BARRICK

COWAL

APPENDIX F
AIR QUALITY IMPACT ASSESSMENT

COWAL GOLD MINE EXTENSION MODIFICATION

Resource Strategies

Pacific Environment Limited

Consulting • Technologies • Monitoring • Toxicology

FINAL DRAFT

COWAL GOLD MINE EXTENSION MODIFICATION – AIR QUALITY IMPACT ASSESSMENT

Barrick c/- Resource Strategies

Job No: 7259

7 September 2013

PROJECT TITLE:	Cowal Gold Mine Extension Modification – Air Quality Impact Assessment
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1 INTRODUCTION

Pacific Environment Limited has been commissioned by Barrick (Cowal) Limited (Barrick), to complete an air quality and greenhouse gas assessment for the for the Cowal Gold Mine (CGM) Extension Modification (the Modification). The purpose of this assessment is to assess potential air quality impacts associated with the Modification for inclusion in the Environmental Assessment.

2 BACKGROUND AND MODIFICATION DESCRIPTION

The CGM is located approximately 38 kilometres (km) north-east of West Wyalong in central New South Wales (NSW). **Figure 2.1** shows the location of the CGM and nearest receptors. The area is sparsely populated with the closest residence located approximately 2 km south-west of the Mining Lease (ML) 1535 boundary. **Figure 2.2** shows the local topography, which is generally flat with some low isolated hills.

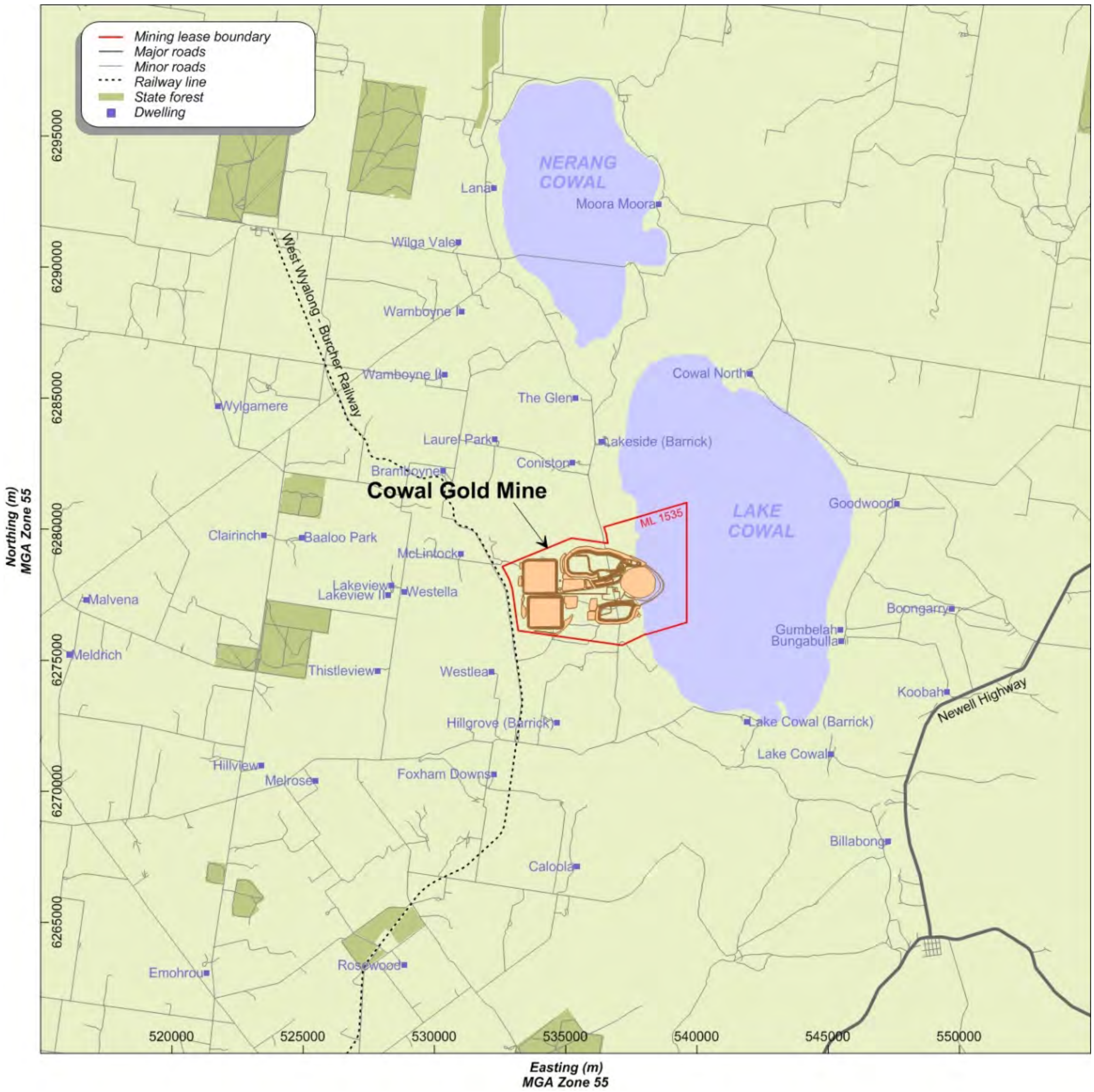


Figure 2.1: Location of study area

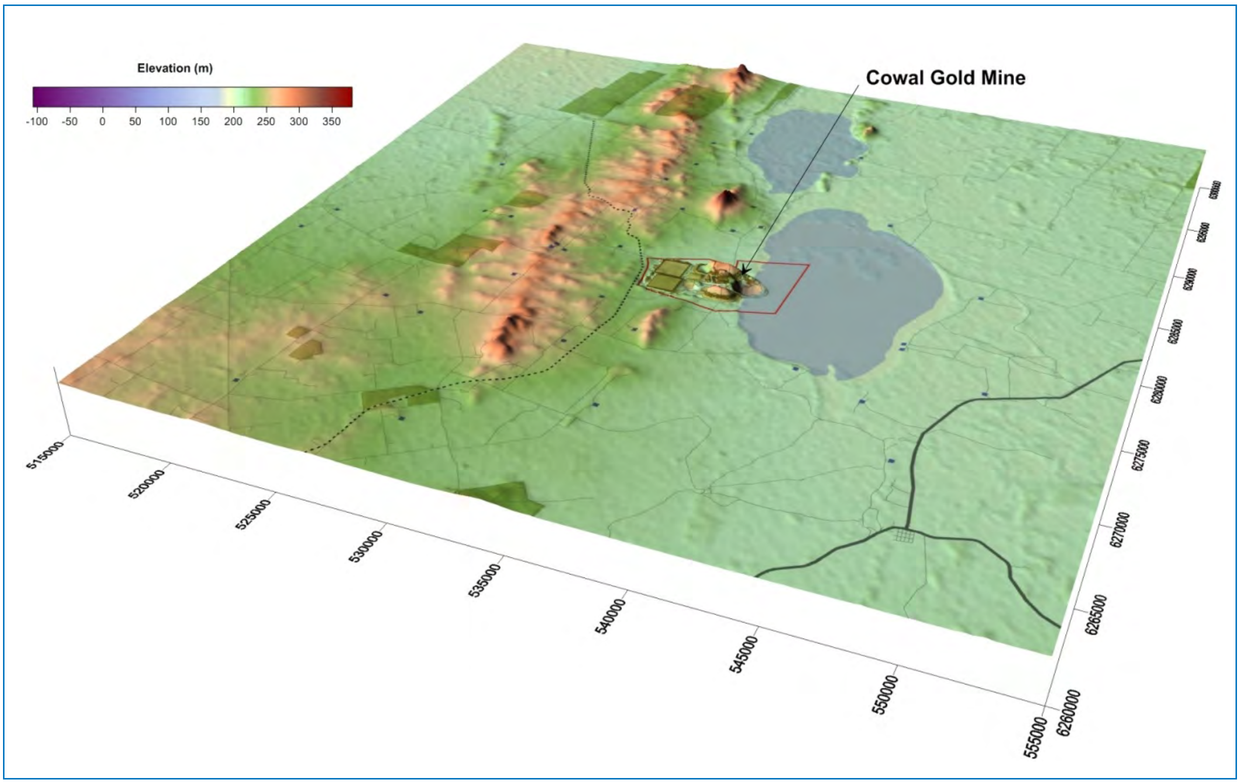


Figure 2.2: Pseudo three dimensional representation of local terrain

2.1 Approved CGM Operations

The CGM is an existing open pit gold mine that commenced in 2004 in accordance with Development Consent 14/98. The major components of CGM include an open pit, a process plant to extract gold from ore, mine waste rock emplacement areas and two tailings storage facilities. Gold is extracted from the ore using a conventional carbon-in-leach cyanide leaching circuit. The CGM is currently approved to produce up to approximately 3.1 million ounces of gold. Up to 7.5 million tonnes (Mt) of ore is processed per year.

The CGM adopts conventional open cut mining methods using excavators, off-road haul trucks and wheel and track dozers. Blasting is required approximately once per day. Mining activities occur 24 hours per day, seven days per week.

2.2 The Proposed Modification

The Modification involves the extension of the CGM open pit to access additional gold-bearing ore and enable the continuation of mining at the CGM for an additional five years (i.e. until 2024). Key components of the Modification relevant to this assessment are;

- extension of the operational life of the CGM by an additional 5 years (i.e. until 2024);
- no change to mining lease tenements (i.e. all mining activities would continue to occur within ML 1535);
- augmentation of the extent and depth of the existing open pit;
- continued development of open pit mining operations at the CGM, including expansion of the extent and depth of the existing open pit;
- an increase in the total quantities of waste rock, ore and tailings produced over the life of the mine;
- continued use of the existing mine fleet;
- an increase in total gold production to approximately 3.8 Moz;

- no change to the existing process plant or its currently installed capacity to continue ore processing at a rate up to 7.5 Mtpa;
- continued and expanded development of the existing mine Northern and Southern Waste Rock Emplacements within ML 1535 for placement of mined waste rock over the life of the CGM, including:
  - raising the maximum design height of the northern waste rock emplacement to 308 (metres Australian Height Datum) mAHD;
  - raising the maximum design height of the southern waste rock emplacement to 283 mAHD; and
  - extension of the northern waste rock emplacement to the west with an additional disturbance footprint of approximately 39 hectares;
- continued and expanded development of soil stockpiles, the relocation of existing soil stockpiles and stockpiling of mineralised material (i.e. potentially commercial ore) within ML 1535;
- continued use of the existing tailings storage facilities for the deposition of tailings produced over the life of the CGM, including raising the maximum design height of:
  - the Northern Tailings Storage Facility to 248 m AHD; and
  - the Southern Tailings Storage Facility to 255 m AHD;
- no change to the approved operating hours (i.e. 24 hours per day, seven days per week) of the CGM; and
- continued progressive rehabilitation of mine landforms (e.g. waste rock emplacements and tailing storage facilities) with a change to the rehabilitation concepts (i.e. the use of rock armouring to enhance stability of the batters of the tailings storage facilities and waste emplacements).

In addition to the open cut mining activities there would continue to be activities associated with tailings storage facilities embankment lifts. These activities would occur during the day and for the purposes of this assessment the tailings embankment lift activities have been conservatively assumed to occur all year round.

The Modification general arrangement is shown on **Figure 2.3**.

2.3 Indicative Mine Schedule and Modification Air Quality Assessment Scenario

A provisional mining and processing schedule for the Modification is provided in **Table 2.1**. Based on this schedule, a single modelling scenario (Year 11 [2015]) has been developed as it is considered to represent the year with the potential for worst case dust emissions.

Year 11 (2015) represents the year of maximum waste rock mined for the Modification and year of maximum total material (i.e. waste rock and ore) mined. While the year of maximum ore extracted occurs in Year 15 (2019), in this year the amount of waste rock extracted would be significantly lower than for Year 11 (2015) (**Table 2.1**) and as such, Year 15 (2019) is not considered to have the potential to generate greater dust emissions than Year 11 (2015).

Year 11 (2015) also represents a year with the greatest potential for wind erosion emissions from exposed areas of waste rock emplacements. In Year 11 (2015) the southern waste rock emplacement would still be active, and the western extension of the northern waste rock emplacement would already have occurred. Following Year 11 (2015) progressive rehabilitation of both the northern and southern waste rock emplacements would occur, reducing the areas exposed with the potential to generate wind erosion emissions.

Figure 2.4 shows the Year 11 (2015) general arrangement for the Modification.

Table 2.1: Indicative mining and ore processing schedule for the Modification

Year	CGM Year	Waste Rock Mined (Mt)	Ore Mined (Mt)	Ore Processed (Mt)	Total Mined (Mt)
2014	10	22.4	8.0	7.2	30.4
2015	**11**	**26.9**	**6.8**	**7.3**	**33.7**
2016	12	18.8	6.8	7.4	25.6
2017	13	11.8	8.9	7.4	20.7
2018	14	9.2	9.8	7.4	19.0
2019	15	2.1	11.2	7.4	13.3
2020	16	1.8	5.9	7.4	7.7
2021	17	0.2	1.4	7.5	1.6
2022	18	0.0	0.0	7.4	0
2023	19	0.0	0.0	7.3	0
2024	20	0.0	0.0	2.1	0

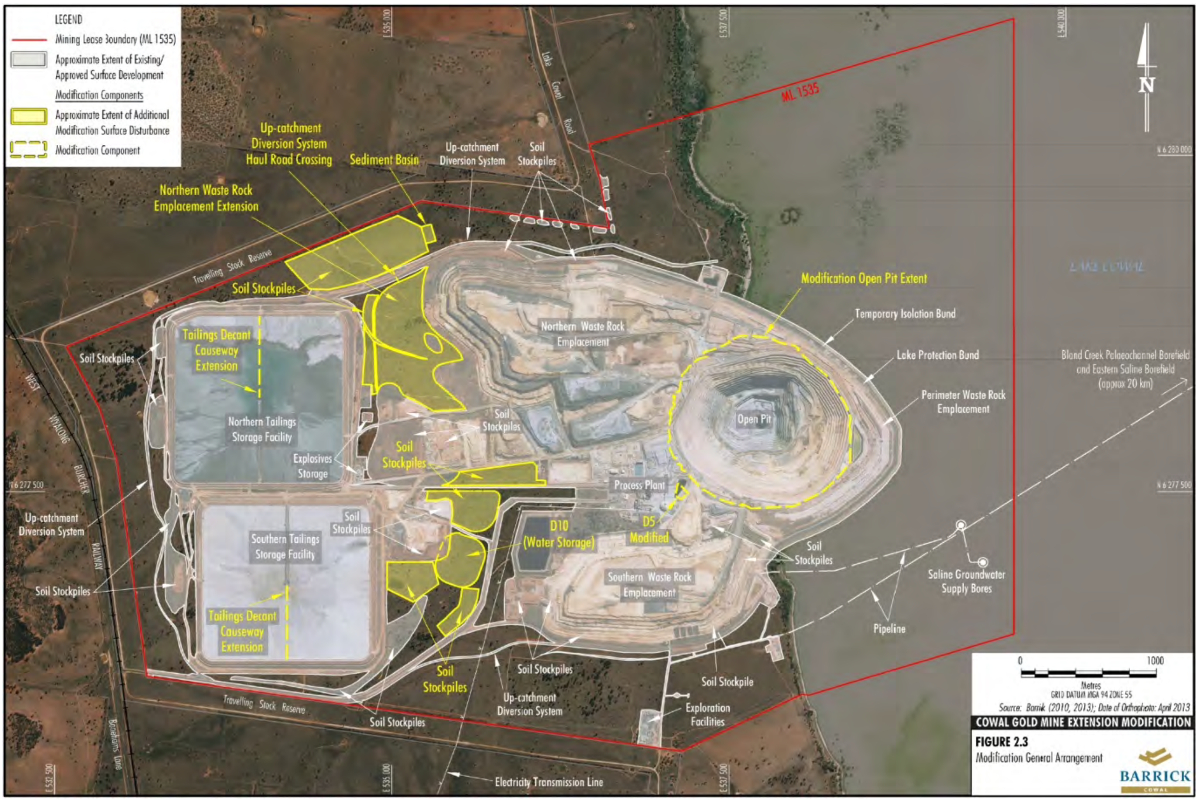


Figure 2.3: Modification General Arrangement

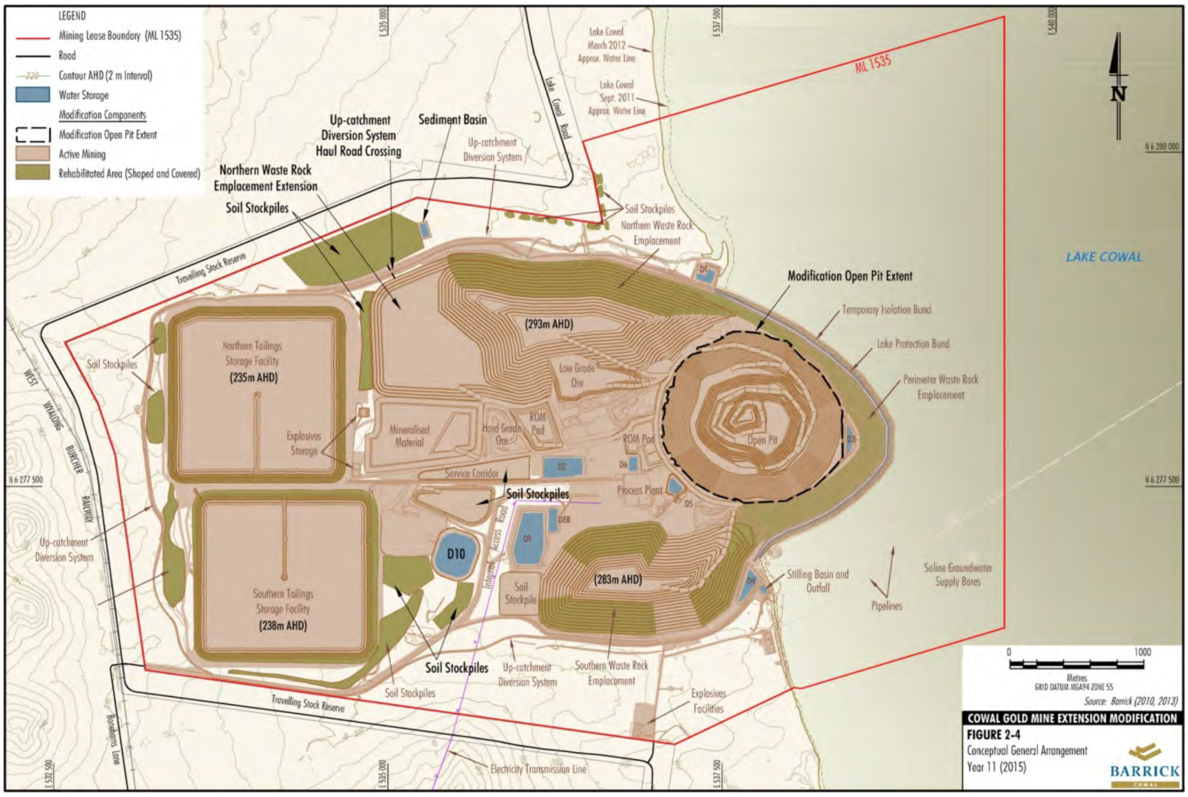


Figure 2.4: Conceptual General Arrangement Year 11 (2015)

3 AIR QUALITY CRITERIA

3.1 Introduction

Mining activities (e.g. the extraction of waste rock and ore by heavy earth moving equipment) generate fugitive dust emissions in the form of particulate matter described as total suspended particulate matter (TSP)[a], particulate matter with equivalent aerodynamic diameters 10 µm or less (PM_{10})[b] and particles with equivalent aerodynamic diameters of 2.5 micrometres (µm) and less ($PM_{2.5}$).

