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BORAL CEMENT – BERRIMA – PROPOSED USE OF SOLID WASTE DERIVED FUEL IN KILN 6 - SUMMARY OF HUMAN HEALTH RISK ASSESSMENT (HHRA) AND SUBSEQUENT EVALUATIONS

Dear Mr Wallace

This letter report by Golder Associates Pty Ltd (Golder) commissioned by Boral Cement Ltd (Boral) independently summarises the human health risk assessment (HHRA) and subsequent evaluations of the HHRA.

The objective of this report is to provide a consolidated summary of the HHRA. The summary is intended to provide confidence to stakeholders (community, government and company) that the HHRA has assessed the potential for human health risks to the community and that the HHRA peer review comments have been adequately addressed.

1.0 INTRODUCTION AND BACKGROUND

Boral Cement Ltd owns and operates the Berrima Cement Works (the “site”). The Works is located on Taylor Avenue, New Berrima. Boral proposed two Solid Waste Derived Fuels (SWDF) for use in the Kiln 6:

- Wood Waste - material left over from industrial processes like milling, furniture making, and building and construction; and
- Refuse Derived Fuel (RDF) - fuel made from the combustible materials recovered and processed from waste streams, such as papers, cardboards, packaging, and construction and demolition materials.

2.0 PREVIOUS REPORTS

Two technical evaluations have been conducted:

- Air Quality Impact Assessment (AQIA). The AQIA report is titled “Boral Cement Berrima Works Use of Solid Waste Derived Fuels in Kiln 6” Revision 1 January 2016. Prepared by Air Quality Professionals (AQP). Referred to in this letter report as AQIA or AQP (2016a)

AQP responded to peer review comments related to HHRA issues on 29th April 2016 in a letter titled “Comments on enRiskS review letter dated 11th February 2016”. Referred to as AQP (2016b).

- Human Health Risk Assessment (HHRA) report is titled “Boral Cement Works Use of Solid Fuel in Kiln 6 – Human Health Risks Assessment – Response to Peer Review”. Report Number 610.15875.00000.0020 HRA dated 5 May 2016. Prepared by SLR. Referred to as the HHRA or SLR (2016).

The above-mentioned reports and the latest update to AQIA are provided in Appendix A.

Both the AQIA and HHRA were reviewed and evaluated by:



- NSW EPA – EPA Review contained within a Letter from the Department of Planning and Environment dated 2nd August 2016 titled “Boral Cement – Berrima – Use of Waste Derived Fuels.

The NSW Environment Protection Authority (EPA) reviewed additional information provided by Boral in relation to air quality and HHRA. The review concluded that the following items required further consideration:

- The assessment of impacts associated with non-direct inhalation exposure pathways (deposited dust and subsequent health effects)
- The risk assessment of airborne particulates (dust in air)
- The assessment of heavy metals (including mercury, thallium and lead)

- enRiskS – Environmental Risk Sciences Pty Ltd – Letter Report dated 18th July 2016 titled “Review – Boral Cement Berrima Works, Use of Solid Waste Derived Fuels in Kiln 6, Human Health Risk Assessment”.

The revised HHRA (May 2016) and the additional information in regard to the air quality modelling (June/July 2016) has provided sufficient information to allow some outstanding matters from the advice provided in May 2016 to be finalised including:

- *Dioxins;*
- *Secondary exposure assessment;*
- *Metals; and*
- *Air toxics;*

Outstanding matters now relate only to:

- *risk assessment for particulates for which an approach has been suggested that would provide a satisfactory resolution without additional modelling*
- *estimated ground level concentrations for PAHs – further information about the calculated emission rate versus the measured emission rates may suffice.*

The peer review letters are provided in Appendix A of this report. The outstanding matters are addressed within Section 3 and relevant Appendices of this report.

3.0 CONSOLIDATION OF MAIN FINDINGS

This report provides a high-level summary and context of the findings in the HHRA in order to address the outstanding technical queries raised by the reviewers.

3.1 Dust in the Air and Health

Dust in the air in technical reports is described as ‘particulate matter’ (PM).

PM can be described by the size of the particles “*median aerodynamic equivalent diameter*” (AED). PM of the same AED will tend to have the same settling velocity and therefore, most authors subdivide particles into AED fractions based on how the particles are generated and where they deposit in human airways. These include:

- < 100 µm – Total suspended particulates (TSP)
- < 10 µm (referred to as PM₁₀) – Particulate matter
- < 10 and >2.5 (PM_{2.5-10}) - Coarse particulate matter (CPM)
- < 2.5 µm (PM_{2.5}) - Fine particulate matter (FPM)

< 0.1 μm ($\text{PM}_{0.1}$), - Ultrafine particulate matter (UFPM)

Particles with a diameter greater than 10 μm have a relatively small suspension half-life and are largely filtered out by the nose and upper airway. For this reason, they are not included in health risk assessments.

The predominant source for PM exposure data is stationary ambient air monitoring stations. In many parts of the world, only PM_{10} monitors are available; however, $\text{PM}_{2.5}$ monitors have also become available in more recent times. These two fractions are the predominant source of exposure estimates for health studies (epidemiological research findings). Monitoring data for ultrafine PM is rare.

Three general observations relevant to PM health effects can be made:

- Most studies are based on measured PM_{10} or $\text{PM}_{2.5}$ in cities. A much smaller subset of studies is available for estimated coarse PM.
- Particulate matter is causally related to health effects; both mortality and morbidity.
- The size fraction that produces the most consistent and strongest evidence for a relationship with health effects is $\text{PM}_{2.5}$.

Therefore, for assessing dust in the air and health, HHRA focused on $\text{PM}_{2.5}$ but also paid attention to the relationship between the dust size fractions (ratio of $\text{PM}_{2.5}$ to PM_{10}).

The HHRA has attempted to apply a new approach to PM HHRA. However, this has not been conducted in a robust manner. Both peer review letters from EPA and enRiskS require additional assessments to be conducted.

The HHRA uses a methodology that is most commonly used for national-scale health impact assessment (HIA), regional assessment and planning of health infrastructure or assessing the impacts of a policy change in relation to air quality and health. For instance, this methodology is useful in predicting the health benefits of altering fuel standards on a national or regional basis.

This method uses demographic and epidemiological techniques in a quantitative manner. The results are typically expressed as the proportion of a health endpoint attributable to a specific cause. The HHRA describes the results as a 'quantitative risk estimate'. The target risk is defined in NSW as one in ten thousand ($1\text{E-}04$ or 1×10^{-4}).

The HHRA did not use the PM risk assessment methodology as intended. The method is intended for comparing before and after or 'what if' type assessments. Therefore, the enRiskS peer review requested SLR to revise the PM HHRA to assess the incremental change in PM due to the use of solid fuel in Kiln 6 and estimate quantitative risk as a consequence of the incremental change. In addition the HHRA uses PM data at individual receptor points rather than a population average exposure as required by the reference methodology (WHO 2006).

Appendix B provides a quantitative assessment of the health risk associated with the proposed waste fuel source.

The enRisk / NSW EPA proposed target health risk of one in ten thousand is achieved for all health parameters evaluated for both $\text{PM}_{2.5}$ and PM_{10} .

3.1 Deposited Dust and subsequent human health risks

There are a large number of ways through which humans may be exposed to industrial emissions. Obviously, direct inhalation is the most important in the majority of circumstances for most pollutants found in industrial emissions. For some substances with the appropriate physiochemical (e.g. solubility in fat), environmental (e.g. persistence) and biological (e.g. poor rates of metabolism and excretion) properties, accumulation through the human food chain is a theoretical possibility. In the HHRA, exposure via inhalation of emission components is referred to as the direct exposure pathway and has been examined in detail.

All other exposure pathways are called secondary exposure pathways. Secondary exposure pathways are not always evaluated in HHRA (SLR 2016). The process of evaluating health risks from exposure via secondary pathways is difficult and uncertain because empirical relations for the movement of most substances from air to other media to which humans may be exposed have not been established. Therefore,

the evaluation of secondary exposure pathways inherently requires many assumptions, which impart unquantifiable uncertainties to the assessment. Consequently, in most risk assessments the secondary exposure pathways are either not considered or unrealistic conjectures are made to establish gross worse case scenarios. In lieu of these approaches, a pragmatic alternative is to perform screening assessments to evaluate the need for, and hence benefit from, a detailed multi-pathway risk assessment. The screening assessment is provided in Appendix C.

Dioxins are bioaccumulative substances and as such a screening assessment has been provided in Appendix C to assess the need for secondary exposure assessment. The method used is to convert the ground level concentration to an intake and compare this to the daily intake for Australians. The incremental intake is 0.0015% Compared to background intake the

Screening trigger criteria for assessing secondary exposure pathways include:

1. *The metal must be capable of being bioaccumulated by plants and animals relevant for the human food chain, and*
2. *The predicted annual ground level concentration increment must be above those measured in rural and remote areas, or*
3. *The direct inhalation hazard quotient for incremental annual average concentration of any given metal is greater than 0.05.*

Appendix C provides a rationale of when such assessments are needed and provides a pre-evaluation using a transparent process. Appendix C focusses on whether emissions to air could result in a build-up of bioaccumulative emission components in the environment and subsequent human exposure through the food chain. It reviews information for dioxins, PAH and metals and concludes that secondary exposure pathways do not need to be considered.

Appendix C considers mercury, thallium and lead as requested by NSW EPA.

3.2 Emission Composition and Health

The air dispersion modelling contained within the Air Quality Impact Assessment (AQP 2016a, 2016b) has predicted ground level air concentrations at 87 locations representing the locations of residential dwellings, residential zones, and non-residential buildings nearby and around the cement works.

For each of these locations (i.e. the receptor locations), the potential for direct health effects has been evaluated with the SLR HHRA for predicted short term and long term exposures. These are called the acute and chronic health effect evaluations respectively. Therefore, the health risks assessed in the HHRA report are those that may be associated with:

- Acute (i.e. short-term) exposures to the emissions. Included are:
 - Systemic health effects, e.g. affects the central nervous system.
 - Irritation (eye and upper respiratory tract).
- Chronic (i.e. long-term) exposures to the emissions. Included are:
 - Systemic effects, e.g. decrease in organ function.
 - Carcinogenic effects.

In all instances, apart from the assessment of cancer, the likelihood of the most sensitive health effect of an emission component has been characterised using a health based air guideline value sourced from authorities. Ambient air guidelines are established to protect the general population (inclusive of sensitive sub-groups) against the most sensitive health effect associated with the chemical. The most sensitive health effect is the one that occurs with the lowest level of exposure.

SLR (2016) describes an assessment of direct acute and chronic health effects for contaminants that maybe discharged to air. These contaminants are described in Section 3.2 of AQP (2016a). The groups of contaminants and the HHRA conclusions are summarised in the subsequent sections.

3.2.1 HHRA for Criteria Pollutants.

Criteria pollutants include particulate matter (PM), sulfur dioxide (SO₂), nitrogen oxides (NO_x) and carbon monoxide (CO) resulting from combustion processes and dry goods handling / milling processes. These emission components are referred to as 'criteria' pollutants as they are common air pollutants and Australian air quality standards are defined for these pollutants.

PM HHRA is summarised in Section 3.1 and Appendix B.

Each of sulfur dioxide (SO₂), nitrogen oxides (NO_x) and carbon monoxide (CO) has been assessed within the SLR HHRA. It is concluded that these are well below the relevant Australian standard and health risks due to exposure to these emission components being unlikely to result in health risks to the community. The peer review comments accept this finding (NSW EPA 2016, enRiskS 2016).

3.2.2 HHRA for Volatile Organic Compounds (VOCs)

These are referred to by AQP as – non-methane hydrocarbons (NMHCs) or VOCs.

Fuel combustion from Kiln 6 produces VOCs. Non-methane hydrocarbons (NMHCs) are an important subset of VOCs that are known to have an important role in air quality due to their high reactivity. This is why AQP and SLR focus on these VOCs.

AQP (2015) uses the indicative breakdown of VOCs in the total NMHCs mix from Portland cement kilns from USEPA (1995) to calculate specific VOCs. The breakdown of NMHCs from USEPA case study includes acetone, benzene, benzoic acid, carbon disulfide, chloromethane, formaldehyde, methylene chloride, naphthalene, phenanthrene, toluene, xylenes and others. Benzene and benzoic acid comprise a large portion, 66.7%, of the NMHCs mix. Other VOCs that account less than 1% individually are summed up as others, totalling 4.7% of the NMHCs mix. In the Human Health Risk Assessment, SLR 2016 used these results as the inherent VOCs from the Kiln to evaluate air quality compliance and also human health risks. enRiskS (2016) requested additional information on the VOC emissions. The additional information is provided in AQP (2016b).

The estimated concentration of each VOCs evaluated in the HHRA was below the respective health based guideline value and in most cases at concentrations at least two orders of magnitude below the health based criteria. Specifically the HHRA found (SLR 2016):

- For direct acute health effects the Hazard Index (HI) was 0.35. The major contributor to the HI is benzene (HQ 0.23 – 66% of HQ) and phenanthrene (HQ 0.1 – 29%). The HI is well below the target of 1.

As a consequence the HHRA concludes that acute health risks due to VOCs are unlikely. The conservative assumptions in this estimation include:

- Maximum emission rate is modelled. This emission rate is a conservative estimate of the total NMHC concentration.
- The maximum value occurs for one hour in a year. That is on most occasions throughout the year the concentration is expected to be well below the maximum concentration.
- For direct chronic health effects, the Hazard Index (HI) was 0.09. The major contributor to the HI is benzene.

The HHRA conclusion is intended to err on the side of safety (i.e. be conservative). The conservatism within HHRA is important to account for uncertainties. The key uncertainty present in the VOC HHRA is whether the assessment of NMHCs characterises all potential VOC emissions that may occur from the variety of solid waste raw materials proposed for use in Kiln 6. AQP (2016b) states that some of the VOCs listed in US EPA (1995) were not included as emission components as they contribute a small percentage (less than 1%) of VOCs. The HHRA does include consideration of the most hazardous VOC (benzene) and other reactive VOCs that are commonly associated with short duration health complaints (formaldehyde). As a general rule,

rotary kilns in the cement manufacture lead to thoroughly mixing at high temperatures. These conditions will result in the destruction of organic contaminants introduced with the fuel at the primary burner (UNEP, 2005). As a rule, the above compounds are present in the exhaust gas of rotary kilns in a characteristic ratio (German VDZ 2008). Eighty-four benzene emission concentrations from 27 German rotary kilns in cement manufacture have been reported (German VDZ 2008). The concentrations range between non-detect (3 of 82) to approximately 8 mg/m³ (2.5 ppm) with an approximate average of 0.6-0.7 ppm. AQP (2016a) estimates that the total NMHC concentration is 40 ppm and that benzene accounts for 31.4% (Table 78 pg 164). This translates to an emission concentration of approximately 13 ppm. This value is approximately 5 times higher than the average benzene concentration measured in 27 German plants. German plants do use waste fuels as a fuel source. These waste fuels include similar wastes proposed to be used in Boral's Kiln No 6.

In summary, the HHRA includes the major species of VOCs detected in rotary kilns, these include reactive VOCs and the modelled emission rates are conservative. AQP (2016b) have further clarified that VOCs not modelled are present at very low percentages (less than 1%). As a consequence, it is concluded that the conservative aspects of the VOC assessment account for any uncertainties in the VOC characterisation.

3.2.3 HHRA for Polycyclic aromatic hydrocarbons (PAH)

The HHRA (SLR 2016) concluded that PAH emissions "lead to a negligible risk in most cases and a tolerable risk in the worst case scenarios". The HHRA peer reviews (NSW EPA 2016, enRiskS 2016) accept these conclusions. Therefore a summary of the conservatism embedded with the HHRA has not been generated.

The emission assumptions have been checked and appear reasonable.

