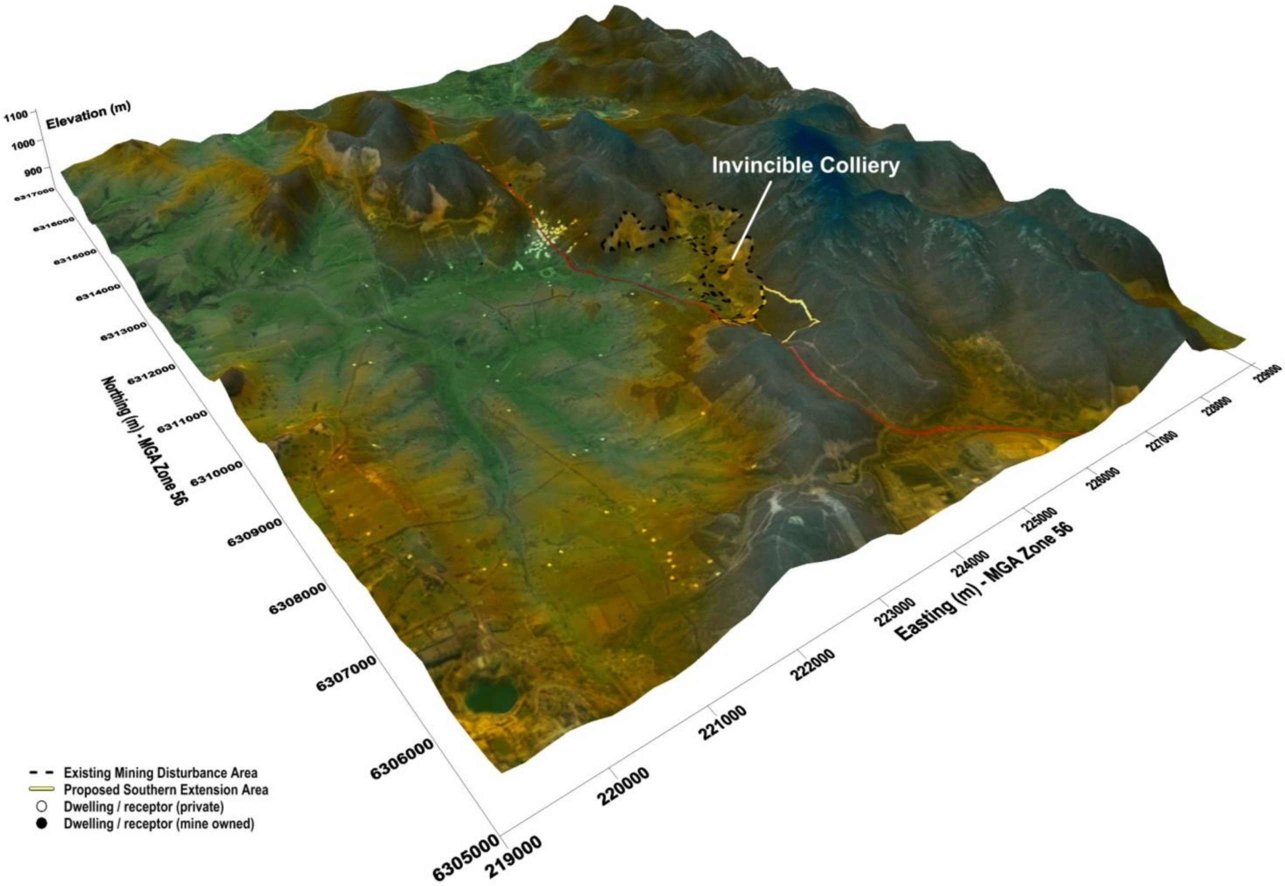

Figure 2 Three-dimensional representation of the local terrain

3. Air Quality Issues

Air quality issues can arise when emissions from an industry or activity lead to a deterioration in the ambient air quality. Potential air quality issues have been identified from a review of the Project and associated activities. This identification process has considered the types of emissions to air and proximity of these emission sources to sensitive receptors.

Emissions to air would be from a variety of activities including material handling, material transport, processing, and wind erosion. These emissions would mainly comprise of particulate matter (TSP, PM_{10} and $PM_{2.5}$) although there would be relatively minor emissions from machinery exhausts such as carbon monoxide (CO), oxides of nitrogen (NO_x) and particulate matter.

In summary, the potential air quality issues associated with the proposed mining activities have been identified as:

- Dust (that is, particulate matter in the form of TSP, deposited dust, PM_{10} or $PM_{2.5}$) from the general mining activities; and
- Emissions of substances from machinery exhausts, that is, diesel exhaust emissions.

The issues identified above are the focus of this assessment.

4. Air Quality Criteria

Air quality is typically quantified by the concentrations of air pollutants in the ambient air, where an air pollutant is a substance that is known to cause health, nuisance and/or environmental effects. With regard to human health and nuisance effects, the air pollutants most relevant to the Project would be particulate matter emissions from blasting, excavation works and material handling and processing activities, as identified in **Section 3**.

There are various classifications of particulate matter with State regulatory authorities often providing standards, goals, objectives, criteria or targets for:

- Total suspended particulates (TSP), to protect against nuisance amenity impacts;
- Particulate matter with equivalent aerodynamic diameter less than or equal to 10 microns (PM_{10}), to protect against health impacts;
- Particulate matter with equivalent aerodynamic diameter less than or equal to 2.5 microns ($PM_{2.5}$), to protect against health impacts; and
- Deposited dust, to protect against nuisance amenity impacts.

The EPA has set air quality criteria for many air pollutants including those listed above. Most of the EPA criteria are drawn from national standards for air quality set by the National Environmental Protection Council of Australia (NEPC) as part of the National Environment Protection Measures (NEPM). To measure compliance with ambient air quality criteria, the Office of Environment and Heritage (OEH) has established a network of monitoring stations across the State and up-to-date records are published on the OEH website.

Air quality impacts from the Project are determined by the level of compliance with the air quality criteria set by the EPA as part of their "Approved Methods for the Modelling and Assessment of Air Pollutants in NSW" (DEC, 2005). These criteria, including the NEPM advisory reporting standards for $PM_{2.5}$, are outlined in **Table 1** and apply to existing and potential sensitive receptors such as such as residences and schools in vicinity of the Project.

The EPA air quality assessment criteria relate to the total concentration of pollutant in the air (that is, cumulative) and not just the contribution from project-specific sources. Therefore, consideration of background levels needs to be made when using these criteria to assess impacts. Further discussion of background levels in the study area is provided in **Section 5.2**.

Table 1 Relevant air quality assessment criteria

Substance	Averaging time	Criterion	Reference
Particulate matter (PM_{10})	24-hour	50 µg/m^3	EPA
	Annual	30 µg/m^3	EPA
Particulate matter ($PM_{2.5}$)	24-hour	25 µg/m^3	NEPM Advisory Reporting Goal
	Annual	8 µg/m^3	NEPM Advisory Reporting Goal
Particulate matter (TSP)	Annual	90 µg/m^3	EPA
Deposited dust	Annual (maximum increase)	2 g/m^2/month	EPA
	Annual (maximum total)	4 g/m^2/month	EPA
Nitrogen dioxide (NO_2)	1-hour	246 µg/m^3	EPA
	Annual	62 µg/m^3	EPA

At the time of this assessment, the NEPM Advisory Reporting Goals for $PM_{2.5}$ had not been adopted by the EPA for assessment of impacts from specific projects. In addition, these goals are intended to apply to the average, or general exposure of a population, rather than to "hot spot" locations.

In December 2015 the Australian Government announced a National Clean Air Agreement (Agreement). This Agreement aims to reduce air pollution and improve air quality with the relevant key action including:

- Strengthened ambient air quality reporting standards for particle pollution. Specifically, *"Taking into account the latest scientific evidence of health impacts, Ministers agreed to strengthen national ambient air quality reporting standards for airborne fine particles. Ministers agreed to adopt reporting standards for annual average and 24-hour $PM_{2.5}$ particles of 8 µg/m^3 and 25 µg/m^3 respectively, aiming to move to 7 µg/m^3 and 20 µg/m^3 respectively by 2025. Ministers also agreed to establish an annual average standard for PM_{10} particles of 25 µg/m^3. Victoria and the Australian Capital Territory will set, and South Australia will consider setting, a more stringent annual average PM_{10} standard of 20 µg/m^3 in the state, while ensuring nationally consistent monitoring and reporting against the agreed National Environment Protection Measure standards. The decision was also taken to review PM_{10} standards in 2018. The review will be co-led by the NSW and Victorian governments, in discussion with other jurisdictions."*

On 25 February 2016 an amendment to the NEPM entered into force and introduced the new national air quality standards for PM_{10} and $PM_{2.5}$, as noted above. While all jurisdictions have agreed to this action, no States (including the NSW EPA or the Department of Planning and Environment) have prescribed a change to their air quality criteria to be used for the assessment of specific projects. As such the criteria in **Table 1** remain current for the assessment of potential Project impacts. The Agreement indicates an initial work plan of two years to progress the actions.

The NSW Voluntary Land Acquisition and Mitigation Policy (2014) includes the NSW Government's policy for voluntary mitigation and land acquisition to address dust (particulate matter) impacts from state significant mining, petroleum and extractive industry developments.

From this Policy, voluntary mitigation rights may apply where, even with best practice management, the development contributes to exceedences of the criteria in **Table 2** at any residence or workplace.

Table 2 Mitigation criteria for particulate matter

Substance	Averaging time	Mitigation criterion	Impact type
Particulate matter (PM_{10})	Annual	30 µg/m^3*	Human health
	24-hour	50 µg/m^3**	Human health
Particulate matter (TSP)	Annual	90 µg/m^3*	Amenity
Deposited dust	Annual	2 g/m^2/month**	Amenity
	Annual	4 g/m^2/month*	Amenity

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

*** Incremental impact (i.e. increase in concentrations due to the development alone).*

Voluntary acquisition rights may apply where, even with best practice management, the development contributes to exceedances of the criteria in **Table 3** at any residence or workplace on privately owned land, or on more than 25% of any privately owned land where there is an existing dwelling or where a dwelling could be built under existing planning controls.

Table 3 Acquisition criteria for particulate matter

Substance	Averaging time	Acquisition criterion	Impact type
Particulate matter (PM_{10})	Annual	30 µg/m^3*	Human health
	24-hour	50 µg/m^3**	Human health
Particulate matter (TSP)	Annual	90 µg/m^3*	Amenity
Deposited dust	Annual	2 g/m^2/month**	Amenity
	Annual	4 g/m^2/month*	Amenity

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

*** Incremental impact (i.e. increase in concentrations due to the development alone).*

The particulate matter levels for comparison with the criteria in **Table 2** and **Table 3** must be calculated in accordance with the EPA's "Approved Methods for the Modelling and Assessment of Air Pollutants in NSW" (DEC, 2005).

5. Existing Environment

This section provides a description of the environmental characteristics in the area, including a review of the local meteorological and ambient air quality conditions. The review considers data collected from existing meteorological and air quality monitoring stations, the locations of which are shown below in **Figure 3**. One of the objectives for reviewing these data was to identify any existing air quality issues as well as the meteorological conditions which typically influence the local air quality conditions.

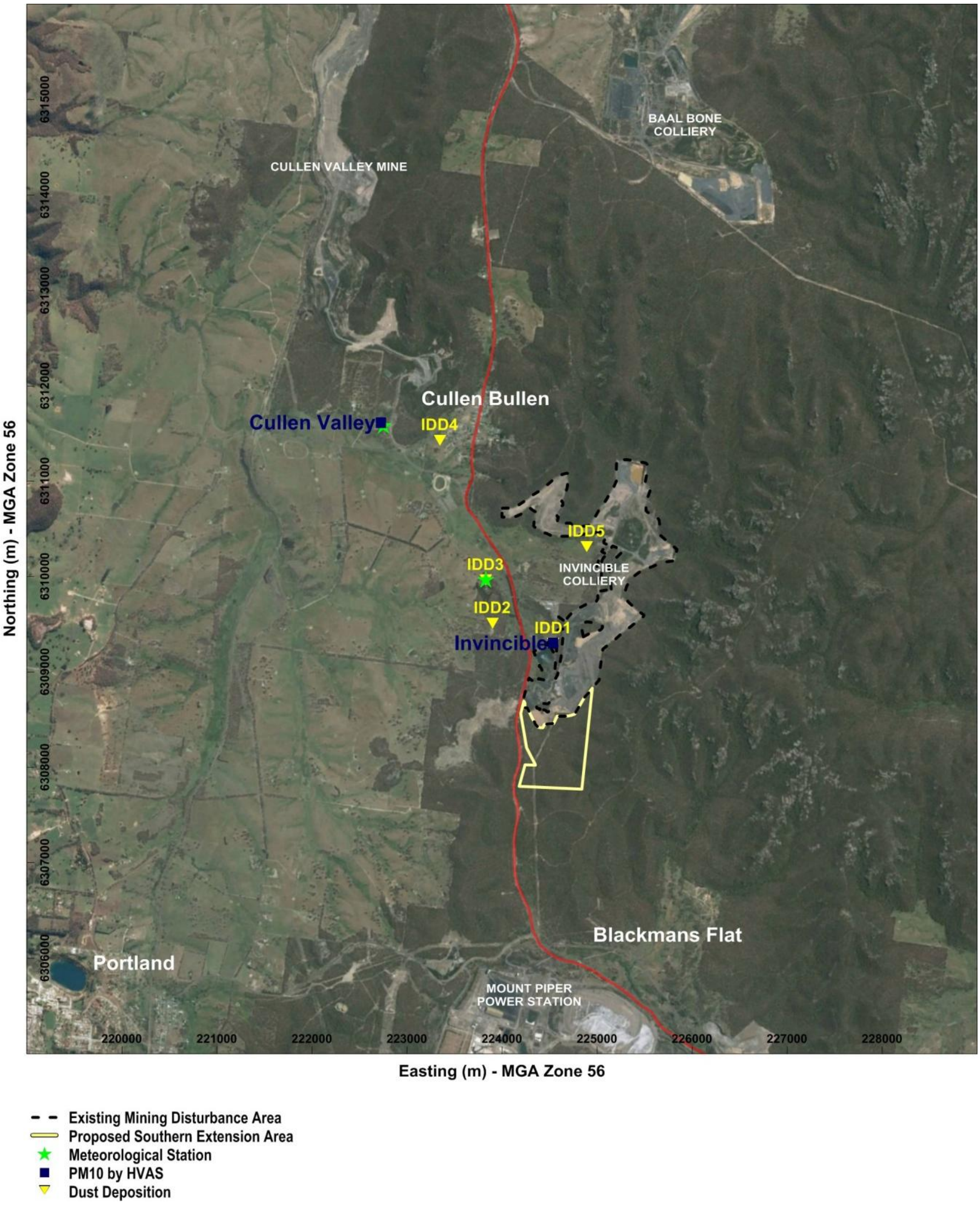

Figure 3 Location of meteorological and air quality monitoring sites

5.1 Meteorological Conditions

Meteorological conditions are important for determining the direction and rate at which emissions from a source will disperse. The key meteorological requirements of air dispersion models are, typically, hourly records of wind speed, wind direction, temperature, atmospheric stability class and mixing layer height. For air quality assessments, a minimum one year of hourly data is usually required, which means that almost all possible meteorological conditions, including seasonal variations, are considered in the model simulations.