This section provides information on the air quality criteria used to assess the predicted impacts of the proposed Modification for the predicted worst case mining scenario. The assessment criteria provide benchmarks, which are intended to protect the community against the adverse effects of air pollutants. These criteria reflect current Australian standards for the protection of health and protection against nuisance effects. To assist in interpreting the significance of predicted concentration and deposition levels, some background discussion on the potential harmful effects of dust is provided below.

3.2 Particulate Matter and Health

The key air quality issue for mining operations is the emission of dust and particulate matter (PM). Mining generates PM from numerous activities including excavating, handling of material, hauling by heavy vehicles, blasting and wind erosion from stockpiles and exposed surfaces. PM is formed when particulate becomes entrained in the atmosphere by the turbulent action of wind, by the mechanical disturbance of materials or through the release of particulate-rich gaseous emissions from combustion sources.

Suspended PM is defined by its size, chemical composition and source. Particle size is an important factor influencing its dispersion and transport in the atmosphere and its potential effects on human health.

The particulate size ranges are commonly described as:

- TSP – total suspended particulate matter refers to all suspended particles in the air. In practice, the upper size range is typically 30 µm – 50 µm.
- PM_{10} – refers to all particles with equivalent aerodynamic diameters of less than 10 µm, that is, all particles that behave aerodynamically in the same way as spherical particles with a unit density.
- $PM_{2.5}$ – refers to all particles with equivalent aerodynamic diameters of less than 2.5 µm diameter (a subset of PM_{10}). Often referred to as the fine particles.
- $PM_{2.5-10}$ – defined as the difference between PM_{10} and $PM_{2.5}$ mass concentrations. Often referred to as coarse particles or the coarse fraction.

Evidence suggests that health effects from exposure to airborne particulate matter are predominantly related to the respiratory and cardiovascular systems. The human respiratory system has in-built defensive systems that prevent larger particles from reaching the more sensitive parts of the respiratory system. Particles larger than 10 µm, while not able to affect health, can soil materials and generally degrade aesthetic elements of the environment. For this reason air quality goals make reference to measures of the total mass of all particles suspended in the air, this is referred to as TSP. In practice particles larger than 30 to 50 µm settle out of the atmosphere too quickly to be regarded as air pollutants. The upper size range for TSP is usually taken to be 30 µm.

[a] TSP refers to all particles suspended in air. In practice, the upper size range is typically 30 µm.

[b] PM_{10} refers to all particles with equivalent aerodynamic diameters of less than 10 µm, that is, all particles that behave aerodynamically in the same way as spherical particles with a unit density.

Both natural and anthropogenic processes contribute to the atmospheric load of particulate matter. Coarse particles ($PM_{2.5-10}$) are derived primarily from mechanical processes resulting in the suspension of dust, soil, or other crustal[c] materials from roads, farming, mining, dust storms, and so forth. Coarse particles also include sea salts, pollen, mould, spores, and other plant parts.

Fine particles or $PM_{2.5}$ are derived primarily from combustion processes, such as vehicle emissions, wood burning, coal burning for power generation, and natural processes, such as bush fires. Fine particles also consist of transformation products, including sulphate and nitrate particles, and secondary organic aerosol from volatile organic compound emissions.

The size of particles determine their behaviour in the respiratory system, including how far the particles are able to penetrate, where they deposit, and how effective the body's clearance mechanisms are in removing them. This is demonstrated in **Figure 3.1** which shows the relative deposition by particle size within various regions of the respiratory tract. Additionally, particle size is an important parameter in determining the residence time and spatial distribution of particles in ambient air and key considerations in assessing exposure.

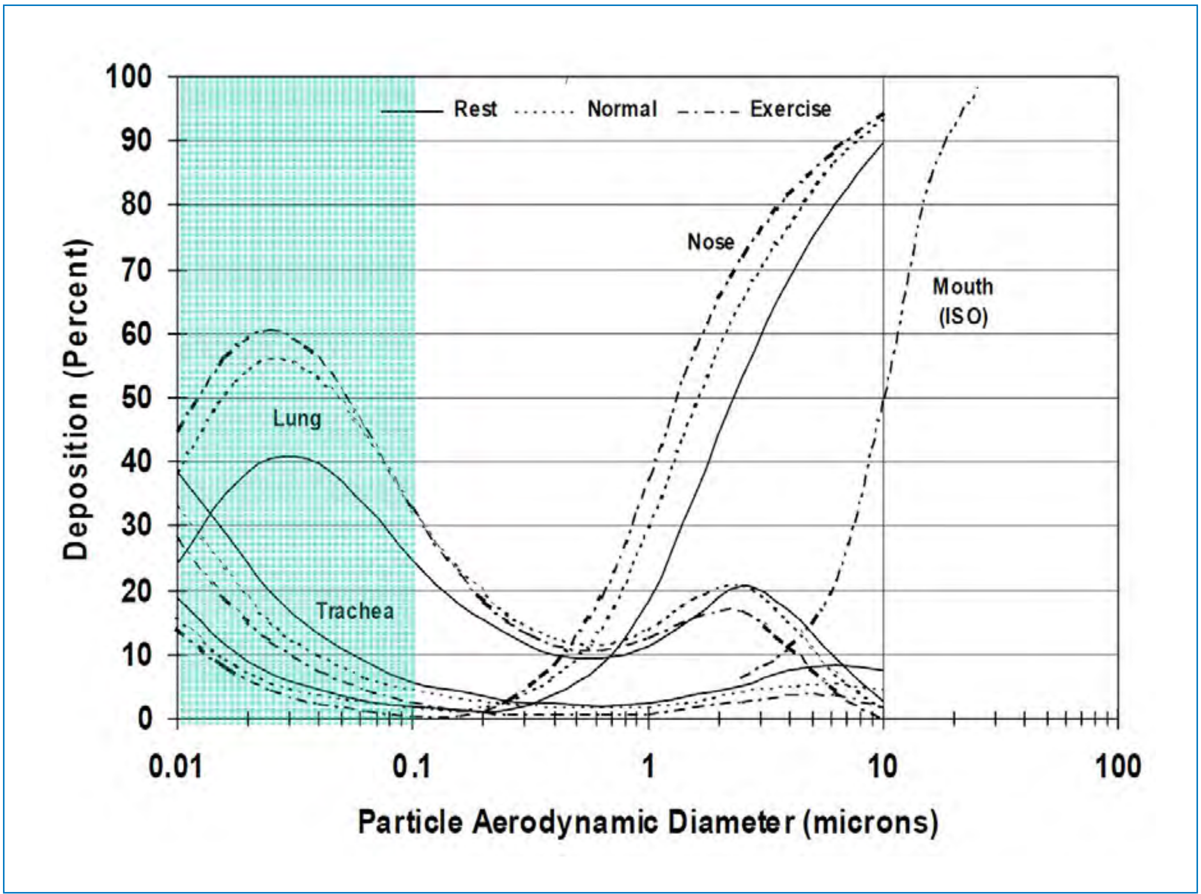


Figure 3.1: Particle Deposition within the Respiratory Tract (Phalen *et al.*, 1991)

3.3 EPA Criteria

The NSW Environment Protection Authority (NSW EPA) *Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in NSW* (Approved Methods) specifies air quality assessment criteria relevant for assessing impacts from air pollution (**NSW EPA, 2005**).

[c] Crustal dust refers to dust generated from materials derived from the earth's crust.

The air quality goals relate to the total dust burden in the air and not just the dust from the Modification. In other words, consideration of background dust levels needs to be made when using these goals to assess potential impacts. These criteria are health-based (that is, they are set at levels to protect against health effects) and are consistent with the *National Environment Protection Measure for Ambient Air Quality* (the Ambient Air-NEPM) (**NEPC, 1998**). However, the NSW EPA's criteria include averaging periods, which are not included in the Ambient Air-NEPM, and also references other measures of air quality, namely dust deposition and TSP.

In May 2003, the National Environment Protection Council (NEPC) released a *Variation to the National Environment Protection (Ambient Air) Measure for particles as $PM_{2.5}$* (Air-NEPM) (**NEPC, 2003**) to include advisory reporting standards for $PM_{2.5}$. The purpose of the variation was to gather sufficient data nationally to facilitate the review of the Ambient Air-NEPM, which is currently underway. The variation includes a protocol setting out monitoring and reporting requirements for $PM_{2.5}$ particles. It is noted that the Ambient Air-NEPM $PM_{2.5}$ advisory reporting standards are not yet impact assessment criteria.

Table 3.1 summarises the air quality goals for pollutants that are relevant to this study.

Table 3.1: EPA Air Quality Criteria

Pollutant	Standard	Averaging Period	Source
TSP	90 µg/m³	Annual	NSW EPA (2005) (cumulative assessment criteria)
PM_{10}	50 µg/m³	24-Hour	NSW EPA (2005) (cumulative assessment criteria)
	30 µg/m³	Annual	NSW EPA (2005) (cumulative assessment criteria)
	50 µg/m³	24-Hour	Ambient Air-NEPM (NEPC, 1998) (allows five exceedances per year)
$PM_{2.5}$	25 µg/m³	24-Hour	Air-NEPM (NEPC, 2003) Advisory Reporting Standard (cumulative)
	8 µg/m³	Annual	Air-NEPM (NEPC, 2003) Advisory Reporting Standard (cumulative)

Notes: µg/m³ – micrograms per cubic metre.

In addition to health impacts, airborne dust also has the potential to cause nuisance effects by depositing on surfaces, including vegetation. Larger particles do not tend to remain suspended in the atmosphere for long periods of time and will fallout relatively close to the source. Dust fallout can soil materials and generally degrade aesthetic elements of the environment and are assessed for nuisance or amenity impacts.

Table 3.2 shows the total and the maximum acceptable increase in dust deposition over the existing dust levels from an amenity perspective. These criteria for dust fallout levels are set to protect against nuisance impacts (**NSW EPA, 2005**).

Table 3.2: EPA Criteria for Dust (Insoluble Solids) Fallout

Pollutant	Averaging period	Maximum incremental increase in deposited dust level	Maximum total deposited dust level (cumulative)
Deposited dust	Annual	2 g/m²/month	4 g/m²/month

Notes: g/m²/month – grams per square metre per month.

3.4 Protection of the Environment Operations Act, 1997

Barrick currently holds Environment Protection Licence (EPL) 11912 issued under Chapter 3 of the NSW Protection of the Environment Operations Act, 1997 (PoEO Act). Relevant to air quality, the EPL includes a requirement to minimise dust emissions.

EPL 11912 does not include emission concentration limits relevant to the CGM process plant. Notwithstanding, Barrick has implemented the pollution control devices, including a fabric filter/baghouse, wet scrubber and cyclone/multicylcone.

4 EXISTING ENVIRONMENT

4.1 Existing Air Quality

Air quality standards and goals refer to pollutant levels that include the contribution from specific projects and existing sources. To fully assess impacts against all the relevant air quality standards and goals listed in **Section 3.3**, it is necessary to have information or estimates on existing dust concentrations and deposition levels in the area in which the Modification is likely to contribute to these levels. It is also important to note that the existing air quality conditions are influenced to some degree by the existing mining operations.

Dust concentration (TSP) and dust deposition data are collected in the vicinity of the CGM. The locations of the monitoring sites are shown in **Figure 4.1**. There is currently one high volume air sampler (HV1) measuring TSP, and 18 dust deposition gauges. There are no PM_{10} data collected at this time.

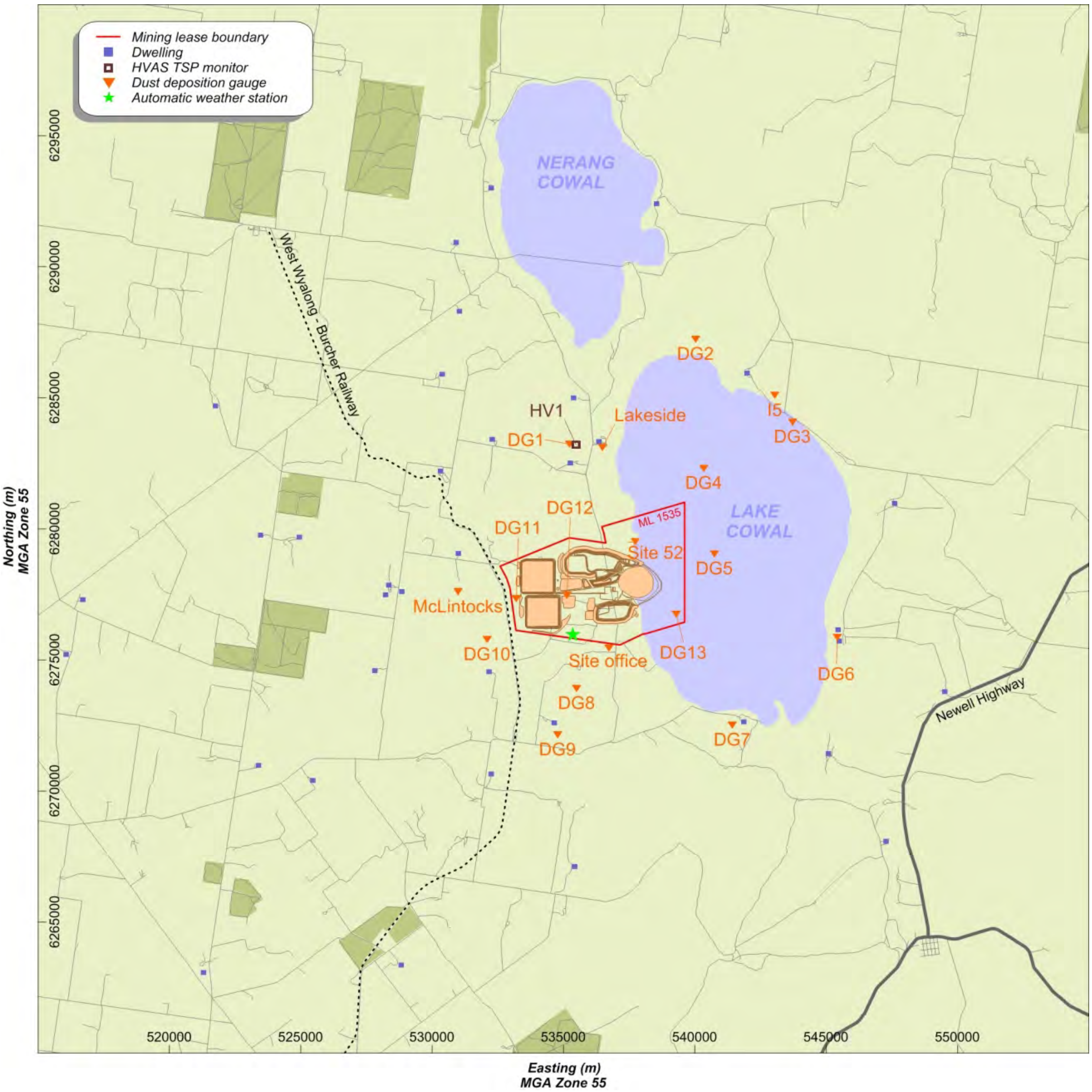


Figure 4.1: Location of monitoring sites for Cowal Gold Mine

4.1.1 TSP Concentrations and Inferred PM_{10} and $PM_{2.5}$ Concentrations

Figure 4.2 shows a time series of the TSP monitoring data since May 2004, collected by high volume air sampler at HV1. HV1 is located approximately 3 km to the north of the CGM (near the Coniston dwelling) and measures the contribution from a range of particulate matter sources, including traffic on unsealed roads, agricultural activities and dust sources associated with the existing CGM.

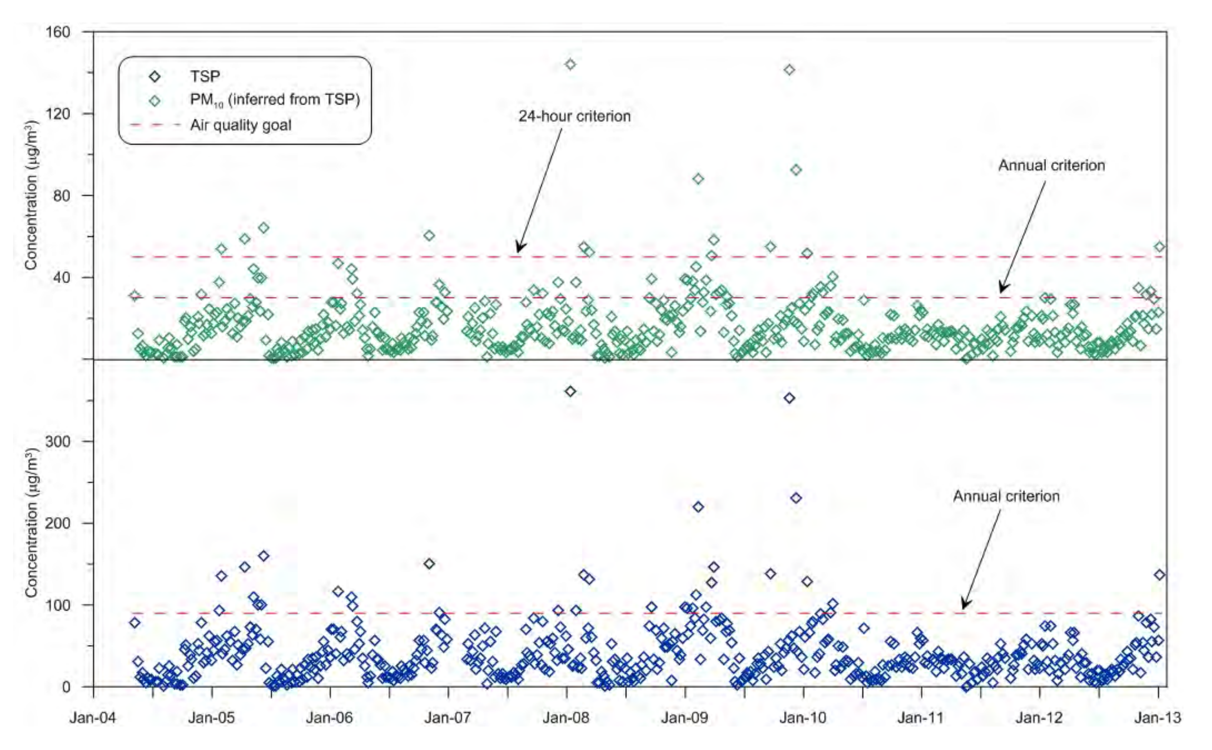


Figure 4.2: Time series for TSP monitoring and PM_{10} inferred data

Figure 4.2 also presents 'Inferred' PM_{10} data since May 2004. These data have been inferred from the daily TSP data 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 in the Hunter Valley (**NSW Minerals Council, 2000**). While the location of the CGM is obviously significantly removed from the Hunter Valley, the crustal nature of the dust would be similar, and the relationship is likely to also be similar.

Typically, the TSP and inferred PM_{10} concentrations in the area are lowest in the winter months and highest in the warmer, summer months. This seasonal cycle is evident in all available years of monitoring data. As noted in the review of climatic data (**Section 4.2**), the summer months tend to be drier than the winter months and the occurrence of bushfires and dust storms would be more common, potentially leading to higher airborne dust concentrations.