3.2.4 HHRA for Metals

3.2.4.1 Acute Health Risk

The acute health risk assessment concludes that the HI (1.09) is above the target HI of 1. The HHRA and the enRiskS peer review both conclude that the acute health risk due to metal emission components is unlikely to result in an unacceptable health risk. The reasons include:

- AQP analysed particulate matter from the Kiln for a range of heavy metals as historic and current emissions testing (from 2011 to 2014). It reported that arsenic, beryllium, cadmium, cobalt, nickel, selenium and mercury were less than the limit of reporting.
- The modelled concentrations are very conservative, the values used are the worst case values beyond the site boundary.
- If the HHRA had used the conservative assumption metals are emitted at ten times the limit of reporting then the acute health risk HI is less than the target of 1.

Given the conservatism built into risk assessment, a hazard quotient (HQ) and hazard index (HI) of less than 1 are generally considered to present no cause for concern.

When the hazard index is greater than 1, a closer examination of the assumptions is needed (HI above 1). This closer examination can either lead to refinement of the risk estimates or management actions to reduce exposure.

For this reason the NSW EPA requested additional justification of the acute health risk estimates given that these are at the target HI of 1.

The HI calculation allows focus on components that are likely contributors to health risks either because their individual exposure levels exceed the health benchmark (as determined by the HQ), or because joint toxic action with other components, including additivity or interactions, may pose a health hazard (as determined by the HI being greater than 1, although individual HQs are less than 1).

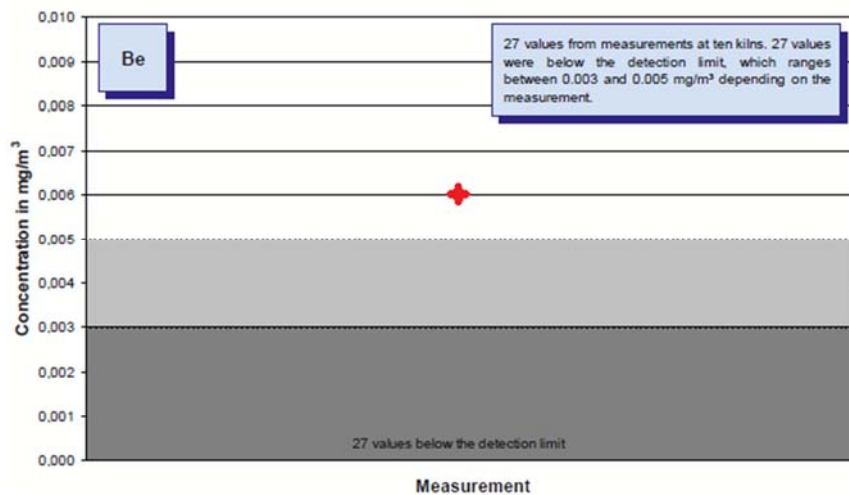
In SLR HHRA two very conservative assumptions have led to the HI conclusion of 1.06:

- The use of the 99.9th percentile based on modelled ground level concentrations. AQP (2016a) conservatively assume that the use of solid waste fuel sources would increase emissions ten fold. The basis of the assumption was not described. Cadmium and Beryllium account for approximately 70% of

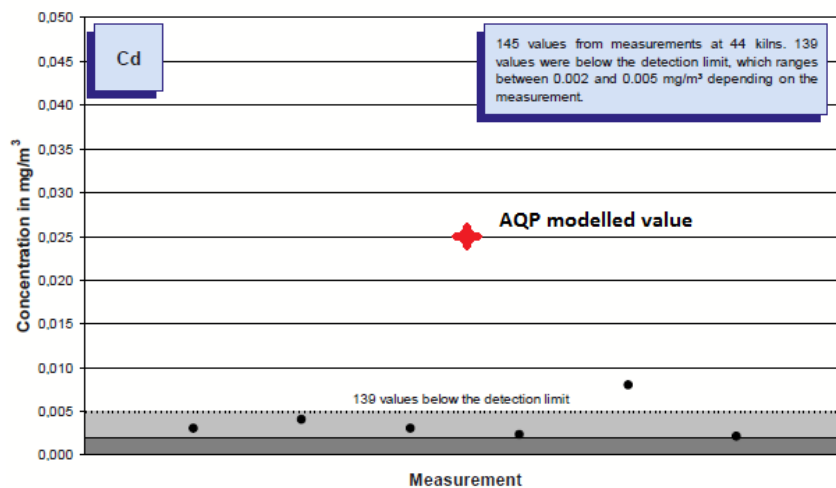
the HI.

To assess the veracity of the assumption Golder compared the assumption of a 10 fold increase in existing emissions with measured emission concentrations from overseas cement kilns. A German report (Umweltdaten 2008) describes the emission components from rotary kilns used for cement manufacture in Germany. The report is useful for a reality check because it includes data for multiple plants using the same manufacturing process with different configurations. In Germany, waste fuel accounts for 54% of the total fuel consumption. The waste fuels include solid waste materials. Figure 1a & b show the comparison between the AQP assumed emission concentration and the measured results from a range of German plants. In both cases, the AQP result overestimates the concentration of cadmium and beryllium.

Figure 1: Comparison of Assumed Input Concentration to the Boral Dispersion Model (AQP 2016) with Measured Data from the German Cement Industry (Um 2008)



The value used in the acute HHRA is well above measured values of German Cement Kilns that use waste fuel sources.



The value used in the acute HHRA is well above measured values of German Cement Kilns that use waste fuel sources.

- The use of regulatory impact criteria rather than health based criteria.

Regulatory impact criteria include other considerations in addition to health. Therefore these are not health based criteria. For example, the NSW acute impact criteria for beryllium is 0.004 while the chronic health based guideline for beryllium is 0.021 µg/m³. From first principles in toxicology, chronic adverse health effects occur at lower concentrations than acute effects. Therefore an acute guideline less than the chronic guideline indicates that there is a large degree of conservatism embedded in the

guideline. The consequence is that the acute guideline for beryllium is at least 5 times more conservative than it should be.

The above discussion is provided to emphasize that the assumptions and conservative aspects contributing to the HHRA overestimate the overall HI. If each individual parameter in a HHRA is overestimated the result is an overestimation of the HI.

To demonstrate this Table 1 presents a comparison of the worst case air concentration to a health based guideline value. For each individual metal the hazard quotient is below 1 and the hazard index is also below 1.

Table 1 Acute Hazard Quotient (HQ) of individual metal species and total Acute Hazard Index (HI)

	GLC Highest 99.9th Percentile beyond site boundary incremental Averaging time 1 hour (µg/m³)	AGV* Acute AGV (Averaging time 1 hour) (µg/m³)	Acute Hazard Quotient (HQ)# (GLC ÷ AGV)
Antimony	0.036	5	<0.01
Arsenic	0.0015	3	<0.01
Beryllium	0.0015	0.02	0.08
Cadmium	0.0061	0.1	0.06
Chromium (total)	0.01	3.99	<0.01
Chromium VI	0.0061	0.39	0.02
Cobalt	0.0036	0.2	0.02
Copper	0.031	10	<0.01
Manganese	0.17	2	0.09
Mercury	0.012	0.25	0.05
Nickel	0.019	0.33	0.06
Selenium	0.007	2	<0.01
Thallium	0.0061	1	<0.01
Tin (inorganic)	0.015	20	<0.01
Vanadium	0.0058	20	<0.01
			Acute Hazard Index (HI)
			0.36

*AGV = Air guideline value. This is a health based guideline value.

As a consequence, Golder concurs with the enRiskS peer review conclusion and HHRA conclusion that acute health risks due to exposure to metals are unlikely.

3.2.5 Chronic Health Risk

enRiskS (2016) note some errors in the health based guidelines used to calculate chronic health risk with the HHRA for metal emission components. NSW EPA (2016) noted that lead should be included in the chronic health risk assessment for metals emission components. To address these comments the HHRA (Table 27 of SLR 2016) has been updated and reproduced below.

Table 2 Chronic Hazard Quotient (HQ) of individual metal species and total Chronic Hazard Index (HI)

Individual NMHC species	Annual Average GLC beyond site boundary ($\mu\text{g}/\text{m}^3$)	Health Based Chronic criteria adopted* ($\mu\text{g}/\text{m}^3$)	Criteria reference	Chronic Hazard Quotient (HQ)
Antimony	0.000825	0.21	USEPA RSLs	<0.01
Arsenic	0.000033	0.016	USEPA RSLs	<0.01
Beryllium	0.000033	0.021	USEPA RSLs	<0.01
Cadmium	0.0001375	0.01	USEPA RSLs	0.01
Chromium (total)	0.00022	0.041 Cr III / 0.0043 Cr VI	TCEQ ESL (LT)	<0.01
Chromium VI	0.0001375	0.1/0.000012	USEPA RSLs	<0.01
Cobalt	0.0000825	0.0063	USEPA RSLs	0.01
Copper	0.000715	1	TCEQ ESL (LT)	<0.01
Lead	0.00033	0.15	USEPA RSLs	<0.01
Manganese	0.003905	0.052	USEPA RSLs	0.08
Mercury	0.000275	0.31	USEPA RSLs	<0.01
Nickel	0.000429	0.015	USEPA RSLs	0.03
Selenium	0.0001595	21	USEPA RSLs	<0.01
Thallium	0.0001375	0.1	TCEQ ESL (LT)	<0.01
Tin (inorganic)	0.00033	2	TCEQ ESL (LT)	<0.01
Vanadium	0.000132	0.1	USEPA RSLs	<0.01
Total				Chronic Hazard Index (HI) 0.13

* Table 27 of the SLR HHRA Updated according to EnRisks report on 18th July 2016

The HQ for each individual metal and the HI for cumulative exposure to metals are below the target HQ and HI of 1. As a consequence, the HHRA conclusion that chronic health risks due to exposure to metals are unlikely is confirmed.

NSW EPA requested comment on whether metals and the potential for impacts via secondary exposure pathways. Secondary pathways due to metal exposure are addressed in Section 3.1 and Appendix B of this letter report.

NSW EPA comments that a cumulative assessment of cancer risk has not been presented within the HHRA. This is an important consideration as a number of the metal emission components and PAH compounds are considered genotoxic carcinogens. For genotoxic carcinogens, it is conventional to undertake a cumulative assessment of cancer risk.

Table 3 provides an assessment of cumulative cancer risk. The total cancer risk is within the range that requires best practice for air toxics (NSW EPA 2005).

Table 3: Cumulative Cancer Risk Assessment

Emission Component	Annual Average GLC (max beyond boundary)	Unit Risk Factor (URF)	Cancer Risk (GLC x URF)
Arsenic	0.000033	0.00015 (WHO 2000)	5.0×10^{-9}
Cadmium	0.0001375	0.00018 (US EPA 1987)	2.5×10^{-8}
Chromium VI	0.0001375	0.0000004 (WHO 2000)	5.5×10^{-11}
Nickel	0.000429	0.000038 (WHO 2000)	1.6×10^{-8}
PAH (BaP Eq)	0.000017	0.087 (WHO 2000)	1.5×10^{-6}
Total Cancer Risk			1.5×10^{-6}

US EPA 1987 – US EPA IRIS Summary for Cadmium. WHO 2000 – Air Quality Guidelines for Europe.

3.2.6 HHRA for Hydrogen halides

The HHRA (SLR 2016) concluded that hydrogen halide is unlikely to present a human health risk. The HHRA peer reviews (NSW EPA 2016, enRisk 2016) accept these conclusions.

Therefore a summary of the conservatism embedded with the HHRA has not been generated.

3.2.7 HHRA for Dioxins

The HHRA (SLR 2016) concluded that dioxins are unlikely to present a human health risk. The HHRA peer reviews (NSW EPA 2016, enRiskS 2016) accept these conclusions.

Additional information on dioxin assumptions and calculations within the air quality impact assessment are provided within AQP (2016b) and these are reproduced in Appendix A.

An assessment of the potential for dioxins to contribute to secondary exposure pathways is provided within Appendix B. The assessment considers the contribution of direct inhalation to the total intake of dioxins. The assessment concludes that the potential contribution is minor and thus a more detailed assessment of secondary exposure pathways is not warranted.

4.0 CONCLUSION

The HHRA and subsequent analysis to address peer review comments have confirmed the HHRA conclusion that the use of SWDF as fuels in Kiln 6 under the conditions proposed by Boral are unlikely to present an unacceptable human health risk to surrounding communities.

We trust that the report meets the project requirements.

Sincerely

GOLDER ASSOCIATES PTY LTD



John Frangos
Principal Toxicologist & Risk Assessor

JF/AM/dl

Attachments: Appendix A: Consultant Reports
Appendix B: Particulate Matter Risk Assessment
Appendix C: Secondary Pathways
Important Information About this Report

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References

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APPENDIX A

Consultant Reports

Report

Boral Cement Berrima Works Use of Solid Waste Derived Fuels in Kiln 6

Revision 1 – January 2016

Air Quality Impact Assessment



Report prepared by:
Tracy Freeman, Principal Air Quality Consultant

For:
Boral Cement

25 January 2016



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Table of contents

List of Tables

List of Figures

Executive Summary

1	Introduction	4
2	Site and Activity Description	6
2.1	Site Overview	6
2.2	Cement Manufacture Process Outline	8
2.3	Burning of NSF in Cement Kilns	8
2.4	Refuse Derived Waste Quantities	10
2.5	Handling and Storage of Raw Materials	10
3	Description of Air Discharges	12
3.1	Sources of Air Discharges	12
3.1.1	Point Sources	12
3.1.2	Fugitive Sources	13
3.1.3	Project New Emission Sources	13
3.2	Nature of Contaminants	14
3.2.1	Overview	14
3.2.2	Fine particulate	15
3.2.3	Oxides of Nitrogen	16
3.2.4	Sulfur Dioxide	16
3.2.5	Volatile Organic Compounds (VOCs)	16
3.2.6	Carbon Monoxide	17
3.2.7	Heavy Metals	17
3.2.8	Polycyclic Aromatic Hydrocarbons (PAHs)	18
3.2.9	Dioxins	18
3.2.10	Odour	19
3.3	Publications and Standards for Burning of NSF	19
3.3.1	European Directive (2010)	19
3.3.2	BREF (2013)	21
3.3.3	UNEP Toolkit (2005)	21

4	Emission Rates and Discharge Parameters – Point Sources	23
4.1	Scope of Monitoring of Existing Emissions	23
4.2	Emission Limits for Standard Fuels	24
4.3	Emission Limits for Non Standard Fuels	25
4.4	Results of Annual Testing Required for Standard Fuels	28
4.4.1	Physical Stack Dimensions and Discharge Parameters	28
4.4.2	Emission Data	29
4.5	Comparison of Annual Test Data with Emission Limits	31
4.6	Other Monitoring Results	32
4.6.1	Gas Flow Data - No.6 Kiln Stack	32
4.6.2	No.6 Kiln Stack Measurements from Voluntary Annual Stack Testing	35
4.6.3	No.6 Kiln Stack Measurements from Continuous Emission Monitoring – Concentration Data	38
4.6.4	No.6 Kiln Stack Measurements from Continuous Emission Monitoring – Mass Emission Rate Data	40
4.6.5	1-hour versus 24-hour data (Peak to Mean)	41
4.7	Emission Rates During NSF Combustion	42
4.8	Emission Rates Used In Dispersion Model	44
4.8.1	Emission Rates for Kiln 6 Stack, Based on Emission Limits Specified on a 24-Hour Average Concentration	44
4.8.2	Other Emission Rates for Kiln 6 Stack	45
4.8.3	TSP Emission Rates for Other Stacks	46
4.8.4	PM ₁₀ and PM _{2.5} Emissions	47
5	Emission Rates and Discharge Parameters – Fugitive Sources	48
5.1	Odour	48
5.2	Dust	49
5.2.1	Sources and methodology for emission rate development	49
5.2.2	Stockpiles and Dusty Surfaces	50
5.2.3	Vehicle-Generated Tracked Dust	52
5.2.4	Movement and Dumping of Materials	53
5.2.5	Crushing	54