There are two relevant meteorological stations; one at Invincible and one at Cullen Valley Mine, the locations of which are shown in **Figure 3**. Meteorological data collected between 2013 and 2016 have been analysed in order to identify a representative year for the modelling. Hourly records of temperature, wind speed and wind direction were obtained, among other parameters. The procedure for identifying a representative meteorological year involved checking for available data, and comparing wind patterns across several years.

Table 4 shows the meteorological data availability. There was 100 per cent data availability for both meteorological stations in 2014.

Table 4 Data availability from the meteorological stations

Year	Invincible meteorological station	Cullen Valley meteorological station
2013	8%	64%
2014	100%	100%
2015	93%	100%
2016	9%	11%

Figure 4 and **Figure 5** show the annual and seasonal wind patterns for Invincible and Cullen Valley Mine respectively, based on data collected in 2014. It can be seen from these wind-roses that, at the Invincible meteorological station, the most common winds in the area are from the northeast and southwest. At the Cullen Valley Mine meteorological station this northeast / southwest pattern is also evident but to a lesser degree with some winds from other sectors also measured, and generally of lighter strength. The wind-patterns for 2014 are also similar to the wind-patterns presented by Pacific Environment (PEL 2014) for data collected at these two stations in 2009 and 2010.

The 2014 calendar year has been selected as the meteorological modelling year. Methods used for incorporating the 2014 data into meteorological modelling (CALMET) and air dispersion modelling (CALPUFF) are discussed in detail in **Section 7**.

Figure 4 Wind-roses for data collected at Invincible meteorological station (2014 data)

Figure 5 Wind-roses for data collected at Cullen Valley mine meteorological station (2014 data)

5.2 Air Quality Conditions

The EPA air quality criteria refer to levels of substances which generally include the Project and existing sources, not just the contribution from local mining activities. To fully assess impacts against all the relevant air quality criteria (see **Section 4**) it is necessary to have information or estimates on the existing air quality conditions. This section provides a description of the existing air quality.

Figure 3 shows the location of monitors which are used to collect information on the existing air quality. The monitoring includes the measurement of particulate matter (as PM_{10}) by high volume air samplers and dust deposition by dust deposition gauges. Concentrations of TSP and $PM_{2.5}$ have not been measured in the region shown by **Figure 3** therefore some estimation of existing levels has been required, based on measured PM_{10} levels.

Measurement data represent the contributions from all sources that have at some stage been upwind of each monitor. In the case of particulate matter (as PM_{10}) for example, the background concentration may contain emissions from many sources such as from mining activities, construction works, bushfires and ‘burning off’, industry, vehicles, roads, wind-blown dust from nearby and remote areas, fragments of pollens, moulds, and so on.

5.2.1 Particulate Matter (as PM_{10})

Concentrations of PM_{10} have been measured at two locations by high volume air samplers, operating on a six day cycle.

Figure 6 shows the measured 24-hour average PM_{10} concentrations from each monitoring site for data collected between 2009 and 2015. The EPA’s short-term air quality assessment criteria for PM_{10} (50 µg/m^3) has also been shown on these graphs. It can be seen from this figure that, in most years, no exceedances of the 50 µg/m^3 criterion were recorded at either site. In 2009 the Invincible monitor recorded four days above 50 µg/m^3 but it is noted that the dust storms in the later part of 2009 also influenced these measurements. There is a seasonal variation in the air quality conditions, with concentrations typically higher in the warmer months.

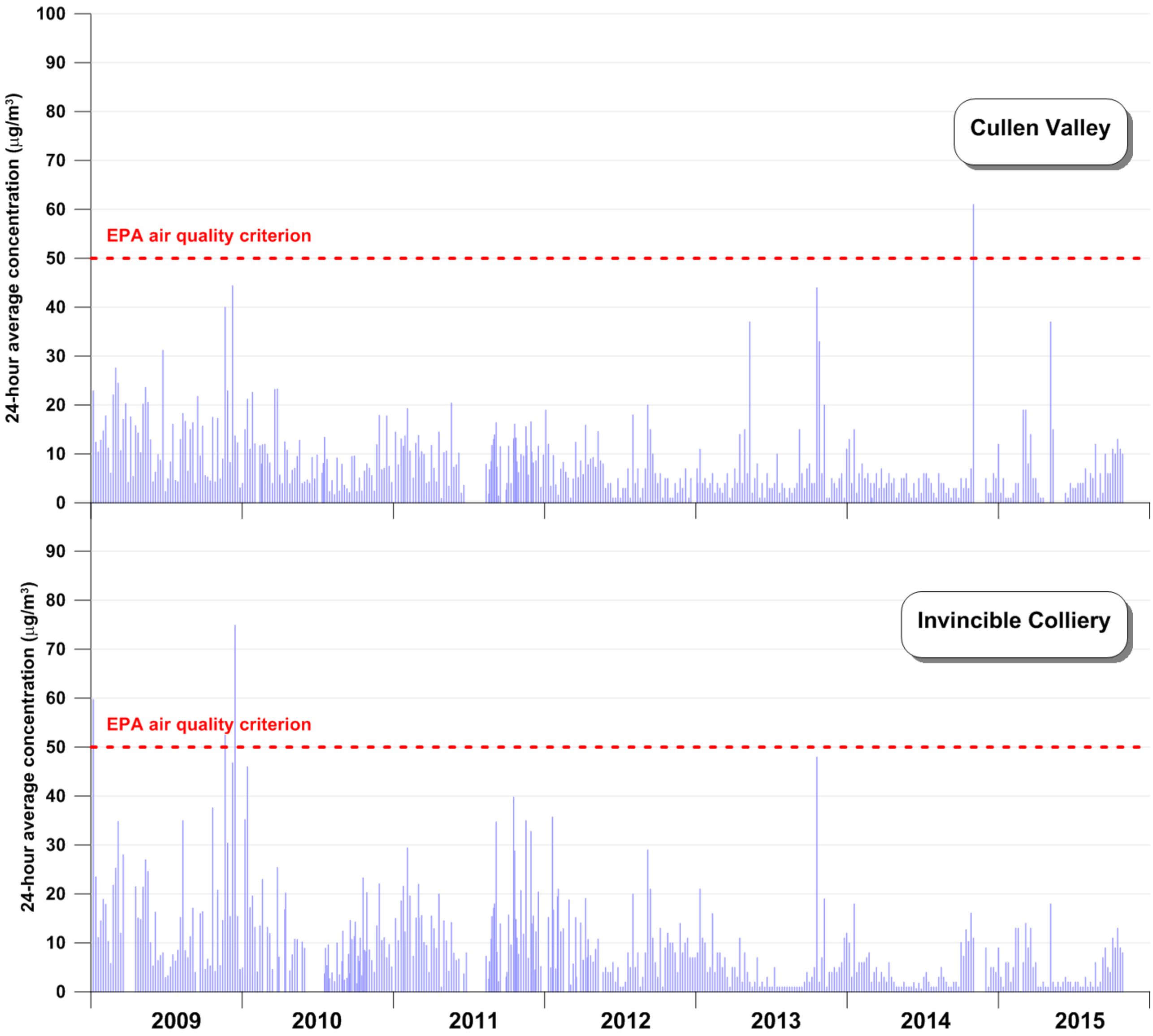

Figure 6 Measured 24-hour average PM_{10} concentrations

Table 5 summarises the measured PM_{10} concentration data for each site and for 24-hour and annual average periods, for comparison with the respective EPA criteria. Annual average PM_{10} concentrations have been below the 30 µg/m^3 criterion when excluding the September 2009 dust storm influence.

Table 5 Summary of measured PM_{10} concentrations

Year	Invincible HVAS	Cullen Valley Mine HVAS	Criterion
Maximum 24-hour average in µg/m^3			
2009	1330	44	50
2010	46	23	
2011	40	20	
2012	36	20	
2013	48	44	
2014	18	61	
2015	18	37	
Number of days above 24-hour average criteria. Note that the high volume samplers collect data up to around 60 days per year			
2009	4	0	5 (NEPM)
2010	0	0	
2011	0	0	
2012	0	0	
2013	0	0	
2014	0	1	
2015	0	0	
Annual average in µg/m^3			
2009	41 (18 without dust storm record)	14	30
2010	11	8	
2011	13	9	
2012	9	6	
2013	5	7	
2014	4	5	
2015	5	7	

5.2.2 Particulate Matter (as $PM_{2.5}$)

Delata Electricity has historically measured $PM_{2.5}$ concentrations at Blackmans Flat and Wallerawang, to the south of the Project. Data for 2010 have been presented by Delta Electricity (2011). There are no other known air quality monitoring stations in the vicinity of Invincible which record concentrations of $PM_{2.5}$. The OEH do however monitor $PM_{2.5}$ in the Hunter Valley at Camberwell, Singleton, and Muswellbrook as part of the Upper Hunter Air Quality Monitoring Network (UHAQMN). These stations use Beta Attenuation Monitors (BAM) for the measurement of $PM_{2.5}$. Recent data from these stations have also been reviewed to gain an understanding of possible levels that may currently be experienced in the vicinity of the Project, noting any differences in sources between the two regions.

Table 6 shows the measured $PM_{2.5}$ results for the Blackmans Flat, Wallerawang and Hunter Valley monitoring sites for data collected between 2010 and 2015. It can be seen from these data that the highest 24-hour average $PM_{2.5}$ concentrations have exceeded the 25 µg/m^3 advisory reporting goal on at least one occasion in the past six years. Annual averages are close to the 8 µg/m^3 advisory reporting goal, exceeding the goal in some years. Bushfire activity between September and November of 2013 was identified as a major cause of the elevated particulate matter concentrations in this year. The Camberwell, Singleton and Muswellbrook monitoring sites are located closer to more sources of $PM_{2.5}$ than found in the vicinity of the Project. Such sources include motor vehicles and wood smoke. The $PM_{2.5}$ concentrations in the vicinity of the Project would therefore be expected to be lower than those measured in the Hunter Valley. For the Project area, Pacific Environment has previously (PEL 2014) estimated an annual average $PM_{2.5}$ concentration of 5 µg/m^3, based on $PM_{2.5}$ to PM_{10} ratios. This approach has been adopted for the current assessment.

Table 6 Summary of measured $PM_{2.5}$ concentrations

Year	Blackmans Flat / Wallerawang	Camberwell (OEH)	Singleton (OEH)	Muswellbrook (OEH)	Advisory Reporting Goal
Maximum 24-hour average in µg/m^3					
2010	29	-	-	-	25
2011	-	23*	22	28	
2012	-	20	20	26	
2013	-	30	23	37	
2014	-	32	29	27	
2015	-	24	25	31	
Number of days above 24-hour average criteria					
2010	2	-	-	-	-
2011	-	0*	0	4	
2012	-	0	0	3	
2013	-	1	0	1	
2014	-	1	1	3	
2015	-	0	0	3	
Annual average in µg/m^3					
2011	-	8.5*	7.6	9.1	8
2012	-	7.5	8.0	10.1	
2013	-	8.2	7.9	9.4	
2014	-	7.8	7.8	9.7	
2015	-	7.2	7.6	8.7	

** Partial dataset. Monitoring commenced at this location in late 2011.*

5.2.3 Particulate Matter (as TSP)

TSP concentrations have not been measured in the vicinity of the Project. Annual average TSP concentrations have been estimated from the PM_{10} measurements by assuming that 40% of the TSP is PM_{10}. This relationship was obtained from data collected by co-located TSP and PM_{10} monitors operated for long periods of time in the Hunter Valley (NSW Minerals Council, 2000). Use of this relationship indicates that the annual average TSP concentration is approximately 26 µg/m^3 which is well below the EPA annual average assessment criterion of 90 µg/m^3.

5.2.4 Deposited Dust

Table 7 shows the annual average deposited dust levels for each gauge from data collected in the past eight years. **Figure 3** shows the location of the monitoring sites. The results in **Table 7** can be compared with the EPA's 4 g/m^2/month criterion. Contaminated monthly samples were excluded from the calculation of these annual averages.

Table 7 Summary of measured deposited dust levels

Year	DM1	DM2	DM3	DM4	DM5	Criterion
Annual average expressed as g/m^2/month						
2008	1.2	0.6	0.7	0.7	0.8	4
2009	1.5	1.1	1.4	1.2	1.5	
2010	1.7	0.7	0.7	0.4	1.1	
2011	1.1	0.7	0.4	0.4	0.7	
2012	1.0	1.1	0.5	0.4	0.9	
2013	0.6	0.5	0.4	0.3	0.5	
2014	0.5	0.6	0.9	0.5	17.6	
2015	0.5	0.5	0.4	0.5	1.0	

It can be seen from **Table 7** that one location (DM5) experienced a deposition level above the EPA's 4 g/m^2/month criterion in 2014. No other monitors have measured deposition levels above 4 g/m^2/month. The average from all years of data and from all sites was 1.2 g/m^2/month.

5.2.5 Nitrogen Dioxide (NO_2)

Delta Electricity has historically measured NO_x and NO_2 concentrations at Blackmans Flat and Wallerawang, to the south of the Project. Data for 2001 have been presented by SKM (2009) and Delta Electricity (2011). There are no other known nearby air quality monitoring stations which measure NO_2. **Table 8** provides a summary of the measured NO_2 concentrations from the Blackmans Flat and Wallerawang sites as well as two OEH monitoring sites in the Hunter Valley; Singleton and Muswellbrook. These data show that the maximum NO_2 concentrations have been well below the EPA's 1-hour average criterion of 246 $\mu g/m^3$. Annual averages have also been well below the EPA's annual average criterion of 62 $\mu g/m^3$. On average, the measurements from Singleton and Muswellbrook are higher than the historical levels measured at Blackmans Flat and Wallerawang and are therefore conservative estimates of NO_2 concentrations in the vicinity of the Project.