The monitoring shows that the 24-hour average PM_{10} concentrations (inferred from the TSP concentrations) have been above the NSW EPA's assessment criterion of 50 µg/m³ on approximately 12 days since 2004. The two highest PM_{10} concentrations to date were approximately 144 µg/m³ on 12 January 2008 and 141 µg/m³ on the 20th November 2009. An analysis of meteorological monitoring data from the CGM automatic weather station (AWS) showed the prevailing winds on 12 January 2008 were from the north-west. Based on the CGM location relative to the monitor, the CGM is unlikely to have contributed to the exceedance on that day. The winds on the 20th November 2009 were also predominantly from the north and therefore not likely to be a result of emissions from the CGM. It should also be noted that there were significant dust storms and high winds across NSW during much of November 2009 which are likely to have contributed to elevated TSP and PM_{10} levels in the CGM area.

In NSW, it is quite common to measure 24-hour average PM_{10} concentrations above the NSW EPA criterion 50 µg/m³ on occasions. Events such as bushfires or dust storms are often the cause of elevated PM_{10} concentrations, which can be observed over large geographical areas.

Table 4.1 summarises the annual average TSP and PM_{10} concentrations for HV1. The inferred annual average PM_{10} concentrations, since monitoring commenced, have ranged between 13 and 25 µg/m³. These levels are below the NSW EPA's annual average criterion of 30 µg/m³. Measured TSP concentrations have been below the NSW EPA annual average assessment criterion of 90 µg/m³ (**Table 4.1**).

Table 4.1: Measured dust concentrations in the study area

Dust classification	Annual average concentration (µg/m³)								Annual Average criterion (µg/m³)
	2005	2006	2007	2008	2009	2010	2011	2012	
TSP	42	43	37	44	63	37	32	36	90
PM_{10} (inferred from TSP)	17	17	15	17	25	15	13	14	30

Background Concentrations for Assessment Purposes

For the purposes of conservatively establishing background levels for this assessment, the average of the annual averages over the entire monitoring period was used. That is, 42 µg/m³ and 17 µg/m³ (40% of 42 µg/m³) were taken to be representative of TSP and PM_{10} concentrations, respectively.

It is noted that this approach to estimating the background levels for the CGM area is considered conservative, as several large dust storms occurred during the 2009 monitoring period and the monitoring data would also contain a contribution from the existing CGM operations.

An estimation of the annual average background value for $PM_{2.5}$ has also been inferred, as there are no direct measurements in the area. Annual average data for 2011 from a number of NSW EPA sites with co-located PM_{10} and $PM_{2.5}$ measurements were analysed, and these values plotted in **Figure 4.3**, showing a relationship between the two particle size groups. Applying the same regression function to the inferred annual average PM_{10} concentrations presented in **Table 4.1** gives an estimated annual average $PM_{2.5}$ concentration of approximately 5.2 µg/m³. This value has been used to represent the annual average $PM_{2.5}$ background for this assessment.

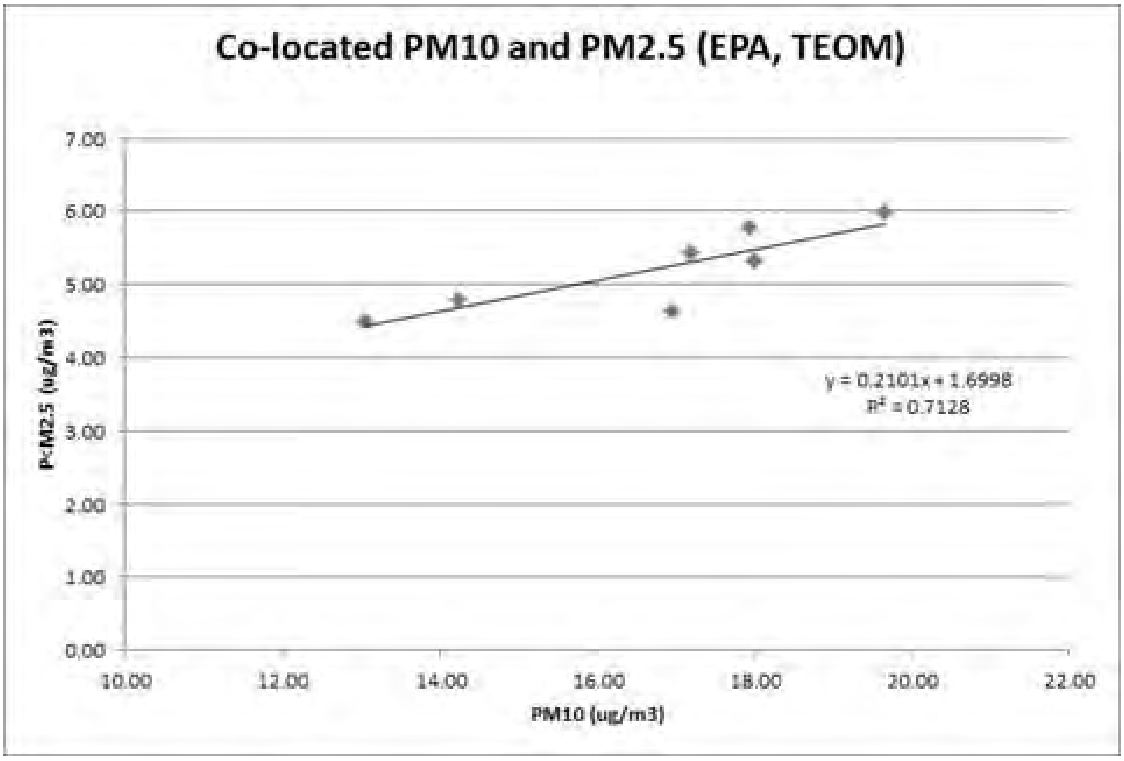


Figure 4.3: Annual average $PM_{2.5}$ and PM_{10} data from co-located TEOMs in 2011 in Bathurst

4.1.2 Dust Deposition

Prior to the development of the CGM, monthly dust deposition was measured at three locations for a one year period (1993 to 1994). All three sites were located within ML 1535 and annual average dust deposition ranged between 1.0 and 1.6 g/m^2/month (**Barrick, 2003**), well below the 4 g/m^2/month NSW EPA annual average criterion.

The current dust deposition monitoring includes gauges at various locations in the vicinity of the CGM (refer **Figure 4.1**). Annual averages from data collected over the five years period from 2008 to 2012 (excluding monitors within ML 1535) are presented in **Table 4.2**.

Table 4.2 : Measured dust deposition in the CGM area

Site	Site description	Annual average dust deposition (insoluble solids) (g/m²/month) EPA criterion = 4 g/m²/month					
		2008	2009	2010	2011	2012	Average
McLintocks	General monitoring site	4.3	4.0	7.7	3.2	18.6	7.6
Lakeside	General monitoring site	6.0	6.4	2.2	2.0	7.3	4.5
I5	General monitoring site	3.4	4.8	5.7	4.4	3.8	4.4
DG1	Private residence (Coniston)	2.5	2.7	1.2	1.2	1.6	1.8
DG2	Bird breeding area	2.6	3.2	3.1	1.3	1.1	2.3
DG3	General monitoring site	4.0	2.7	4.7	1.2	2.0	2.9
DG4	Native flora area and bird breeding area	3.6	3.1	4.3	0.9	2.1	2.8
DG6	Private residence (Gumbelah)	**8.4**	**4.8**	**5.7**	1.9	**6.5**	**5.5**
DG7	Barrick-owned residence	6.7	5.4	7.4	3.2	4.7	5.5
DG8	Native flora area	4.7	3.6	1.4	0.8	2.3	2.6
DG9	Native flora area	3.2	3.9	1.6	1.2	1.5	2.3
DG10	Native flora area	3.9	3.8	1.2	3.4	1.9	2.8

Note: Bold values represent exceedances of EPA criterion at private receivers.

The monitoring results presented in **Table 4.2** show that dust deposition levels above 4 g/m²/month were measured at several locations. In the case of the McLintocks gauge, which measured an average of 7.6 g/m²/month, the on-site DG11, which is in the same direction as McLintocks, yet much closer to mining activities, measured an average of 4.2 g/m²/month over the same period. Hence the dust deposition at McLintocks is most likely to be due to localised sources to that gauge. Likewise, the Lakeside gauge measured an average of 4.5 g/m²/month, compared with the closely located DG1, which measured an average of only 1.8 g/m²/month. Gauge I5 measured an average of 4.4 g/m²/month, compared with DG4, in the same direction as McLintocks, yet much closer to mining activities, measured an average of 2.8 g/m²/month over the same period, also DG3, which is closely located to I5, measured an average dust deposition of 2.9 g/m²/month. This would indicate that the exceedance of 4 g/m²/month at these gauges is due to localised activities (very close to the gauge) and unlikely to be due to the mining activity at CGM. Similarly, gauges DG6 and DG7 returned an average of 5.5 g/m²/month. These gauges are distant from mining activities and are most likely influenced by other more localised dust sources.

As gauge DG6 represents a private residence, dust levels for 2012 have been further investigated for this gauge. June 2012 (representing the collection period of 21st May to 12th June), had an unusually high result of 18.4 g/m²/month. This location is most likely to be impacted by dust from the CGM when winds are blowing from the west-northwest. Whilst a small proportion of winds from this direction were recorded during June, winds were predominately from the southeast and south-southeast (as shown in **Figure 4.4**).

The next highest result at this gauge in 2012 was recorded in the month up to 16 April, with a level for this period of 10.1 g/m²/month. During this period, very few winds came from the direction of the CGM (**Figure 4.4**). September (28 August – 26 September 2012) also reported an elevated dust deposition result (7.2 g/m²/month). Whilst this period did show a small proportion of winds from the west-northwest, the majority of winds were from other wind directions (predominately the southwest quadrant). These results indicate that elevated dust levels recorded at DG6 in 2012 are not likely to be the result of activities at the CGM.

It is also worth noting that winds on an annual basis are not generally from the west-northwest (refer to **Section 4.3**) and as such it is unlikely that the CGM is the dominant source of annual dust levels at DG6.

Figure 4.4: Windroses for selected periods

Background deposition levels for assessment purposes.

Given that these gauges are heavily influenced by the activities in the immediate area, this makes it difficult to determine what the background deposition rate is likely to be. Gauges DG1, DG2, DG3 and DG9 represent sites in different directions from the existing CGM and appear to be less influenced by significant localised activities. The average of these levels, over the latest five year monitoring period, indicates that background levels may be of the order of 2.5 g/m^2/month.

4.1.3 Summary of Background Air Quality

In summary, the background dust levels assumed for this study are:

- annual average TSP of 42 µg/m^3;
- annual average PM_{10} of 17 µg/m^3;
- dust deposition of 2.5 g/m^2/month; and
- annual average $PM_{2.5}$ of 5.2 µg/m^3.

These background levels are considered to be highly conservative for the purpose of assessment for the Modification as they include any contribution from the CGM, resulting in double counting when these adopted background levels are considered cumulatively with modelled impacts from the CGM incorporating the Modification.

4.2 Local Climate Conditions

The Bureau of Meteorology (BoM) collects climatic information at Wyalong Post Office Station (station number 073054) approximately 38 km to the south-west of CGM. A range of climatic information collected from the Wyalong Post Office Station site is presented in **Table 4.3**.

Temperature data from **Table 4.3** indicate that the warmest month is January with a mean maximum temperature of 32.8ºC. July is typically the coolest month with a mean minimum temperature of 3.0ºC.

Humidity data indicate that the mean of the 9.00 am relative humidity observations are highest in June and July and lowest in December and January, with values of 87% and 54% respectively. The mean of the 3.00 pm observations are highest in July (62%) and lowest in January (32%) (**Table 4.3**).

Over the year, rain falls (1 millimetre [mm]) on approximately 51 days with the average monthly rainfall ranging between 35.3 mm in April to 46.1 mm in October.

Table 4.3: Climate information for Wyalong Post Office

Statistic Element	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Mean maximum temperature (°C)	32.8	31.9	28.7	23.6	18.6	14.9	14.0	15.9	19.5	23.4	27.2	30.6	23.4
Mean minimum temperature (°C)	17.5	17.5	14.5	10.0	6.7	4.1	3.0	3.9	6.1	9.4	12.6	15.4	10.1
Mean rainfall (mm)	41.7	39.2	37.9	35.3	39.1	42.1	41.8	39.1	36.6	46.1	36.8	44.2	480
Mean number of days of rain 1mm	3.3	3.2	3.1	3.4	4.3	5.4	5.9	5.6	4.7	4.7	3.6	3.8	51
Mean 9.00am temperature (°C)	23.1	22.1	19.6	15.9	11.2	7.6	6.6	8.7	12.5	16.7	18.9	21.7	15.4
Mean 9.00am relative humidity (%)	54	61	62	66	78	87	87	79	69	58	58	54	68
Mean 3.00pm temperature (°C)	31.4	30.6	27.5	22.9	18.1	14.2	13.3	15.2	18.4	22.6	26.1	29.1	22.4
Mean 3.00pm relative humidity (%)	32	35	37	43	51	61	62	53	46	39	35	34	44

Source: **BoM (2013)** website.
Climate averages for Station: 073054 Wyalong Post Office, Commenced: 1895; Last record: 2013; Latitude (deg S): -33.93; Longitude (deg E): 147.24; State: NSW.

4.3 Dispersion Meteorology

The Gaussian dispersion model used for this assessment requires information about the dispersion characteristics of the area. In particular, data are required on wind speed, wind direction, atmospheric stability class[d] and mixing height[e].

The NSW EPA has listed requirements for meteorological data that are used for air dispersion modelling in the Approved Methods (**NSW EPA, 2005**). The requirements are as follows:

- data must span at least one year;
- data must be at least 90% complete; and
- data must be representative of the area in which emissions are modelled.

A complete year of data for 2012 have been made available for the purposes of this assessment from the AWS installed at the CGM site. The data included 15-minute records of temperature, wind speed, wind direction and sigma-theta (the standard deviation of the horizontal wind direction). These data contained all the necessary parameters required to determine stability class and were processed into a file containing hourly averages, suitable for the dispersion model.

[d] In dispersion modelling, stability class is used to categorise the rate at which a plume will disperse. In the Pasquill-Gifford stability class assignment scheme, as used in this study, there are six stability classes - A through to F. Class A relates to unstable conditions such as those that might be found on a sunny day with light winds. In such conditions plumes will spread rapidly. Class F relates to stable conditions, such as when the sky is clear, the winds are light and an inversion is present. Plume spreading is slow in these circumstances. The intermediate classes B, C, D and E relate to intermediate dispersion conditions.

[e] The term mixing height refers to the height of the turbulent layer of air near the earth's surface into which ground-level emissions will be rapidly mixed. A plume emitted above the mixed-layer will remain isolated from the ground until such time as the mixed-layer reaches the height of the plume. The height of the mixed-layer is controlled mainly by convection (resulting from solar heating of the ground) and by mechanically generated turbulence as the wind blows over the rough ground.

The 2012 data were compared against data from 2009, 2010 and 2011 for the same AWS. The 2012 data had an excellent data capture rate (over 99.9%) and was representative of larger meteorological data set for the site. **Table 4.4** shows dispersion characteristics for these years of data, rainfall for each year is also shown. As well as comparing these dispersion characteristics, windroses for the various years were also compared. Data for 2012 was found to be representative of the period from 2009-2012.

Table 4.4: Dispersion characteristics in CGM area in 2012

Year	Rainfall[1] (mm)	Calms (%)	Average wind speed (m/s)	Stability class distribution					
				A	B	C	D	E	F
2009	532	1.6	3.6	7.1	4.0	7.3	43.8	31.4	6.4
2010	697	2.5	3.1	5.8	4.0	8.6	41.0	31.3	9.3
2011	715	3.0	3.2	4.7	4.3	9.2	43.0	31.3	7.5
2012	538	3.7	3.2	5.0	4.7	12.0	41.6	28.5	8.3
All years	620	2.7	3.3	5.7	4.3	9.3	42.4	30.6	7.9

Source: **BoM, 2013.** Burcher Post Office, BoM station number 50010, 33.52ºS, 147.25ºE, elevation 220 m, 19 km from CGM.
Note: m/s – metres per second.

Annual and seasonal windroses have been prepared from the on-site meteorological data for 2012 and are shown in **Figure 4.5**. Over the year, the area experiences winds from all directions, but most commonly from the south-south-west. Autumn and spring windroses are similar to the annual windrose. In summer, there is an addition of a significant proportion of winds from the east-northeast. Winter winds are generally from the western sector. The area does not frequently experience low wind speeds, with calm periods (that is, winds less than or equal to 0.5 metres per second [m/s]) measured only 3.7% of the time. The mean wind speed in 2012 data was approximately 3.2 m/s.

To use the wind data to assess dispersion it is necessary to also have available data on atmospheric stability. A stability class was calculated for each hour of the meteorological data using sigma-theta according to the method recommended by the United States Environmental Protection Agency (US EPA) (**US EPA, 1986**).

Table 4.4 shows the frequency of occurrence of the stability categories expected in the CGM area.

The most common stability class in the area was determined to be D class at 41.5%. Under D class conditions, pollutant emissions disperse rapidly.

Joint wind speed, wind direction and stability class frequency tables for the on-site meteorological data are provided in **Appendix A**.