6	Description of Local Environment	55
6.1	Topography.....	55
6.2	Land Use	56
6.3	Meteorology	60
6.4	Ambient Monitoring Data from AQMS.....	63
6.4.1	Annual Average PM ₁₀ and TSP	63
6.4.2	24-hour Average PM ₁₀ and TSP	63
6.4.3	Heavy Metals.....	70
7	Dispersion Model Methodology	71
7.1	Dispersion Model Selection	71
7.2	Selection of Representative Year of Meteorology.....	71
7.3	TAPM Model.....	72
7.4	CALMET Model	72
7.5	CALPUFF Model	73
7.5.1	Receptors and Terrain	73
7.5.2	Point Source Inputs	76
7.5.3	Area Source Inputs	77
7.5.4	Volume Source Inputs	78
7.5.5	Other Inputs	78
7.6	Assessment Criteria	79
7.6.1	Assessment Criteria for PM ₁₀ , PM _{2.5} , SO ₂ , NO ₂ , Lead and Hydrogen Fluoride.....	79
7.6.2	Assessment Criteria for TSP	80
7.6.3	Assessment Criteria for NMHCs	80
7.6.4	Assessment Criteria for Odour	81
7.6.5	Assessment Criteria for Other Contaminants	82
7.7	Background Concentrations	84
7.7.1	Representative Monitoring Sites.....	84
7.7.2	Annual Average Data for NO ₂ , PM ₁₀ , PM _{2.5} and TSP	87
7.7.3	PM ₁₀ and PM _{2.5} 24-hour Average Data	88
7.7.4	Odour	92
7.7.5	Dioxins, Organics, PAHs, and Heavy Metals - Background Data	93
7.7.6	Hydrogen Fluoride.....	99
7.8	NO _x to NO ₂ Oxidation Calculations.....	99

8	Dispersion Model Results	100
8.1	NO _x and NO ₂	100
8.1.1	Model Output – one hour average.....	100
8.1.2	NO-to-NO ₂ conversion using Method 1	100
8.1.3	NO-to-NO ₂ conversion using Method 2 - “Ozone Limiting Method”	100
8.1.4	NO-to-NO ₂ conversion using Method 3 - “Janssen Method”	113
8.1.5	Annual Average	122
8.1.6	Summary	126
8.2	SO ₂	127
8.2.1	Incremental concentrations	127
8.2.2	Cumulative concentrations	127
8.2.3	Summary	127
8.3	TSP.....	132
8.3.1	Model Output – Point Sources	132
8.3.2	Fugitive Emissions Sensitivity Tests.....	135
8.3.3	Model Output – Point Source and Fugitive Source Emissions	137
8.3.4	Summary	138
8.4	PM ₁₀	140
8.4.1	Model Output – Point Sources	140
8.4.2	Handling of Fugitive Emissions.....	144
8.4.3	Fugitive and Point Sources Combined.....	144
8.4.4	Annual Average PM ₁₀ Cumulative Assessment and Comparison with Ambient Air Quality Assessment Threshold Criteria	147
8.4.5	24-hour Average PM ₁₀ Cumulative Assessment and Comparison with Ambient Air Quality Assessment Threshold Criteria	147
8.4.6	Peak Incremental Annual Average GLCs at any Off-Site Receptor	153
8.4.7	Summary	154
8.5	PM _{2.5}	155
8.5.1	Model Output – Point Sources	155
8.5.2	Handling of Fugitive Emissions.....	158
8.5.3	Fugitive and Point Sources Combined.....	158
8.5.4	Annual Average PM _{2.5} Cumulative Assessment and Comparison with Ambient Air Quality Assessment Threshold Criteria	161

8.5.5	24-Hour Average PM _{2.5} Cumulative Assessment and Comparison with Ambient Air Quality Assessment Threshold Criteria	161
8.5.6	Peak Incremental Annual Average GLCs at any Off-Site Receptor	162
8.5.7	Summary	163
8.6	NMHC	164
8.6.1	1-Hour Average GLCs	164
8.6.2	Annual Average GLCs	165
8.7	Dioxins	166
8.8	PAHs	166
8.9	Heavy Metals	167
8.9.1	Lead	167
8.9.2	1-Hour Average GLCs for Other Heavy Metals	167
8.9.3	Annual Average GLCs for Other Heavy Metals	168
8.10	Halides and Other	169
8.11	Odour	171
9	Conclusion	174
10	References	176

Appendices

- Appendix 1: Single calendar year (January – December) windroses for Berrima AQMS, 2010 – 2014**
- Appendix 2: Comparison of meteorological data for single year versus longer term trends - Mossvale site**
- Appendix 3: Windroses for 24-hour periods when high PM₁₀ concentrations are measured at AQMS**
- Appendix 4: Comparison of TAPM windrose for Berrima with measured data**
- Appendix 5: Dispersion model output plots – NO and NO₂**
- Appendix 6: Dispersion model output plots – SO₂**
- Appendix 7: Dispersion model output plots – TSP from point sources**
- Appendix 8: Dispersion model output plots – TSP model sensitivity tests**
- Appendix 9: Dispersion model output plots – TSP cumulative sources**
- Appendix 10: Dispersion model output plots – PM₁₀**
- Appendix 11: Dispersion model output plots – PM_{2.5}**
- Appendix 12: Dispersion model output plots – NMHC**
- Appendix 13: Dispersion model output plots – Dioxins**
- Appendix 14: Dispersion model output plots – PAHs**
- Appendix 15: Dispersion model output plots – Heavy metals**
- Appendix 16: Dispersion model output plots – Hydrogen fluoride**

List of Tables

Table 1: Quantities of different types of waste fuels used in the German cement industry (reproduced from BREF (2013) Table 6.3)	9
Table 2: Approved and proposed classes and quantities of standard and waste derived fuel	10
Table 3: Point sources at Berrima site	13
Table 4: European Directive 2010/75/EU - Operating Conditions for Co-Incineration of Waste	20
Table 5: Emission limits for solid particles, for burning of standard fuels; listed in conditions L3.1-3.4 and M2.2 of EPL1698	24
Table 6: Emission limits for other contaminants from No.6 Kiln Stack, for burning of standard fuels; listed in conditions L3.1-3.4 and M2.1 of EPL1698	25
Table 7: Emission limits for pollutants from No.6 Kiln Stack, for burning of NSF; listed in conditions L3.5-3.7 of EPL1698	26
Table 8: Comparison of current emission limits and monitoring methods for pollutants from No.6 Kiln Stack, for burning of Standard Fuels and NSF	27
Table 9: Summary of Stack Dimensions	28
Table 10: Summary of physical discharge parameters, from stack test data collected during annual testing in 2011, 2012, 2013 and 2014	29
Table 11: Measurements of emissions of particulates (TSP) and NO _x from No.6 Kiln Stack by annual testing in 2011-2014, required by EPL during combustion of Standard Fuels	30
Table 12: Measurements of emissions of particulates (TSP) from Cement Mill vents and No.6 Kiln Cooler Stack by annual stack testing in 2011-2014, as required by EPL during combustion of Standard Fuels	31
Table 13: Emission limits from EPL1698 for solid particles, for burning of standard fuels; compared to annual stack test data 2011-2014	31
Table 14: Emission limits from EPL1698 for other contaminants from No.6 Kiln Stack, for burning of standard fuels; compared to test data 2011-2014	32
Table 15: Summary of No.6 Kiln Stack discharge parameters, from 2012 and 2013 continuous emissions monitoring data (1-hour average calculated from 5-minute raw data)	33
Table 16: Measurements of emissions of TSP, PM ₁₀ and PM _{2.5} from No.6 Kiln Stack, from annual monitoring campaigns	35
Table 17: Measurements of emissions of SO ₂ from No.6 Kiln Stack, from annual monitoring campaigns	35
Table 18: Measurements of emissions of VOCs from No.6 Kiln Stack, from annual monitoring campaigns	35

Table 19: Measurements of emissions of heavy metals from No.6 Kiln Stack, from annual monitoring campaigns. Any concentrations below method detection limit reported as “not detected”.	36
Table 20: Measurements of emissions of heavy metals from No.6 Kiln Stack, from annual monitoring campaigns. Any concentrations below method detection limit reported as half of the method detection limit	37
Table 21: Measurements of emissions of hexavalent chromium from No.6 Kiln Stack, from annual monitoring campaigns	37
Table 22: Measurements of emissions of halides and sulfuric acid mist/sulfur trioxide from No.6 Kiln Stack, from annual monitoring campaigns	38
Table 23: Measurements of emissions of PAHs and Dioxins from No.6 Kiln Stack, from annual monitoring campaigns	38
Table 24: Summary of No.6 Kiln Stack emission concentrations (mg/Nm ³ at 10% O ₂), 1-hour averages calculated from 2012 and 2013 continuous emissions monitoring data. Minimum kiln feed throughput 250 tph.	39
Table 25: Summary of No.6 Kiln Stack emission concentrations (mg/Nm ³ at 10% O ₂), 24-hour midday-midday averages calculated from 2012 and 2013 continuous emissions monitoring data. Minimum kiln feed throughput 250 tph.	39
Table 26: Summary of No.6 Kiln Stack mass emission rates (g/s), 1-hour averages calculated from 2012 and 2013 continuous emissions monitoring data. Minimum kiln feed throughput 250 tph.....	40
Table 27: Summary of No.6 Kiln Stack mass emission rates (g/s), 24-hour midday-midday averages calculated from 2012 and 2013 continuous emissions monitoring data. Minimum kiln feed throughput 250 tph.	40
Table 28: Peak-to-mean (1-hour:24-hour) based on concentration data.	41
Table 29: Peak-to-mean (1-hour:24-hour) based on mass emission rate data.	42
Table 30: Results of emission testing during NSF burning trials in 2003 (Source: BCSC, 2003).....	43
Table 31: Calculated No.6 Kiln Stack mass emission rates for dispersion model for NO _x , TSP and NMHC, based on concentrations specified as a 24-hour average. Emissions assumed to occur continuously, every hour of the year.	45
Table 32: Assumed emission rates for dispersion model for heavy metals and other trace pollutants in Kiln 6 Stack. Emissions assumed to occur continuously, every hour of the year.	46
Table 33: Assumed TSP emission rates for Cooler Stack and Cement Mills. Emissions assumed to occur continuously, every hour of the year.....	47
Table 34: Assumed PM ₁₀ and PM _{2.5} emission rates for all stacks. Emissions assumed to occur continuously, every hour of the year.	47
Table 35: List of areas defined as fugitive dust sources for dispersion model (refer also Figure 7)	52
Table 36: List of areas defined as fugitive dust sources for dispersion model (refer also Figure 7)	52

Table 37: Annual average PM ₁₀ and TSP concentrations at Berrima monitoring site (calculated from 24-hour average data measured on a 1-day-in-6 basis.	63
Table 38: Summary of results of heavy metal testing at AQMS, 2011-2014. 24-hour average concentrations measured in particulate during 1-day-in-6 testing programme.	70
Table 39: Discharge parameters for Kiln Cooler Stack and No.6 and No.7 Cement Mills.....	77
Table 40: Discharge parameters for No.6 Kiln Stack.....	77
Table 41: Summary of assumed dimensions for volume sources in the dispersion model.	78
Table 42: Impact assessment criteria for PM ₁₀ , PM _{2.5} , NO ₂ , SO ₂ , lead and hydrogen fluoride	79
Table 43: Assumed breakdown of composition of organic pollutants present in kiln stack discharge and relevant air quality criteria	81
Table 44: Odour assessment criteria from “Approved Methods” guidelines.....	82
Table 45: Impact assessment criteria for trace pollutants	83
Table 46: 24-hour average ambient air quality monitoring data statistics for OEH sites at Bringelly, Bargo, Macarthur and Oakdale for NO ₂ , SO ₂ , ozone, PM ₁₀ and PM _{2.5} – 1 January 2010 to 31 December 2014.....	86
Table 47: Annual average concentrations of NO ₂ and PM ₁₀ at Bargo and PM _{2.5} at Camden (source, NSW EPA website)	87
Table 48: Comparison of 24-hour average ambient air quality monitoring data statistics for OEH sites at Bargo and Camden, and Berrima AQMS site operated by Boral – January 2011 to December 2014	91
Table 49: Five highest daily average PM ₁₀ concentrations measured in Bargo for each of the calendar years 2010-2014	92
Table 50: Five highest daily average PM _{2.5} concentrations measured in Camden for each of the calendar years 2013 and 2014.....	92
Table 51: Dioxins measured in NSW EPA ambient monitoring programme (NSW EPA, 2002)	93
Table 52: Overall average and maximum 24-hour average concentrations of organics measured in Wollongong, 1997-2001 (from NSW EPA, 2004a).	95
Table 53: Heavy metals measured in ambient air by NSW EPA (2002)	98
Table 54: 1-hour average incremental ground level concentration of NO ₂ at potentially sensitive discrete receptors. NO-to-NO ₂ conversion using Method 2 (ozone-limiting method). Excludes background concentrations.....	102
Table 55: 1-hour average cumulative ground level concentrations of NO ₂ at potentially sensitive discrete receptors. NO-to-NO ₂ conversion using Method 2 (ozone-limiting method). Includes contemporaneous background concentrations from Bargo and Camden.	104
Table 56: 1-hour average incremental ground level concentration of NO ₂ at potentially sensitive discrete receptors. NO-to-NO ₂ conversion using Method 3 (Janssen method). Excludes background concentrations.....	114

Table 57: 1-hour average cumulative ground level concentrations of NO ₂ at potentially sensitive discrete receptors. NO-to-NO ₂ conversion using Method 3 (Janssen method). Includes contemporaneous background concentrations from Bargo and Camden (Bargo data excluding peak values recorded 17-21 October 2013).....	117
Table 58: Annual average incremental ground level concentrations of NO ₂ at potentially sensitive discrete receptors. NO-to-NO ₂ conversion using either Method 2 (ozone limiting method) or Method 3 (Janssen method).	123
Table 59: Annual average cumulative (incremental plus background) ground level concentrations of NO ₂ at potentially sensitive discrete receptors. NO-to-NO ₂ conversion using Method 2 (ozone limiting method) or Method 3 (Janssen method) and either Bargo or Camden contemporaneous hourly background data (Bargo data excluding peaks 17-21 October 2013).	124
Table 60: Incremental ground level concentrations of SO ₂ at potentially sensitive discrete receptors.....	128
Table 61: Cumulative ground level concentrations of SO ₂ at potentially sensitive discrete receptors.	130
Table 62: Annual average incremental ground level concentration of TSP at potentially sensitive discrete receptors, point sources only. Kiln and mills are assumed to operate 24 hours per day, 365 days per year at steady state.....	133
Table 63: Annual average ground level concentrations of TSP at potentially sensitive discrete receptors, all fugitive and point sources. Kiln, and mills and material handling are assumed to operate 24 hours per day, 365 days per year at steady state. Background concentration contributions from outside the Works are assumed to be nil.	139
Table 64: 24-hour average incremental ground level concentration of PM ₁₀ at potentially sensitive discrete receptors, point sources only.	142
Table 65: Annual average incremental ground level concentration of PM ₁₀ at potentially sensitive discrete receptors, point sources only.	143
Table 66: 24-hour average incremental ground level concentration of PM ₁₀ at potentially sensitive discrete receptors, fugitive and point sources combined (Kiln 6 stack emissions at proposed Licence limit).	145
Table 67: Annual average incremental ground level concentration of PM ₁₀ at potentially sensitive discrete receptors, fugitive and point sources combined (Kiln 6 stack emissions at proposed Licence limit).	146
Table 68: Number of exceedances of NSW EPA criteria for 24-hour average PM ₁₀ (50 µg/m ³) at each discrete receptor – cumulative concentrations of PM ₁₀ from all fugitive and point sources plus contemporaneous background data from Bargo.	149
Table 69: Number of exceedances of NSW EPA criteria for 24-hour average PM ₁₀ (50 µg/m ³) at each discrete receptor – cumulative concentrations of PM ₁₀ from all fugitive and point sources plus contemporaneous background data from Camden.	150
Table 70: Breakdown of highest occurring cumulative GLCs at receptors 23, 57, 75 and 88; and incremental and background contributions to the cumulative GLCs. Grey shading = background above 50 µg/m ³ or exceeding 47 µg/m ³	152
Table 71: Maximum incremental annual average concentrations of PM ₁₀ occurring off-site.....	153