Table 8 Summary of measured NO_2 concentrations

Year	Blackmans Flat	Wallerawang	Singleton (OEH)	Muswellbrook (OEH)	Criterion
Maximum 1-hour average in $\mu g/m^3$					
2001	79	59	-	-	246
2008	62 (maximum of two sites)		-	-	
2009	62 (maximum of two sites)		-	-	
2010	103 (maximum of two sites)		-	-	
2012	-	-	82	90	
2013	-	-	84	86	
2014	-	-	74	80	
2015	-	-	66	86	
Annual average in $\mu g/m^3$					
2001	10	10	-	-	62
2012	-	-	18	21	
2013	-	-	18	18	
2014	-	-	16	21	
2015	-	-	16	18	

5.3 Assumed Background Levels

One of the objectives for reviewing the air quality monitoring data was to determine appropriate background levels to be added to model predictions for the assessment of potential cumulative impacts, that is, mining contribution plus non-mining contribution. The estimated background levels that apply at sensitive receptors are shown below in **Table 9**. These levels (or approach adopted) have been added to model predictions to determine the potential cumulative impacts.

Table 9 Assumed non-modelled background levels that apply at sensitive receptors

Substance	Averaging time	Assumed background level that applies at sensitive receptors	Notes
Particulate matter (PM_{10})	24-hour	23 µg/m^3	95th percentile of Invincible and Cullen Valley PM_{10} monitoring data for 2009 to 2015.
Particulate matter (PM_{10})	Annual	10 µg/m^3	Average of Invincible and Cullen Valley PM_{10} monitoring data for 2009 to 2015.
Particulate matter ($PM_{2.5}$)	24-hour	11 µg/m^3	Estimated from 24-hour PM_{10}.
	Annual	5 µg/m^3	Estimated from annual PM_{10}.
Particulate matter (TSP)	Annual	26 µg/m^3	Estimated from PM_{10}, assuming 40% of TSP is PM_{10}.
Deposited dust	Annual	1.2 g/m^2/month	Average of Invincible dust deposition monitoring data for 2008 to 2015.
Nitrogen dioxide (NO_2)	1-hour	90 µg/m^3	Maximum measured value from Singleton and Muswellbrook.
	Annual	21 µg/m^3	Maximum measured value from Singleton and Muswellbrook.

6. Emissions to Air

The most significant emission to air from the Project will be dust (particulate matter) due to material handling, material transport, processing, wind erosion, and blasting. Estimates of these emissions are required by the dispersion model. Total dust emissions have been estimated by analysing the material handling schedule, equipment listing and mine plans and identifying the location and intensity of dust generating activities. Operations have been combined with emissions factors developed both locally and by the US EPA.

The emission factors used for this assessment have been drawn largely from the following sources:

- *Emission Estimation Technique Manual for Mining* (NPI, 2012);
- AP 42 (US EPA, 1985 and updates); and
- ACARP Project C22027 (ACARP 2015).

A dust emission inventory has been developed for a worst-case scenario. Specifically, the stage plan for Year 2, where haul distances are near their longest, has been combined with the maximum proposed production of 1.2 Mt ROM coal and overburden handling volume of 4.2 million bank cubic metres (Mbcm). This scenario has been developed to simulate the potential worst-case air quality impacts at nearest sensitive receptors which may occur over the proposed life of the Project.

Table 10 shows the estimated annual TSP, PM_{10} and $PM_{2.5}$ emissions due to the Project for the potential worst case operations assuming maximum production of 1.2 Mtpa. It can be seen from these estimates that haulage over unsealed roads is estimated to be the most significant source of dust. **Appendix A** provides details of the dust emission calculations, including assumptions, emission controls and allocation of emissions to modelled locations.

Table 10 Estimated particulate matter emissions due to the Project

Activity	Annual emissions for Project at maximum production (kg/y)		
	TSP	PM_{10}	$PM_{2.5}$
Stripping topsoil by dozer	10376	2526	1089
Drilling overburden	9204	4786	276
Blasting overburden	28600	14872	858
Excavators loading overburden to trucks	7769	3674	556
Hauling overburden from pit to dump	93865	27738	2816
Unloading overburden to dump	7769	3674	556
Dozers shaping overburden	20752	5052	2179
Dozers working on overburden for rehabilitation	20752	5052	2179
Drilling coal	9204	4786	276
Blasting coal	28600	14872	858
Dozers working on coal	24812	7909	546
Loading ROM coal to trucks	57399	8255	1091
Hauling ROM coal from pit to hopper / ROM pad	30039	8877	901
Unloading ROM coal to ROM pad	12000	5040	228
ROM coal rehandle to hopper	1200	504	23
Transferring ROM coal to CHPP or crusher	177	84	13
Coal crushing and loading stockpiles	4460	1896	95
Handling coal at CHPP	19	9	0
Dozers on ROM coal stockpiles	12406	3955	273
Dozers on product coal stockpiles	5305	1529	117
Conveyer to product stockpiles	8	4	1

Activity	Annual emissions for Project at maximum production (kg/y)		
	TSP	PM_{10}	$PM_{2.5}$
Loading product coal to trucks	480	204	24
Wind erosion from active pits	12735	6367	955
Wind erosion from active dumps	16705	8353	1253
Wind erosion from partially rehabilitated dumps	21144	10572	1586
Wind erosion from ROM coal stockpiles	388	194	29
Wind erosion from product coal stockpile	974	487	73
Grading roads	4884	1727	54
Total	**442,025**	**152,997**	**18,904**

7. Approach to Assessment

7.1 Overview

This assessment has followed the EPA's "Approved Methods of the Modelling and Assessment of Air Pollutants in New South Wales" (DEC, 2005), which specifies how assessments based on the use of air dispersion models should be undertaken. The "Approved Methods" include guidelines for the preparation of meteorological data, reporting requirements and air quality assessment criteria to assess the significance of dispersion model predictions.

The CALPUFF computer-based air dispersion model has been used to predict ground-level concentrations and deposition levels due to the identified emission sources, and the model predictions have been compared with relevant air quality criteria. The choice of model has considered the expected transport distances for the emissions, as well as the potential for temporally and spatially varying flow fields due to influences of the locally complex terrain, non-uniform land use, and potential for stagnation conditions characterised by calm or very low wind speeds with variable wind directions.

The CALPUFF model, through the CALMET meteorological processor, simulates complex meteorological patterns that exist in a particular region. The effects of local topography and changes in land surface characteristics are accounted for by this model. The model comprises meteorological modelling as well as dispersion modelling, both of which are described below.

7.2 Meteorological Modelling

The air dispersion model used for this assessment, CALPUFF, requires information on the meteorological conditions in the modelled region. This information is typically generated by the meteorological pre-processor, CALMET, using surface observation data from local weather stations and upper air data from radio-sondes or numerical models, such as the CSIRO's prognostic model known as TAPM (The Air Pollution Model). CALMET also requires information on the local land-use and terrain. The result of a CALMET simulation is a year-long, three-dimensional output of meteorological conditions that can be used as input to the CALPUFF air dispersion model.

There are no known meteorological stations in the vicinity of the Project that collect suitable upper air data for CALMET. The necessary upper air data were therefore generated by TAPM, using influence from the surface observations at the Invincible meteorological station. CALMET was then set up with two surface observations stations (Invincible and Cullen Valley Mine) and one upper air station (based on TAPM output for the Invincible site). The meteorological modelling followed the guidance of TRC (2011) and adopted the "observations" mode.

Key model settings for TAPM are shown below in **Table 11**.

Table 11 Model settings and inputs for TAPM

Parameter	Value(s)
Model version	4.0.5
Number of grids (spacing)	4 (30 km, 10 km, 3 km, 1 km)
Number of grids point	35 x 35 x 25
Year(s) of analysis	2014, with one "spin-up" day.
Centre of analysis	Invincible (33°19' S, 151°2' E)
Terrain data source	Default
Land use data source	Default
Meteorological data assimilation	Invincible meteorological station. Radius of influence = 10 km. Number of vertical levels for assimilation = 4

Table 12 lists the model settings and input data for CALMET.

Table 12 Model settings and inputs for CALMET

Parameter	Value(s)
Model version	6.334
Terrain data source(s)	SRTM and Project DEM
Land-use data source(s)	Digitized from aerial imagery
Meteorological grid domain	10 km x 12 km
Meteorological grid resolution	0.2 km
Meteorological grid dimensions	50 x 60 x 9
Meteorological grid origin	219000 mE, 6305000 mN
Surface meteorological stations	Invincible meteorological station - Observations of wind speed, wind direction, temperature and humidity - TAPM for ceiling height, cloud cover and air pressure. Cullen Valley mine meteorological station - Observations of wind speed and wind direction
Upper air meteorological stations	Invincible meteorological station - Upper air data file for the location of Invincible derived by TAPM - Biased towards surface observations (-1, -0.8, -0.6, -0.4, -0.2, -0.1, 0, 0, 0)
Simulation length	8760 hours (1 Jan 2014 to 31 Dec 2014)
R1, R2	0.5, 1
RMAX1, RMAX2	5, 20
TERRAD	3

Terrain information was extracted from the NASA Shuttle Research Topography Mission database which has global coverage at approximately 90 metre resolution (in addition to the Project DEM). Land use data were extracted from aerial imagery. **Figure 7** shows the model grid, land-use and terrain information, as used by CALMET. It is noted that the extent of some land-uses will change over time, such as mining areas, however the model has been tested and changes from grassland to barren land (i.e. mining areas) were found to have very little influence on the modelling results.

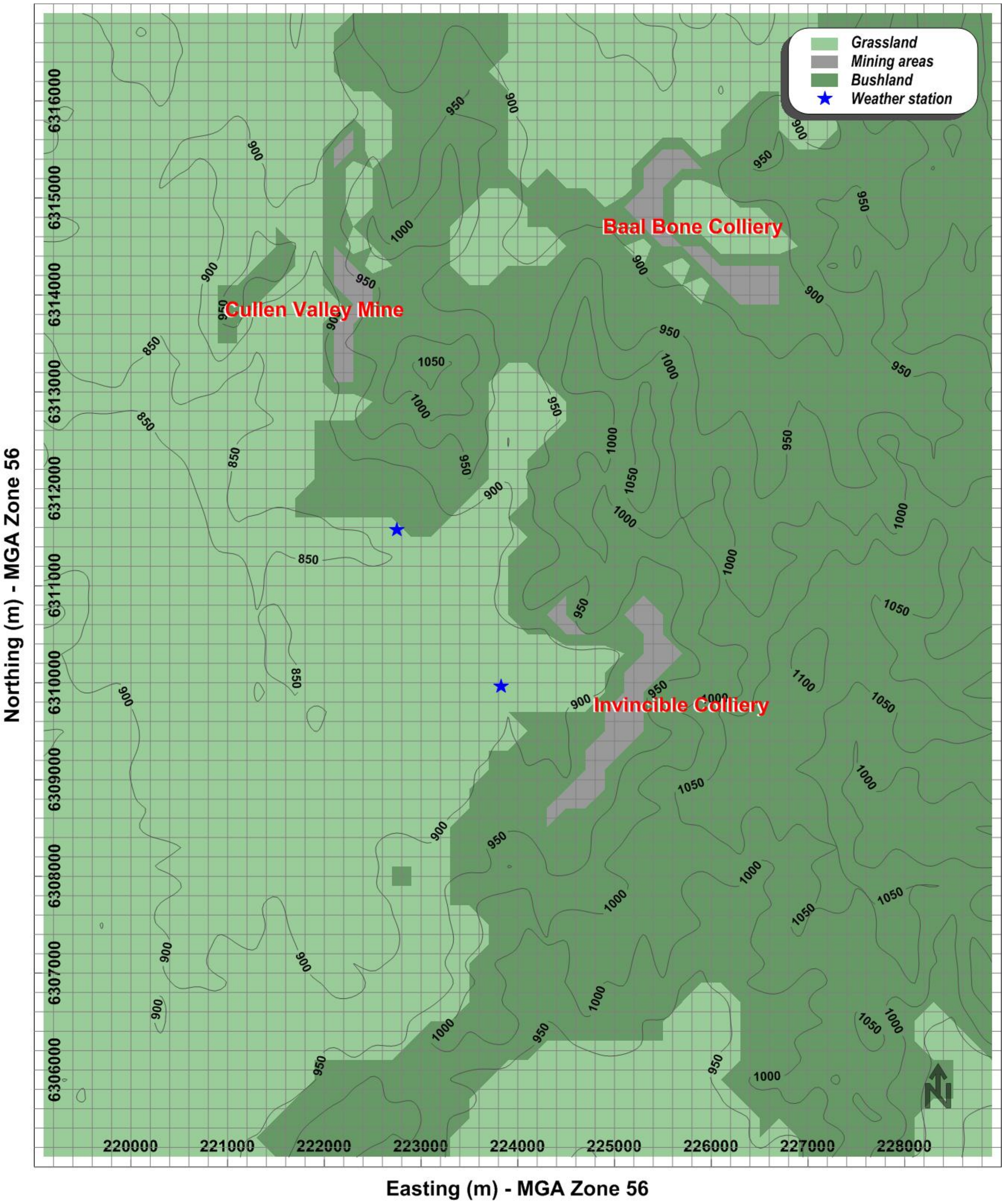

Figure 7 Model grid, land-use and terrain information

Figure 8 shows a snapshot of winds as simulated by the CALMET model under stable conditions. This plot shows the effect of the topography on local wind flows for this particular hour, and highlights the non-uniform wind patterns in the area.