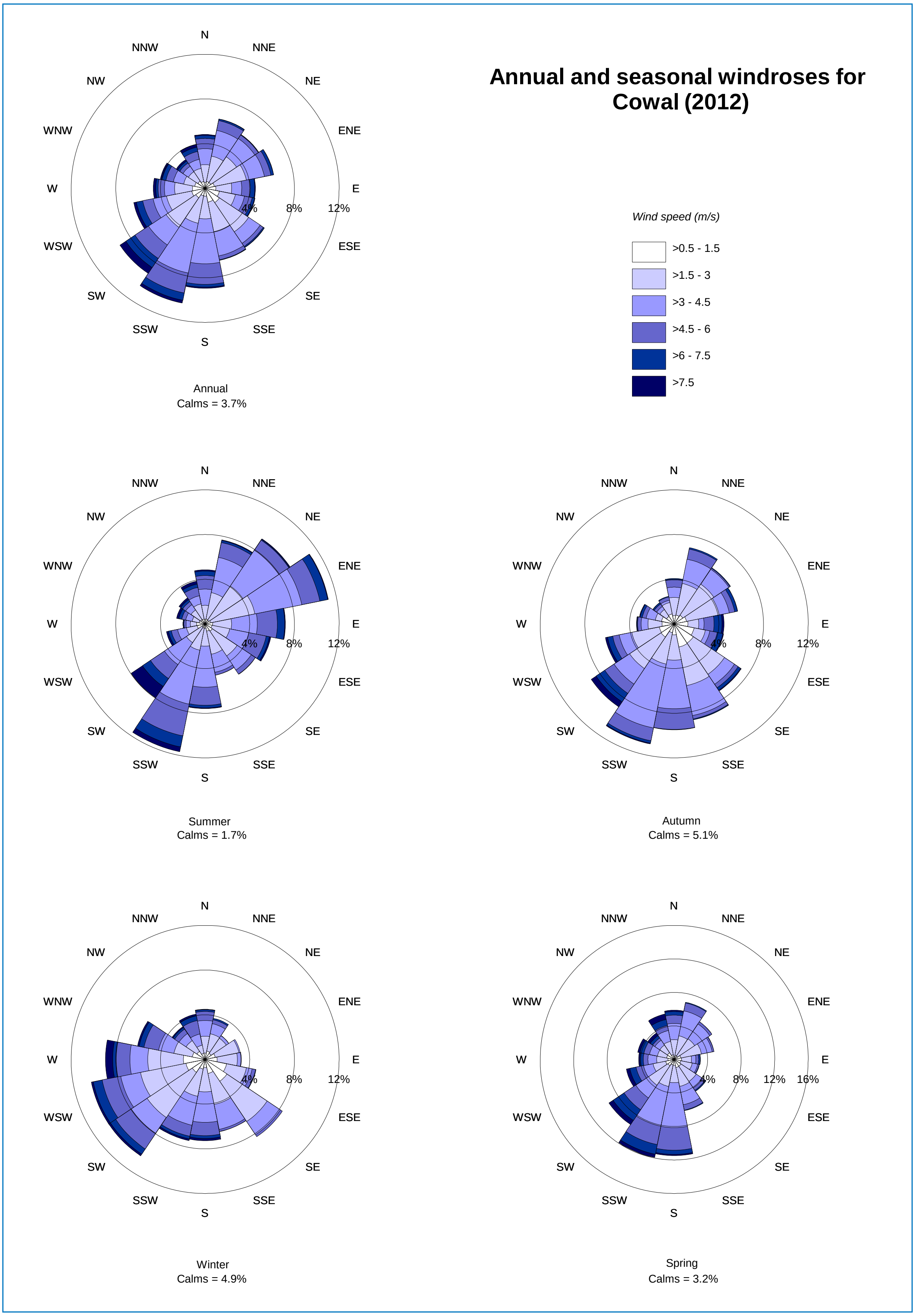


Figure 4.5: Annual and seasonal windroses for Cowal Gold Mine in 2012

5 STUDY APPROACH AND METHODOLOGY

5.1 Dispersion Modelling

For the purposes of assessing the impact of the Modification, 2015 was selected as the representative 'worst-case' scenario, as discussed in **Section 2.3**. An emissions inventory for 2015 was developed (see **Section 5.3**) and a modelling study carried out using ISCST3 (the ISC model), to estimate annual average PM_{10}, TSP and $PM_{2.5}$ concentrations, 24-hour average PM_{10} and $PM_{2.5}$ concentrations and annual average dust deposition quantities in the area surrounding the CGM.

The ISC model has been used for this assessment consistent with the previous air quality assessment conducted for the approved CGM (**Holmes Air Sciences, 2008**). In addition the ISC model is considered suitable for this assessment given the relatively flat topography surrounding the CGM (**Figure 2.2**) (i.e. there is limited intervening topography between the CGM and the closest private dwellings that would affect the dispersion of dust from the CGM).

The ISC model is fully described in the user manual and the accompanying technical description (**USEPA, 1995a** and **USEPA, 1995b**). The modelling has been based on the use of three particle-size categories (0 to 2.5 µm – $PM_{2.5}$, referred to as FP [Fine Particles], 2.5 to 10 µm - referred to as CM [coarse matter] and 10 to 30 µm - referred to as the Rest). Emission rates of TSP have been calculated using emission factors derived from **USEPA (1985)** and **SPCC (1983)**.

The distribution of particles has been derived from measurements in the **SPCC (1986)** study. The distribution of particles in each particle size range is as follows:

- $PM_{2.5}$ (FP) is 4.7% of the TSP;
- $PM_{2.5-10}$ (CM) is 34.4% of TSP; and
- PM_{10-30} (Rest) is 60.9% of TSP.

Emission rates of TSP in 2015 have been calculated using emission factors developed by the US EPA. Modelling was undertaken for each of the size fractions which are assumed to emit according to the distribution above and deposit from the plume in accordance with the deposition rate appropriate for particles with an aerodynamic diameter equal to the geometric mass mean of the particle size range.

The resultant predicted concentrations are then combined as follows to determine the concentrations of each size fraction:

- $PM_{2.5}$ = FP;
- PM_{10} = FP + CM; and
- TSP = FP + CM+ Rest.

The location of modelled sources and the 36 residential receptors are shown in **Figure 2.1**. A further 180 (non-residential) receptors were modelled in the area surrounding the mine to allow for dust contours to be developed.

Meteorological data from 2012 was used in the modelling (**Section 4.3**).

The 24-hour PM_{10} results calculated by the ISC model when modelled for multiple receptor locations representing the maximum predicted 24-hour average PM_{10} levels for each receptor location throughout that year of modelled data. To further analyse the variation in 24-hour average PM_{10} levels at the nearest residence to the CGM, the ISC model was run with daily output for five residential receptors. These receptors were chosen to represent different directions downwind from the CGM.

5.2 Dust Control on Haul Roads

Preliminary emissions estimations indicated that of the potential dust sources associated with the Modification, emissions from the hauling of waste and ore contributes more than any other source group. Historically, modelling assessments for mine sites apply a haul road control level of 75% (representing control via Level 2 watering). In accordance with the modelling scenario presented in this report, an additional level of control on hauling (80% control) has been applied to emissions estimations to represent on-site haul road watering and the use of the PetroTac dust suppressant, consistent with current best practice.

This level of control is supported by **Buonicore and Davis (1992)** who state that a level of control of 90% is expected to be achieved by increasing the application rate of water and/or through the use of dust suppressants. The study states that 90% control can only be maintained provided the moisture content of the surface material is approximately 8% (refer to **Figure 5.1**). The 80% control level is also supported by **Sinclair Knight Merz (2005)** who derived an equation that shows control benefits for increased watering up to 95%.

The above observations are further reinforced within **US EPA (2006)**. **Figure 5.2** presents the relationship between the instantaneous control efficiency due to watering and the resulting increase in surface moisture. The moisture ratio “M” (shown on the x-axis) is calculated by dividing the surface moisture content of the watered road by the surface moisture content of the uncontrolled road.

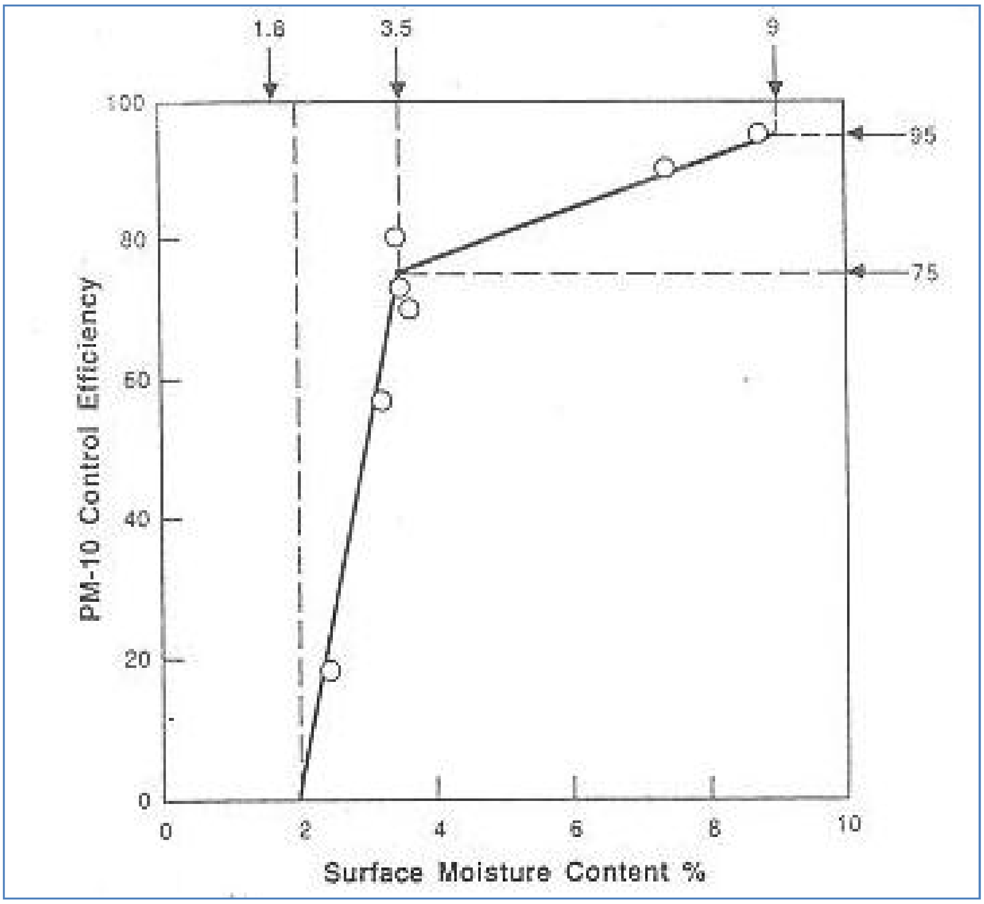


Figure 5.1: Watering Control Effectiveness for Unpaved Roads (Buonicore and Davis, 1992)

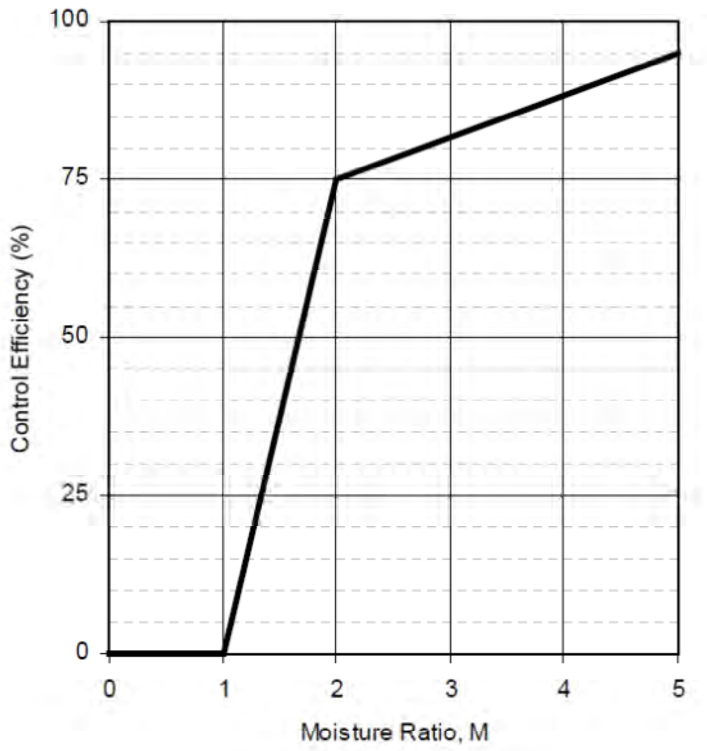


Figure 5.2: Watering Control Effectiveness for Unpaved Travel Surfaces (US EPA, 2006)

US EPA (2006) states that as the watered surface dries, both the ratio M and the predicted instantaneous control efficiency (shown on the y-axis) decrease. **Figure 5.2** shows that between the uncontrolled surface moisture content and a value twice as large, a small increase in moisture content results in a large increase in control efficiency. Beyond that, control efficiency grows slowly with increased moisture content. For example, if the uncontrolled surface moisture content was 2%, and the addition of water increased this to 4%, a 75% reduction in emissions could be expected. However, increasing the surface moisture content further to 6% would only result in an additional 5% control.

Notwithstanding the above, it is clear from **Figure 5.2**, that while returns diminish beyond 75% control, theoretical control efficiencies from the application of water alone may reach up to 95%.

5.3 Emission Estimates

Operations for the CGM incorporating the Modification in 2015 have been analysed and estimates of dust emissions for the individual activities have been made. Emission factors developed both locally and by the US EPA, have been applied to estimate the amount of dust produced by each activity. The emission factors applied are the most reliable and up-to-date for determining dust generation rates. Mining plans for the Modification have been analysed and an emissions inventory has been prepared for 2015.

TSP emissions for 2015 have been estimated and are provided below in **Table 5.1**.

The haulage of waste rock to the northern waste rock emplacement is the most significant dust generating activity that would occur at the site in 2015. The projected activities for the CGM incorporating the Modification in 2015 focus heavily on removal of waste rock, as discussed in **Section 2.2**. The estimated total annual emission of TSP for 2015 operations is approximately 2,790 tonnes/year. The table in **Appendix B** summarises the emissions calculations.

Table 5.1: Emission Estimates for the Eastern Extension

Activity	TSP emission (kg/year)
TSF Lift Construction	
Scrapers/dozers working on tailings	62,118
Loading trucks	1,489
Trucks hauling	45,624
Trucks unloading	1,489
Grader	10,923
Mining Operations	
Drilling	16,151
Blasting	57,458
Loading overburden to trucks	54,272
Hauling waste rock to northern emplacement area	1,042,266
Hauling waste rock to southern emplacement area	298,858
Emplacing waste rock at northern emplacement	38,405
Emplacing waste rock at southern emplacement	12,802
Dozer working on emplacement areas, pits and stockpiles	159,530
Loading ore to trucks	12,945
Hauling ore to ROM pad	294,140
Unloading ore to ROM pad	12,945
Rehandling ore to crusher	5,559
Primary ore crushing	11,096
Loading to coarse ore stockpile	13,896
Ore processing in mill	13,896
Wind erosion, open pit	113,880
Wind erosion, northern emplacement area	203,232
Wind erosion, southern emplacement area	66,576
Wind erosion, stockpiles and exposed areas	67,452
Wind erosion, Tailings storage dams	122,640
Grading roads	50,320
TOTAL	**2,789,961**

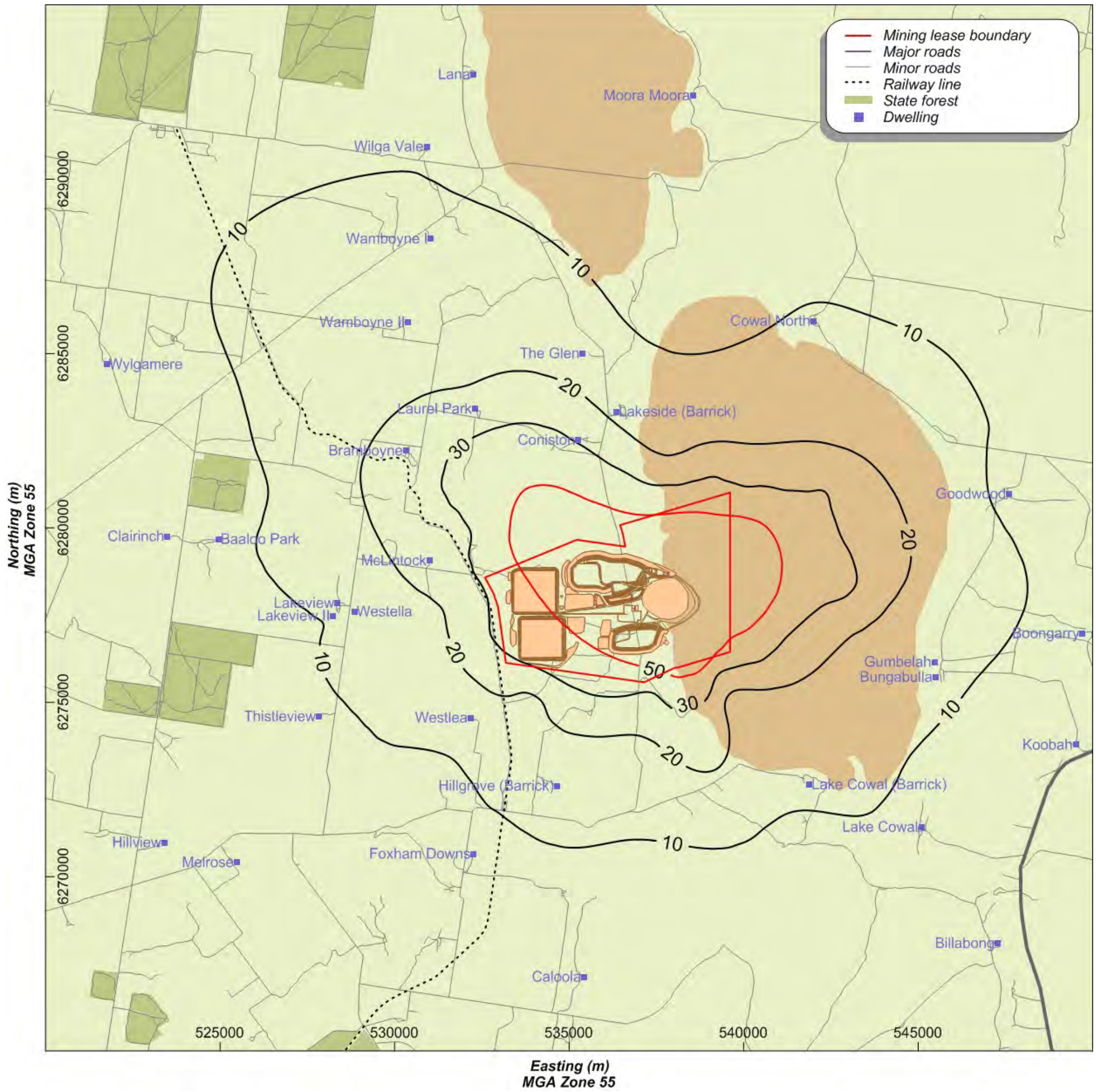
Note: kg/year – kilograms per year.
ROM – run-of-mine.

6 MODELLING RESULTS

6.1 CGM Only – Incorporating the Modification

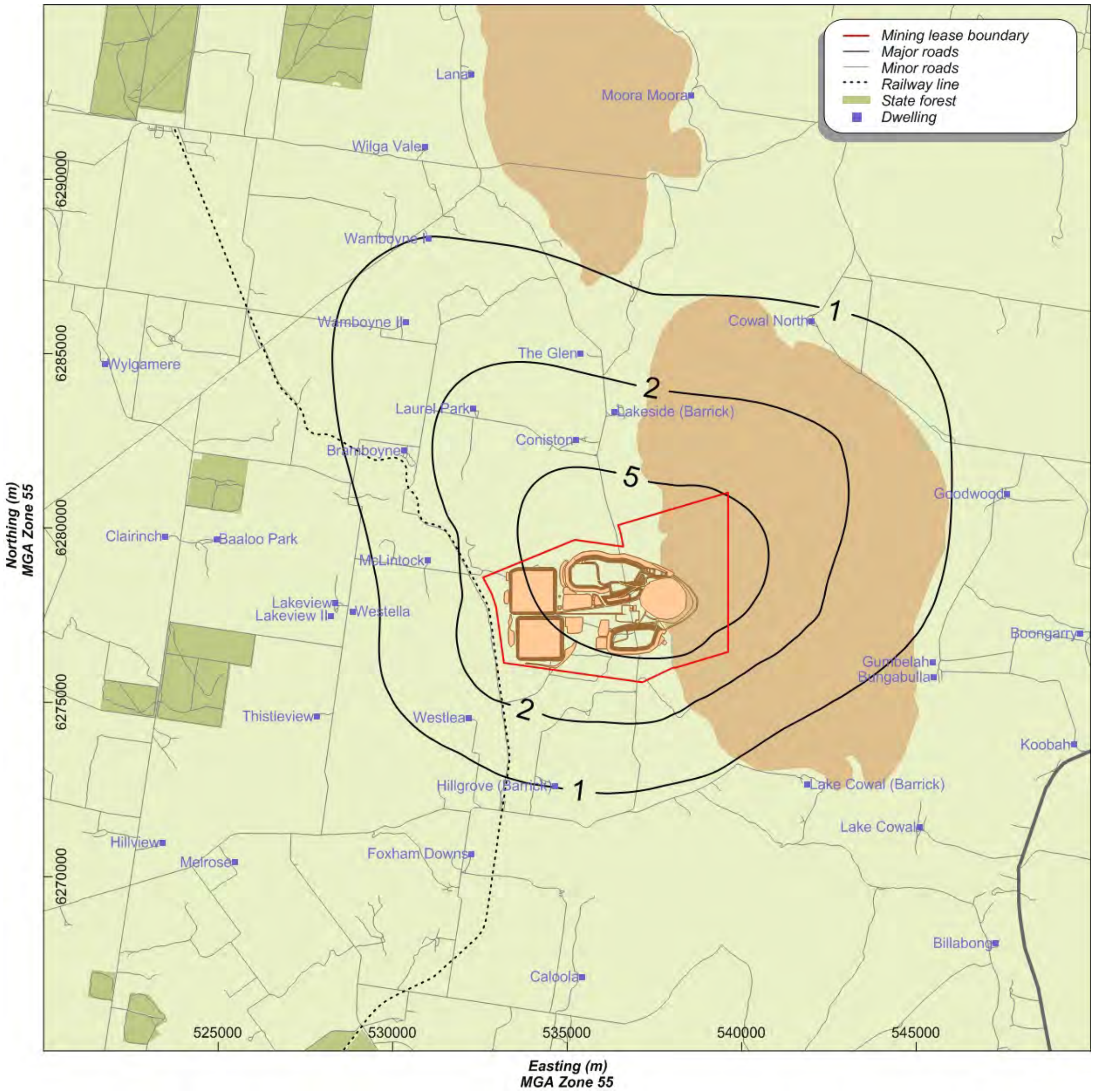
Figure 6.1 to **Figure 6.4** present the predicted $PM_{2.5}$, PM_{10} and TSP concentrations and dust deposition levels across the modelling domain, due to operations at the CGM incorporating the Modification only (i.e. the results do not include background levels). The results at residential receptors are also summarised in **Table 6.1**. No exceedances of relevant 24-hour average or annual average PM_{10} criteria or the 24-hour average $PM_{2.5}$ advisory standard are predicted at any private receiver due to the emissions from the CGM incorporating the Modification only.