Table 72: 24-hour average incremental ground level concentration of PM _{2.5} at potentially sensitive discrete receptors, point sources only.	156
Table 73: Annual average incremental ground level concentration of PM _{2.5} at potentially sensitive discrete receptors, point sources only.	157
Table 74: 24-hour average incremental ground level concentration of PM _{2.5} at potentially sensitive discrete receptors, fugitive and point sources combined.	159
Table 75: Annual average incremental ground level concentration of PM _{2.5} at potentially sensitive discrete receptors, fugitive and point sources combined.	160
Table 76: Number of exceedances of NSW EPA criteria for 24-hour average PM _{2.5} (25 µg/m ³) at each discrete receptor – cumulative concentrations of PM _{2.5} from all fugitive and point sources plus contemporaneous background data from Camden.	162
Table 77: Maximum incremental concentrations of PM _{2.5} occurring off-site	163
Table 78: Incremental individual NMHC species GLCs, 99.9 th percentile maximum concentration predicted outside Works boundary.....	164
Table 79: Maximum incremental annual average concentrations of NMHCs occurring off-site.....	166
Table 80: Heavy metal GLCs and comparison to assessment criteria	168
Table 81: Maximum incremental annual average concentrations of heavy metals occurring off-site	169
Table 82: Halide and other chemical species GLCs, and comparison to assessment criteria	170
Table 83: 1-hour average 99 th percentile incremental ground level concentrations of odour at potentially sensitive discrete receptors.	172

List of Figures

Figure 1: Location of Berrima Cement Works.....	4
Figure 2: Overview of cement manufacture process at Berrima Works.....	6
Figure 3: Aerial photograph of Berrima Works with locations of various activities indicated. Aerial photography from nearmap, imagery dated 22 May 2014.	7
Figure 4: Stack Locations	12
Figure 5: Cumulative frequency of No.6 Kiln stack gas flow rates, 0°C, dry, 10% O ₂ . Compiled from 1-hour average data with feed rate of at least 250tph, collected continuously over 2012 and 2013.	33
Figure 6: Cumulative frequency of No.6 Kiln stack gas velocities and temperatures at stack conditions. Velocity was calculated from records of gas flow at STP. Compiled from 1-hour average data with feed rate of at least 250tph, collected continuously over 2012 and 2013.	34
Figure 7: Location of fugitive dust and odour sources used in dispersion model	51
Figure 8: Location of two transfer point sources included in the dispersion model (with the emission from these two sources representing the emissions from all transfer points).	54
Figure 9: Topographical map of region around Berrima Works.	55
Figure 10: Land owned by Boral Cement around Berrima Works, March 2015.	56
Figure 11: Land Use Zones around Berrima Works. Heavy blue line shows boundary of land owned by Boral Cement (as of March 2015).....	58
Figure 12: Berrima Works location and surrounding dwelling locations (red circle = dwelling or building where use and occupancy is unclear; yellow circle = non-residential development). Image from nearmap, aerial flown 22 May 2014.	59
Figure 13: Location of ambient monitoring site. Image from nearmap.....	60
Figure 14: Ambient air quality monitoring station (AQMS). Photo taken 19 March 2015.	61
Figure 15: Windrose of meteorological monitoring data for Berrima site; January 2010 – December 2014, data recorded at 1-hour frequency.	62
Figure 16: TSP and PM ₁₀ ambient monitoring data (24-hour average, 1-day-in-6 sampling), from Berrima ambient monitoring station; 2 January 2011 to 30 December 2014.	64
Figure 17: Cumulative frequency of PM ₁₀ ambient monitoring data (24-hour average, 1-day-in-6 sampling), from Berrima ambient monitoring station; 2 January 2011 to 30 December 2014.....	65
Figure 18: 24-hour average TSP concentration measured at AQMS (1-day-in-6 basis) as a function of daily average wind speed. Showing only days where the wind was blowing from the direction of the Works for at least 11 out of the 24 hours – i.e. Works upwind of AQMS for some or most of the day.....	67
Figure 19: 24-hour average PM ₁₀ concentration measured at AQMS (1-day-in-6 basis) as a function of daily average wind speed. Showing only days where the wind was blowing from the direction of the Works for at least 11 out of the 24 hours – i.e. Works upwind of AQMS for some or most of the day.....	67

Figure 20: 24-hour average TSP concentration measured at AQMS (1-day-in-6 basis) as a function of daily average wind speed. Showing only days where the wind was blowing from the direction of the Works for no more than 4 out of the 24 hours – i.e. Works <i>not</i> upwind of AQMS for most of the day.	68
Figure 21: 24-hour average PM ₁₀ concentration measured at AQMS (1-day-in-6 basis) as a function of daily average wind speed. Showing only days where the wind was blowing from the direction of the Works for no more than 4 out of the 24 hours – i.e. Works <i>not</i> upwind of AQMS for most of the day.	68
Figure 22: Ratio of PM ₁₀ to TSP 24-hour average concentration measured at AQMS (1-day-in-6 basis) as a function of daily average wind speed. Showing only days where the wind was blowing from the direction of the Works for at least 11 out of the 24 hours – i.e. Works upwind of AQMS for some or most of the day.....	69
Figure 23: Ratio of PM ₁₀ to TSP 24-hour average concentration measured at AQMS (1-day-in-6 basis) as a function of daily average wind speed. Showing only days where the wind was blowing from the direction of the Works for no more than 4 out of the 24 hours – i.e. Works <i>not</i> upwind of AQMS for most of the day.....	69
Figure 24: Windrose of meteorological data for Berrima site 2013. Top – CALMET simulation using fine grid. Bottom – measured data.....	74
Figure 25: Discrete receptors representing potentially sensitive locations.	75
Figure 26: Summary of building dimension data for dispersion model inputs.....	76
Figure 27: OEH Air Quality Monitoring Sites to the south of Sydney (additional sites at Bathurst, Albury and Wagga Wagga not shown due to scale of map).	85
Figure 28: Daily variation in 24-hour average PM ₁₀ concentration at Bargo and Camden monitoring sites, from 1 January 2010 to 31 December 2014. Data source: OEH website.....	88
Figure 29: Scatter plot showing contemporaneous Bargo and Camden PM ₁₀ data (24-hour average, October 2012 to December 2014).....	89
Figure 30: Scatter plot showing contemporaneous Bargo and Camden PM ₁₀ data (24-hour average, October 2012 to December 2014), showing only Bargo data <50 µg/m ³	89
Figure 31: Comparison of cumulative frequency of PM ₁₀ ambient monitoring data at Berrima (24-hour average, 1-day-in-6 sampling) and Bargo and Camden (daily sampling); January 2011 to December 2014 (Berrima and Bargo); October 2012 to December 2014 (Camden).	90
Figure 32: List of organic compounds tested in NSW EPA ambient air quality study (NSW EPA, 2004a).....	94
Figure 33: Overall average, minimum 24-hour average and maximum 24-hour average concentrations of organics measured in Wollongong, 1997-2001 (from NSW EPA, 2004a).	95
Figure 34: Average 24-hour PAH concentrations reported in NSW EPA (2004b) by site and season. Concentrations expressed as BaP-TEQ.	96
Figure 35: Incremental NO ₂ concentrations in ambient air predicted at each discrete receptor using ozone limiting method; 1-hr average, both maximum and 99.9 th percentile values shown compared to NSW EPA ambient air quality assessment threshold for NO ₂	103

Figure 36: Bargo and Camden 1-hour average NO ₂ concentration data used for contemporaneous background assessment.	106
Figure 37: Cumulative NO ₂ concentrations in ambient air predicted at each discrete receptor using ozone limiting method; 1-hr average, both maximum and 99.9 th percentile values shown compared to NSW EPA ambient air quality assessment threshold for NO ₂	107
Figure 38: Cumulative NO ₂ concentrations in ambient air predicted at each discrete receptor using ozone limiting method; 1-hr average, both maximum and 99.9 th percentile values shown compared to NSW EPA ambient air quality assessment threshold for NO ₂	108
Figure 39: Cumulative NO ₂ concentrations in ambient air predicted at each discrete receptor using ozone limiting method; 1-hr average, both maximum and 99.9 th percentile values shown compared to NSW EPA ambient air quality assessment threshold for NO ₂	109
Figure 40: Spatial distribution of cumulative NO ₂ concentrations in ambient air using ozone limiting method; 1-hr average, including contemporaneous background data contribution from Bargo (including background data measured 17-21 October 2013).	110
Figure 41: Spatial distribution of cumulative NO ₂ concentrations in ambient air using ozone limiting method; 1-hr average, including contemporaneous background data contribution from Bargo (excluding background data measured 17-21 October 2013).	111
Figure 42: Spatial distribution of cumulative NO ₂ concentrations in ambient air using ozone limiting method; 1-hr average, including contemporaneous background data contribution from Camden.	112
Figure 43: Incremental NO ₂ concentrations in ambient air predicted at each discrete receptor using Method 3 (Janssen method); 1-hr average, both maximum and 99.9 th percentile values shown compared to NSW EPA ambient air quality assessment threshold for NO ₂	115
Figure 44: Cumulative NO ₂ concentrations in ambient air predicted at each discrete receptor using Janssen method; 1-hr average, both maximum and 99.9 th percentile values shown compared to NSW EPA ambient air quality assessment threshold for NO ₂	118
Figure 45: Cumulative NO ₂ concentrations in ambient air predicted at each discrete receptor using ozone limiting method; 1-hr average, both maximum and 99.9 th percentile values shown compared to NSW EPA ambient air quality assessment threshold for NO ₂	119
Figure 46: Spatial distribution of cumulative NO ₂ concentrations in ambient air using Janssen method; 1-hr average, including contemporaneous background data contribution from Bargo (excluding background data measured 17-21 October 2013).	120
Figure 47: Spatial distribution of cumulative NO ₂ concentrations in ambient air using Janssen method; 1-hr average, including contemporaneous background data contribution from Camden.	121
Figure 48: Location of receptor 88. Photo from nearmap, date of imagery 22 May 2014.	138
Figure 49: Spatial distribution of 99 th percentile odour concentrations at discrete receptors.	173

Executive Summary

Boral Cement Ltd owns and operates the Berrima Cement Works. The site produces approximately 1.3 million tonnes of clinker per year for grey cement and is the largest cement production site of all of the Boral Cement operations. The site operates one kiln and two cement mills. The kiln is fuelled primarily using coal, burning approximately 220 thousand tonnes per year. A small amount of diesel and heavy oil is also used during kiln start-ups. Up until 2013 coal was sourced from the nearby Medway Colliery but since the colliery's closure, coal is currently sourced from the Illawarra area by road. This reliance on coal contributes to the total energy cost at the facility, which represents 40% of Boral's costs in the cement production process.

Boral Cement holds the Development Consent (DA 401-11-2002-i) for Kiln 6 and Environment Protection Licence no. 1698 (the "EPL") for the site. The two documents regulate the discharges of contaminants to air from the burning of Standard Fuels (such as coal, diesel, and heavy oil). From 2005, the DA and EPL also allow for the burning of "Non-Standard Fuels" (NSF) in the kiln with specific air discharge conditions. However, the use of these fuels has not been explored beyond trial stage as approval to construct the necessary infrastructure had not been pursued at that time.

Due to a number of market pressures, Boral is now seeking to expedite the use of these and other NSF, specifically solid waste-derived fuel (SWDF). Boral seeks approval to modify the EPL and DA for the use of SWDF as a partial coal replacement in Kiln 6; changes to the air emission limits of particulate matter (PM), nitrous oxides (NO_x) and volatile organic compounds (VOC); and construction of a fuel storage and kiln feeding system. Together these proposals are referred to as "the Project").

All SWDF proposed to be used by Boral would be consistent with the EPA's NSW Energy from Waste Policy (2014). These fuels would be sorted, tested and shredded off-site by authorised waste suppliers to maintain compliance with relevant specifications and recycling quota.

This report provides an air impact assessment for discharges to air associated with site operations, both when standard fuels and NSF are being used in the kiln. The methodology used to carry out this air impact assessment follows the guidelines in "Approved Methods for the Modelling and Assessment of Air Pollutants in NSW" (2005)¹ (herein referred to as the "Approved Methods" guidelines).

A review of stack monitoring data has been carried out. The review included annual stack testing reports for the last four years and continuous emission monitoring for two years. The substances included in the review were discharges of total suspended particulate (TSP), fine particulate (PM₁₀), ultra-fine particulate (PM_{2.5}), nitrogen oxides (NO_x) comprising nitric oxide (NO) and nitrogen dioxide (NO₂), sulfur dioxide (SO₂), VOCs represented by measurements of non-methane hydrocarbons (NMHC), dioxins, polycyclic aromatic hydrocarbons (PAHs), heavy metals, chlorine and chloride, fluoride, and sulfuric acid mist/sulfur trioxide. The review, presented in this report, demonstrates that the Works is complying fully with the air discharge requirements of the DA and EPL for the burning of standard fuels.

Due to the introduction of the Energy from Waste Policy in NSW, Boral Cement has proposed the following variations to maximum emission concentrations in the EPL for the burning of non standard fuels (NSF) to

¹ Department of Environment and Conservation (NSW) (now known as NSW Environment Protection Authority (EPA)). DEC 2005/361, published August 2005.

align the licence limits with current NSW regulations (all concentrations expressed as dry, standard temperature and pressure, and 10% O₂):

- TSP: 50 mg/Nm³, calculated over a midday-to-midday 24-hour basis
- NO_x: 1000 mg/Nm³, calculated over a midday-to-midday 24-hour basis
- VOC (as NMHC): 40 ppm, calculated over a midday-to-midday 24-hour basis

No changes are proposed to other emission limits in the EPL or DA for NSF.

Dispersion modelling has been carried out using the advanced model known as CALPUFF, to predict ambient concentrations of pollutants discharged from the Works site and to demonstrate that emissions at these proposed limits during burning of NSF meet the environmental outcomes adopted by the NSW EPA. Meteorological data from 2013 was used as the basis of the dispersion calculations. Pollutants included in the dispersion modelling included TSP, PM₁₀, PM_{2.5}, NO₂, SO₂, NMHC, dioxins, PAHs, heavy metals, halides, and sulfuric acid mist. Fugitive dust emissions from raw material stockpiling and handling were also modelled for TSP, PM₁₀ and PM_{2.5} emissions, as well as potential odour emissions from a proposed new storage building for solid waste derived fuel. Model results were extracted for 87 discrete receptor points in the environment around the Works site, representing the locations of residential dwellings, residential zones, and non-residential buildings. One additional discrete receptor was also used for particulate modelling analysis.

The predicted concentrations were combined with background data and compared to assessment criteria specified by NSW EPA in the 2005 Guideline publication “Approved Methods for the Modelling and Assessment of Air Pollutants in NSW”. For some of the NMHC individual chemical species, no assessment criteria are specified by NSW EPA, so applicable assessment criteria were adopted from the United States.

The modelling found that with the exception of 24-hour average PM₁₀, for all pollutants the maximum applicable ground level concentrations were lower than the relevant ambient air assessment threshold limits, and therefore no adverse impacts are expected. In the PM₁₀ modelling, not only stack emissions were included but also all possible fugitive sources of PM₁₀ such as stockpiles and exposed areas. The PM₁₀ from open sources is estimated using emission factors, not actual measurements. These factors are conservative, which may in many cases overestimate the impacts.