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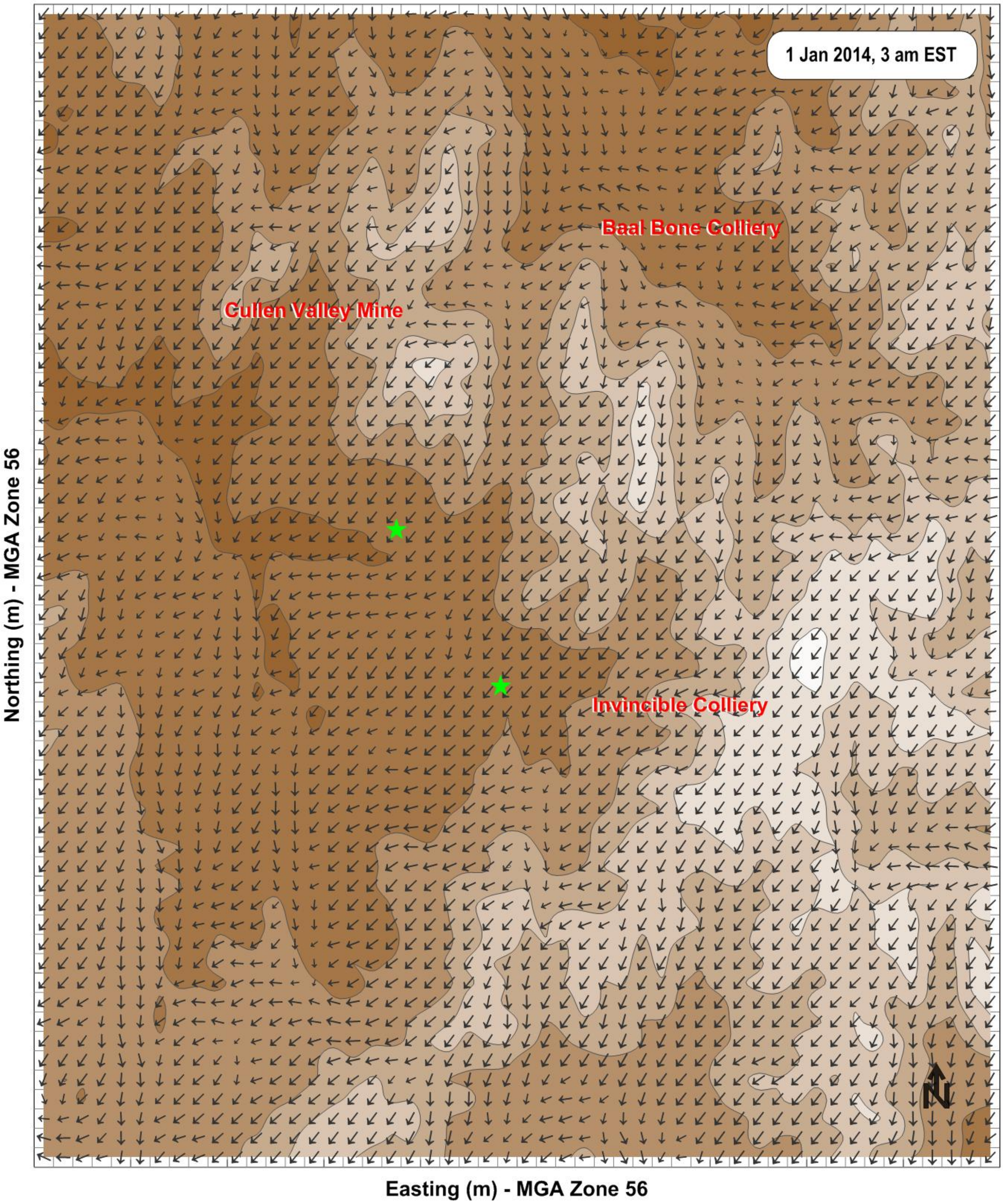

Figure 8 Example of CALMET simulated ground-level wind flows

7.3 Dispersion Modelling

Ground-level concentration and deposition levels due to the emission sources have been predicted using the air dispersion model known as CALPUFF (Version 6.42). CALPUFF is a Lagrangian dispersion model that simulates the dispersion of pollutants within a turbulent atmosphere by representing emissions as a series of puffs emitted sequentially. Provided the rate at which the puffs are emitted is sufficiently rapid, the puffs overlap and the serial release is representative of a continuous release.

The CALPUFF model differs from traditional Gaussian plume models (such as AUSPLUME and ISCST3) in that it can model spatially varying wind and turbulence fields that are important in complex terrain, long-range transport and near calm conditions. It is the preferred model of the United States Environmental Protection Agency for the long-range transport of pollutants and for complex terrain (TRC 2007). CALPUFF has the ability to model the effect of emissions entrained into the thermal internal boundary layer that forms over land, both through fumigation and plume trapping. CALPUFF is an air dispersion model which has been approved by the EPA for these types of assessments (DEC 2005).

The modelling was performed using the emission estimates from **Section 6** and using the meteorological information provided by the CALMET model, described in **Section 7.2**. Predictions were made at 717 discrete receptors, including sensitive receptors and monitoring locations, to allow for contouring of results. The list of receptors can be provided on request.

Mining operations were represented by a series of volume sources located according to the location of activities for the modelled scenario. **Figure 9** shows the location of the modelled sources for the Project in the conceptual stage of operations, where the emissions from the dust generating activities listed in **Table 10** were assigned to one or more of these source locations (refer to **Appendix A** for details of the allocations).

Dust emissions for all modelled mine-related sources have been considered to fit in one of three categories, as follows:

- Wind insensitive sources, where emissions do not vary with wind speed (for example, dozers, trucks etc).
- Wind sensitive sources, where emissions vary with the hourly wind speed, raised to the power of 1.3, a generic relationship published by the US EPA (1987). This relationship has been applied to sources such as loading and unloading of waste to/from trucks and results in increased emissions with increased wind speed.
- Wind sensitive sources, where emissions also vary with the hourly wind speed, but raised to the power of 3, a generic relationship published by Skidmore (1998). This relationship has been applied to sources including wind erosion from stockpiles, overburden dumps or active pits, and results in increased emissions with increased wind speed.

Emissions from each volume source were developed on an hourly time step, taking into account the level of activity at that location and, in some cases, the hourly wind speed. This approach ensured that light winds corresponded with lower dust generation and higher winds, with higher dust generation.

Activities were assumed to take place only between the hours of 7 am and 6 pm, except for wind erosion sources which were assumed to occur for 24 hours per day, and coal loading and transport operations (7 am to 10 pm). Activities were modelled for all days in the meteorological year, a conservative approach.

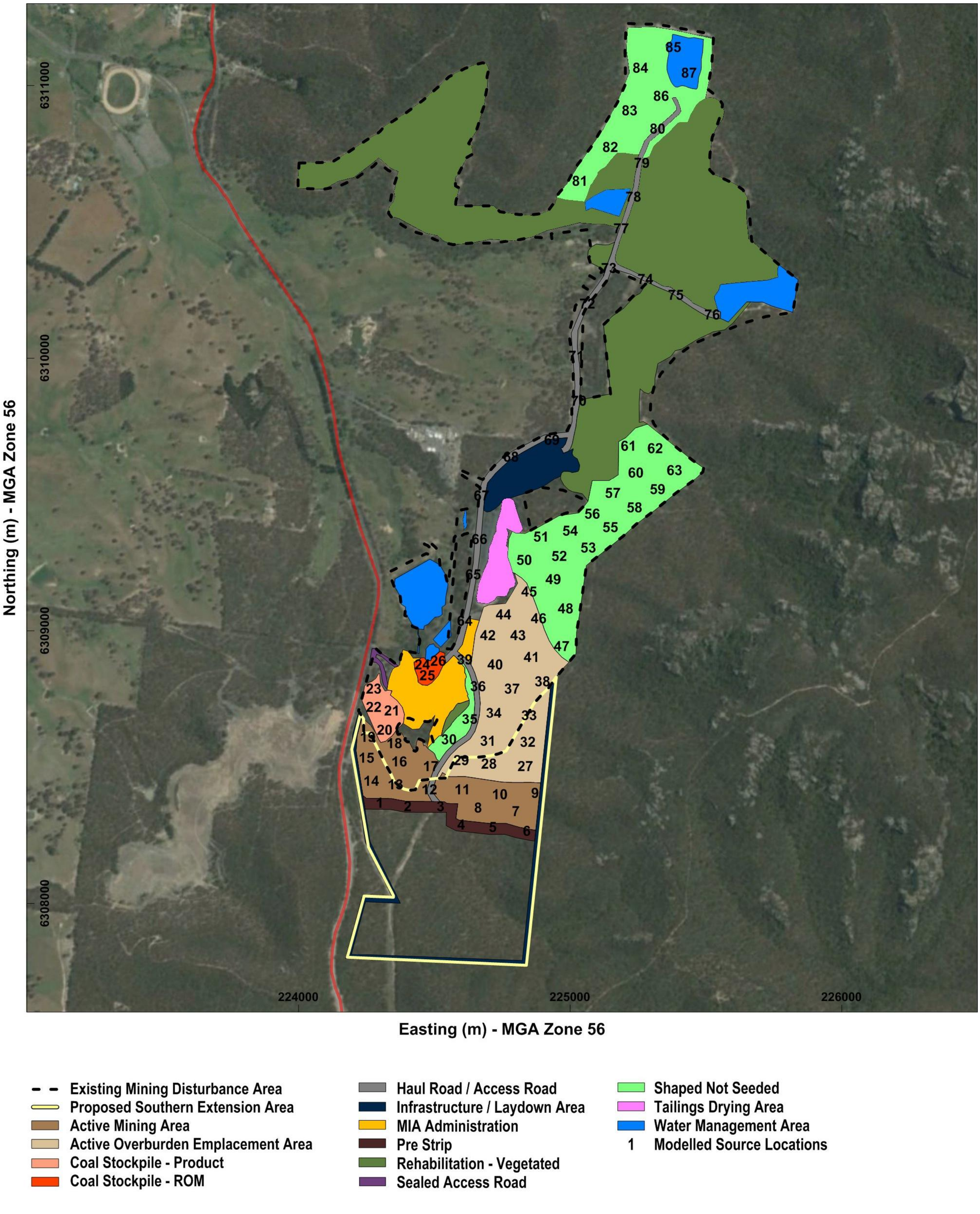

Figure 9 Location of modelled sources for worst-case operations at maximum production

Key model settings and inputs for CALPUFF are provided in **Table 13**.

Table 13 Model settings and inputs for CALPUFF

Parameter	Value(s)
Model version	6.42
Computational grid domain	50 x 60
Chemical transformation	None
Dry deposition	Yes
Wind speed profile	ISC rural
Puff element	Puff
Dispersion option	Turbulence from micrometeorology
Time step	3600 seconds (1 hour)
Terrain adjustment	Partial plume path
Number of volume sources	87. See Figure 9
Number of discrete receptors	717

Finally, the model predictions at identified sensitive receptors were then compared with the EPA air quality criteria, previously discussed in **Section 4**. Contour plots have also been created to show the spatial distribution of model predictions and Project contribution to local air quality.

8. Assessment of Impacts

This section provides an assessment of the key air quality issues associated with the Project, primarily based on model predictions and comparisons to air quality criteria. One objective of this study was to predict the extent of air quality impacts due to the Project, and to identify potential changes in air quality over existing levels. Contour plots have also been prepared and are discussed below.

8.1 Particulate Matter (as PM_{10})

Figure 10 shows the predicted maximum 24-hour average PM_{10} concentrations due to the Project with maximum production. The relevant criterion is 50 µg/m^3. This criterion is represented in **Figure 10** by the 27 µg/m^3 contour which takes into consideration the assumed maximum background levels of 23 µg/m^3. It can be seen from these results that the Project is not predicted to cause exceedances of the EPA's criterion at any off-site sensitive receptor location.

Figure 11 shows the predicted annual average PM_{10} concentrations due to the Project with maximum production. The relevant criterion is 30 µg/m^3. This criterion is represented in **Figure 11** by the 20 µg/m^3 contour which takes into consideration the assumed background levels of 10 µg/m^3. These results show that the Project will not cause exceedances of the EPA's criterion at any off-site sensitive receptor location.

Based on the model results, no off-site sensitive receptors are expected to experience PM_{10} concentrations above EPA criteria. This conclusion will not change as a result of the National Clean Air Agreement which proposes the establishment of an annual average standard for PM_{10} of 25 µg/m^3, which may replace the EPA's current criterion of 30 µg/m^3.

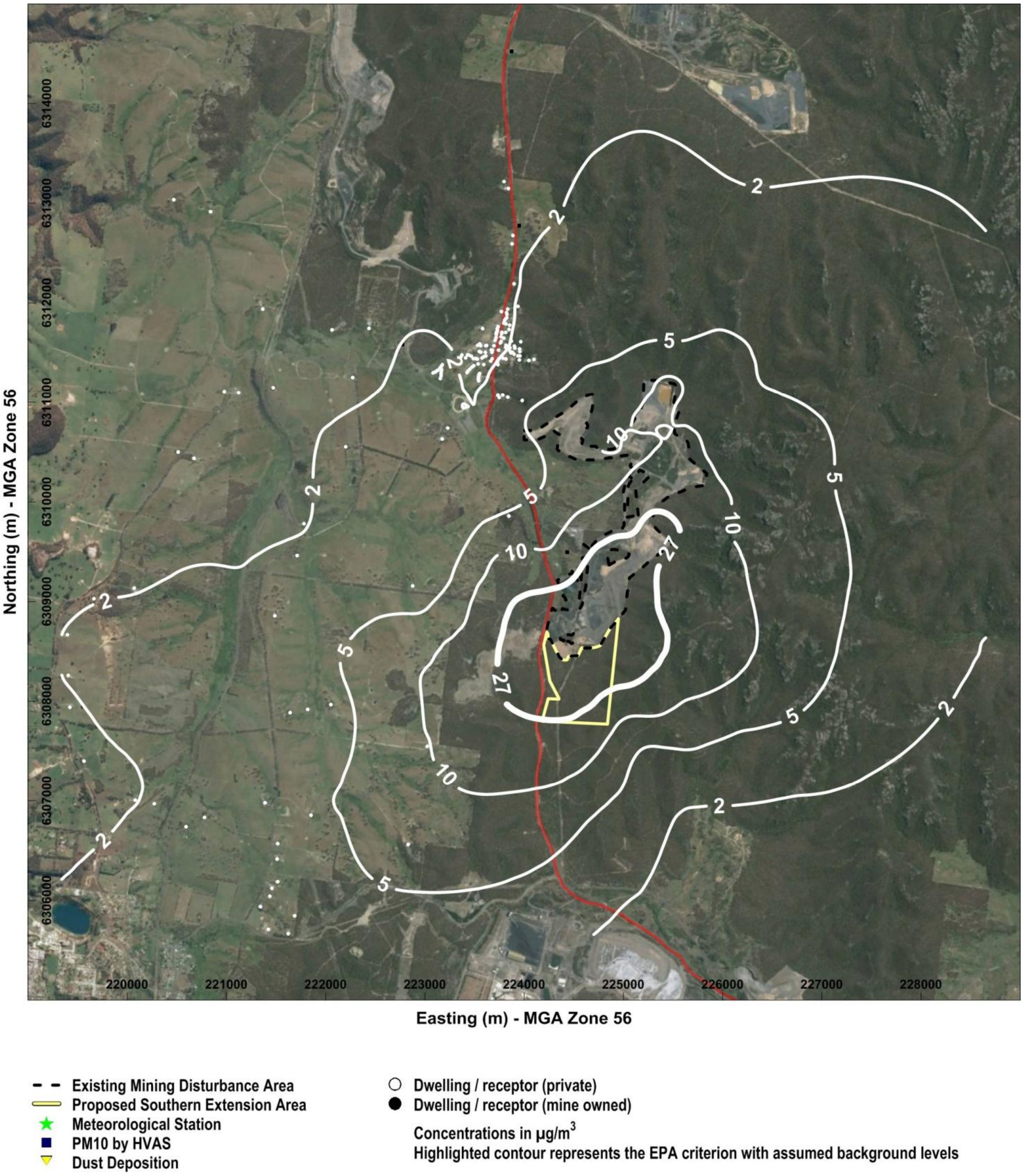

Figure 10 Predicted maximum 24-hour average PM_{10} concentrations due to the Project at maximum production