The results indicate that operations at the CGM incorporating the Modification would result in minor (i.e. well below criteria/advisory standards) annual average $PM_{2.5}$, PM_{10}, TSP concentrations and dust deposition levels at all private receivers.



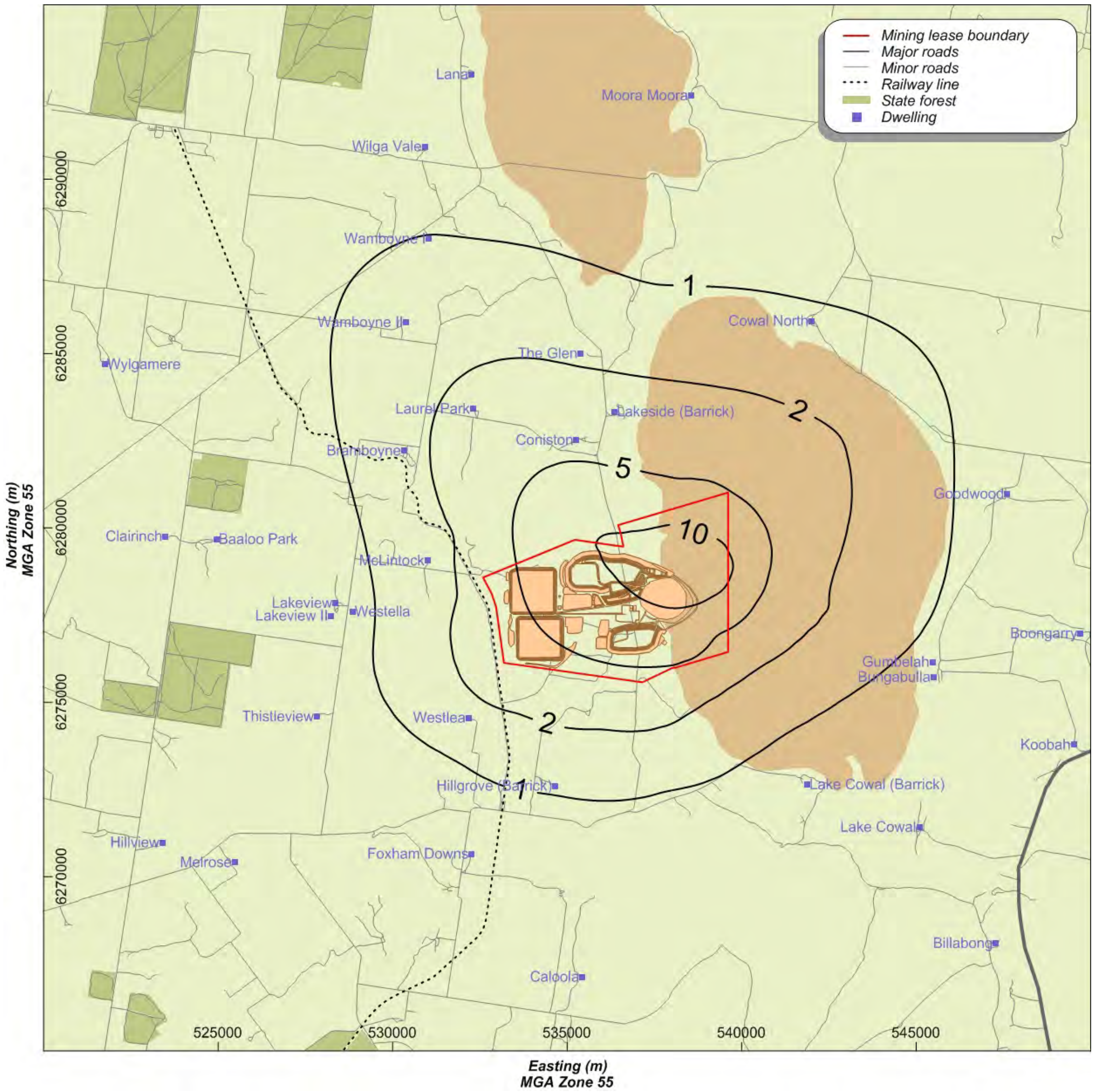
Species: PM10	Location: Cowal Gold Mine	Scenario: Modified CGM Only	Percentile: N/A	Averaging Time: 24-hour
Model Used: ISCST3	**Units:** µg/m³	**Guideline:** N/A	**Met Data:** 2012	**Plot:** C. Isley

Figure 6.1: Predicted 24-hour average PM_{10} concentrations in 2015 – Modified CGM Only



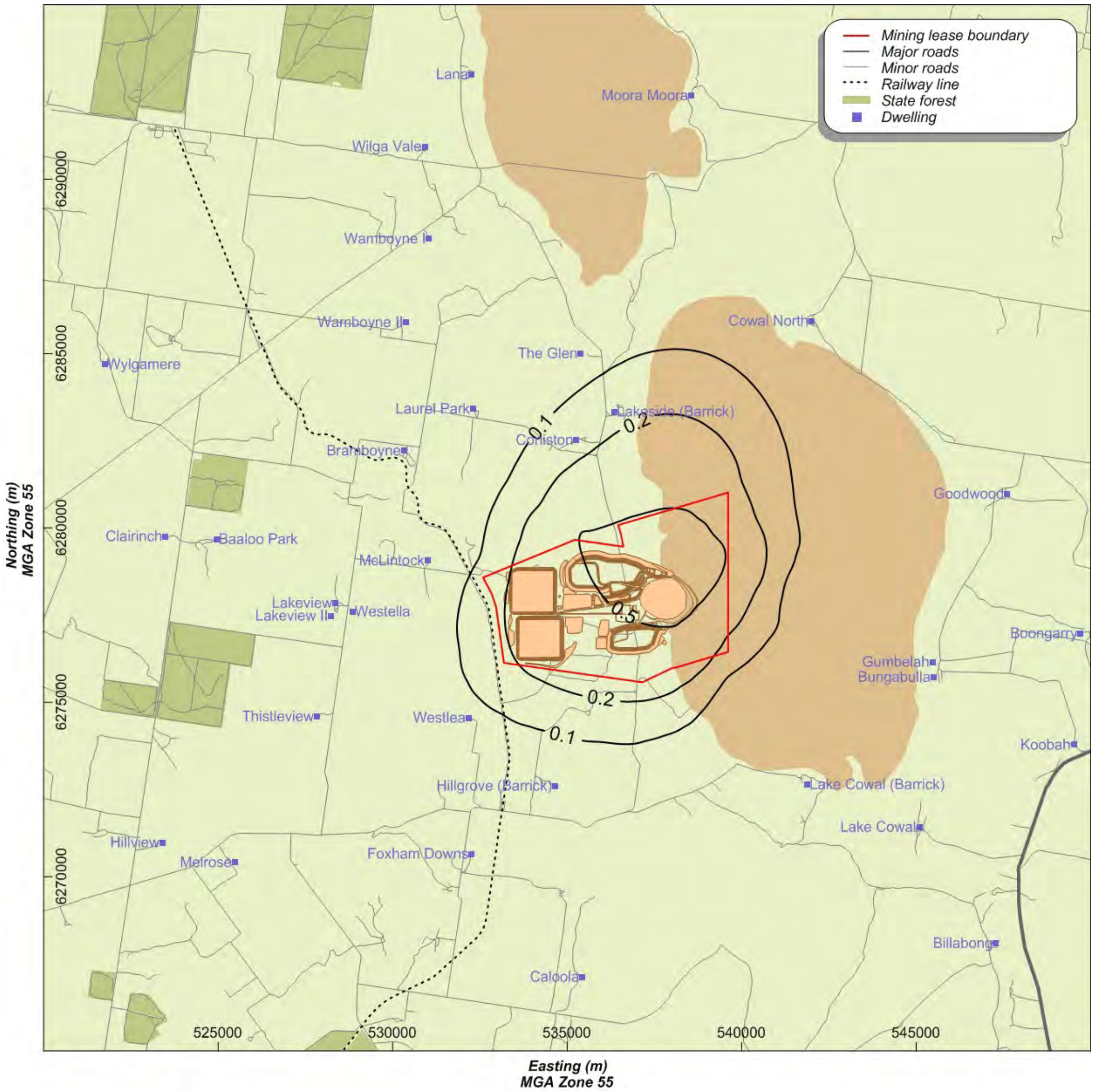
Species: PM10	Location: Cowal Gold Mine	Scenario: Modified CGM Only	Percentile: N/A	Averaging Time: Annual
Model Used: ISCST3	**Units:** µg/m³	**Guideline:** N/A	**Met Data:** 2012	**Plot:** C. Isley

Figure 6.2: Predicted annual average PM_{10} concentrations in 2015 – Modified CGM Only



Species: TSP	Location: Cowal Gold Mine	Scenario: Modified CGM Only	Percentile: N/A	Averaging Time: Annual
Model Used: ISCST3	**Units:** µg/m³	**Guideline:** N/A	**Met Data:** 2012	**Plot:** C. Isley

Figure 6.3: Predicted annual average TSP concentrations in 2015 – Modified CGM Only



Species: Deposition	**Location:** Cowal Gold Mine	**Scenario:** Modified CGM Only	**Percentile:** N/A	**Averaging Time:** Annual
Model Used: ISCST3	**Units:** g/m²/month	**Guideline:** 2	**Met Data:** 2012	**Plot:** C. Isley

Figure 6.4: Predicted annual average dust deposition levels in 2015 – Modified CGM Only

Table 6.1: Summary of predicted PM_{10}, TSP and deposition due to emissions from the Modified CGM

Receiver	24-hour average (µg/m³)		Annual average			
	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	TSP (µg/m³)	Deposition (g/m²/month)
Criteria / Advisory Standard	**25**	**50**	**8**	**30**	**90**	**2**
McLintock	4.1	25.4	0.3	1.6	1.7	0.05
Laurel Park	3.4	22.3	0.4	2.4	2.5	0.04
Coniston	4.3	28.8	0.7	3.7	3.9	0.16
Lakeside (Barrick)	2.9	18.1	0.5	2.6	2.8	0.16
The Glen	2.8	15.6	0.3	1.7	1.8	0.06
Bramboyne	3.3	21.8	0.3	1.5	1.6	0.03
Wamboyne I	2.3	11.6	0.2	1.0	1.0	0.01
Wamboyne II	2.5	15.3	0.2	1.4	1.4	0.02
Baaloo Park	2.0	9.4	0.1	0.5	0.5	0.01
Clairinch	1.7	7.6	0.1	0.4	0.4	0.01
Lakeview II	2.0	10.2	0.1	0.7	0.7	0.02
Lakeview	2.2	11.6	0.1	0.7	0.7	0.02
Westella	2.3	12.0	0.2	0.8	0.8	0.03
Thistleview	1.7	8.3	0.1	0.7	0.7	0.02
Hillview	0.9	3.8	0.1	0.3	0.3	0.01
Melrose	0.9	4.7	0.1	0.3	0.3	0.01
Westlea	2.2	12.1	0.3	1.4	1.5	0.06
Hillgrove (Barrick)	2.9	15.7	0.2	1.0	1.1	0.05
Lake Cowal (Barrick)	1.8	12.0	0.1	0.7	0.7	0.02
Lake Cowal	1.4	8.4	0.1	0.4	0.4	0.01
Billabong	1.7	9.1	0.1	0.3	0.3	0.00
Koobah	1.5	6.3	0.1	0.3	0.3	0.01
Goodwood	1.9	8.0	0.1	0.7	0.8	0.01
Cowal North	1.8	10.9	0.3	1.1	1.3	0.04
Moora Moora	1.0	3.9	0.1	0.4	0.5	0.01
Lana	1.3	5.6	0.1	0.5	0.5	0.01
Wilga Vale	1.8	9.5	0.1	0.7	0.8	0.01
Bungabulla	2.1	11.7	0.1	0.7	0.8	0.02
Gumbelah	2.2	11.4	0.2	0.8	0.9	0.02
Wylgamere	1.7	8.6	0.1	0.3	0.4	0.00
Malvena	0.9	3.6	0.0	0.1	0.2	0.00
Meldrich	0.5	2.3	0.0	0.2	0.2	0.00
Emohrou	0.5	2.6	0.0	0.1	0.2	0.00
Foxham Downs	1.2	6.0	0.1	0.6	0.7	0.03
Rosewood	0.7	3.0	0.0	0.2	0.2	0.01
Caloola	1.6	6.6	0.1	0.4	0.5	0.01

The receiver with the highest predictions, both 24-hour (28.8 µg/m³) and annual average (3.7 µg/m³), is Coniston, which is located to the north of the site. A time series plot of the 24-hour average PM_{10} predictions for each day at the Coniston residence is shown in **Figure 6.5**. It shows that the majority (98%) of 24-hour PM_{10} concentrations over the 365 day modelled period are predicted to be less than 20 µg/m³.

Further analysis of potential cumulative 24-hour average PM_{10} impacts can be found in **Section 6.3**.

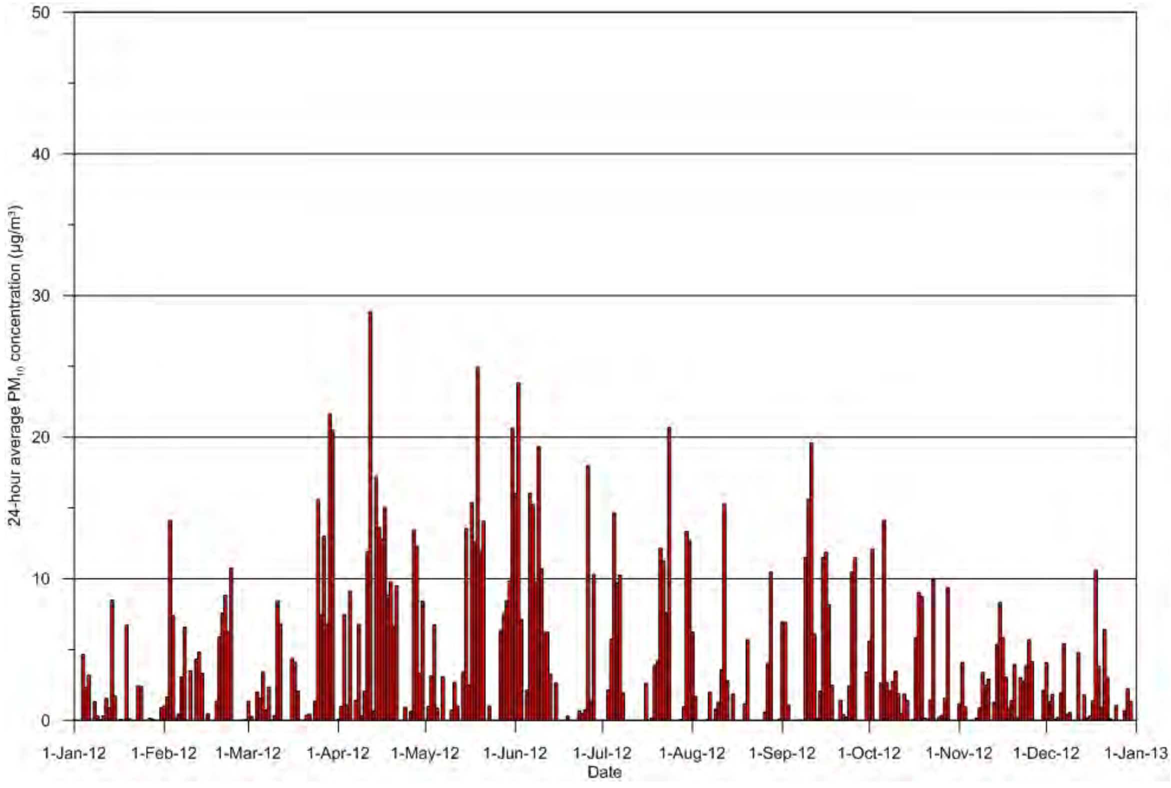


Figure 6.5: Time series of daily predicted 24-hour average PM_{10} concentrations at Coniston

6.2 Cumulative Annual Average Assessment

Table 6.2 presents the predicted annual average cumulative concentrations and dust deposition levels at residential receptors. These results represent the sum of the CGM incorporating the Modification predictions (**Table 6.1**), and the estimated background levels (**Section 4.1.3**). When comparing the values in **Table 6.1** and **Table 6.2**, it can be seen that the contribution from the CGM incorporating the Modification operations are a relatively small component of the cumulative values, particularly for TSP and dust deposition. Contour plots of predictions for the modelling domain are presented in contour plots from **Figure 6.6** to **Figure 6.8**.