It was concluded that the NO_x and NMHC assessments robustly demonstrated that there is minimal risk that the EPA’s 1-hour average NO₂ and NMHC impact assessment criteria will be exceeded at any time if the proposed 24-hour average emission concentrations for NO_x and NMHC during burning of NSF are incorporated into the EPL.

In regards to 24-hour average PM₁₀, for most of the discrete receptors, no additional exceedances of the 24-hour average PM₁₀ air quality criteria over and above current impacts are caused by the presence of the Works compared to the Works not being there at all. However a small number of discrete receptors near the site boundary do show some possible additional exceedances of the 24-hour PM₁₀ criteria compared with background levels, although this is dependent entirely on the magnitude of the fugitive dust concentrations. Those fugitive dust concentrations are considered to be over-estimates of actual maximum incremental GLCs at receptors close to the site boundary because of the assumptions required for the fugitive dust dispersion analysis. The real-life long-term PM₁₀ measured data from the local ambient air quality monitoring station indicates that PM₁₀ levels at that location stay consistently below the NSW 24-hr and annual limits.

It was concluded that there would be no effective change to off-site local air quality impacts of PM₁₀ due to the Project as the model results are insensitive to Kiln 6 stack PM₁₀ emission rates at the equivalent TSP emission concentrations proposed during the burning of NSF.

1 Introduction

Boral Cement Ltd owns and operates the Berrima Cement Works (the “site”). The Works is located on Taylor Avenue, New Berrima. The location is shown in Figure 1. The site operates one kiln and two cement mills along with storage and stockpile facilities, and produces approximately 1.3 million tonnes of clinker per year for grey cement. The Works is the largest cement production site of all of the Boral Cement operations.

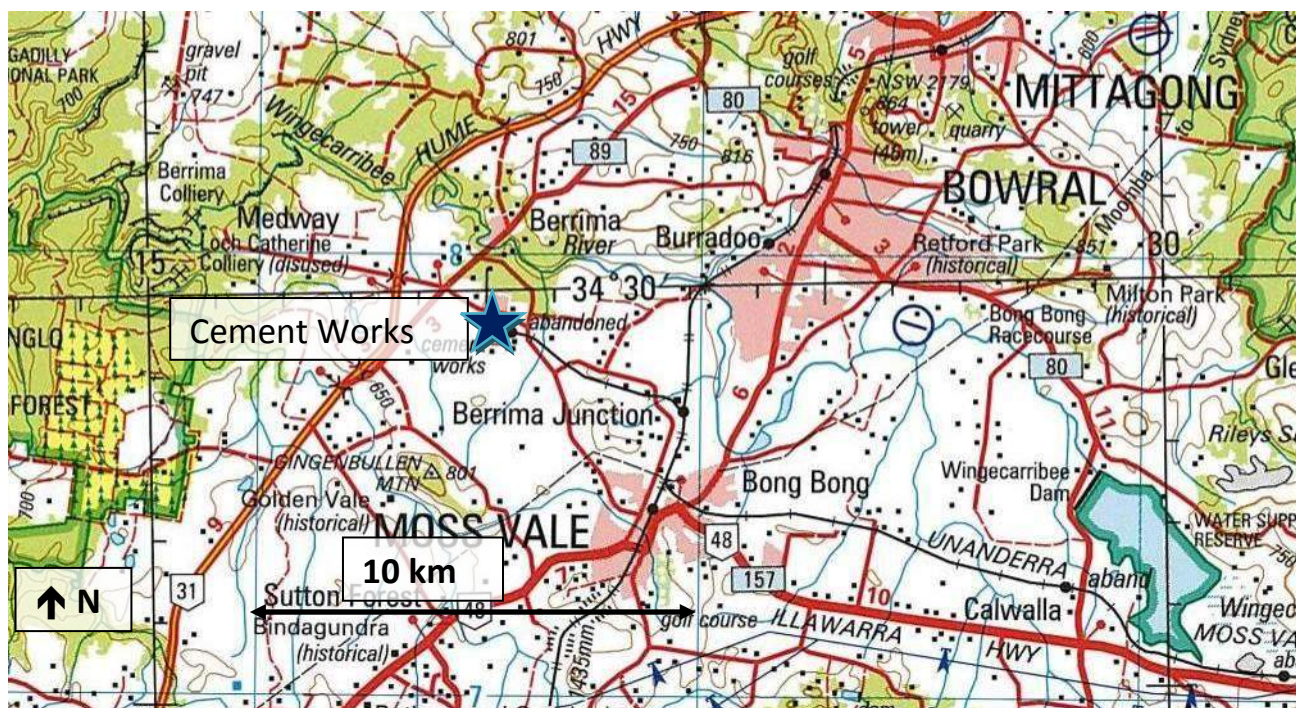


Figure 1: Location of Berrima Cement Works.

Cement manufacture is an energy intensive process due to the high temperatures required for the production of clinker. The kiln is fuelled primarily using coal, burning approximately 220 thousand tonnes per year to heat the kiln to a temperature of up to 1500°C. A small amount of diesel and heavy oil is also used during kiln start-up. Up until 2013 coal was sourced from the nearby Medway Colliery but since the colliery's closure, coal is currently sourced from the Illawarra area by road. This reliance on coal contributes to the total energy cost at the facility, which represents 40% of Boral's costs in the cement production process.

Boral Cement holds a Development Consent (DA 401-11-2002-i) for Kiln 6, last modified in August 2012, and Environment Protection Licence no. 1698 (the “EPL”) for the site, last updated 31 May 2013. The DA and EPL regulate the discharges of contaminants to air from the burning of Standard Fuels (such as coal, diesel, and heavy oil). From 2005, the DA and EPL also allow for the burning of “Non-Standard Fuels” (NSF) in the kiln with specific air discharge conditions. These NSF include spent aluminium electrode carbon (Hi Cal 50), liquid oil residues (AKF1) and waste tyre chips (AKF5). However, the use of these fuels has not been explored beyond trial stage as approval to construct the necessary infrastructure had not been pursued at that time.

Due to a number of market pressures, Boral is now seeking to expedite the use of these and other NSF, specifically solid waste-derived fuel (SWDF). Boral seeks approval to modify the EPL and DA for the following activities (“the Project”):

- Use of Solid Waste Derived Fuel (SWDF) as a partial coal replacement in Kiln 6;
- Changes to the air emission limits of particulate matter (PM), nitrous oxides (NOx) and volatile organic compounds (VOC); and
- Construction of a fuel storage and kiln feeding system.

The fuels that are the subject of this modification to the DA and EPL are the following SWDF:

- Wood Waste - material left over from industrial processes like milling, furniture making, and building and construction: and
- Refuse Derived Fuel (RDF) - fuel made from the combustible materials recovered and processed from waste streams, such as papers, cardboards, packaging, construction and demolition materials, and small municipal waste component.

All SWDF proposed to be used by Boral would be consistent with the EPA’s NSW Energy from Waste Policy (2014). These fuels would be sorted, tested and shredded off-site by authorised waste suppliers to maintain compliance with relevant specifications.

This report provides an air impact assessment for discharges to air associated with site operations, both when standard fuels and NSF are being used in the kiln. The methodology used to carry out this air impact assessment follows the guidelines in “Approved Methods for the Modelling and Assessment of Air Pollutants in NSW”² (herein referred to as the “Approved Methods” guidelines).

² Department of Environment and Conservation (NSW) (now known as NSW Environment Protection Authority (EPA)). DEC 2005/361, published August 2005.

2 Site and Activity Description

2.1 Site Overview

Activities carried out at the site are summarised in Figure 2.

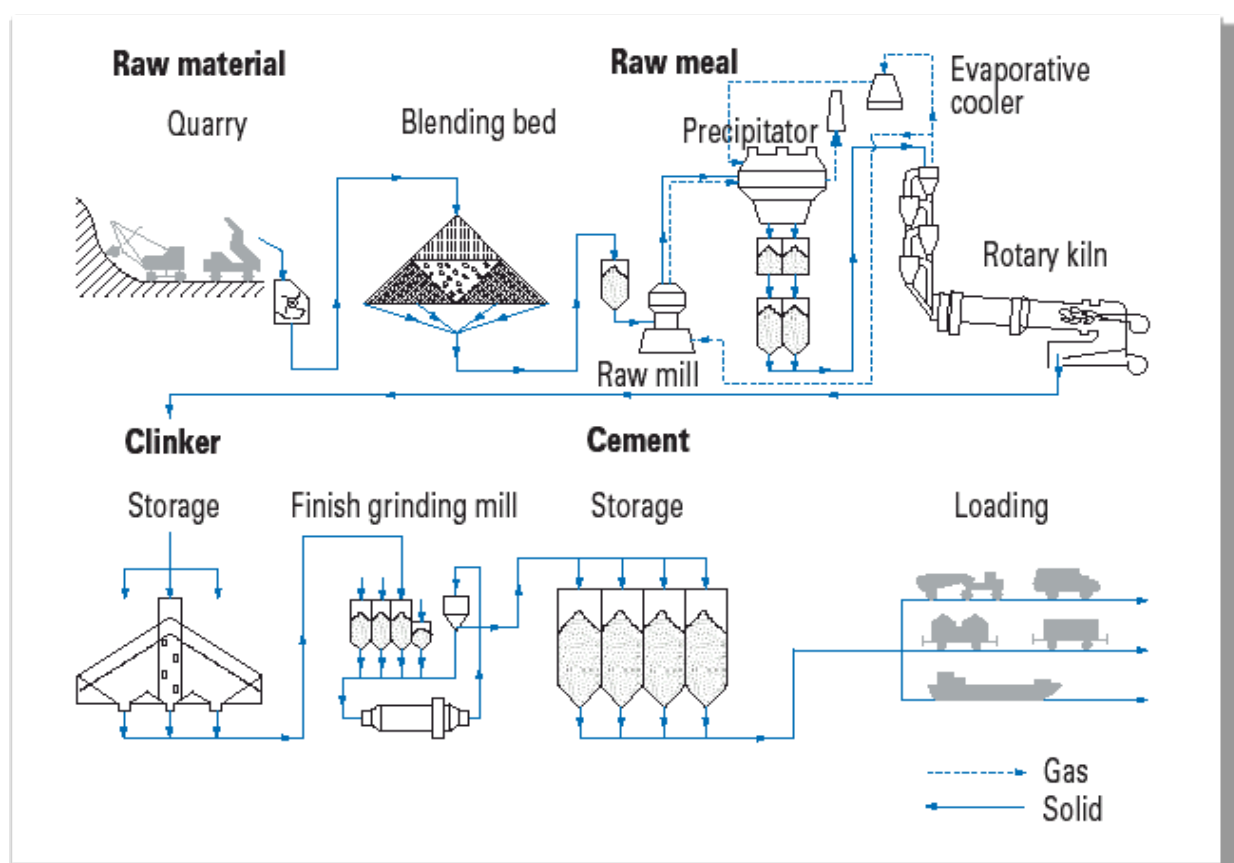


Figure 2: Overview of cement manufacture process at Berrima Works.

Cement manufacture starts with the principal raw materials of clay, limestone, shale, and smaller quantities of other materials. Limestone is transported via rail, while shale is quarried on site and other materials are transported via road.

The raw materials are heated to around 1400-1500°C in a long horizontal rotating kiln. The product leaving the kiln is called clinker. This is cooled, and ground or milled together with gypsum and other additives to produce cement.

Figure 3 shows a map of the site with the locations of various activities marked. Further description of the kiln processes is provided in the following section.



Figure 3: Aerial photograph of Berrima Works with locations of various activities indicated. Aerial photography from nearmap, imagery dated 22 May 2014.

2.2 Cement Manufacture Process Outline

The Berrima site currently uses one kiln, known as the No.6 Kiln. All older kilns at the site have been demolished. The No.6 Kiln utilises what is known as the “dry process” of clinker manufacture, where the raw materials are ground and dried to raw meal before entering the kiln. This process utilises less energy per tonne of clinker manufactured compared with other available processes such as the “wet process” technology where the raw materials are ground in water to form a pumpable slurry.

Within the kiln, the raw material is fed to the top of the precalciner tower where it is heated up to 900°C before entering the upper end of the kiln. Then it gradually moves downward towards the lower end where a burner provides counter-current heating. The rotary kilns in the cement manufacture are different from the classic firing processes as feed materials and off-gases pass each other counter-currently thus leading to a thoroughly mixing, high temperatures (>1400°C at the hot end where clinker is formed), and long residence times (5-7s) of the gases. These conditions will result in the destruction of any organic contaminants introduced with the fuel at the primary burner (UNEP, 2005).

The exhaust gases and associated waste heat from the kiln flow countercurrently to the material flow, providing heat to the precalciner.

As the hot clinker comes off the end of the lower end of the kiln it is rapidly cooled by ambient air in a clinker cooler. This involves blowing large volumes of air through the clinker. The air stream is filtered to reduce particulate concentrations, and is then discharged through a separate stack. Part of the cooler air stream is diverted back to the burner areas of the kiln and the precalciners, to supply oxygen for combustion. The site also uses two Cement Mills, known as the No.6 and No.7 Cement Mills, to mill the final cement product. The No.5 Cement Mill is still present on site but has been decommissioned.

2.3 Burning of NSF in Cement Kilns

Different types of waste materials can replace primary raw materials and/or fossil fuels in cement manufacturing and therefore contribute to saving natural resources. This practice is common in Europe. Characteristics of the clinker burning process itself allow environmentally beneficial waste-to-energy and material recycling applications. The essential process characteristics for the use of waste can be summarised as follows (BREF, 2013):

- Maximum temperatures of approx. 2000°C (main firing system, flame temperature) in rotary kilns.
- Gas retention times of about 8 seconds at temperatures above 1200°C in rotary kilns.
- Material temperatures of about 1450°C in the sintering zone of the rotary kiln.
- Oxidising gas atmosphere in the rotary kiln.
- Gas retention time in the secondary firing system of more than 2 seconds at temperatures of above 850°C; in the precalciner, the retention times are correspondingly longer and temperatures are higher.
- Solids temperatures of 850°C in the secondary firing system and/or the calciner.
- Uniform burnout conditions for load fluctuations due to the high temperatures at sufficiently long retention times.
- Destruction of organic pollutants due to the high temperatures at sufficiently long retention times.

- Sorption of gaseous components like HF, HCl, SO₂ on alkaline reactants.
- High retention capacity for particle-bound heavy metals.
- Short retention times of exhaust gases in the temperature range known to lead to 'denovo-synthesis' of PCDD/F.
- Complete utilisation of fuel ashes as clinker components and hence, simultaneous material recycling (e.g. also as a component of the raw material) and energy recovery.
- Product-specific wastes are not generated due to a complete material utilisation into the clinker matrix.
- Chemical-mineralogical incorporation of non-volatile heavy metals into the clinker matrix.

Examples of the types and amounts of wastes used in German cement kilns, as listed in BREF (2013), are shown in Table 1.

Table 1: Quantities of different types of waste fuels used in the German cement industry (reproduced from BREF (2013) Table 6.3)

Types of fuel	Quantity (kt/yr)	
	2003	2004
Liquid waste fuel		
Waste oil	116	100
Used solvents	48	72
Solid waste fuel		
End-of-life tyres	247	290
Wood	48	42
Animal meal	452	439
Sewage sludge	4	48
Bleaching earth	20	11
Production-specific waste	626	862
Separated fractions of mixed municipal waste	155	157

Essentially, cement kilns offer a superior solution for handling wastes due to high temperatures and residence times with no solid residues. The preheater acts as an efficient acid gas scrubber (high limestone/lime environment). All ash from the combustion of fuels and collected particulate from emission control equipment is combined into the clinker.