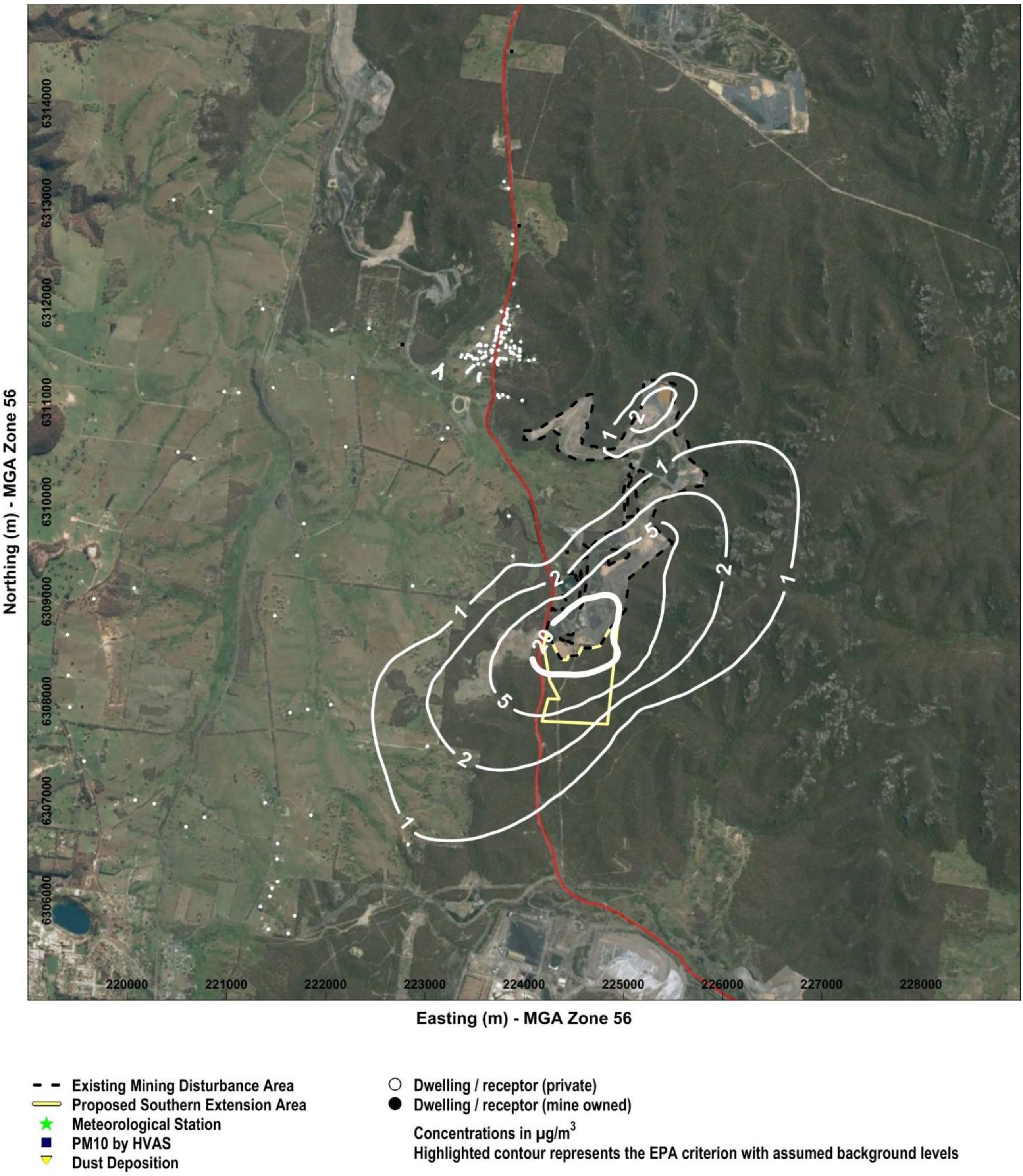

Figure 11 Predicted annual average PM_{10} concentrations due to the Project at maximum production

8.2 Particulate Matter (as $PM_{2.5}$)

The results for $PM_{2.5}$ are shown in **Figure 12** and **Figure 13**, for maximum 24-hour and annual averages respectively. **Figure 12** shows that maximum 24-hour average $PM_{2.5}$ concentrations, due to the Project, will not exceed the advisory reporting goal of 25 µg/m^3 at any off-site sensitive receptor location. Similarly, annual average $PM_{2.5}$ concentrations (**Figure 13**) are predicted to be below the advisory reporting goal of 8 µg/m^3. These results show that the Project will not cause adverse $PM_{2.5}$ impacts.

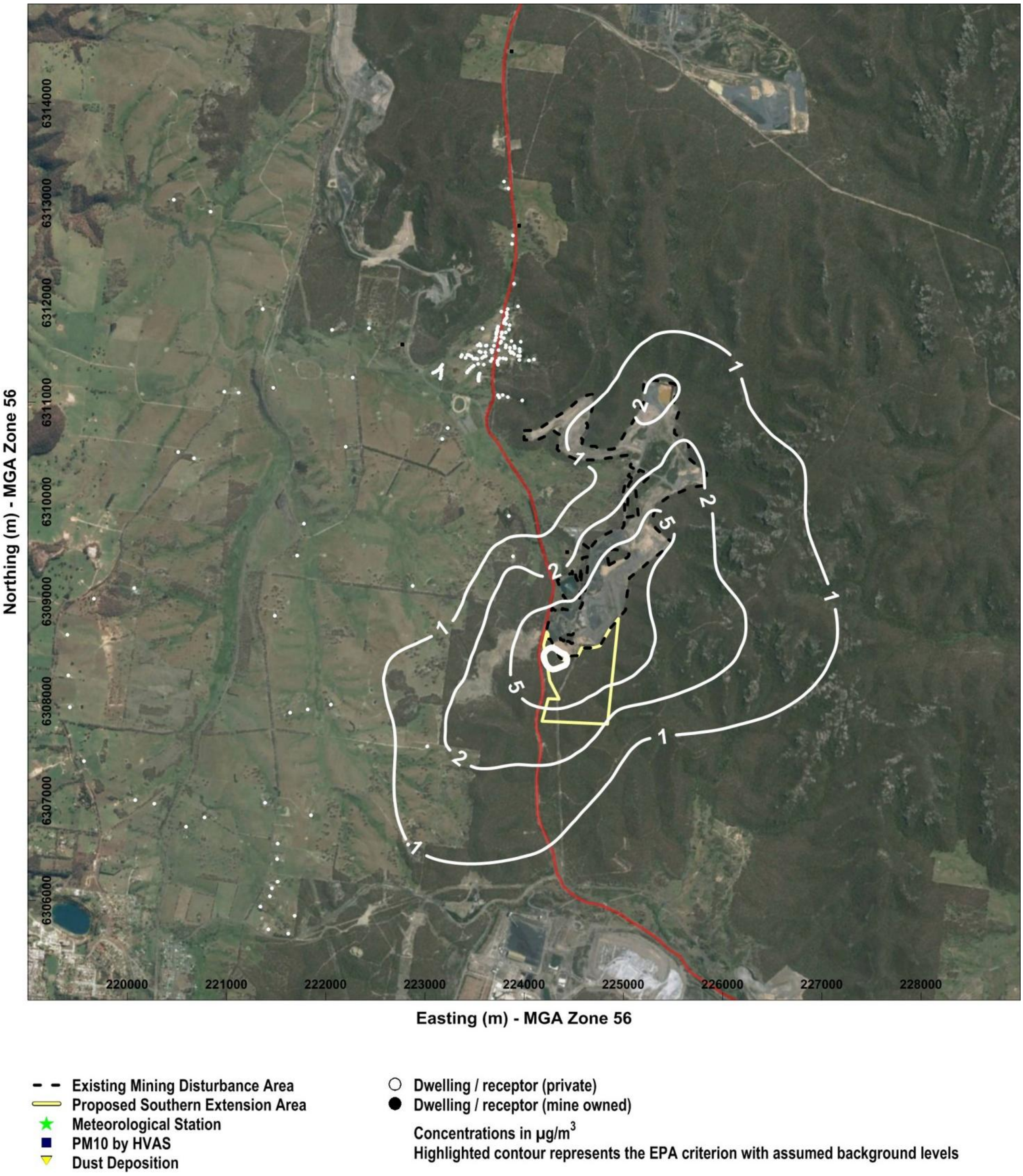

Figure 12 Predicted maximum 24-hour average $PM_{2.5}$ concentrations due to the Project at maximum production

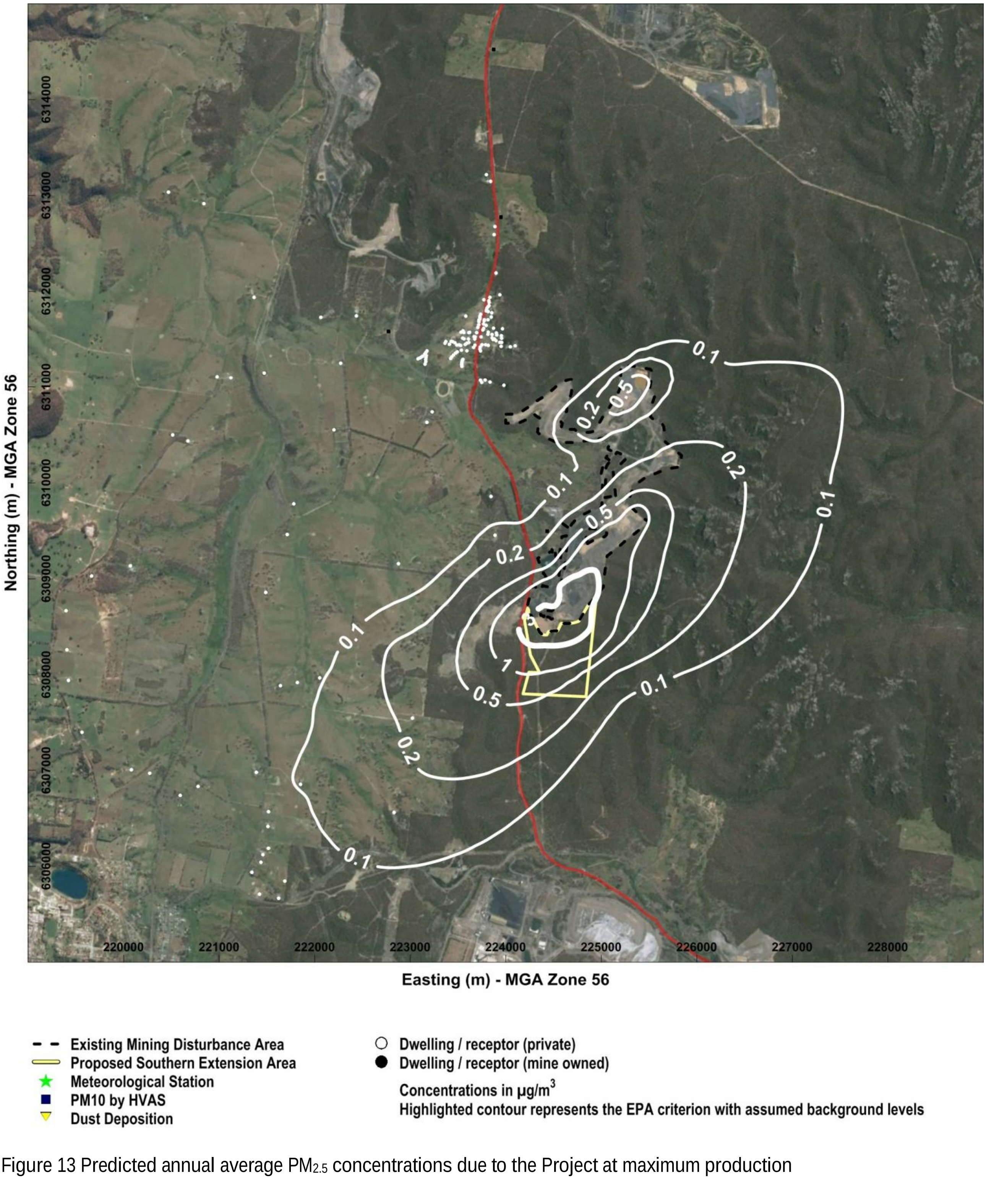

Figure 13 Predicted annual average $PM_{2.5}$ concentrations due to the Project at maximum production

8.3 Particulate Matter (as TSP)

Figure 14 shows the predicted annual average TSP concentrations due to the Project with maximum production. The relevant criterion is 90 µg/m^3 which is represented in **Figure 14** by the 64 µg/m^3 contour, taking into consideration the assumed average background levels of 27 µg/m^3. It can be seen from these results that the Project is not predicted to cause exceedances of the EPA's criterion at any off-site sensitive receptor location. These results show that the Project will not cause adverse TSP impacts.