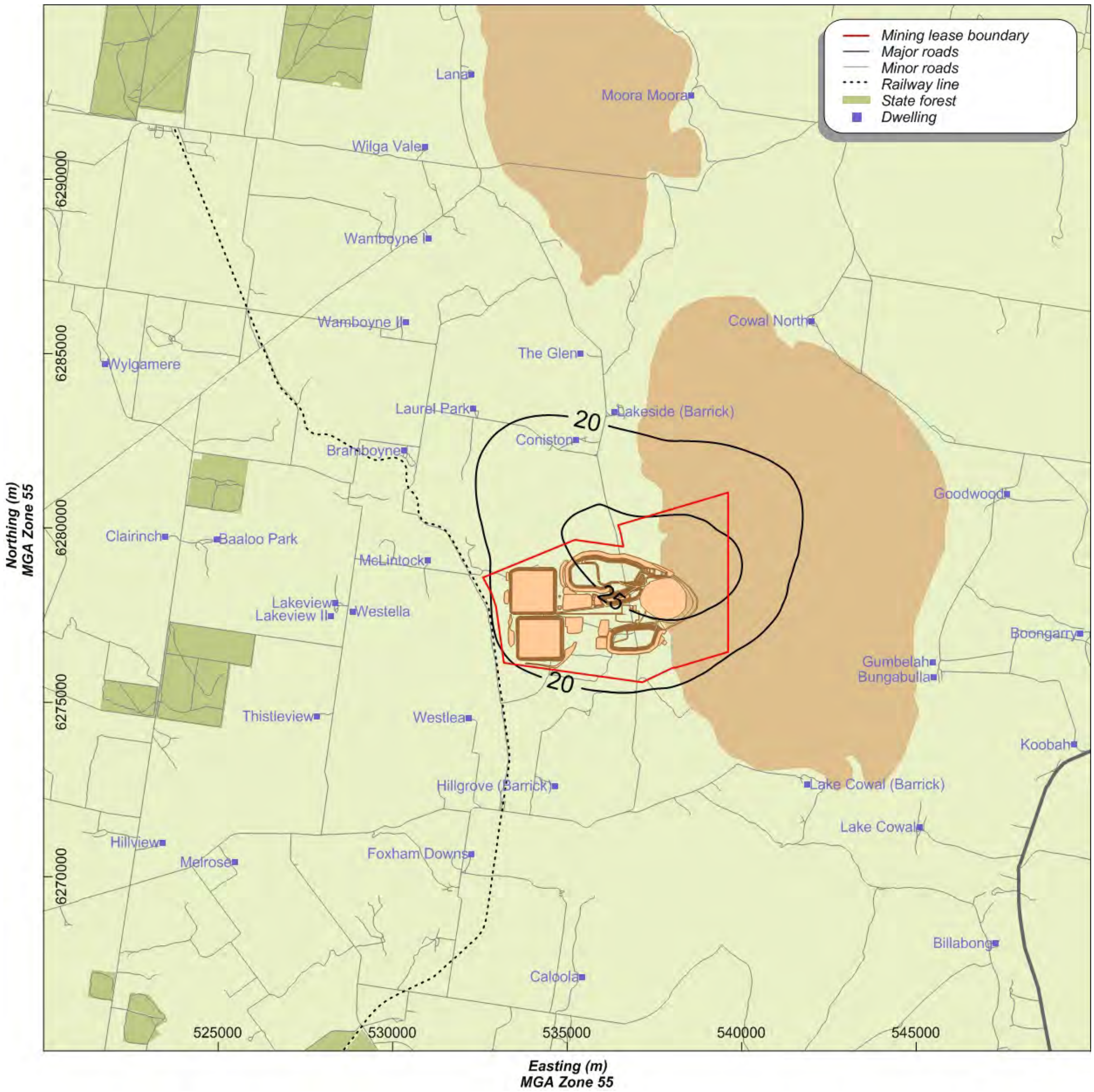
Table 6.2: Summary of predicted annual average cumulative PM_{10}, TSP and deposition due to emissions from the CGM Incorporating the Modification

Property	$PM_{2.5}$ (µg/m³) (including background)	PM_{10} (µg/m³) (including background)	TSP (µg/m³) (including background)	Deposition (g/m²/month) (including background)
Criteria/Advisory Standard	**8**	**30**	**90**	**4**
Estimated Background	**5.2**	**17**	**42**	**2.5**
McLintock	5.5	18.6	43.7	2.6
Laurel Park	5.6	19.4	44.5	2.5
Coniston	5.9	20.7	45.9	2.7
Lakeside (Barrick)	5.7	19.6	44.8	2.7
The Glen	5.5	18.7	43.8	2.6
Bramboyne	5.5	18.5	43.6	2.5
Wamboyne I	5.4	18.0	43.0	2.5
Wamboyne II	5.4	18.4	43.4	2.5
Baaloo Park	5.3	17.5	42.5	2.5
Clairinch	5.3	17.4	42.4	2.5
Lakeview II	5.3	17.7	42.7	2.5
Lakeview	5.3	17.7	42.7	2.5
Westella	5.4	17.8	42.8	2.5
Thistleview	5.3	17.7	42.7	2.5
Hillview	5.3	17.3	42.3	2.5
Melrose	5.3	17.3	42.3	2.5
Westlea	5.5	18.4	43.5	2.6
Hillgrove (Barrick)	5.4	18.0	43.1	2.6
Lake Cowal (Barrick)	5.3	17.7	42.7	2.5
Lake Cowal	5.3	17.4	42.4	2.5
Billabong	5.3	17.3	42.3	2.5
Koobah	5.3	17.3	42.3	2.5
Goodwood	5.3	17.7	42.7	2.5
Cowal North	5.5	18.1	43.1	2.5
Moora Moora	5.3	17.4	42.4	2.5
Lana	5.3	17.5	42.5	2.5
Wilga Vale	5.3	17.7	42.7	2.5
Bungabulla	5.3	17.7	42.7	2.5
Gumbelah	5.4	17.8	42.8	2.5
Wylgamere	5.3	17.3	42.3	2.5
Malvena	5.2	17.1	42.1	2.5
Meldrich	5.2	17.2	42.2	2.5
Emohrou	5.2	17.1	42.1	2.5
Foxham Downs	5.3	17.6	42.6	2.5
Rosewood	5.2	17.2	42.2	2.5
Caloola	5.3	17.4	42.4	2.5

The cumulative annual average ground-level PM_{10} concentrations for CGM operations in 2015 are shown in **Figure 6.6**. These predicted PM_{10} levels are well below the assessment criterion of 30 µg/m³.

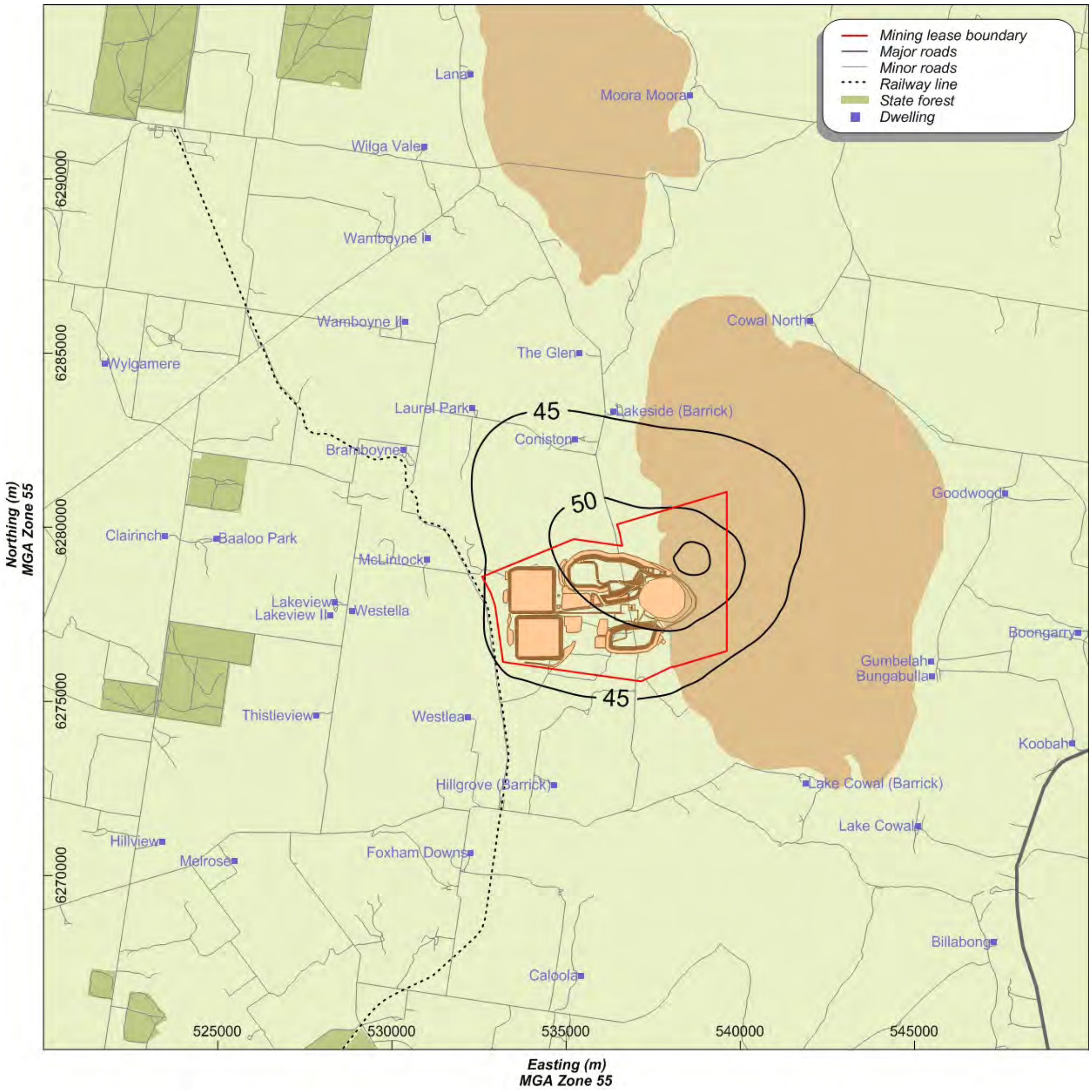
The predicted TSP levels are well below the assessment criterion of 90 µg/m³, even when added to a conservative background level of 42 µg/m³, as shown in **Figure 6.7**. Predicted dust deposition levels are also well below the cumulative assessment criteria of 4 g/m²/month. Again, the annual average dust deposition due to CGM operations is small compared with existing background levels.

It should be noted that while there are no background measurements of $PM_{2.5}$, it is unlikely that the NEPM advisory standards would be exceeded due to CGM operations. As shown in **Table 6.1**, the highest predicted 24-hour $PM_{2.5}$ concentration was 4.3 µg/m³, less than 20% of the 25 µg/m³ standard. The highest annual prediction was 0.7 µg/m³, less than 10% of the 8 µg/m³ standard.



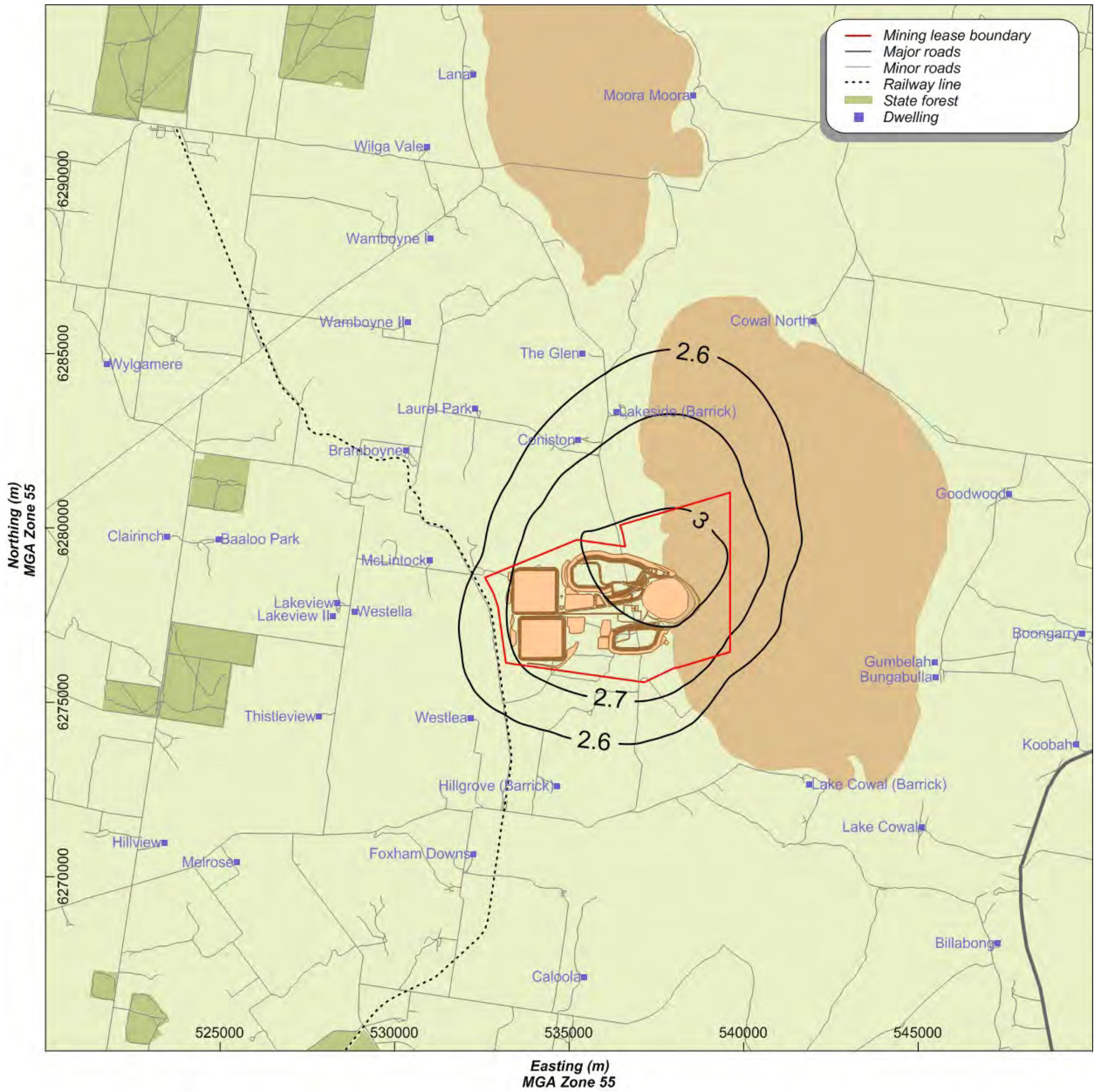
Species: PM₁₀	Location: Cowal Gold Mine	Scenario: Cumulative	Percentile: N/A	Averaging Time: Annual
Model Used: ISCST3	**Units:** µg/m³	**Guideline:** 30 µg/m³	**Met Data:** 2012	**Plot:** C. Isley

Figure 6.6: Predicted cumulative annual average PM_{10} concentrations in 2015



Species: TSP	Location: Cowal Gold Mine	Scenario: Cumulative	Percentile: N/A	Averaging Time: Annual
Model Used: ISCST3	**Units:** µg/m³	**Guideline:** 90 µg/m³	**Met Data:** 2012	**Plot:** C. Isley

Figure 6.7: Predicted cumulative annual average TSP concentrations in 2015



Species: Dust Deposition	Location: Cowal Gold Mine	Scenario: Cumulative	Percentile: N/A	Averaging Time: Annual
Model Used: ISCST3	**Units:** µg/m³	**Guideline:** 4 g/m²/month	**Met Data:** 2012	**Plot:** C. Isley

Figure 6.8: Predicted cumulative annual average dust deposition in 2015

6.3 Cumulative 24-hour Average PM_{10}

In comparison to existing approved CGM operations, the potential for an increase in cumulative 24-hour PM_{10} impacts at private receivers during the life of the Modification would be related to at least one of the following occurring:

- the Modification results in an increase in mine-only impacts from the CGM; and/or
- there is an increase in background PM_{10} concentrations (e.g. due to additional industrial sources).

It is not expected that the CGM's contribution to cumulative 24-hour PM_{10} concentrations would increase due to the Modification, given the following:

- The Modification is an extension to the mine life of the existing CGM, not increased production.
- As operations would continue to occur within the existing ML 1535, the Modification would not move sources of dust emissions materially closer to private receivers.
- Modelling for this assessment further indicates that maximum mine-only 24-hour PM_{10} concentrations from the CGM incorporating the Modification would be similar to those predicted for the currently approved operations. For example, the highest predicted 24-hour PM_{10} concentration for the Modification is 28.8 µg/m³ at Coniston. A maximum 24-hour PM_{10} concentration of 33 µg/m³ was predicted for the currently approved operations at Coniston (**Holmes Air Sciences, 2008**).

In addition, there are no other existing or proposed industrial sources of dust emissions in the vicinity of the CGM.

Given the above, no additional potential 24-hour PM_{10} impacts are expected during the life of the Modification (i.e. in addition to the existing approved CGM operations).

The existing CGM has been operating since 2005. Monitoring conducted for the CGM indicates that the 24-hour average PM_{10} concentrations (inferred from the TSP concentrations) are generally below the NSW EPA's assessment criterion of 50 µg/m³ (**Section 4.1.1**).

Notwithstanding the above, this assessment considered the quantitative assessment of potential 24-hour PM_{10} impacts associated with the Modification consistent with the methodologies presented in the Approved Methods (i.e. the Level 1 and Level 2 approaches). However, these involve the use of measured contemporaneous PM_{10} concentrations, of which none are available that could be considered representative. Any monitored background concentrations would also include contributions from the existing operations at the CGM, which when added to the predicted concentrations for the CGM incorporating the Modification would result in double counting.

As such, neither the Level 1 or Level 2 approach is considered to be appropriate or representative of potential cumulative 24-hour PM_{10} impacts for the Modification.

As mentioned previously, this modification will result in lower production levels than those which have been approved, and as such, predicted concentrations are estimated to be lower. It is unlikely that there will be any additional exceedances of the 24-hour PM_{10} criterion due to the Modification.

7 GREENHOUSE GAS ASSESSMENT

7.1 Introduction

GHG emissions have been estimated based on the methods outlined in the following documents:

- The World Resources Institute/World Business Council for Sustainable Development (WRI/WBCSD) *The Greenhouse Gas Protocol – A Corporate Accounting and Reporting Standard Revised Edition* (GHG Protocol) (**WRI/WBCSD, 2004**);
- *Commonwealth National Greenhouse and Energy Reporting (Measurement) Determination 2008*; and
- The Commonwealth Department of Climate Change and Energy Efficiency (DCCEE) *National Greenhouse Accounts Factors July 2012* (**DCCEE, 2012**).

The GHG Protocol establishes an international standard for accounting and reporting of GHG emissions. The GHG Protocol has been adopted by the International Standard Organisation, endorsed by GHG initiatives (such as the Carbon Disclosure Project) and is compatible with existing GHG trading schemes.

Three 'scopes' of emissions (scope 1, scope 2 and scope 3) are defined for GHG accounting and reporting purposes, as described below. This terminology has been adopted in Australian GHG reporting and measurement methods and has been employed in this assessment. The 'scope' of an emission is relative to the reporting entity. Indirect scope 2 and scope 3 emissions will be reportable as direct scope 1 emissions from another facility.

1) Scope 1: Direct Greenhouse Gas Emissions

Direct GHG emissions are defined as those emissions that occur from sources that are owned or controlled by the reporting entity. Direct GHG emissions are those emissions that are principally the result of the following types of activities undertaken by an entity:

- Generation of electricity, heat or steam. These emissions result from combustion of fuels in stationary sources.
- Physical or chemical processing. Most of these emissions result from manufacture or processing of chemicals and materials (e.g. the manufacture of cement, aluminium, etc.).
- Transportation of materials, products, waste and employees. These emissions result from the combustion of fuels in entity owned/controlled mobile combustion sources (e.g. trucks, trains, ships, aeroplanes, buses and cars).
- Fugitive emissions. These emissions result from intentional or unintentional releases (e.g. equipment leaks from joints, seals, packing, and gaskets, and venting); hydroflurocarbon emissions during the use of refrigeration and air conditioning equipment; and CH_4 leakages from gas transport.