In 2004, Boral upgraded Kiln 6 and installed additional equipment specifically suited to the burning of SWDF. The key features of this equipment are:

- A large volume pre-calciner combustion vessel, which gives fuels longer time to burn out (>6 seconds) at high temperatures (>800°C). This means that all of the solid fuel is given the chance to burn out and minimises residues like smoke;
- The raw mill dust collector, which filters kiln exhaust gas particulates and provides additional high efficiency cleaning capacity to minimise stack emissions; and
- The installation of continuous monitoring equipment for key gaseous pollutants, which allows prompt response to any adverse trends in stack emissions.

2.4 Refuse Derived Waste Quantities

In addition to the currently permitted non-standard fuels Hi Cal 50, AKF1 and AKF5, Boral proposes to use up to 100,000 tonnes per year of SWDF in Kiln 6 operations. This would replace 20-30% of the coal used in the facility. Table 2 compares the quantities of fuel that Boral currently has approval to use with the quantities proposed by this modification.

Table 2: Approved and proposed classes and quantities of standard and waste derived fuel

Fuel	Category	Tonnes per annum	% of total fuel by mass	Tonnes per annum	% of total fuel by mass
		Current		Proposed	
Natural Gas, Fuel Oil, Diesel	Standard fuel	No limit		No change	
Coal	Standard fuel	No limit	≥ 60.0	No limit	No limit
Coke Fines	Standard fuel	No limit	≤ 30.0	No limit	≤ 30.0
Aluminium electrode carbon (Hi Cal 50)	SWDF	10,000	≤ 6.0	10,000	≤ 6.0
Liquid Oil Residues (AKF1)	Liquid waste	20,000	≤ 4.7	20,000	≤ 4.7
Waste Tyres (AKF5)	SWDF	30,000	≤ 21.0	100,000	≤ 50
Wood Waste	SWDF	Not currently approved			
RDF	SWDF				

The quality and composition of the SWDF will be strictly controlled by Boral through supplier contracts.

2.5 Handling and Storage of Raw Materials

The two main raw ingredients of cement are calcium carbonate and silica. Calcium carbonate is sourced from limestone while the silica can be sourced from clay, sand or even silica present in any ash that may be present in the fuel used to drive the high temperature reaction process occurring in the cement clinker manufacturing kiln. Minor additions of alumina and iron (which are beneficial minor ingredients in cement) are made to adjust the raw meal chemistry where the major raw materials are deficient in these compounds.

Limestone, the main raw material for cement manufacture at Berrima, is extracted at the Boral Cement Marulan Quarry. The limestone is extracted, crushed and blended on the quarry site and loaded onto rail wagons for transport to the Berrima plant. Each shipment is approximately 2,100 tonnes. The limestone is unloaded at the plant 24 hours per day and is stockpiled in two blending beds of about 21,000 tonnes capacity.

Blue shale is quarried at the works from a quarry located about 500 metres west of the plant. Extraction of the raw material from this quarry entails excavation and transport of blue shale which is then crushed and separately added to the limestone and other raw material streams before raw milling. The blue shale is extracted and loaded using heavy machinery similar to that used for road making and general earth moving.

The preparation process involves the crushing, drying, grinding, proportioning and finally blending of all the raw material components to provide a material (raw meal), which is chemically and physically uniform. The raw meal is produced to a specified chemical composition and particle size for reaction in the cement kiln. The raw meal is then dried before it is passed to the kiln. The equipment for drying and grinding the raw materials comprises a vertical spindle raw mill using hot kiln gases for drying the raw materials. This process reduces the raw material moisture content from 6% to less than 1% and reduces the raw material particle size down to a size such that 98% of the material is less than 0.2mm.

3 Description of Air Discharges

3.1 Sources of Air Discharges

Air discharges from the site are defined as either point sources (i.e. discharged from a stack or vent such as the kiln and cement mills) or fugitive sources (i.e. open to the air and/or spread over an area such as stockpiles).

3.1.1 Point Sources

There are four point source emissions at the Berrima Works site. The location of each stack or vent at the site is shown in Figure 4. These four sources of air discharges are listed in Table 3. A fifth emission point listed in the EPL is the No.5 Cement Mill Stack – (referred to as Point 7 in the EPL). This discharge no longer operates at the Works and has been omitted from consideration in this report.

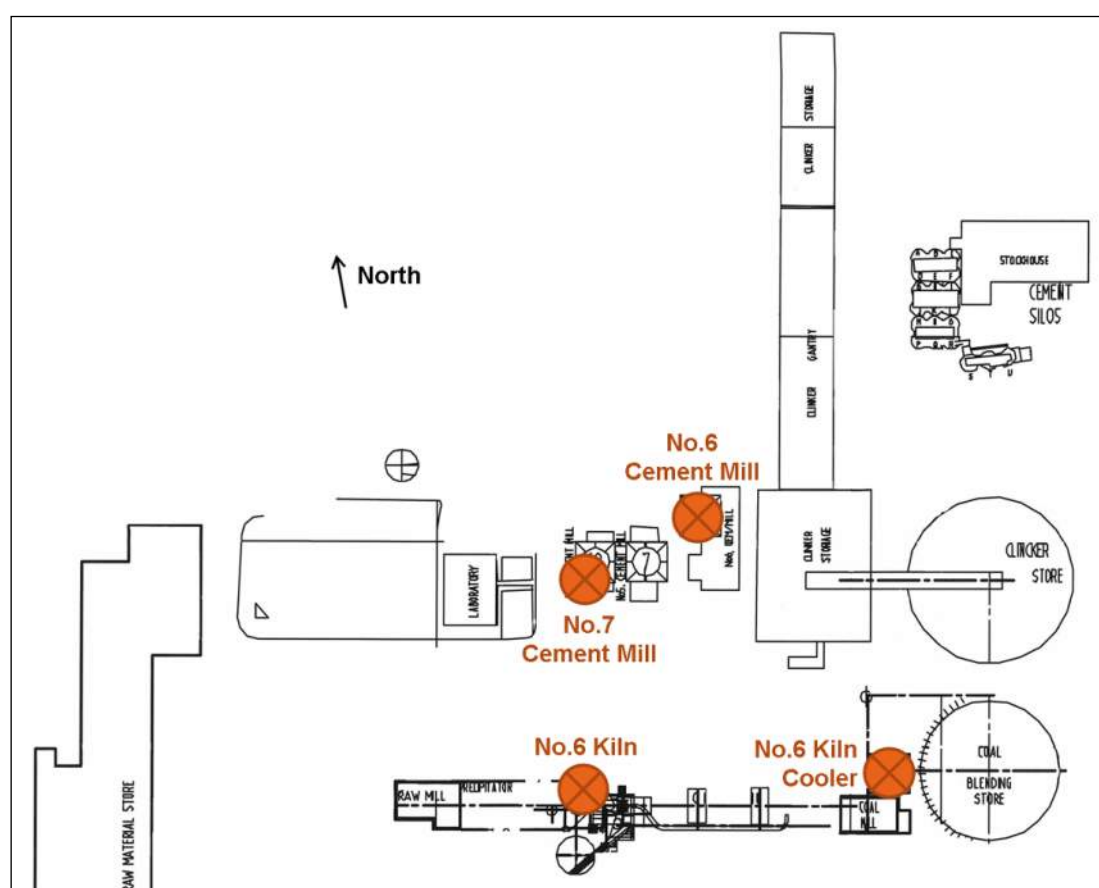


Figure 4: Stack Locations

Table 3: Point sources at Berrima site

Name	Description	Type of particulate control equipment	EPL1698 stack reference number
No.6 Kiln Stack	Stack discharging exhaust gases from the kiln.	Full exhaust gas flow split between electrostatic precipitator (ESP) and bagfilter.	2
No.6 Cement Mill	Vent discharging from side of No.6 Cement Mill building.	Bagfilter	4
No.6 Kiln Cooler	Stack discharging large volumes of air used to cool clinker after it comes out of the kiln.	Bagfilter	5
No.7 Cement Mill	Vent at end of a large duct coming out of the side of the No.7 Cement Mill building.	Bagfilter	10

3.1.2 Fugitive Sources

There are a number of sources of fugitive dust and fine particulate emissions at the Works. These can generally be grouped into the following categories:

- Stockpiles of bulk dry materials such as coal, blue shale, yellow shale, steel or blast furnace slag, cement fibreboard, and gypsum.
- Trucks and loaders generating dust from vehicle tracks and movement of materials.
- Unpaved roads and dusty surfaces in stockpile areas.
- Quarry area.
- Crushing and mixing of materials prior to kiln processing.

The locations of these fugitive dust sources were shown in Figure 3. The nature and magnitude of these dust sources are discussed in Section 5.2.

3.1.3 Project New Emission Sources

A new storage and handling facility will be required for SWDF such as waste tyre chips (AKF5), wood waste and RDF. The SWDF fuel storage, handling and feeding system will comprise:

- A receival and storage building located on the southern side of the Kiln 6 pre-heater tower. The building would be 33m long, 50m wide and 13m high;
- A RDF bale feed conveyor to feed plastic wrapped bales into the receival shed;

- A de-bailer and moving floor system at the back end of the storage shed;
- An enclosed conveyor from the storage building to the existing pre-calciner vessel located in the preheater tower;
- A screw conveyor and air sealing device around the pre-calciner within the preheater tower; and
- A designated ground outdoor storage area for SWDF received in the form of covered (plastic wrapped) bails or within covered delivery vehicles.

RDF will be brought onto the site in wrapped bales, and will only be unwrapped within the storage building. There may be some odour associated with the RDF, depending on the original waste stream from which the RDF has been recovered. As such, it is possible that there may be some odour within the storage building.

Fugitive emissions of odour from within the storage building are the only potential new air emission identified within the Project.

3.2 Nature of Contaminants

3.2.1 Overview

Contaminants discharged to air from the Berrima Works, with or without the use of NSF, may include:

1. Fine particulate, sulfur dioxide (SO₂), nitrogen oxides (NO_x) and carbon monoxide (CO) resulting from combustion processes and dry goods handling/milling processes.
2. Smaller amounts of other air contaminants, including:
 - a. Volatile organic compounds, or “VOCs” - also represented by the organic compound group “non methane hydrocarbons” or “NMHCs”
 - b. Polycyclic aromatic hydrocarbons, or “PAHs”
 - c. Heavy metals
 - d. Hydrogen halides (such as hydrogen chloride, hydrogen fluoride), chlorine and sulfuric acid mist/sulfur trioxide
 - e. Dioxins
3. Dust emissions from raw material and bulk dry goods handling and storage, and yard areas.
4. Odour emissions from storage and handling of SWDF.

The following sections describe the nature of these contaminants in further detail. Emissions of these contaminants at the Berrima site are presented in Section 4.

3.2.2 Fine particulate

The particulate matter discharged from the various sources at the site, including Kiln 6 and Cement Mill stacks as well as stockpiles and open sources, will be comprised of a variety of size fractions that will vary for each source:

- Larger depositable dust material generally greater than 50 μm in diameter. This size fraction poses a nuisance potential due to soiling of surfaces and can cause irritation to eyes and nose. Because it is relatively large in size, deposited particulate usually falls out of the air within a short distance of the source.
- The finer material, defined as suspended particulate and commonly referred to as Total Suspended Particulate or TSP. TSP, especially the fraction less than 20 μm in size, can travel large distances downwind.
- Particulate less than 10 μm in diameter (known as PM_{10}). This is the portion of TSP that poses the greatest potential health effect. PM_{10} is able to penetrate the upper respiratory tract and consequently has the potential to impact on public health.
- Particulate less than 2.5 μm in diameter (known as $\text{PM}_{2.5}$). $\text{PM}_{2.5}$ is a subset of PM_{10} . $\text{PM}_{2.5}$ can penetrate even further into the lung and is suspected of being the fraction of PM_{10} that is responsible for health impacts that can lead to an increase in morbidity and mortality in particular circumstances.

The particulate discharged from the Kiln 6 and Cement Mill stacks at the site is likely to contain little depositable material, as all stack discharge points are fitted with particulate reduction control equipment (refer Table 3). A large proportion of the particulate is likely to be in the PM_{10} , with a subset of that particulate in the $\text{PM}_{2.5}$ range as well.

The stack monitoring summarised in Section 4 measures mainly total suspended particulate (TSP), with some measurements of PM_{10} and $\text{PM}_{2.5}$.

An indication of likely size fractions within the TSP measure can be taken from the USEPA AP42 database (USEPA, 1995). The relevant size fractions for PM_{10} specified in AP42 are as follows:

<i>Source</i>	<i>Cumulative mass percent equal to or less than 10 microns</i>	<i>Cumulative mass percent equal to or less than 2.5 microns</i>
Dry kiln with fabric filter	84%	45%
Clinker cooler with gravel bed filter	76%	40%

The AP42 data should only be used in the absence of site-specific data, because the mass percent of TSP depends on the total TSP measured which in turn depends on the efficiency of the emission control technology. The AP42 document does not give similar size fraction data for cement mills.

PM_{10} discharged from Kiln 6 was measured in the 2011, 2013 and 2014 annual stack testing programmes (refer Table 16), and the emission rate of PM_{10} was found to be 61-74% of the total TSP emission rate.

PM_{2.5} discharged from Kiln 6 was also measured in the 2013 and 2014 annual stack testing programmes (refer Table 16), and the emission rate of PM_{2.5} was found to be 30-33% of the total TSP emission rate.

3.2.3 Oxides of Nitrogen

NO_x is an expression of the total amount of both nitric oxide (NO) and nitrogen dioxide (NO₂) in a gas, with the mass of NO_x calculated by assuming that all of the NO has been oxidised to NO₂.

NO_x is generated during combustion processes and therefore will be present in the No.6 Kiln Stack discharge. In stack emissions from processes like the cement kiln, the NO_x is predominately made up of NO. NO is slowly converted to NO₂ in the environment through complex atmospheric reactions.

The continuous emissions monitoring programme in the No.6 Kiln Stack records both NO and NO₂ concentrations. As shown in Section 4.6.3, NO₂ emissions make up a very small proportion of the total NO_x emissions from the No.6 Kiln Stack.

Only the concentration of the NO₂ fraction of NO_x is regulated in ambient air. To determine the resulting ambient concentrations of NO₂ in the atmosphere, it is necessary to determine how much NO_x will be converted to NO₂.

The “Approved Methods” guidelines provide three alternative methods for estimating NO-NO₂ oxidation rates. In this report all three methods were utilised to test the sensitivity of each method to the resultant air quality concentrations. This analysis is presented later in the report in Section 8.1.

3.2.4 Sulfur Dioxide

Sulfur dioxide (SO₂) emissions from dry process kilns are mostly linked to sulfur in the raw material feed (such as ferrous sulphide (FeS) or organic sulfur) rather than fuel sulfur.

A significant amount of sulfur passing through the kiln is retained in the clinker product, as cement kiln systems have highly alkaline internal environments that can absorb up to 95% of potential SO₂ emissions (USEPA, 1995).

3.2.5 Volatile Organic Compounds (VOCs)

Volatile organic compounds (VOCs) are organic chemical compounds that have high enough vapour pressures under normal conditions to significantly vaporize and enter the atmosphere. A wide range of carbon-based molecules, such as aldehydes, ketones, and other light hydrocarbons are VOCs. For example, formaldehyde, benzene, chloroform and carbon disulfide are all classed as VOCs.

VOCs are discharged to air in trace amounts in the gaseous combustion products of fuel burning, and therefore may be discharged from the kiln stack.

For the purpose of the stack testing carried out at Berrima Works, the VOC is understood to be non-methane hydrocarbons (NMHC).

3.2.6 Carbon Monoxide

Carbon monoxide (CO) is present in small amounts in all discharges from fuel burning equipment as a result of inefficient or incomplete fuel combustion. In this case the only stack that is a potential emitter of CO is the kiln stack, as this is the only stack that discharges gaseous products of fuel combustion.