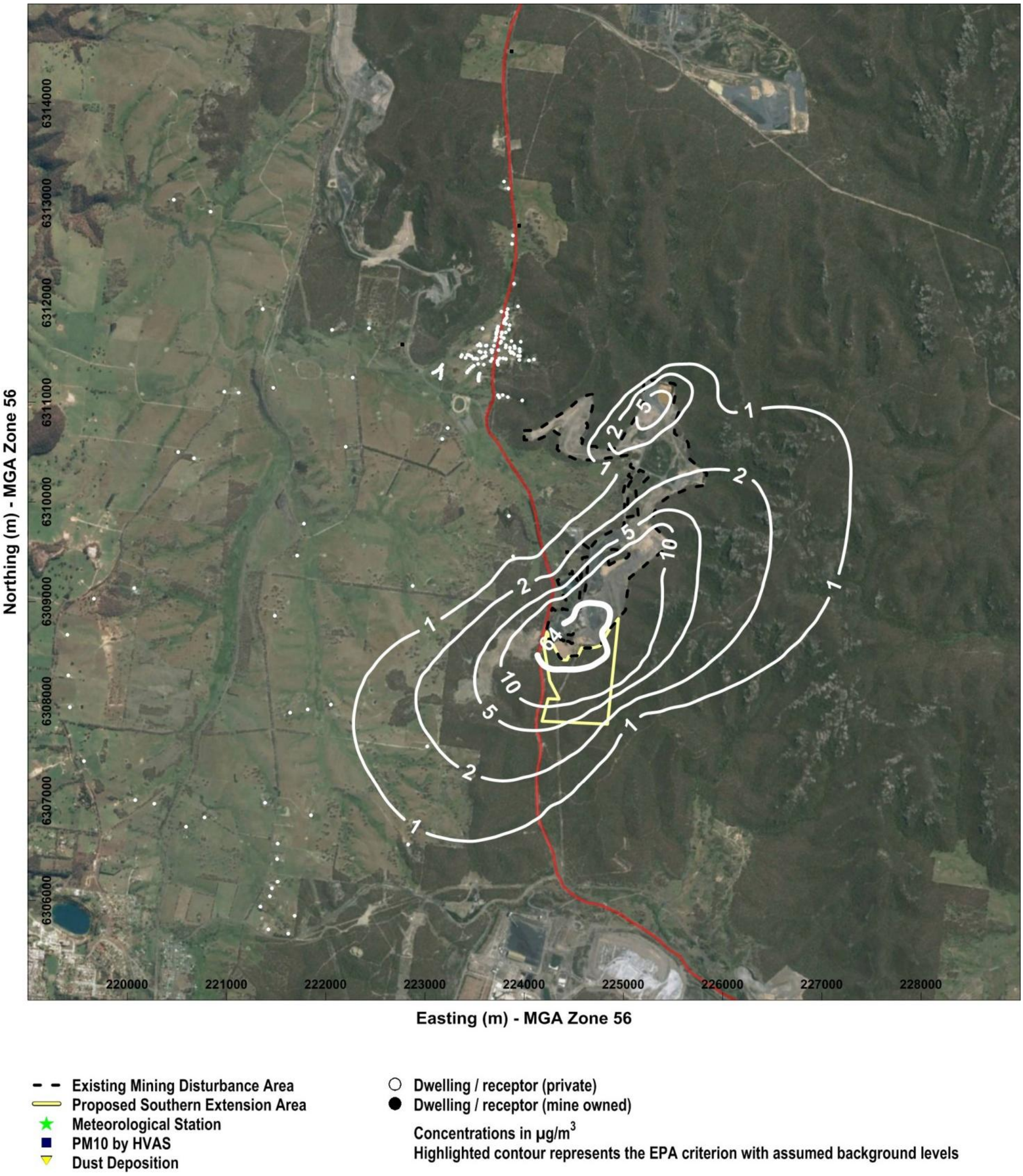

Figure 14 Predicted annual average TSP concentrations due to the Project

8.4 Deposited Dust

Figure 15 shows the predicted annual average dust deposition levels due to the Project with maximum production. The relevant criterion is 4 g/m^2/month which is represented in **Figure 15** by the 2.8 g/m^2/month contour, taking into consideration the assumed average background levels of 1.2 g/m^2/month. It can be seen from these results that the Project is not predicted to cause exceedances of the EPA's criterion at any off-site sensitive receptor location. Similarly, the model predictions are below the EPA's incremental criterion (that is, 2 g/m^2/month). These results show that the Project will not cause adverse dust deposition impacts.

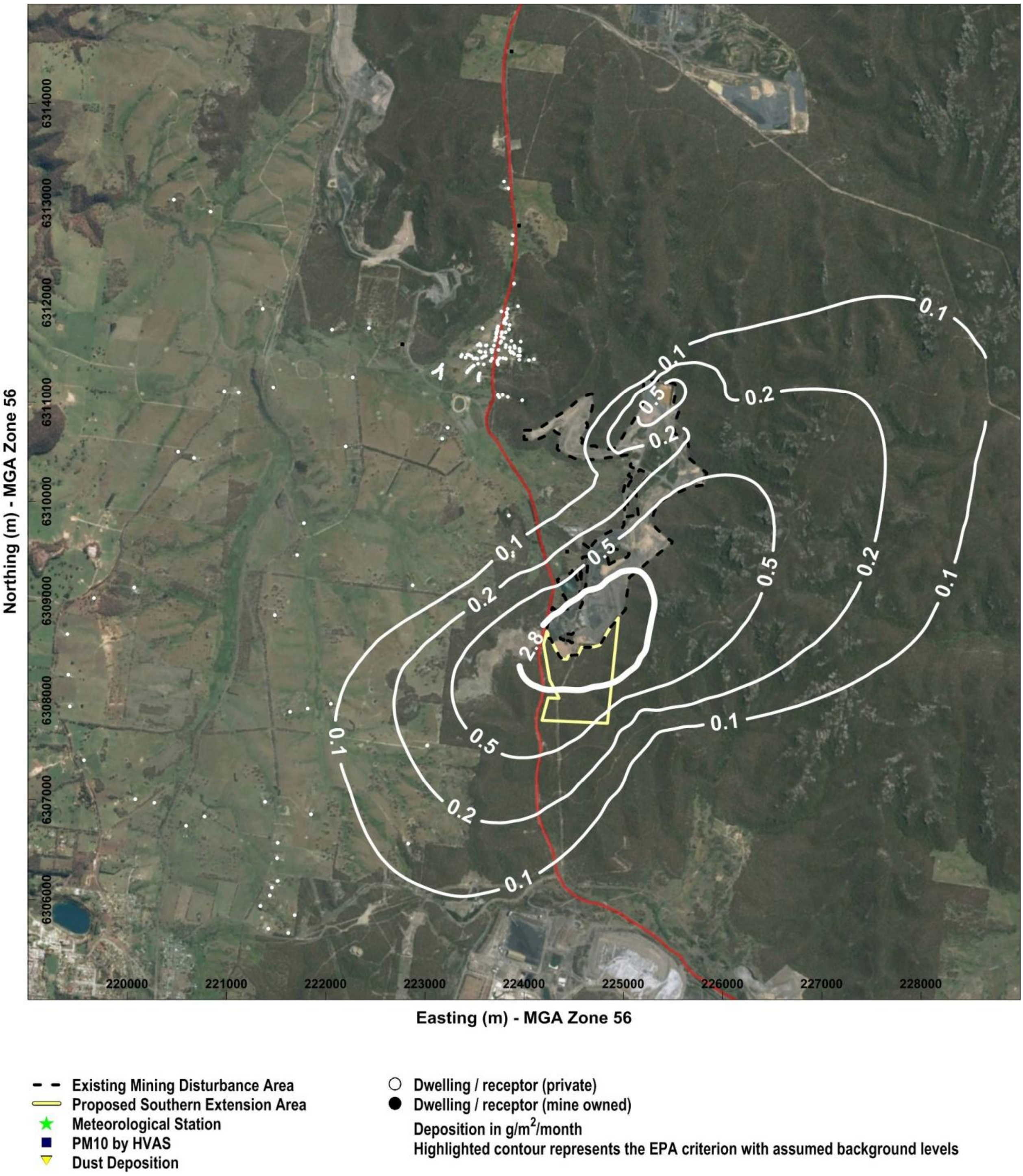

Figure 15 Predicted annual average deposited dust levels due to the Project at maximum production

8.5 Diesel Exhaust Emissions

Emissions from diesel exhausts associated with off-road vehicles and equipment at mine sites are often deemed a lower air quality impact risk than dust emissions from the material handling activities. This is because of the relatively few emission sources involved, for example when compared to a busy motorway, and the large distances between the sources and sensitive receptors. Nevertheless a review of the potential impacts has been completed and detailed in this section.

The most significant emissions from diesel exhausts are products of combustion including carbon monoxide (CO), oxides of nitrogen (NO_x) and particulate matter (PM_{10} including $PM_{2.5}$). It is the NO_x, or more specifically NO_2, and PM_{10} (including $PM_{2.5}$) which have been reviewed in this section.

Potential impacts due to diesel exhaust emissions have been examined by:

- Quantifying the emissions of NO_x and PM_{10} due to machinery exhausts
- Discussing PM_{10} emissions in the context of overall site emissions
- Predicting off-site NO_2 concentrations using a dispersion model and comparing these predictions to air quality criteria

Castlereagh Coal has predicted that the maximum site fuel consumption in any year of production will be 4,682,000 litres. This value has been used to estimate emissions of NO_x and PM_{10} due to machinery exhausts.

8.5.1 Particulate Matter (as PM_{10})

Mine site particulate matter emission factors, such as those from the NPI and US EPA, are typically derived from monitoring downwind of the activity or equipment of interest. This means that the emission factors capture the contributions from all components of that activity. In the case of trucks travelling on unsealed roads, the emission factors represent the contribution from both wheel generated particulates and the exhaust particulates.

Control factors are often applied to the calculated emission, as has been done in this assessment, but it is recognised that application of the control factor may only be relevant to one component of the emission. In the haulage by truck activity example, 80% control has been applied to the emissions from this activity, due to watering. This approach means that 80% control has also been applied to the exhaust component, an assumption which may be unrealistic and with the potential to under-estimate emissions. The effect of this assumption has been reviewed below.

Table 14 shows the steps for estimating the overall site PM_{10} emissions on the assumption that 80% control is not applied to haul truck exhaust emissions. An emission factor from the EPA's Air Emissions Inventory for 2008 (EPA 2012) has been used.

Table 14 Estimated PM_{10} emissions from diesel exhausts

Item	Value
Maximum fuel used in any one year (litres)	4,682,000
Diesel exhaust emission factor (kg/kL)	2.84
Diesel exhaust emissions - trucks only, assuming 50% of fuel used is by trucks (kg/y)	6,648
(1) Total site emissions (from **Table 10**) (kg/y)	143,341
(2) Total site emissions assuming 80% control not applied to truck exhaust (kg/y)	148,660
Per cent change between emission calculation approaches (1 and 2) (%)	4%

From these calculations there may be, at most, up to a four per cent difference in total site PM_{10} emissions between the two approaches. This is a conservative estimate since the diesel exhaust emission factor is relevant to equipment and emission standards as of 2008. Based on this outcome there would be no change to the conclusions of the assessment, in terms of potential particulate matter impacts.

8.5.2 Nitrogen Dioxide (NO_2)

Emissions of NO_x from diesel exhausts have been estimated using fuel consumption data, provided by Umwelt, and an emission factor from the EPA's Air Emissions Inventory for 2008 (EPA 2012). **Table 15** shows the calculations.

Table 15 Estimated NO_X emissions from diesel exhausts

Item	Value
Maximum fuel used in any one year (litres)	4,682,000
Diesel exhaust emission factor (kg/kL)	40.77
Diesel exhaust emissions – all equipment (kg/y)	190,885

The NO_x emission estimates from **Table 15** have been modelled using the source locations from **Figure 9** to provide an indication of the off-site NO_2 concentrations due to diesel exhaust emissions. **Figure 16** shows the predicted maximum 1-hour average NO_2 concentrations, which assumes that 20% of the NO_x is NO_2 at the locations of maximum ground-level concentrations. **Appendix B** provides justification for the 20% assumption.

The results in **Figure 16** show that the Project will not cause exceedances of the EPA's 246 µg/m^3 criterion at sensitive receptors. The criterion is represented in **Figure 16** by the 156 µg/m^3 contour which takes into consideration the assumed maximum background levels of 90 µg/m^3.

Figure 17 shows the predicted annual average NO_2 concentrations due to the Project. With the addition of conservative background levels (21 µg/m^3 from **Table 9**) the results show compliance with the EPA's 62 µg/m^3 criterion at sensitive receptor locations.