2) Scope 2: Energy Product Use Indirect Greenhouse Gas Emissions

Scope 2 emissions are a category of indirect emissions that account for GHG emissions from the generation of purchased energy products (principally, electricity, steam/heat and reduction materials used for smelting) by the entity.

Scope 2 in relation to CGM covers purchased electricity, defined as electricity that is purchased or otherwise brought into the organisational boundary of the entity.

3) Scope 3: Other Indirect Greenhouse Gas Emissions

Scope 3 emissions are defined as those emissions that are a consequence of the activities of an entity, but which arise from sources not owned or controlled by that entity. Some examples of scope 3 activities provided in the GHG Protocol are extraction and production of purchased materials, transportation of purchased fuels, and use of sold products and services.

In the case of the CGM incorporating the Modification, scope 3 emissions will include emissions associated with the extraction, processing and transport of fuels. The GHG Protocol provides that reporting scope 3 emissions is optional. If an organisation believes that scope 3 emissions are a significant component of the total emissions inventory, these can be reported along with scope 1 and scope 2. However, the GHG Protocol notes that reporting scope 3 emissions can result in double counting of emissions and can also make comparisons between organisations and/or products difficult because reporting is voluntary. Double counting needs to be avoided when compiling national (country) inventories under the Kyoto Protocol. The GHG Protocol also recognises that compliance regimes are more likely to focus on the “point of release” of emissions (i.e. direct emissions) and/or indirect emissions from the purchase of electricity.

7.2 Existing Greenhouse Gas and Energy Reporting Requirements

Barrick currently reports annual GHG emission and energy consumption from the CGM to the federal government in accordance with the requirements of the National Greenhouse Gas and Energy Reporting System (NGERS). GHG emissions from the CGM are also reported annually as part of Barrick’s Responsibility Report.

7.3 Greenhouse Gas Emission Estimates

Emissions of carbon dioxide (CO_2) and methane (CH_4) would be the most significant GHGs for the CGM incorporating the Modification. These gases are formed and released during the combustion of fuels used on-site.

Inventories of GHG emissions can be calculated using published emission factors. Different gases have different greenhouse warming effects (referred to as global warming potentials) and emission factors take into account the global warming potentials of the gases created during combustion. The estimated emissions are referred to in terms of CO_2 equivalent (CO_2-e) emissions by applying the relevant global warming potential. The GHG assessment has been conducted using the NGA Factors, published by the **DCCEE (2012)**.

Relevant GHG sources included in the assessment are as follows:

- fuel consumption (diesel, unleaded petrol (ULP and propane (as LPG)) during mining operations – scope 1;
- explosives consumption (ammonium nitrate fuel oil [ANFO]) during mining operations – scope 1;
- indirect emissions associated with on-site electricity use – scope 2;
- indirect emissions associated with the production and transport of fuels – scope 3; and
- indirect emissions associated with electricity lost in transmission and distribution networks – scope 3.

A summary of the annual GHG emissions is provided in **Table 7.1**. Given that there is no increase in waste rock or ore production rates, or ore processing rates, associated with the Modification, annual GHG emissions are unlikely to increase comparative to the operation CGM operations. Detailed emission calculations are provided in **Appendix C**.

8 MONITORING AND MITIGATION MEASURES

8.1 Dust Emissions

Emissions associated with the operation of the Modification would be generated from two primary sources as follows:

- wind blown dust from exposed areas and from disturbed locations where there is no vegetation cover; and
- dust generated by mining activities including the mechanical disturbance of soils and waste rock when using conventional mining equipment, the haulage of materials within ML 1535 and particles from diesel exhausts in activities where diesel powered equipment is used.

Air quality management and mitigation measures are currently implemented at the CGM in accordance with the *Cowal Gold Project Dust Management Plan* (**Barrick**, **2003**) to control windblown and mine generated dust. These management and mitigation measures include the procedures outlined in **Table 8.1** and **Table 8.2**.

Table 8.1: Control methods for exposed area dust sources

Source	Control Methods
General Areas Disturbed by Mining	Areas for soil stripping will be minimised to reduce the area of exposed ground at any one time. Exposed areas would be reshaped, topsoiled and revegetated as soon as practicable to minimise the generation of wind erosion dust.
Mine Waste Rock Emplacements	Exposed active work areas on mine waste rock emplacement surfaces would be watered to suppress dust where practicable.
Soil Stockpiles	Long-term soil stockpiles would be revegetated with a cover crop.
Material Handling and Stockpiles	Prevention of truck overloading to reduce spillage during ore loading/unloading and hauling. All conveyors would incorporate wind covers as necessary. The surface of all stockpiles would be treated to minimise dust emissions as required. Such treatment would include application of water.

Source: Barrick (2003).

Table 7.1: Summary of Estimated CO_2-e (tonnes) – All Scopes

Year	Scope 1 Emissions (t CO_2-e)					Scope 2 Emissions (t CO_2-e)	Scope 3 Emissions (t CO_2-e)				
	Diesel	ULP	Propane (as LPG)	Blasting	*Scope 1 Total*	Electricity	Diesel	ULP	Propane (as LPG)	Electricity	*Scope 3 Total*
2014	64,237	83	2,001	961	67,282	195,211	4,899	6	167	39,930	45,002
2015	71,210	93	2,028	1,155	74,486	197,922	5,430	7	169	40,484	46,091
2016	54,094	70	2,056	807	57,028	200,634	4,125	5	172	41,039	45,341
2017	43,740	57	2,056	506	46,359	200,634	3,336	4	172	41,039	44,550
2018	40,148	52	2,056	395	42,651	200,634	3,062	4	172	41,039	44,276
2019	28,104	37	2,056	90	30,286	200,634	2,143	3	172	41,039	43,356
2020	16,271	21	2,056	77	18,425	200,634	1,241	2	172	41,039	42,453
2021	3,381	4	2,084	9	5,478	203,345	258	0	174	41,593	42,025
2022	0	0	2,056	0	2,056	200,634	0	0	172	41,039	41,210
2023	0	0	2,028	0	2,028	197,922	0	0	169	40,484	40,653
2024	0	0	583	0	583	56,937	0	0	49	11,646	11,695
Total	**321,184**	**417**	**21,061**	**4,000**	**346,662**	**2,055,139**	**24,493**	**32**	**1,758**	**420,369**	**446,652**

Table 8.2: Control methods for mine generated dust sources

Source	Control Methods
Haul Road	All roads and trafficked areas would have water or sealant (e.g. Petro Tac, a water emulsified bitumen sealant) using water trucks or other methods and regularly maintained (using graders) to minimise the generation of dust. Routes would be clearly marked. Obsolete roads would be ripped and re-vegetated.
Minor Roads	Development of minor roads would be limited and the locations of these would be clearly defined. Regularly used minor roads would be watered and regularly maintained. Obsolete minor roads would be ripped and re-vegetated.
Materials Handling	Prevention of truck overloading to reduce spillage during ore loading/unloading and hauling. A water spray dust suppression system would be used at the primary crusher bin during truck dumping of raw ore. All conveyors would incorporate wind covers as necessary. Freefall height during ore/waste stockpiling would be limited.
Soil Stripping	Access tracks used for soil stripping during the loading and unloading cycle would be watered. Soil stripping would be limited to areas required for mining operations.
Drilling	Dust aprons would be lowered during drilling for collection of fine dust. Water injection or dust suppression sprays would be used when high levels of dust are being generated.
Blasting	Fine material collected during drilling would not be used for blast stemming. Adequate stemming would be used at all times.
Equipment Maintenance	Emissions from mobile equipment exhausts would be minimised by the implementation of a maintenance programme to service equipment in accordance with the equipment manufacturer specifications.
Process Plant	A baghouse and associated collection hood/ducting would be used to filter off-gas emissions (i.e. to remove dust particles) from the gold room doré melt furnace. This control method reduces the potential for any minor environmental emissions from the gold smelting process and maximises the retention of gold product.

Source: Barrick (2003).

These management and mitigation measures would be continued for the Modification.

The existing CGM air quality monitoring program includes:

- an on-site meteorological station;
- a network of 18 static dust gauges within and surrounding the CGM area (including gauges proximal to nearby residences, bird breeding areas, native flora areas and Lake Cowal);
- TSP monitoring to the north of the CGM; and
- an air quality monitoring review program.

The existing air quality monitoring program would be continued for the Modification.

The *Cowal Gold Project Dust Management Plan* (**Barrick**, **2003**) would be revised and updated for the Modification, subject to the conditions of any modified Development Consent for the CGM.

9 CONCLUSIONS

This report has assessed the potential impacts on air quality from the continued operations at the CGM associated with the Modification. Dispersion modelling has been used to predict off-site dust concentration and deposition levels due to the dust generating activities that would occur as part of the Modification. The modelling took account of the local meteorology and terrain and used dust emission estimates to predict the air quality impacts for the worst case mining scenario (Year 11 [2015]). This scenario was determined to be representative of potential worst case emissions for the Modification, as it is the year of maximum total material (i.e. waste rock and ore) mined.

Predictions of air quality impacts considered the effects of other non-mining sources of dust. Model predictions at privately-owned residential receptors were compared with the relevant air quality criteria and advisory standards.

Analysis of the dispersion modelling results indicates that predicted emissions for operations at the CGM incorporating the Modification would comply with relevant annual average and 24-hour average $PM_{2.5}$, PM_{10}, TSP and dust deposition assessment criteria/advisory standards at all nearby private residential properties.

No additional potential 24-hour impacts are expected during the life of the Modification (i.e. in addition to the existing approved CGM operations).

Barrick would continue to manage potential impacts associated with the CGM through a range of dust controls in accordance with the *Cowal Gold Project Dust Management Plan* (**Barrick**, **2003**) which would be revised and updated for the Modification as required.

GHG emissions for the Modification, as a result of fuel and explosives use and electricity consumption, have been estimated. Barrick would continue to calculate and repeat annual GHG emissions and energy consumption from the CGM in accordance with existing NGERS requirements.

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Appendix A: Joint Wind Speed, Wind Direction and Stability Class Frequency Tables

STATISTICS FOR FILE: F:\Cowal\2012.isc
MONTHS: All
HOURS : All
OPTION: Frequency

PASQUILL STABILITY CLASS 'A'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.000800	0.005598	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.006398
NE	0.001257	0.006055	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.007312
ENE	0.000571	0.004913	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.005484
E	0.000914	0.002513	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003427
ESE	0.000685	0.001599	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002285
SE	0.000343	0.001828	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002171
SSE	0.000571	0.002056	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002628
S	0.000228	0.001714	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001942
SSW	0.000457	0.002285	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002742
SW	0.000343	0.001485	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001828
WSW	0.000228	0.001257	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001485
W	0.000228	0.001142	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001371
WNW	0.000457	0.002056	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002513
NW	0.000228	0.000914	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001142
NNW	0.001028	0.001257	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002285
N	0.001714	0.002399	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004113
CALM									0.000685
TOTAL	0.010054	0.039072	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.049811

MEAN WIND SPEED (m/s) = 2.03
NUMBER OF OBSERVATIONS = 436

PASQUILL STABILITY CLASS 'B'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.000800	0.004227	0.002742	0.000000	0.000000	0.000000	0.000000	0.000000	0.007769
NE	0.000571	0.004113	0.001942	0.000000	0.000000	0.000000	0.000000	0.000000	0.006626
ENE	0.000571	0.003199	0.001142	0.000000	0.000000	0.000000	0.000000	0.000000	0.004913
E	0.000343	0.001142	0.000685	0.000000	0.000000	0.000000	0.000000	0.000000	0.002171
ESE	0.000571	0.000685	0.000571	0.000000	0.000000	0.000000	0.000000	0.000000	0.001828
SE	0.000343	0.001142	0.000800	0.000000	0.000000	0.000000	0.000000	0.000000	0.002285
SSE	0.000000	0.001371	0.000685	0.000000	0.000000	0.000000	0.000000	0.000000	0.002056
S	0.000228	0.001371	0.001714	0.000000	0.000000	0.000000	0.000000	0.000000	0.003313
SSW	0.000000	0.000800	0.002856	0.000000	0.000000	0.000000	0.000000	0.000000	0.003656
SW	0.000228	0.000457	0.003427	0.000000	0.000000	0.000000	0.000000	0.000000	0.004113
WSW	0.000000	0.000228	0.001028	0.000000	0.000000	0.000000	0.000000	0.000000	0.001257
W	0.000114	0.000685	0.000571	0.000000	0.000000	0.000000	0.000000	0.000000	0.001371
WNW	0.000000	0.000228	0.000800	0.000000	0.000000	0.000000	0.000000	0.000000	0.001028
NW	0.000114	0.000914	0.000343	0.000000	0.000000	0.000000	0.000000	0.000000	0.001371
NNW	0.000228	0.000457	0.000343	0.000000	0.000000	0.000000	0.000000	0.000000	0.001028
N	0.000228	0.000571	0.001028	0.000000	0.000000	0.000000	0.000000	0.000000	0.001828
CALM									0.000343
TOTAL	0.004341	0.021593	0.020679	0.000000	0.000000	0.000000	0.000000	0.000000	0.046955

MEAN WIND SPEED (m/s) = 2.71
NUMBER OF OBSERVATIONS = 411

PASQUILL STABILITY CLASS 'C'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.000800	0.006284	0.010282	0.003656	0.000000	0.000000	0.000000	0.000000	0.021021
NE	0.000685	0.005941	0.006741	0.000800	0.000000	0.000000	0.000000	0.000000	0.014167
ENE	0.000571	0.006055	0.003085	0.000000	0.000000	0.000000	0.000000	0.000000	0.009711
E	0.000685	0.002628	0.002056	0.000914	0.000000	0.000000	0.000000	0.000000	0.006284
ESE	0.001371	0.001257	0.000343	0.000114	0.000000	0.000000	0.000000	0.000000	0.003085
SE	0.000114	0.002171	0.002285	0.000571	0.000000	0.000000	0.000000	0.000000	0.005141
SSE	0.000343	0.001257	0.002285	0.000114	0.000000	0.000000	0.000000	0.000000	0.003999
S	0.000000	0.000800	0.005141	0.004798	0.000000	0.000000	0.000000	0.000000	0.010739
SSW	0.000228	0.001028	0.003199	0.004113	0.000000	0.000000	0.000000	0.000000	0.008568
SW	0.000114	0.000800	0.005027	0.005712	0.000000	0.000000	0.000000	0.000000	0.011653
WSW	0.000343	0.000571	0.002285	0.001714	0.000000	0.000000	0.000000	0.000000	0.004913
W	0.000000	0.000228	0.000685	0.000571	0.000000	0.000000	0.000000	0.000000	0.001485
WNW	0.000114	0.000228	0.001599	0.000800	0.000000	0.000000	0.000000	0.000000	0.002742
NW	0.000457	0.000343	0.001371	0.000343	0.000000	0.000000	0.000000	0.000000	0.002513
NNW	0.000114	0.000571	0.001028	0.002171	0.000000	0.000000	0.000000	0.000000	0.003884
N	0.000228	0.002171	0.004113	0.002970	0.000000	0.000000	0.000000	0.000000	0.009482
CALM									0.000343
TOTAL	0.006169	0.032332	0.051525	0.029361	0.000000	0.000000	0.000000	0.000000	0.119730

MEAN WIND SPEED (m/s) = 3.59
NUMBER OF OBSERVATIONS = 1048

PASQUILL STABILITY CLASS 'D'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.001142	0.008683	0.009939	0.005484	0.001142	0.000228	0.000000	0.000000	0.026619
NE	0.001257	0.009597	0.011082	0.002628	0.000343	0.000114	0.000114	0.000000	0.025134
ENE	0.003199	0.009482	0.010625	0.004798	0.002171	0.000114	0.000000	0.000000	0.030390
E	0.002056	0.004456	0.005141	0.007083	0.003999	0.000685	0.000000	0.000000	0.023421
ESE	0.003999	0.005370	0.004113	0.006855	0.001714	0.000228	0.000000	0.000000	0.022278
SE	0.005027	0.011539	0.004227	0.001942	0.001257	0.000343	0.000000	0.000000	0.024335
SSE	0.005027	0.007312	0.005255	0.001599	0.000228	0.000000	0.000000	0.000000	0.019422
S	0.002513	0.006055	0.011082	0.010168	0.002285	0.000800	0.000114	0.000000	0.033017
SSW	0.001714	0.004913	0.010282	0.011653	0.006512	0.002399	0.000114	0.000000	0.037587
SW	0.003199	0.004570	0.005598	0.008454	0.009825	0.004456	0.001142	0.000228	0.037473
WSW	0.002970	0.005255	0.004684	0.007540	0.006284	0.000800	0.000800	0.000114	0.028447
W	0.003427	0.003427	0.003085	0.003884	0.002171	0.001599	0.000685	0.000000	0.018279
WNW	0.003085	0.003427	0.002970	0.005941	0.002856	0.001714	0.000000	0.000000	0.019993
NW	0.002628	0.002056	0.001599	0.001828	0.002399	0.001599	0.000000	0.000228	0.012339
NNW	0.001714	0.005255	0.004341	0.004570	0.003427	0.002171	0.000571	0.000114	0.022164
N	0.001599	0.009140	0.010282	0.005484	0.003085	0.000343	0.000228	0.000000	0.030161
CALM									0.004684
TOTAL	0.044556	0.100537	0.104307	0.089912	0.049697	0.017594	0.003770	0.000685	0.415743

MEAN WIND SPEED (m/s) = 3.98
NUMBER OF OBSERVATIONS = 3639

PASQUILL STABILITY CLASS 'E'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.000914	0.001485	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002399
NE	0.001257	0.002513	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.003999
ENE	0.002171	0.005370	0.001828	0.000228	0.000000	0.000000	0.000000	0.000000	0.009597
E	0.002856	0.002513	0.001028	0.000914	0.000000	0.000000	0.000000	0.000000	0.007312
ESE	0.003656	0.003313	0.002742	0.000800	0.000000	0.000000	0.000000	0.000000	0.010511
SE	0.006512	0.013253	0.005370	0.000343	0.000000	0.000000	0.000000	0.000000	0.025477
SSE	0.005827	0.011539	0.013367	0.000457	0.000000	0.000000	0.000000	0.000000	0.031189
S	0.002399	0.009025	0.023535	0.003542	0.000000	0.000000	0.000000	0.000000	0.038501
SSW	0.002399	0.010968	0.030390	0.002628	0.000000	0.000000	0.000000	0.000000	0.046384
SW	0.004227	0.015081	0.006855	0.001028	0.000000	0.000000	0.000000	0.000000	0.027191
WSW	0.004456	0.013024	0.005370	0.000571	0.000000	0.000000	0.000000	0.000000	0.023421
W	0.006169	0.009368	0.003427	0.000228	0.000000	0.000000	0.000000	0.000000	0.019193
WNW	0.003427	0.004684	0.004113	0.000914	0.000000	0.000000	0.000000	0.000000	0.013138
NW	0.002171	0.004913	0.002742	0.000571	0.000000	0.000000	0.000000	0.000000	0.010396
NNW	0.001485	0.003542	0.002056	0.000685	0.000000	0.000000	0.000000	0.000000	0.007769
N	0.001257	0.001371	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.002856
CALM									0.005827
TOTAL	0.051182	0.111962	0.103279	0.012910	0.000000	0.000000	0.000000	0.000000	0.285159