CO discharges from industrial fuel burning in the presence of sufficient oxygen almost always has very minor potential to cause adverse effects because of the high combustion efficiency of the fuel burning equipment and the relatively high air impact criteria for CO compared to other combustion gases such as SO₂ or NO₂. CO emissions have therefore not been considered in this air impact assessment.

3.2.7 Heavy Metals

Emissions of metal compounds from cement kilns can be grouped into three general classes:

- Volatile metals, including mercury (Hg) and thallium (Tl);
- Semivolatile metals, including antimony (Sb), cadmium (Cd), lead (Pb), selenium (Se), zinc (Zn), potassium (K), and sodium (Na); and
- Refractory or nonvolatile metals, including barium (Ba), chromium (Cr), arsenic (As), nickel (Ni), vanadium (V), manganese (Mn), copper (Cu), and silver (Ag).

Although the partitioning of these metal groups is affected by kiln operating conditions, the refractory metals tend to concentrate in the clinker, while the volatile and semivolatile metals tend to be discharged to air (USEPA, 1995).

Metals in feed and fuel are volatile at high temperatures experienced in the kiln burning zone but then condense as temperatures decrease. In general, the more volatile metals condense on small dust particles, and the high boiling point metals tend to remain in the clinker. This, to a large degree, depends on the quantities of metals present in the feed and fuel, the manufacturing process, and the chloride content. Volatile metals such as thallium and mercury tend to remain unbonded and are emitted to atmosphere primarily in elemental form.

Chromium can be present as either the hexavalent (+6) oxidation state or the less toxic trivalent (+3) oxidation state. In the Berrima kiln, the hexavalent chromium emission has been measured in each of the annual stack testing programmes in addition to total chromium.

3.2.8 Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are a large group of organic compounds comprising two or more benzene rings, some of which are at least suspected of being carcinogenic. Benzene, toluene, xylene and styrene are classified as VOCs, rather than PAHs, due to having only one benzene ring.

PAHs arise from the incomplete combustion of solid and liquid fuels. PAHs can occur in both the gaseous phase or attached to fine particles. PAHs are a potential contaminant mainly where combustion occurs, in this case from the kiln stack. The high temperature burning condition and excess oxygen requirement in the kiln minimises the potential for PAH formation.

There are 44 different PAHs. Benzo(a)pyrene (BaP) is generally considered the most relevant and hazardous, and is commonly used as an indicator species for PAHs. BaP is a minor component of PAHs, but extremely important because of the chemical's highly toxic and carcinogenic properties. It is used as an indicator species for a wide range of compounds, some of which are also toxic and/or carcinogenic.

Some PAHs are less carcinogenic than BaP (by one to three orders of magnitude), and a few are more active. In order to provide more reasonable estimates of the carcinogenicity of PAH mixtures, schemes have been devised that are similar to the toxicity equivalence factor approaches for evaluating dioxins (see next section) based on the relative potency of individual PAHs compared to BaP.

3.2.9 Dioxins

“Dioxins” and “furans” are shorthand expressions for a large family of chemical compounds that belong to a class of environmental pollutants known as organochlorines. These pollutants are collectively referred to as dioxins in this report.

Dioxins are discharged to air whenever hydrocarbon fuels, especially coal, wood and oil, are burned; and so kiln stack is a potential source of dioxins at the Berrima Works. A chlorine source is required for dioxin formation, but this can be as simple as chlorides in the raw materials or salt present in the combustion air. Dioxin formation depends on the fuels and the type of boiler or combustion unit in which they are burned. The toxicity of the various dioxin species acts in an additive fashion. The toxic potency of a mixture of dioxin-like compounds (i.e. the “toxic equivalents”, or “TEQ”) is the sum of the products of the concentration of each compound present in the mixture multiplied by the relative toxicity of each compound.

The formation of dioxins in thermal processes is a complex process and many factors are important. The material being burned, the conditions of combustion, the composition of the particulate matter generated, and the design and operation of the burners all exert influence over dioxin formation.

A review report released by the United National Environment Programme (UNEP, 2005) notes that provided combustion is good and excess oxygen is present in the exhaust gases, the main factor controlling dioxin emissions in the air discharge from a cement kiln is the temperature of the dust collection device in the gas cleaning system. The UNEP report highlights the importance of stack gas temperature of less than 200°C into the particulate control equipment (electrostatic precipitator or bagfilter). The UNEP report also states that in a dry process kiln with preheater (such as that at the Berrima Works), this prerequisite is inherent in the process.

3.2.10 Odour

Odour is not air quality issue currently associated with site operations at the Works. However, as discussed in Section 3.1.3 there is the potential for odour emissions associated with the handling of RDF in the proposed new storage building. Any odour associated with the RDF will be combusted within the kiln and will not be present in the kiln discharge stack.

Odour is measured using the units “Odour Units” or “OU”. Odour concentrations are measured using dynamic dilution olfactometry according to AS/NZS 4323.3:2001 (R2014)³ where odour samples are diluted to varying degrees and presented to a panel of human sniffers. The measure of 1 OU is defined in the Standard as the dilution at which half of the panel cannot detect the presence of the odour.

3.3 Publications and Standards for Burning of NSF

Guidelines and standards for methods of, and emissions from, the burning of NSF in cement kilns or similar industrial situations are found in a number of references:

- Directive 2010/75/EU of the European Parliament and of the Council on Industrial Emissions (Integrated Pollution Prevention and Control) (24 November 2010) (integrating and superceding the earlier European Directive on the Incineration of Waste 2000/76/EC (2000)).
- Best Available Techniques Reference Document for the Production of Cement, Lime and Magnesium Oxide (the “BREF”), European Commission (2013)
- UNEP Toolkit (2005) – as previously referred to in Section 3.2.9.

Whilst these references provide using information for the burning of NSF with minimised environmental impacts, none of these references have regulatory status in New South Wales.

The following paragraphs summarise relevant recommendations from these references for the burning of NSF, correlated with the proposal for the Berrima site.

3.3.1 European Directive (2010)

This reference relates broadly to industrial emissions into air, including the incineration or co-incineration of wastes. Emission limits specific to the burning of wastes in the cement industry are provided. In this reference, burning of NSF in a cement kiln to supplement coal usage falls into the definition of a “co-incineration” activity.

The reference defines a number of general operating conditions required for co-incineration, which are summarised in Table 4 along with comments about the proposed operation at Berrima relative to these recommendations.

³ AS/NZS 4323.3:2001 (R2014). Stationary source emissions - Determination of odour concentration by dynamic olfactometry.

Table 4: European Directive 2010/75/EU - Operating Conditions for Co-Incineration of Waste

Eur Dir (2010) Clause	Requirement	Berrima Proposed Operating Condition
Article 50(2)	Waste co-incineration plants shall be designed, equipped, built and operated in such a way that the gas resulting from the co-incineration of waste is raised in a controlled and homogeneous fashion and even under the most unfavourable conditions, to a temperature of 850°C for two seconds. If hazardous wastes with a content of more than 1% of halogenated organic substances, expressed as chlorine, are co-incinerated, the temperature has to be raised to 1100°C.	Inherent temperature conditions in the cement kiln allow compliance with this requirement
Article 50(4)	Incineration and co-incineration plants shall have and operate an automatic system to prevent waste feed: (a) At start-up, until the <i>[required temperature as specified in Article 50(2)]</i> has been reached (b) Whenever the <i>[required temperature as specified in Article 50(2)]</i> is not maintained (c) Whenever the continuous measurements required by this Directive show that any emission limit value is exceeded due to disturbances or failures of the purification devices. <i>[an allowed exceedance duration is also provided in Article 46(6), listed below]</i> .	(a) and (b) Boral Cement will not use NSF unless steady state conditions are established – in which case the required temperatures are met. (c) The Berrima feed system is automatic and allows precise feed composition. It will be able to stop NSF feed as per licence conditions, subject to the agreed disturbance duration.
Article 50(5)	Any heat generated by waste incineration or waste co-incineration plants shall be recovered as far as practicable.	This occurs through the use of the precalciner (described in Section 2.2).
Article 46(1)	Waste gases from waste incineration and waste co-incineration plants shall be discharged in a controlled way by means of a stack the height of which is calculated in such a way as to safeguard human health and the environment.	The ability of the Berrima Works to comply with this requirement is demonstrated by the dispersion modelling in this report.
Article 46(2)	Emissions into air from waste incineration plants and waste co-incineration plants shall not exceed the emission limit values set out in Parts 3 and 4 of Annex VI or determined in accordance with Part 4 of that Annex.	Proposed emission limit values are set out in Section 4.8. Limits set out in Part 4 of Annex VI are met for heavy metals, halides, dioxins, and SO ₂ . Alternative limits are proposed for particulate, NO _x and NMHC.
Article 46(6)	Without prejudice to Article 50(4)(c) [described above], the waste incineration plant or waste co-incineration plant shall under no circumstances continue to incinerate waste for a period of more than 4 hours uninterrupted where emission limit values are exceeded. The cumulative duration of operation in such conditions over 1 year shall not exceed 60 hours. The time limit set out in the second subparagraph shall apply to those furnaces which are linked to one single waste gas cleaning device.	Boral Cement intends to propose similar wording to this Article within the modifications to the EPL. The second subparagraph is considered to apply to the Berrima Works, as although there is both an ESP and a bagfilter linked to the kiln gas exhaust neither has sufficient capacity to fully treat the full gas airstream.

3.3.2 BREF (2013)

This document describes best available techniques (BAT) for the cement industry for management of emissions to air from the manufacture of cement, including the use of co-incineration of waste fuels. The term “best available techniques” as applied in BREF (2013) means⁴:

“the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole:

(a) ‘techniques’ includes both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned;

(b) ‘available techniques’ means those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator;

(c) ‘best’ means most effective in achieving a high general level of protection of the environment as a whole.”

The BREF notes that a typical kiln size in the European Union has come to be around 3000 tonnes of clinker per day, which is similar to the size of the Berrima kiln. Therefore recommendations for BAT in the BREF are likely to be applicable to the Berrima site, although site specific and national factors may also need to be given consideration.

The BAT methods recommended for handling NSF for combustion in a kiln are very similar to that recommended in the UNEP Toolkit (see below).

3.3.3 UNEP Toolkit (2005)

This reference focusses on dioxin and furan releases and methods of minimising the generation of these contaminants. The cement production industry and the use of alternative waste fuels in kilns is expressly recognised in the document. The reference states that in most cases, primary process operational measures (as listed below) have been shown to be sufficient to comply with an emission limit of 0.1 ng I-TEQ/Nm³ (@10% O₂) in existing modern installations such as the Berrima site.

The following primary process operational measures are recommended in the UNEP Toolkit.

- Quick cooling of kiln exhaust gases to lower than 200°C in wet kilns (already inherent in dry preheater/precalciner kilns);
- Limit alternative raw material feed as a part of the raw material mix if it includes organics (not applicable to Berrima site);
- No alternative fuel feed added during start-up and shut-down;

⁴ European Directive (2010), Article 3(10)

- Monitoring and stabilization of process parameters:
 - Homogeneous raw material mix and fuels
 - Regular dosage
 - Excess oxygen.

The Berrima Works meets all of these recommended operational measures.

The Toolkit also states that co-processing of alternative fuels or alternative raw materials, fed to the main burner or the preheater/precalciner does not influence or change the dioxin/furan emissions. This is supported by studies of cement kiln emissions around the world and in developing countries, which are referenced in the Toolkit.

Plant measurements at the Berrima Works show that the typical temperature of the stack gases at the inlets to the ESP and bagfilter are substantially less than 200°C. Therefore, the operation of the ESP and bag filter in the kiln stack exhaust stream at the Works is conducive to minimising dioxin formation. This is confirmed by dioxin measurements collected at the Works, as shown from the stack testing data in Section 4.

4 Emission Rates and Discharge Parameters – Point Sources

4.1 Scope of Monitoring of Existing Emissions

A range of sampling and analysis programmes are conducted at the Berrima site to monitor air discharges from the four discharge points. These programmes are as follows:

1. Monitoring required by the EPL during combustion of standard fuels:
 - a. Annual stack testing. This applies to all four discharge points.
 - b. Continuous measurement in No.6 Kiln stack of total suspended particulate (TSP) (required in EPL since 30 March 2012, although the measurement has been conducted for several years outside of this EPL requirement as a voluntary process control measure).
2. Additional monitoring that is only required by the EPL during combustion of NSF (a requirement that has not been initiated yet because the site hasn't been using any NSF) – this testing is currently carried out voluntarily by the site during combustion of standard fuels as well:
 - a. Additional annual testing on discharges from No.6 Kiln stack, as would be required if NSF were being used, as well as testing of PAHs.
 - b. Continuous measurement in No.6 Kiln stack of nitric oxide (NO), nitrogen dioxide (NO₂), NMHCs, methane, oxygen, carbon monoxide (CO), and sulfur dioxide (SO₂).

All monitoring is carried out or equipment is maintained and calibrated by independent, suitably qualified contractors. In accordance with Special Condition E2 of the EPL and condition 4.1B of the DA (required only when NSF are used, currently undertaken on a voluntary basis), Boral Cement also operates an ambient air quality monitoring station (AQMS) beyond the site boundary which records meteorological data continuously and TSP, PM₁₀ and heavy metals on a one-day-in-six basis. The results of the ambient monitoring are described in Section 5.

4.2 Emission Limits for Standard Fuels

Conditions L3.1 to L3.4 in EPL1698 define permitted contaminant emission limits for the four discharge points, during the burning of standard fuels. Conditions M2.1 and M2.2 specify the required monitoring frequency and method. Also, conditions 3.10, 3.10A and 4.1 of the DA refer to the Kiln 6 emissions for standard fuels.

Table 5 summarises these emission limits and monitoring requirements for all four discharge points for solid particles (assumed equivalent to total suspended particulate or TSP). Fine particulate is the only contaminant that has the potential to be discharged from the two Cement Mill vents and the No.6 Kiln Cooler Stack.

Table 6 lists emission limits and monitoring requirements for other pollutants identified in the No.6 Kiln Stack discharge.

Table 5: Emission limits for solid particles, for burning of standard fuels; listed in conditions L3.1-3.4 and M2.2 of EPL1698

Discharge point (and EPL point reference number)	Solid particles 100 percentile concentration limit	Monitoring required**	Averaging period and gas reference conditions for concentration limit
No.6 Kiln Stack (2)	95 mg/Nm ³ &	Campaign & CEM ^α	Dry, STP*, 10% O ₂ Averaging period as per test method for campaign monitoring 24-hour average calculated from hourly averages of CEM data for continuous monitoring
No.6 Cement Mill (4)	100% mg/Nm ³	Campaign	
No.6 Kiln Cooler (5)	100% mg/Nm ³	Campaign	
No.7 Cement Mill (10)	20 mg/Nm ³	Campaign	

* Standard temperature and pressure - 0°C or 273K, and 101.3kPa.

** "Campaign" = annual test. "CEM" = continuous emissions monitoring.

& "Nm³" = normal cubic metres at reference conditions – dry, STP.

% New limit specified in EPL update of 30 March 2012 – prior to this update, the applicable limit was 250 mg/Nm³.

≠ New limit specified in EPL update of 30 March 2012 – prior to this update, the applicable limit was 175 mg/Nm³.

α CEM only required since EPL update of 30 March 2012.

Table 6: Emission limits for other contaminants from No.6 Kiln Stack, for burning of standard fuels; listed in conditions L3.1-3.4 and M2.1 of EPL1698

Contaminant	100 percentile concentration limit	Monitoring required ^{&}	Assumed gas reference conditions for concentration limit
Nitrogen oxides	1000 mg/Nm ³	Campaign	Dry, STP*, 10% O ₂ Averaging period as per test method.
Mercury	0.1 mg/Nm ³	Campaign	
Cadmium	0.1 mg/Nm ³	Campaign	
Hazardous substances**	1.0 mg/Nm ³	Campaign	

* Standard temperature and pressure - 0°C or 273K, and 101.3kPa.