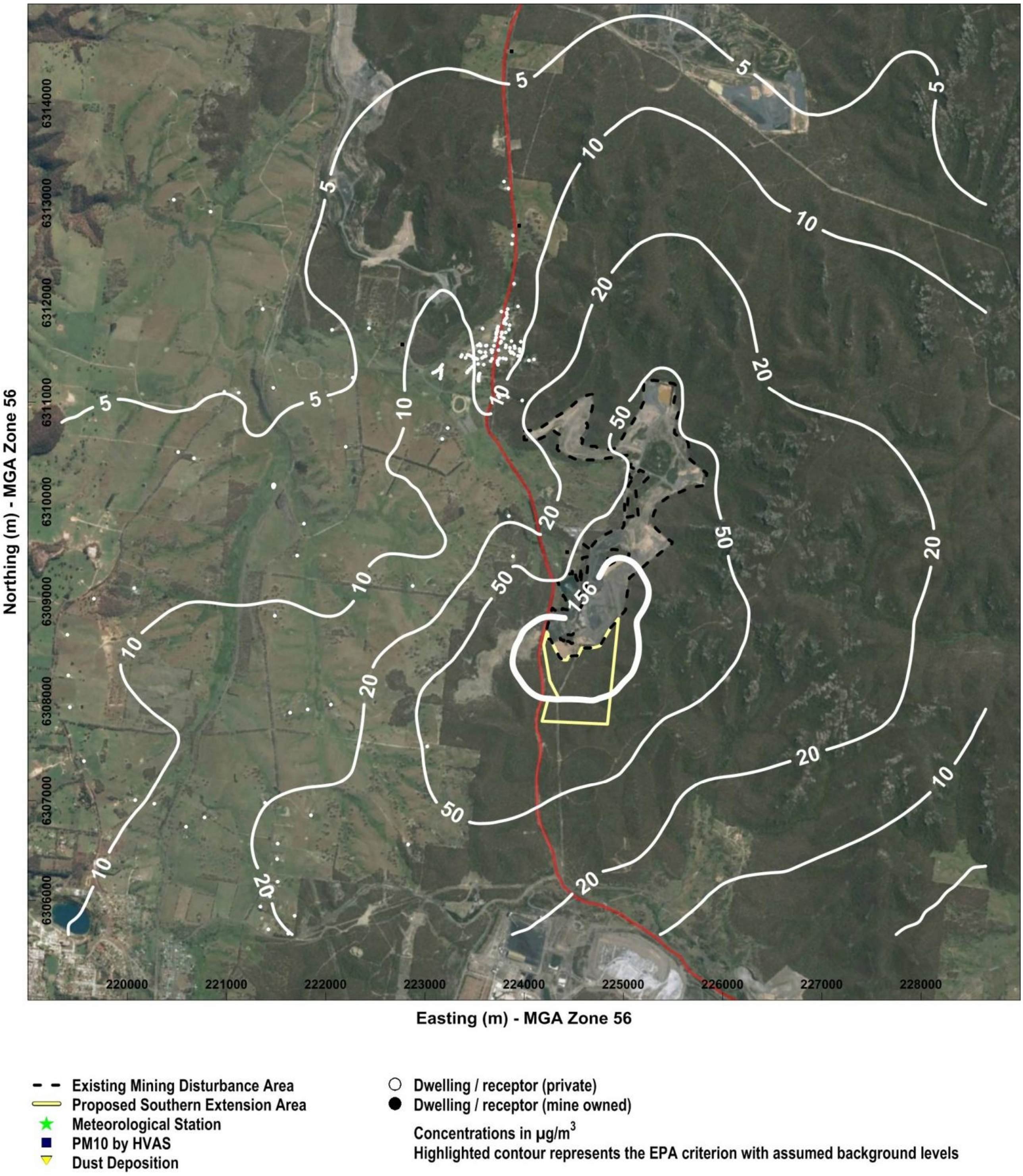

Figure 16 Predicted maximum 1-hour average NO_2 concentrations due to diesel exhausts

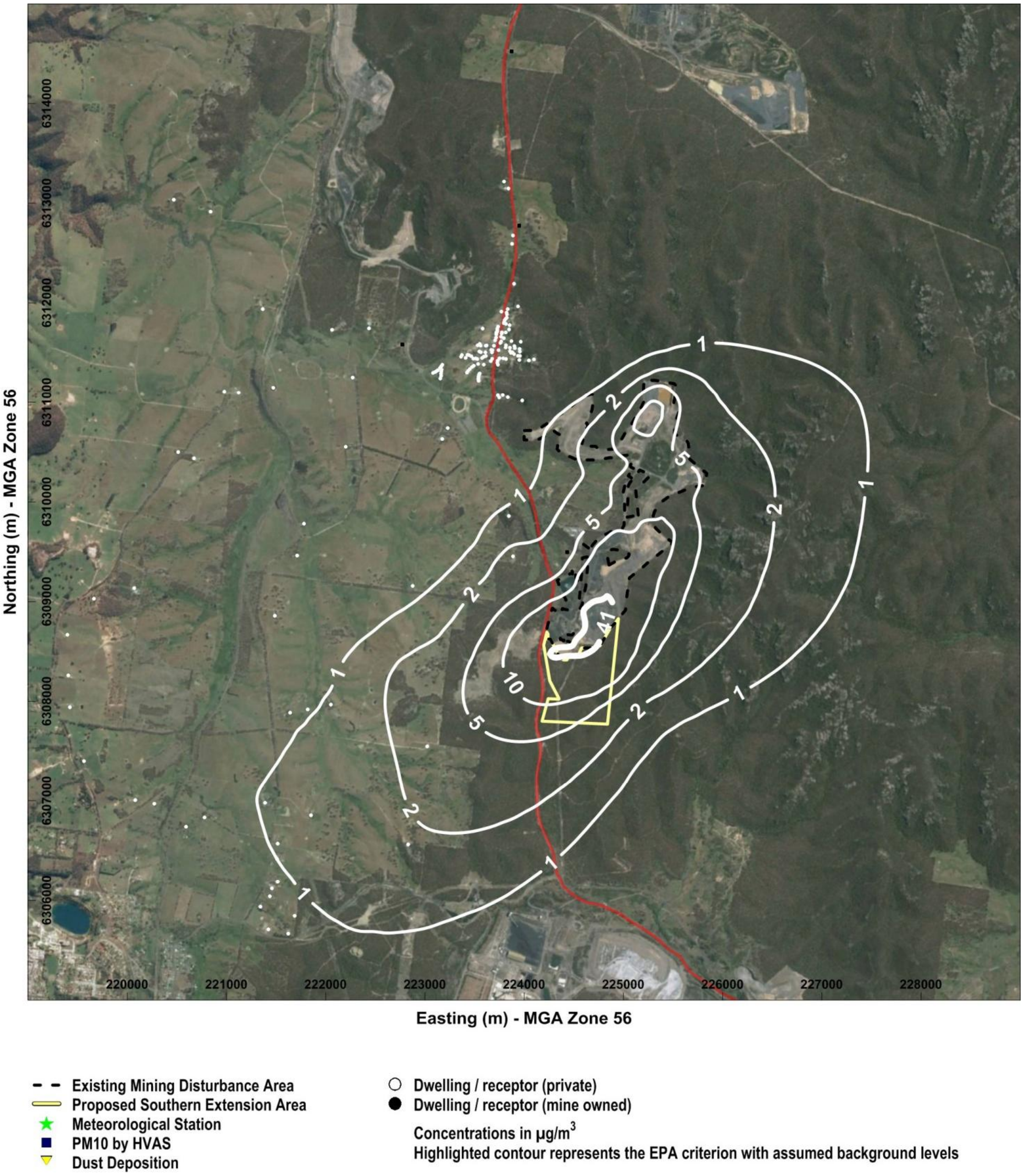

Figure 17 Predicted annual average NO_2 concentrations due to diesel exhausts

9. Management and Monitoring

Table 16 summarises the standard dust management measures which are proposed as part of the Project. The assumed emission control factors for the modelling are also listed.

Table 16 Dust management measures

Activity	Dust management measures	Assumed emission control for this assessment (%)
Stripping topsoil by scraper	Watering of haul routes	50
Drilling overburden and coal	Water injection, dust curtains	70
Hauling overburden and coal on unsealed roads	Watering of haul routes	80
Coal processing	Enclosure	70
Dozers or loaders on ROM and product coal stockpiles	Watering / moist travel routes	50
Conveyors to stockpiles	Water sprays	70
Wind erosion from partially rehabilitated dumps	Partial rehabilitation / stabilisation	30
Wind erosion from ROM and product coal stockpiles	Water sprays	50
Grading roads	Watering of haul routes	50

In addition to the measures listed above the Project will incorporate specific dust control strategies. Air quality management would include the modification or suspension of activities in response to the following triggers:

- Visual conditions, such as visible dust from trucks above wheel height; or
- Meteorological conditions, such as dry, windy conditions, with winds blowing towards sensitive receptors.

The air quality monitoring currently operated by Shoalhaven Coal will be reviewed and consolidated to meet the needs of the Project. Specifically, the locations and types of monitoring will consider the location of sensitive receptors, prevailing meteorological conditions, and location of mining activities.

10. Conclusions

This report has assessed the potential air quality impacts of the Invincible Southern Extension Project.

The potential air quality issues were identified as:

- Dust (that is, particulate matter in the form of TSP, PM_{10} or $PM_{2.5}$) from the general mining activities; and
- Emissions of substances from machinery exhausts, that is, diesel emissions.

A detailed review of the existing environment was carried out. The review found that air quality in the region was generally good with average concentrations of PM_{10} well below EPA criteria. However, there has been an occasional exceedance of the EPA's 50 µg/m^3 24-hour criterion for PM_{10} in the past seven years (specifically, five days in the past seven years).

The computer-based dispersion model known as CALPUFF was used to predict the potential air quality impacts of the Project, including background levels. The dispersion modelling accounted for meteorological conditions, land use and terrain information and used emission estimates to predict the off-site air quality impacts. Model predictions were compared to EPA criteria.

Based on model predictions which were below EPA criteria, it was concluded that the Project will not cause adverse air quality impact at any off-site sensitive receptor location. Emissions from diesel exhausts associated with off-road vehicles and equipment were also investigated and, again, the Project is not expected to result in any adverse air quality impacts, based on model predictions which showed compliance with air quality criteria.

The conclusions above will not change as a result of the National Clean Air Agreement which, of relevance, proposes the establishment of an annual average standard for PM_{10} of 25 µg/m^3 (as distinct from the current criterion of 30 µg/m^3) and adoption of the current $PM_{2.5}$ advisory report goals as standards.

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Appendix A. Emission calculations

Emission calculations

Invincible Colliery

Activity	Annual emissions (kg/y) TSP	PM10	PM2.5	Control (%)	Intensity	Units	TSP Factor	Units	PM10 Factor	Units	PM2.5 Factor	Units	Variables Area (m2)	(ws/2.2)^1.3	Moisture (%)	Drop distance (m)	kg/VKT	t/truck	km/trip	Silt (%)	Speed (km/h)
Stripping topsoil by dozer	10376	2526	1089	50	1240	h/y	16.7	kg/h	4.07415	kg/h	1.757	kg/h	-	-	2	-	-	-	-	10	-
Drilling overburden	9204	4786	276	70	52000	holes/y	0.59	kg/hole	0.31	kg/hole	0.018	kg/hole	-	-	-	-	-	-	-	-	-
Blasting overburden	28600	14872	858	0	130	blasts/y	220.0	kg/blast	114.4	kg/blast	6.6	kg/blast	10000	-	-	-	-	-	-	-	-
Excavators loading overburden to trucks	7769	3674	556	0	7560000	t/y	0.00103	kg/t	0.00049	kg/t	0.0001	kg/t	-	0.87	2	-	-	-	-	-	-
Hauling overburden from pit to dump	93865	27738	2816	80	7560000	t/y	0.06208	kg/t	0.01835	kg/t	0.002	kg/t	-	-	-	-	4	100	1.6	-	-
Unloading overburden to dump	7769	3674	556	0	7560000	t/y	0.00103	kg/t	0.00049	kg/t	0.0001	kg/t	-	0.87	2	-	-	-	-	-	-
Dozers shaping overburden	20752	5052	2179	0	1240	h/y	16.7	kg/h	4.07415	kg/h	1.757	kg/h	-	-	2	-	-	-	-	10	-
Dozers working on overburden for rehabilitation	20752	5052	2179	0	1240	h/y	16.7	kg/h	4.07415	kg/h	1.757	kg/h	-	-	2	-	-	-	-	10	-
Drilling coal	9204	4786	276	70	52000	holes/y	0.59	kg/hole	0.31	kg/hole	0.018	kg/hole	-	-	-	-	-	-	-	-	-
Blasting coal	28600	14872	858	0	130	blasts/y	220.0	kg/blast	114.4	kg/blast	6.6	kg/blast	10000	-	-	-	-	-	-	-	-
Dozers working on coal	24812	7909	546	0	1240	h/y	20.0	kg/h	6.4	kg/h	0.440	kg/h	-	-	8	-	-	-	-	7	-
Loading ROM coal to trucks	57399	8255	1091	0	1200000	t/y	0.04783	kg/t	0.00688	kg/t	0.001	kg/t	-	-	8	-	-	-	-	-	-
Hauling ROM coal from pit to hopper / ROM pad	30039	8877	901	80	1200000	t/y	0.12516	kg/t	0.03699	kg/t	0.004	kg/t	-	-	-	-	4	62	2	-	-
Unloading ROM coal to ROM pad	12000	5040	228	0	1200000	t/y	0.01	kg/t	0.0042	kg/t	0.000	kg/t	-	-	-	-	-	-	-	-	-
ROM coal rehandle to hopper	1200	504	23	0	120000	t/y	0.01	kg/t	0.0042	kg/t	0.000	kg/t	-	-	-	-	-	-	-	-	-
Transferring ROM coal to CHPP or crusher	177	84	13	0	1200000	t/y	0.00015	kg/t	0.00007	kg/t	0.0000	kg/t	-	0.87	8	-	-	-	-	-	-
Coal crushing and loading stockpiles	4460	1896	95	0	1115000	t/y	0.00400	kg/t	0.00170	kg/t	0.0001	kg/t	-	-	-	-	-	-	-	-	-
Handling coal at CHPP	19	9	0	70	85000	t/y	0.00074	kg/t	0.00035	kg/t	0.0000	kg/t	-	0.87	8	-	-	-	-	-	-
Dozers on ROM coal stockpiles	12406	3955	273	50	1240	h/y	20.0	kg/h	6.4	kg/h	0.440	kg/h	-	-	8	-	-	-	-	7	-
Dozers on product coal stockpiles	5305	1529	117	50	1240	h/y	8.6	kg/h	2.5	kg/h	0.188	kg/h	-	-	11	-	-	-	-	5	-
Conveyer to product stockpiles	8	4	1	0	85000	t/y	0.00009	kg/t	0.00004	kg/t	0.0000	kg/t	-	0.87	11	-	-	-	-	-	-
Loading product coal to trucks	480	204	24	0	1200000	t/y	0.00040	kg/t	0.00017	kg/t	0.0000	kg/t	-	-	-	-	-	-	-	-	-
Wind erosion from active pits	12735	6367	955	0	15	ha	876.0	kg/ha/y	438.0	kg/ha/y	65.7	kg/ha/y	-	-	-	-	-	-	-	-	-
Wind erosion from active dumps	16705	8353	1253	0	19	ha	876.0	kg/ha/y	438.0	kg/ha/y	65.7	kg/ha/y	-	-	-	-	-	-	-	-	-
Wind erosion from partially rehabilitated dumps	21144	10572	1586	30	34	ha	876.0	kg/ha/y	438.0	kg/ha/y	65.7	kg/ha/y	-	-	-	-	-	-	-	-	-
Wind erosion from ROM coal stockpiles	388	194	29	50	1	ha	876.0	kg/ha/y	438.0	kg/ha/y	65.7	kg/ha/y	-	-	-	-	-	-	-	-	-
Wind erosion from product coal stockpile	974	487	73	50	2	ha	876.0	kg/ha/y	438.0	kg/ha/y	65.7	kg/ha/y	-	-	-	-	-	-	-	-	-
Grading roads	4884	1727	54	50	15872	km	0.61547	kg/VKT	0.2176	kg/VKT	0.007	kg/VKT	-	-	-	-	-	-	-	-	8
	442025	152997	18904																		