MEAN WIND SPEED (m/s) = 2.62
NUMBER OF OBSERVATIONS = 2496

PASQUILL STABILITY CLASS 'F'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.001028	0.000457	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001485
NE	0.001142	0.000571	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001714
ENE	0.001142	0.000685	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001828
E	0.002399	0.000457	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002856
ESE	0.002628	0.001257	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003884
SE	0.005141	0.002513	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.007655
SSE	0.004456	0.003999	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.008454
S	0.004456	0.001714	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.006169
SSW	0.002513	0.005027	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.007540
SW	0.002856	0.009254	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.012110
WSW	0.003656	0.003656	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.007312
W	0.001942	0.001257	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003199
WNW	0.001599	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001828
NW	0.001257	0.000571	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001828
NNW	0.001142	0.000800	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001942
N	0.001828	0.000343	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002171
CALM									0.010625
TOTAL	0.039187	0.032789	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.082600

MEAN WIND SPEED (m/s) = 1.38
NUMBER OF OBSERVATIONS = 723

ALL PASQUILL STABILITY CLASSES

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.005484	0.026734	0.022964	0.009140	0.001142	0.000228	0.000000	0.000000	0.065692
NE	0.006169	0.028790	0.019993	0.003427	0.000343	0.000114	0.000114	0.000000	0.058951
ENE	0.008226	0.029704	0.016680	0.005027	0.002171	0.000114	0.000000	0.000000	0.061922
E	0.009254	0.013710	0.008911	0.008911	0.003999	0.000685	0.000000	0.000000	0.045470
ESE	0.012910	0.013481	0.007769	0.007769	0.001714	0.000228	0.000000	0.000000	0.043871
SE	0.017480	0.032446	0.012681	0.002856	0.001257	0.000343	0.000000	0.000000	0.067063
SSE	0.016223	0.027533	0.021593	0.002171	0.000228	0.000000	0.000000	0.000000	0.067748
S	0.009825	0.020679	0.041471	0.018508	0.002285	0.000800	0.000114	0.000000	0.093682
SSW	0.007312	0.025020	0.046727	0.018394	0.006512	0.002399	0.000114	0.000000	0.106478
SW	0.010968	0.031646	0.020907	0.015195	0.009825	0.004456	0.001142	0.000228	0.094368
WSW	0.011653	0.023992	0.013367	0.009825	0.006284	0.000800	0.000800	0.000114	0.066834
W	0.011882	0.016109	0.007769	0.004684	0.002171	0.001599	0.000685	0.000000	0.044899
WNW	0.008683	0.010853	0.009482	0.007655	0.002856	0.001714	0.000000	0.000000	0.041243
NW	0.006855	0.009711	0.006055	0.002742	0.002399	0.001599	0.000000	0.000228	0.029590
NNW	0.005712	0.011882	0.007769	0.007426	0.003427	0.002171	0.000571	0.000114	0.039072
N	0.006855	0.015995	0.015652	0.008454	0.003085	0.000343	0.000228	0.000000	0.050611
CALM									0.022507
TOTAL	0.155490	0.338284	0.279790	0.132183	0.049697	0.017594	0.003770	0.000685	1.000000

MEAN WIND SPEED (m/s) = 3.17
NUMBER OF OBSERVATIONS = 8753

FREQUENCY OF OCCURENCE OF STABILITY CLASSES

A : 5.0%
B : 4.7%
C : 12.0%
D : 41.6%
E : 28.5%
F : 8.3%

STABILITY CLASS BY HOUR OF DAY

Hour	A	B	C	D	E	F
01	0000	0000	0000	0134	0186	0043
02	0000	0000	0000	0130	0184	0049
03	0000	0000	0000	0135	0160	0068
04	0000	0000	0000	0132	0172	0062
05	0000	0000	0000	0126	0173	0065
06	0000	0000	0000	0137	0176	0046
07	0011	0010	0009	0211	0088	0033
08	0020	0015	0046	0228	0036	0021
09	0032	0019	0099	0216	0000	0000
10	0035	0047	0106	0178	0000	0000
11	0047	0053	0130	0136	0000	0000
12	0054	0062	0121	0129	0000	0000
13	0056	0061	0125	0124	0000	0000
14	0060	0043	0113	0149	0000	0000
15	0056	0038	0118	0153	0000	0000
16	0042	0035	0103	0185	0000	0000
17	0016	0023	0060	0221	0038	0008
18	0007	0005	0018	0188	0117	0030
19	0000	0000	0000	0140	0179	0046
20	0000	0000	0000	0111	0198	0057
21	0000	0000	0000	0107	0204	0055
22	0000	0000	0000	0118	0200	0048
23	0000	0000	0000	0122	0198	0046
24	0000	0000	0000	0129	0187	0046

STABILITY CLASS BY MIXING HEIGHT

Mixing height	A	B	C	D	E	F
<=500 m	0041	0026	0083	0898	2398	0701
<=1000 m	0143	0157	0420	1257	0041	0007
<=1500 m	0252	0228	0545	1112	0057	0015
<=2000 m	0000	0000	0000	0256	0000	0000
<=3000 m	0000	0000	0000	0111	0000	0000
>3000 m	0000	0000	0000	0005	0000	0000

Appendix B: Emission Calculations

Table B1: TSP emissions inventory for the Modification – 2015

ACTIVITY	TSP emission/year	Intensity	units	Emission factor	units	Variable 1	units	Variable 2	units	Variable 3	units	Variable 4	units	Variable 5	units	Variable 6	units
TSF Lift Construction																	
TC - Scrapers/dozers working on tailings	62,118	8,874	h/y	14.0	kg/h											50	% control
TC - Loading trucks	1,489	782,000	t/y	0.00190	kg/t	1.608	average (ws/2.2)^1.3	2	moisture content - %								
TC - Trucks hauling	45,624	782,000	t/y	0.292	kg/t	40	t/load	55	Average vehicle gross mass (t)	4.4	km/return trip	2.65	kg/VKT	5	% silt content	80	% control
TC - Trucks unloading	1,489	782,000	t/y	0.00190	kg/t	1.608	average (ws/2.2)^1.3	2	moisture content - %								
TC - Grader	10,923	17,748	km	0.61547	kg/VKT	8	Grader speed - km/h	1	number of graders								
Mining Operations																	
Drilling	16,151	91,250	holes/y	0.59	kg/hole											70	% control for use of aprons
Blasting	57,458	365	blasts/y	157	kg/blast	8000	Area of blast - m2										
Loading waste to trucks	54,272	26,900,000	t/y	0.00202	kg/t	1.608	average (ws/2.2)^1.3	2	moisture content - %								
Hauling waste to northern emplacement area	1,042,266	20,175,000	t/y	0.258	kg/t	192	t/load	208	Average vehicle gross mass (t)	9.3	km/return trip	4.83	kg/VKT	5	% silt content	80	% control
Hauling waste to southern emplacement area	298,858	6,725,000	t/y	0.222	kg/t	192	t/load	208	Average vehicle gross mass (t)	5.0	km/return trip	4.83	kg/VKT	5	% silt content	80	% control
Emplacing waste at northern emplacement	38,405	20,175,000	t/y	0.00190	kg/t	1.608	average (ws/2.2)^1.3	2	moisture content - %								
Emplacing waste at southern emplacement	12,802	6,725,000	t/y	0.00190	kg/t	1.608	average (ws/2.2)^1.3	2	moisture content - %								
Dozer working on emplacement areas, pits and stockpiles	159,530	21,900	h/y	7.3	kg/h	5	silt content - %	2	moisture content - %								
Loading ore to trucks	12,945	6,800,000	t/y	0.00190	kg/t	1.608	average (ws/2.2)^1.3	2	moisture content - %								
Hauling ore to ROM pad	294,140	6,800,000	t/y	0.216	kg/t	192	t/load	208	Average vehicle gross mass (t)	8.6	km/return trip	4.83	kg/VKT	5	% silt content	80	% control
Unloading ore to ROM pad	12,945	6,800,000	t/y	0.00190	kg/t	1.608	average (ws/2.2)^1.3	2	moisture content - %								
Rehandling ore to crusher	5,559	2,920,000	t/y	0.00190	kg/t	1.608	average (ws/2.2)^1.3	2	moisture content - %								
Primary ore crushing and screening	11,096	7,300,000	t/y	0.01520	kg/t											90	% control for water sprays
Loading to coarse ore stockpile	13,896	7,300,000	t/y	0.00190	kg/t	1.608	average (ws/2.2)^1.3	2	moisture content - %								
Ore processing in mill	13,896	7,300,000	t/y	0.00190	kg/t	1.608	average (ws/2.2)^1.3	2	moisture content - %								
Wind erosion, open pit	113,880	130	ha	0.1	kg/ha/h	8760	h/y										
Wind erosion, northern emplacement area	203,232	232	ha	0.1	kg/ha/y	8760	h/y										
Wind erosion, southern emplacement area	66,576	76	ha	0.1	kg/ha/y	8760	h/y										
Wind erosion, stockpiles and exposed areas	67,452	77	ha	0.1	kg/ha/y	8760	h/y										
Wind erosion, Tailings storage dams	122,640	140	ha	0.1	kg/ha/y	8760	h/y										
Grading roads	50,320	81,760	km	0.61547	kg/VKT	8	Grader speed - km/h	2	number of graders								

The dust emission inventories have been prepared using the operational description of the proposed mining activities provided by Barrick. Estimated emissions are presented for all significant dust generating activities associated with the operations. The relevant emission factor equations used for the study are described below. The emission factors derived from the application of the equation, with variables applicable to the Modified CGM, are shown in the fifth column of the table above.

Scrapers

An emission rate of 14 kilograms per hour (kg/h) has been used for scrapers working on the tailings (**SPCC, 1983**).

Loading/unloading to trucks and stockpiles

Each tonne of material loaded/unloaded would generate a quantity of TSP that would depend on the wind speed and the moisture content. Equation 1 (**US EPA, 1985**) shows the relationship between these variables.

Equation 1

$E_{TSP} = k \times 0.0016 \times [(U/2.2)^{1.3} / (M/2)^{1.4}]$ kilograms per tonne (kg/t)

where,

k = 0.74

U = wind speed (m/s)

M – moisture content (%)

Drilling waste rock

The emission factor used for drilling has been taken to be 0.59 kg/hole (**US EPA, 1985**).

Blasting waste rock

TSP emissions from blasting were estimated using the US EPA emission factor equation given in Equation 2 (**US EPA, 1985**).

Equation 2

$E_{TSP} = 0.00022 \times A^{1.5}$ kg/blast

where,

A = area to be blasted in square metre (m^2)

Hauling material by truck

TSP emissions from hauling on unpaved roads were estimated using the US EPA emission factor equation given in Equation 3 (**US EPA, 1985**).

Equation 3

$E_{TSP} = 1.38 \times [(s/12)^{0.7}] \times [(GVM \times 1.1023 / 3)^{0.45}]$ kg per vehicles kilometres travelled (kg/VKT)

where,

s = silt content (%)

GVM = gross vehicle mass (t)

Dozers on stockpiles and in-pit

Emissions from dozers have been calculated using the US EPA emission factor equation given in Equation 4 (**US EPA, 1985**).

Equation 4

$E_{TSP} = 2.6 \times [s^{1.2} / M^{1.3}]$ kg/hour

where,

s = silt content (%)

M – moisture content (%)

Primary and secondary ore crushing

There are currently no specific emission factors for these activities however, in practice, these would form a very small contribution of the overall dust emissions from the mine. In the absence of a specific emission factor for primary and secondary ore crushing, US EPA emission factors for tertiary crushing and screening were used (0.0125+0.0027 kg/t) (**US EPA, 1985**).

Wind erosion from stockpiles

The emission factor used for wind erosion has been taken to be 0.1 kg/ha/h (**US EPA, 1985**).

Grading roads

Estimates of TSP emissions from grading roads have been made using the US EPA emission factor equation given in Equation 5 (**US EPA, 1985**).

Equation 5

$E_{TSP} = 0.0034 \times s^{2.5}$ kg/VKT

where,

s = silt content (%)

Appendix C: GHG Emission Calculations

C.1 Fuel Consumption

C.1.1 Diesel

Greenhouse gas (GHG) emissions from diesel consumption were estimated using the following equation:

Equation 1:

$$E_{CO_2-e} = \frac{Q \times EF}{1000}$$

where:

E_{CO2-e}	=	Emissions of GHG from diesel combustion	($t\ CO_2$-e)[1]
Q	=	Estimated combustion of diesel	(GJ)[2]
EF	=	Emission factor (scope 1 or scope 3) for diesel combustion	(kg CO_2-e/GJ)[3]

[1] tCO_2-e = tonnes of carbon dioxide equivalent.
[2] GJ = gigajoules.
[3] kg CO_2-e/GJ = kilograms of carbon dioxide equivalents per gigajoule.

The quantity of diesel consumed (Q) in each year is based on 2012 usage numbers provided by Barrick.

The quantity of diesel consumed in GJ is calculated using an energy content factor for diesel of 38.6 gigajoules per kilolitre (GJ/kL). The Scope 1 and Scope 3 emission factors are 69.5 and 5.3 kg CO_2-e/GJ respectively.

GHG emission factors and energy content for diesel were sourced from the NGA Factors (**DCCEE, 2012**). The estimated annual and total life of mine GHG emissions from diesel usage are presented in the table below.

Table C.1: Estimated CO_2-e (tonnes) for Diesel Consumption

Year	Usage (kL)	Emissions (t CO_2-e)		Total
		Scope 1	Scope 3	
2014	23,945	64,237	4,899	69,135
2015	26,544	71,210	5,430	76,640
2016	20,164	54,094	4,125	58,219
2017	16,305	43,740	3,336	47,076
2018	14,966	40,148	3,062	43,210
2019	10,476	28,104	2,143	30,247
2020	6,065	16,271	1,241	17,511
2021	1,260	3,381	258	3,639
2022	0	0	0	0
2023	0	0	0	0
2024	0	0	0	0
Total	**119,725**	**321,184**	**24,493**	**345,677**

C.1.2 Unleaded Petrol

GHG emissions from unleaded petrol (ULP) consumption were estimated using Equation 1 as in **Section C.1.1**.

The quantity of ULP consumed in each year is based on 2012 usage numbers provided by Barrick.

The quantity of ULP consumed in GJ is calculated using an energy content factor for ULP of 34.2 gigajoules per kilolitre (GJ/kL). The Scope 1 and Scope 3 emission factors are 69.6 and 5.3 kg CO_2-e/GJ respectively.

GHG emission factors and energy content for ULP were sourced from the NGA Factors (**DCCEE, 2012**). The estimated annual and total life of mine GHG emissions from ULP usage are presented in the table below.

Table C.2: Estimated CO_2-e (tonnes) for ULP Consumption

Year	Usage (kL)	Emissions (t CO_2-e)		Total
		Scope 1	Scope 3	
2014	35	83	6	90
2015	39	93	7	100
2016	30	70	5	76
2017	24	57	4	61
2018	22	52	4	56
2019	15	37	3	39
2020	9	21	2	23
2021	2	4	0	5
2022	0	0	0	0
2023	0	0	0	0
2024	0	0	0	0
Total	**175**	**417**	**32**	**449**

C.1.2 Propane (used as LPG)

GHG emissions from Propane consumption were estimated using Equation 1 as in **Section C.1.1**.

The quantity of Propane consumed in each year is based on 2012 usage numbers provided by Barrick.

The quantity of Propane consumed in GJ is calculated using an energy content factor for Propane of 25.7 gigajoules per kilolitre (GJ/kL). The Scope 1 and Scope 3 emission factors are 59.9 and 5 kg CO_2-e/GJ respectively.

GHG emission factors and energy content for Propane were sourced from the NGA Factors (**DCCEE, 2012**). The estimated annual and total life of mine GHG emissions from Propane usage are presented in the table below.

Table C.3: Estimated CO_2-e (tonnes) for Propane Consumption

Year	Usage (kL)	Emissions (t CO_2-e)		Total
		Scope 1	Scope 3	
2014	1,300	2,001	167	2,167
2015	1,318	2,028	169	2,198
2016	1,336	2,056	172	2,228
2017	1,336	2,056	172	2,228
2018	1,336	2,056	172	2,228
2019	1,336	2,056	172	2,228
2020	1,336	2,056	172	2,228
2021	1,354	2,084	174	2,258
2022	1,336	2,056	172	2,228
2023	1,318	2,028	169	2,198
2024	379	583	49	632
Total	**13,681**	**21,061**	**1,758**	**22,819**

C.2 Explosives Use

Emissions from explosive usage were estimated based on the using the following equation:

$$E_{co2-e} = Q \times EF$$

where:

$E_{CO2\text{-}e}$	=	Emissions of greenhouse gases from explosives	(t CO_2-e/annum)
Q	=	Quantity of explosive used (assumed ANFO)	(t)
EF	=	Scope 1 emission factor	(t CO_2-e/tonne explosive)

Greenhouse gas emission factors were sourced from the NGA Factors February 2008. It is noted that the AGO Factors and Methods were replaced by the NGA Factors (**DCCEE, 2012**), however the emission factor for explosives was excluded from the latest version. Emissions from explosives do not have to be reported under NGERS.

The quantity of explosives consumed in each year is based on an explosives intensity rate (t explosives/waste rock), calculated from usage numbers provided by Barrick.

The scope 1 emission factor is 0.167 t CO_2-e/GJ.

Greenhouse gas emission factors and energy content for explosives were sourced from the NGA Factors (**DCCEE, 2012**). The estimated annual and total life of mine GHG emissions from explosive usage are presented in the table below.

Table C.4: Estimated CO_2-e (tonnes) for Explosives

Year	Usage (t)	Scope 1 Emissions (t CO_2-e)
2014	5,757	961
2015	6,913	1,155
2016	4,832	807
2017	3,033	506
2018	2,364	395
2019	540	90
2020	463	77
2021	51	9
2022	0	0
2023	0	0
2024	0	0
Total	**23,952**	**4,000**

Electricity

GHG emissions from electricity usage were estimated using the following equation:

$$E_{CO_2-e} = \frac{Q \times EF}{1000}$$

where:

E_{CO2-e}	=	Emissions of greenhouse gases from electricity usage	(t CO_2-e/annum)
Q	=	Estimated electricity usage	(kWh/annum)[1]
EF	=	Emission factor (Scope 2 or Scope 3) for electricity usage	(kg CO_2-e/kWh)[2]

[1] kWh/annum = kilowatt hours per annum

[2] kg CO_2-e/kWh = kilograms of carbon dioxide equivalents per kilowatt hour

The quantity of electricity consumed in each year is based on 2012 usage numbers provided by Barrick.

The Scope 2 and Scope 3 emission factors are 0.88 and 0.18 kg CO_2-e/kWh respectively.

GHG emission factors for electricity were sourced from the NGA Factors (**DCCEE, 2012**). The estimated annual and total life of mine GHG emissions from electricity usage are presented in the table below.

Table C.5: Estimated CO_2-e (tonnes) for Electricity

Year	Usage (kWh)	Emissions (t CO_2-e)		Total
		Scope 2	Scope 3	
2014	221,830,840	195,211	39,930	235,141
2015	224,911,824	197,922	40,484	238,407
2016	227,992,808	200,634	41,039	241,672
2017	227,992,808	200,634	41,039	241,672
2018	227,992,808	200,634	41,039	241,672
2019	227,992,808	200,634	41,039	241,672
2020	227,992,808	200,634	41,039	241,672
2021	231,073,792	203,345	41,593	244,938
2022	227,992,808	200,634	41,039	241,672
2023	224,911,824	197,922	40,484	238,407
2024	64,700,662	56,937	11,646	68,583
Total	**2,335,385,788**	**2,055,139**	**420,369**	**2,475,509**