Invincible Southern Extension Year 2 at maximum production: Activities and source allocations.

```
 --------------------------------      14-Jun-2016 09:48
  DUST EMISSION CALCULATIONS XL1
 --------------------------------

 Output emissions file  : C:\Users\slakmaker\Projects\IA105400_Invincible\calpuff\Y02\emiss.vol
 Meteorological file    : NA
 Number of dust sources : 87
 Number of activities   : 28

  -----ACTIVITY SUMMARY-----
 ACTIVITY NAME : Stripping topsoil by dozer
 ACTIVITY TYPE : Wind insensitive
 DUST EMISSION : 10376 kg/y TSP  2526 kg/y PM10  1089 kg/y PM2.5
 FROM SOURCES  : 6
1 2 3 4 5 6
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

 ACTIVITY NAME : Drilling overburden
 ACTIVITY TYPE : Wind insensitive
 DUST EMISSION : 9204 kg/y TSP  4786 kg/y PM10  276 kg/y PM2.5
 FROM SOURCES  : 13
7 8 9 10 11 12 13 14 15 16 17 18 19
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

 ACTIVITY NAME : Blasting overburden
 ACTIVITY TYPE : Wind insensitive
 DUST EMISSION : 28600 kg/y TSP  14872 kg/y PM10  858 kg/y PM2.5
 FROM SOURCES  : 13
7 8 9 10 11 12 13 14 15 16 17 18 19
 HOURS OF DAY  :
0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0

 ACTIVITY NAME : Excavators loading overburden to trucks
 ACTIVITY TYPE : Wind sensitive
 DUST EMISSION : 7769 kg/y TSP  3674 kg/y PM10  556 kg/y PM2.5
 FROM SOURCES  : 13
7 8 9 10 11 12 13 14 15 16 17 18 19
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

 ACTIVITY NAME : Hauling overburden from pit to dump
 ACTIVITY TYPE : Wind insensitive
 DUST EMISSION : 93865 kg/y TSP  27738 kg/y PM10  2816 kg/y PM2.5
 FROM SOURCES  : 27
7 8 9 10 11 12 13 14 15 16 17 18 19 27 28 29 31 32 33 34 37 38 40 41 42 43 44
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

 ACTIVITY NAME : Unloading overburden to dump
 ACTIVITY TYPE : Wind sensitive
 DUST EMISSION : 7769 kg/y TSP  3674 kg/y PM10  556 kg/y PM2.5
 FROM SOURCES  : 14
27 28 29 31 32 33 34 37 38 40 41 42 43 44
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

 ACTIVITY NAME : Dozers shaping overburden
 ACTIVITY TYPE : Wind insensitive
 DUST EMISSION : 20752 kg/y TSP  5052 kg/y PM10  2179 kg/y PM2.5
 FROM SOURCES  : 14
27 28 29 31 32 33 34 37 38 40 41 42 43 44
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

 ACTIVITY NAME : Dozers working on overburden for rehabilitation
 ACTIVITY TYPE : Wind insensitive
 DUST EMISSION : 20752 kg/y TSP  5052 kg/y PM10  2179 kg/y PM2.5
 FROM SOURCES  : 29
30 35 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 80 81 82 83 84 85 86 87
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

 ACTIVITY NAME : Drilling coal
 ACTIVITY TYPE : Wind insensitive
 DUST EMISSION : 9204 kg/y TSP  4786 kg/y PM10  276 kg/y PM2.5
 FROM SOURCES  : 13
7 8 9 10 11 12 13 14 15 16 17 18 19
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

 ACTIVITY NAME : Blasting coal
 ACTIVITY TYPE : Wind insensitive
 DUST EMISSION : 28600 kg/y TSP  14872 kg/y PM10  858 kg/y PM2.5
 FROM SOURCES  : 13
7 8 9 10 11 12 13 14 15 16 17 18 19
 HOURS OF DAY  :
0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0

 ACTIVITY NAME : Dozers working on coal
 ACTIVITY TYPE : Wind insensitive
 DUST EMISSION : 24812 kg/y TSP  7909 kg/y PM10  546 kg/y PM2.5
 FROM SOURCES  : 13
7 8 9 10 11 12 13 14 15 16 17 18 19
```

```
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

 ACTIVITY NAME : Loading ROM coal to trucks
 ACTIVITY TYPE : Wind sensitive
 DUST EMISSION : 57399 kg/y TSP  8255 kg/y PM10  1091 kg/y PM2.5
 FROM SOURCES  : 13
7 8 9 10 11 12 13 14 15 16 17 18 19
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

 ACTIVITY NAME : Hauling ROM coal from pit to hopper / ROM pad
 ACTIVITY TYPE : Wind insensitive
 DUST EMISSION : 30039 kg/y TSP  8877 kg/y PM10  901 kg/y PM2.5
 FROM SOURCES  : 20
7 8 9 10 11 12 13 14 15 16 17 18 19 24 25 26 30 35 36 39
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

 ACTIVITY NAME : Unloading ROM coal to ROM pad
 ACTIVITY TYPE : Wind sensitive
 DUST EMISSION : 12000 kg/y TSP  5040 kg/y PM10  228 kg/y PM2.5
 FROM SOURCES  : 3
24 25 26
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

 ACTIVITY NAME : ROM coal rehandle to hopper
 ACTIVITY TYPE : Wind sensitive
 DUST EMISSION : 1200 kg/y TSP  504 kg/y PM10  23 kg/y PM2.5
 FROM SOURCES  : 3
24 25 26
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

 ACTIVITY NAME : Transferring ROM coal to CHPP or crusher
 ACTIVITY TYPE : Wind sensitive
 DUST EMISSION : 177 kg/y TSP  84 kg/y PM10  13 kg/y PM2.5
 FROM SOURCES  : 3
24 25 26
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

 ACTIVITY NAME : Coal crushing and loading stockpiles
 ACTIVITY TYPE : Wind insensitive
 DUST EMISSION : 4460 kg/y TSP  1896 kg/y PM10  95 kg/y PM2.5
 FROM SOURCES  : 3
24 25 26
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

 ACTIVITY NAME : Handling coal at CHPP
 ACTIVITY TYPE : Wind insensitive
 DUST EMISSION : 19 kg/y TSP  9 kg/y PM10  0 kg/y PM2.5
 FROM SOURCES  : 3
24 25 26
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

 ACTIVITY NAME : Dozers on ROM coal stockpiles
 ACTIVITY TYPE : Wind insensitive
 DUST EMISSION : 12406 kg/y TSP  3955 kg/y PM10  273 kg/y PM2.5
 FROM SOURCES  : 3
24 25 26
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

 ACTIVITY NAME : Dozers on product coal stockpiles
 ACTIVITY TYPE : Wind insensitive
 DUST EMISSION : 5305 kg/y TSP  1529 kg/y PM10  117 kg/y PM2.5
 FROM SOURCES  : 4
20 21 22 23
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

 ACTIVITY NAME : Conveyer to product stockpiles
 ACTIVITY TYPE : Wind sensitive
 DUST EMISSION : 8 kg/y TSP  4 kg/y PM10  1 kg/y PM2.5
 FROM SOURCES  : 4
20 21 22 23
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

 ACTIVITY NAME : Loading product coal to trucks
 ACTIVITY TYPE : Wind sensitive
 DUST EMISSION : 480 kg/y TSP  204 kg/y PM10  24 kg/y PM2.5
 FROM SOURCES  : 4
20 21 22 23
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

 ACTIVITY NAME : Wind erosion from active pits
 ACTIVITY TYPE : Wind erosion
 DUST EMISSION : 12735 kg/y TSP  6367 kg/y PM10  955 kg/y PM2.5
 FROM SOURCES  : 19
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
 HOURS OF DAY  :
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

 ACTIVITY NAME : Wind erosion from active dumps
 ACTIVITY TYPE : Wind erosion
```

```
 DUST EMISSION : 16705 kg/y TSP  8353 kg/y PM10  1253 kg/y PM2.5
 FROM SOURCES  : 15
27 28 29 31 32 33 34 36 37 38 40 41 42 43 44
 HOURS OF DAY  :
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

 ACTIVITY NAME : Wind erosion from partially rehabilitated dumps
 ACTIVITY TYPE : Wind erosion
 DUST EMISSION : 21144 kg/y TSP  10572 kg/y PM10  1586 kg/y PM2.5
 FROM SOURCES  : 29
30 35 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 80 81 82 83 84 85 86 87
 HOURS OF DAY  :
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

 ACTIVITY NAME : Wind erosion from ROM coal stockpiles
 ACTIVITY TYPE : Wind erosion
 DUST EMISSION : 388 kg/y TSP  194 kg/y PM10  29 kg/y PM2.5
 FROM SOURCES  : 3
24 25 26
 HOURS OF DAY  :
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

 ACTIVITY NAME : Wind erosion from product coal stockpile
 ACTIVITY TYPE : Wind erosion
 DUST EMISSION : 974 kg/y TSP  487 kg/y PM10  73 kg/y PM2.5
 FROM SOURCES  : 4
20 21 22 23
 HOURS OF DAY  :
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

 ACTIVITY NAME : Grading roads
 ACTIVITY TYPE : Wind insensitive
 DUST EMISSION : 4884 kg/y TSP  1727 kg/y PM10  54 kg/y PM2.5
 FROM SOURCES  : 80
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56
57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0
```

Appendix B. Relationship between total NO_x and NO_2 ratio

Emissions from combustion sources comprise of oxides of nitrogen (NO_x) including nitric oxide (NO) and nitrogen dioxide (NO_2). In general, at the point of emission, NO will comprise the greatest proportion of the total NO_x emission. Typically this is 90% by volume of the NO_x. The remaining 10% will comprise mostly NO_2. It is the NO_2 which has been linked to adverse health effects.

Ultimately however, much of the NO emitted into the atmosphere is oxidised to NO_2. The rate at which this oxidisation takes place depends on prevailing atmospheric conditions including temperature, humidity and the presence of other substances in the atmosphere such as ozone. It can vary from a few minutes to many hours. The rate of conversion is important because from the point of emission to the point of maximum ground-level concentration there will be an interval of time during which some oxidation will take place. If the dispersion is sufficient to have diluted the plume to the point where the concentration is very low then the level of oxidation is unimportant. However, if the oxidation is rapid and the dispersion is slow then high concentrations of NO_2 can occur.

In NO_x monitoring data near significant emission sources (for example, power stations and motorways) the percentage of NO_2 in the NO_x is (as a rule) inversely proportional to the total NO_x concentration, and when NO_x concentrations are high, the percentage of NO_2 in the NO_x is typically of the order of 20%. This is demonstrated by **Figure B1** which shows that, for high NO_x concentrations, the NO_2 to NO_x ratio reduces to less than 20%.

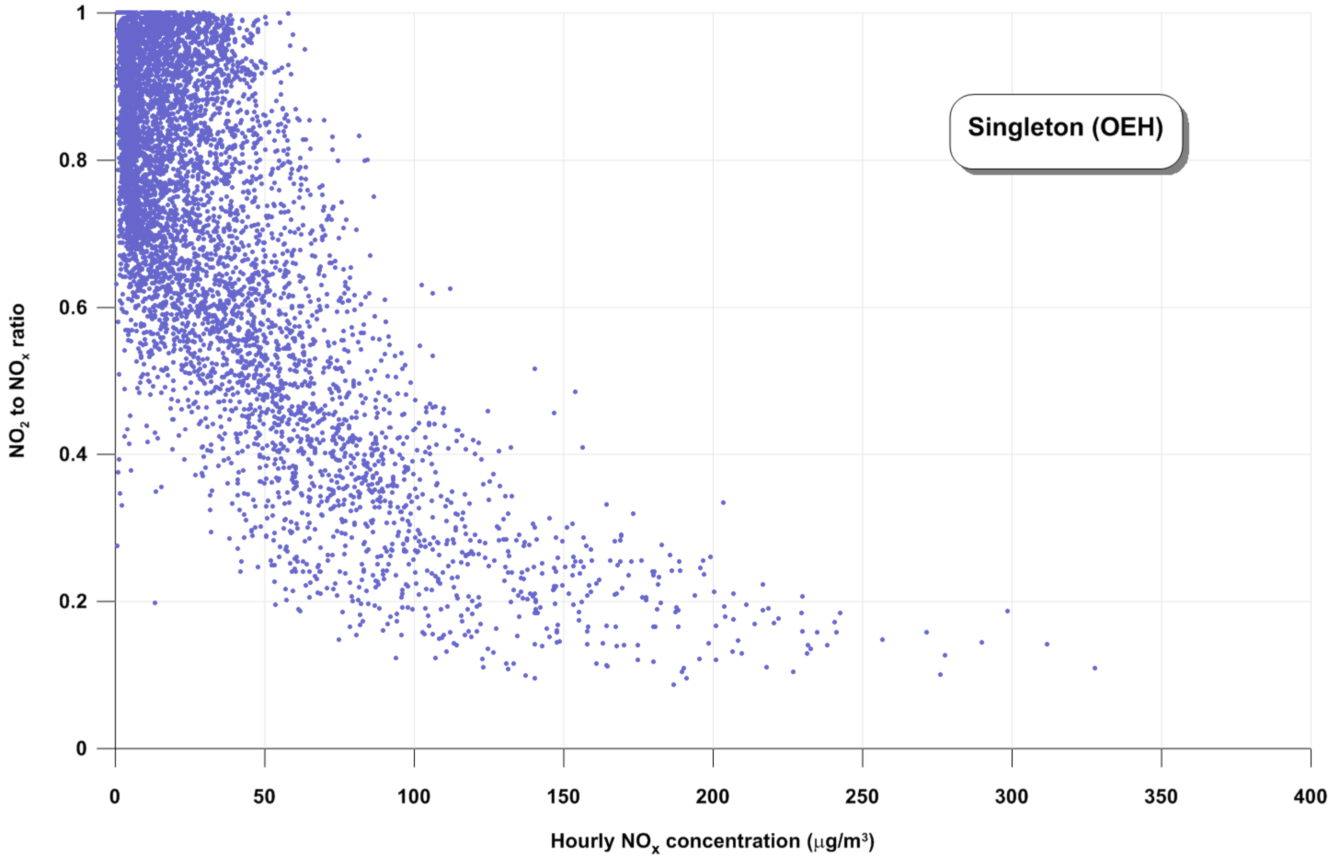

Figure B1 Measured NO_2 to NO_x ratios from hourly average data collected at Singleton by the OEH in 2014