& "Campaign" = annual test.

** *Hazardous substances* is defined in Condition L3.5 as the aggregate of a number of heavy metals, being Antimony (Sb), Arsenic (As), Beryllium (Be), Cadmium (Cd), Chromium (Cr), Cobalt (Co), Lead (Pb), Manganese (Mn), Mercury (Hg), Nickel (Ni), Selenium (Se), Tin (Sn), and Vanadium (V).

4.3 Emission Limits for Non Standard Fuels

Conditions L3.5 to L3.7 of EPL1698 define permitted contaminant emission limits for the No.6 Kiln Stack during the burning of NSF. Also, conditions 3.10, 3.10A and 4.1 of the DA refer to the Kiln 6 emissions for NSFs. Table 7 summarises these limits for particulates, NO_x and VOCs.

In addition to the parameters listed in Table 7, monitoring is also required (due to Condition M2.4) for hexavalent chromium and carbon monoxide. However no limits are specified for these pollutants.

The emission limits and monitoring required during burning of NSF are more stringent and onerous than during burning of Standard Fuels for some pollutants. The differences are summarised in Table 8. For all pollutants for which monitoring is required for both fuel types, the emission limits are lower for NSF compared to the limits for Standard Fuels. The reason behind the setting of different limits for NSF is unclear, as the potential environmental impact of each pollutant is the same regardless of the type of fuel being burned.

Table 7: Emission limits for pollutants from No.6 Kiln Stack, for burning of NSF; listed in conditions L3.5-3.7 of EPL1698

Contaminant	100 percentile concentration limit	Monitoring required ^{&}	Gas reference conditions and averaging period for concentration limit
Nitrogen oxides	800 mg/Nm ³	Campaign (Special Freq) and CEM	Dry, STP*, 10% O ₂ Averaging period as per test method for campaign monitoring. Averaging period 1-hr for CEM
Solid particles (TSP)	30 mg/Nm ³	Campaign (Special Freq) and CEM	Dry, STP*, 10% O ₂ Averaging period as per test method for campaign monitoring. Averaging period 24-hr for CEM
Volatile organic compounds	20 ppm	Campaign (Special Freq) and CEM	Dry, 10% O ₂ Averaging period as per test method. Reference conditions and averaging period for CEM not specified (EPL states "to be agreed to by the EPA").
Cadmium + Thallium	0.05 mg/Nm ³	Campaign (Special Freq)	Dry, STP*, 10% O ₂ Averaging period as per test method.
Chlorine	200 mg/Nm ³	Campaign (Special Freq)	Dry, STP*, 10% O ₂ Averaging period as per test method.
Dioxins and Furans	0.1 ng/Nm ³	Campaign (Special Freq)	Dry, STP*, 10% O ₂ Averaging period as per test method.
Hazardous substances**	0.5 mg/Nm ³	Campaign (Special Freq)	Dry, STP*, 10% O ₂ Averaging period as per test methods
Hydrogen chloride	10 mg/Nm ³	Campaign (Special Freq)	Dry, STP*, 10% O ₂ Averaging period as per test method.
Hydrogen fluoride	1 mg/Nm ³	Campaign (Special Freq)	Dry, STP*, 10% O ₂ Averaging period as per test method.
Mercury	0.05 mg/Nm ³	Campaign (Special Freq)	Dry, STP*, 10% O ₂ Averaging period as per test method.
Sulfur dioxide	50 mg/Nm ³	Campaign (Special Freq) and CEM	Dry, STP*, 10% O ₂ Averaging period as per test method. Reference conditions and averaging period for CEM not specified (EPL states "to be agreed to by the EPA").
Sulfuric acid mist and/or sulfur trioxide	100 mg/Nm ³	Campaign (Special Freq)	Dry, STP*, 10% O ₂ Averaging period as per test method.

* Standard temperature and pressure - 0°C or 273K, and 101.3kPa.

& "Campaign (Special Freq)" = annual test or sub-yearly frequency stack tests, with a special frequency defined which allows for the frequency interval to be extended over time to a maximum of 12 monthly if test results are favourable. "CEM" = continuous emissions monitoring.

** *Hazardous substances* is defined in Condition L3.5 as the aggregate of a number of heavy metals, being Antimony (Sb), Arsenic (As), Beryllium (Be), Cadmium (Cd), Chromium (Cr), Cobalt (Co), Lead (Pb), Manganese (Mn), Mercury (Hg), Nickel (Ni), Selenium (Se), Tin (Sn), and Vanadium (V).

Table 8: Comparison of current emission limits and monitoring methods for pollutants from No.6 Kiln Stack, for burning of Standard Fuels and NSF

Contaminant	Non Standard Fuels		Standard Fuels	
	100 percentile concentration limit	Monitoring required ^{&}	100 percentile concentration limit	Monitoring required ^{**}
Nitrogen oxides	800 mg/Nm ^{3*}	Campaign and CEM	1000 mg/Nm ³	Campaign
Solid particles (TSP)	30 mg/Nm ³	Campaign and CEM	95 mg/Nm ³	Campaign and CEM
Volatile organic compounds	20 ppm	Campaign and CEM	No limit specified	
Cadmium + Thallium	0.05 mg/Nm ³	Campaign	0.1 mg/Nm ³ Cadmium only	Campaign
Chlorine	200 mg/Nm ³	Campaign		
Dioxins and Furans	0.1 ng/Nm ³	Campaign		
Hazardous substances ^{**}	0.5 mg/Nm ³	Campaign	1.0 mg/Nm ³	Campaign
Hydrogen chloride	10 mg/Nm ³	Campaign		
Hydrogen fluoride	1 mg/Nm ³	Campaign		
Mercury	0.05 mg/Nm ³	Campaign		
Sulfur dioxide	50 mg/Nm ³	Campaign and CEM		
Sulfuric acid mist and/or sulfur trioxide	100 mg/Nm ³	Campaign		

* All Nm³ = standard temperature and pressure - 0°C or 273K, dry gas and 101.3kPa, 10% O₂.

& "Campaign (Special Freq)" = annual test or sub-yearly frequency stack tests, with a special frequency defined which allows for the frequency interval to be extended over time to a maximum of 12 monthly if test results are favourable. "CEM" = continuous emissions monitoring.

** *Hazardous substances* is defined in Condition L3.5 as the aggregate of a number of heavy metals, being Antimony (Sb), Arsenic (As), Beryllium (Be), Cadmium (Cd), Chromium (Cr), Cobalt (Co), Lead (Pb), Manganese (Mn), Mercury (Hg), Nickel (Ni), Selenium (Se), Tin (Sn), and Vanadium (V).

4.4 Results of Annual Testing Required for Standard Fuels

4.4.1 Physical Stack Dimensions and Discharge Parameters

Physical stack dimensions and discharge parameters for the four emission points, based on information supplied by Boral Cement and the four annual testing campaigns of 2011, 2012, 2013 and 2014, are summarised in Table 9 and Table 10.

Table 9: Summary of Stack Dimensions

Name	Height, m	Diameter or equivalent diameter at stack tip, m	Stack discharge configuration
No.6 Kiln Stack	85m	3.0m	Vertical discharge
No.6 Cement Mill	17m (to mid-height of duct)	1.75m ^a	Horizontal discharge
No.6 Kiln Cooler	37m	2.4m	Vertical discharge
No.7 Cement Mill	8m (to mid-height of duct)	1.91m ^b	Discharge angled upwards but not vertical

- a. Rectangular duct 1604mm x 1500mm. Area of opening = 2.406m². Equivalent diameter to give same area of a circle = 1.75m.
- b. Rectangular duct 1800mm x 1600mm. Area of opening = 2.88m². Equivalent diameter to give same area of a circle = 1.91m.

Table 10: Summary of physical discharge parameters, from stack test data collected during annual testing in 2011, 2012, 2013 and 2014

Name		Measured Temp, °C	Gas flow rate, STP, Nm ³ /min ^a	Moisture, %	Velocity at stack tip (m/s)
No.6 Kiln Stack	No. of test data points	26			
	Range	101-114	6322-8445	13-17	29-35
	Average	106	7275	14	30
No.6 Cement Mill	No. of test data points	3 ^d			
	Range	77-85	1285-1343	2.1-3.4	12.6-13.1 ^d
	Average	84	1314	2.7	13 ^{b,d}
No.6 Kiln Cooler	No. of test data points	4 pairs, test data below is average of each pair			
	Range	57-104.5	1722-3412	0.81-1.75	7.8-19
	Average	87	2562	1.2	14
No.7 Cement Mill	No. of test data points	4 pairs, test data below is average of each pair			
	Range	98-104	740-943	3.9-8.9	6.8-8.6
	Average	102	815	6.1	7.7 ^c

- Normal cubic metres per minute including correction to dry gas, 0°C and 101.3kPa.
- Because this stack has a horizontal discharge, the emission is treated as having zero momentum flux in dispersion model (i.e. no dispersion assistance due to vertical momentum).
- Assuming approximate angle of discharge of 30 degrees above horizontal, vertical component of exhaust velocity is 3.7m/s (calculated from $7.7 \times \sin(30 \text{ degrees})$, where $\sin(30^\circ) = 0.5$). This was used in the dispersion model.
- Discharge is measured by taking separate measurements in two contributing ducts (each of different size, flow, temperature) before they merge at discharge point. Reported data is the weighted sum of both ducts. One pair of test measurements taken in each duct in each of 2011, 2012, 2013 and 2014, however data reported for 2011 and 2014 has been eliminated due to anomalous results.

4.4.2 Emission Data

Concentrations and mass emission rates for the various pollutants measured during the annual stack test campaigns in 2011, 2012, 2013 and 2014, as required during combustion of standard fuels, are summarised in Table 11 and Table 12.

TSP measured in the No.6 Kiln Cooler Stack were higher in 2014 than in previous years, although still within the licence limits. Boral Cement advised that the higher emission concentrations were due to worn baghouse filters, which were reaching the end of their useful life. The filters have since been replaced with emissions returning to normal levels. The 2014 data is considered to be an outlier, and is excluded from the average calculations.

Table 11: Measurements of emissions of particulates (TSP) and NO_x from No.6 Kiln Stack by annual testing in 2011-2014, required by EPL during combustion of Standard Fuels

Pollutant	Concentrations, mg/Nm ³ corrected to 10% O ₂					Mass emission rates, kg/hr				
	2011	2012	2013	2014	Average [#]	2011	2012	2013	2014	Average
TSP*	15.3 16.6	19.8 18.8	56.8 53.9	14.7	28.0	8.2 9.4	9.2 9.9	28.8 26.9	7.6	14.3
NO _x ^{&}	891	687	641	728	728	422	325	327	376	362
Cadmium	nd [%]	nd	0.0059	0.0091		nd	nd	0.0028	0.0050	0.0039
Mercury	0.0076	0.0039	0.012	0.010	0.0084	0.0041	0.0018	0.0058	0.0054	0.0043
Hazardous substances**	0.031	0.046	0.094	0.091	0.066	0.016	0.021	0.046	0.050	0.033
Hazardous substances with half MDL for nd [@]	0.034	0.081	0.098	0.093	0.076	0.018	0.035	0.047	0.051	0.038

* For TSP, each year there were two test measurements on separate days except 2014 where one test was reported as invalid.

& NO_x = sum of NO and NO₂, expressed as NO₂

Average calculated only from years where results were above detection levels, except for last row where average includes half of metal detection limit for any metals that were reported as "not detected".

% nd = not detected; below level of detection for test method

** *Hazardous substances* is defined in Condition L3.5 as the aggregate of a number of heavy metals, being Antimony (Sb), Arsenic (As), Beryllium (Be), Cadmium (Cd), Chromium (Cr), Cobalt (Co), Lead (Pb), Manganese (Mn), Mercury (Hg), Nickel (Ni), Selenium (Se), Tin (Sn), and Vanadium (V).

@ Includes half of method detection limit for any heavy metals that were reported as "not detected"

Table 12: Measurements of emissions of particulates (TSP) from Cement Mill vents and No.6 Kiln Cooler Stack by annual stack testing in 2011-2014, as required by EPL during combustion of Standard Fuels

Discharge point	Concentrations, mg/Nm ³ *					Mass emission rates				
	<i>Data for each year is average of a pair of individual samples</i>					<i>Data for each year is average of a pair of individual samples</i>				
	2011	2012	2013	2014	Average	2011	2012	2013	2014	Average
Units of g/s										
No.6 Kiln Cooler	1.24	3.88	3.11	56.8 [@]	2.74 (excl. 2014)	0.185	0.401	0.495		0.36 (excl. 2014)
Cement Mill 6 ^{\$}	N/A [%]	4.19	3.84	N/A [%]	4.02	N/A [%]	0.323	0.310	N/A [%]	0.316
Cement Mill 7	3.90	8.76	15.9	8.08	9.15	0.189	0.497	0.727	0.360	0.443
Units of kg/hr										
No.6 Kiln Cooler						0.051	0.111	0.137		0.100 (excl. 2014)
Cement Mill 6 ^{\$}						N/A [%]	0.090	0.086	N/A [%]	0.088
Cement Mill 7						0.053	0.138	0.202	0.100	0.123

* Normal cubic metres per minute including correction to dry gas, 0°C and 101.3kPa.

\$ Accumulated results from tests on Duct A and Duct B, concentration is weighted average of the individual test data.

% Data reported for 2011 and 2014 was eliminated due to anomalous test results.

@ Outlier data due to faulty/worn bagfilters. Data excluded from average calculations.

4.5 Comparison of Annual Test Data with Emission Limits

Emissions data collected from the annual stack testing as required during combustion of Standard Fuels is compared with the relevant EPL & DA limits in Table 13 and Table 14. The measurements reported in these tables are all below the EPL/DA limits.

Table 13: Emission limits from EPL1698 for solid particles, for burning of standard fuels; compared to annual stack test data 2011-2014

Discharge point	Solid particles concentration limit	Results from annual stack test data
No.6 Kiln Stack	95 mg/Nm ³ *	Max measured concentration: 56.8 mg/Nm ³
No.6 Cement Mill	100 mg/Nm ³ (reduced from 250 mg/Nm ³ in March 2012)	Max measured concentration: 4.2 mg/Nm ³
No.6 Kiln Cooler	100 mg/Nm ³ (reduced from 175 mg/Nm ³ in March 2012)	Max measured concentration: 56.8 mg/Nm ³ (outlier measured in 2014). Max measured concentration excluding 2014 = 3.9 mg/Nm ³
No.7 Cement Mill	20 mg/Nm ³	Max measured concentration: 15.9 mg/Nm ³

* All Nm³ = dry gas, standard temperature and pressure - 0°C or 273K, and 101.3kPa, 10% O₂.

Table 14: Emission limits from EPL1698 for other contaminants from No.6 Kiln Stack, for burning of standard fuels; compared to test data 2011-2014

Contaminant	100 percentile concentration limit	Stack testing results
Nitrogen oxides	1000 mg/Nm ³ *	Max measured concentration from annual tests: 891 mg/Nm ³
Cadmium	0.1 mg/Nm ³	Max measured concentration: 0.0091 mg/Nm ³
Mercury	0.1 mg/Nm ³	Max measured concentration: 0.012 mg/Nm ³
Hazardous substances**	1.0 mg/Nm ³	Max measured concentration: 0.094 mg/Nm ³ (excluding half MDL) Max measured concentration: 0.099 mg/Nm ³ (including half MDL for metals which were reported as not detected)

* All Nm³ = dry gas, standard temperature and pressure - 0°C or 273K, and 101.3kPa, 10% O₂.

** *Hazardous substances* is defined in Condition L3.5 as the aggregate of a number of heavy metals, being Antimony (Sb), Arsenic (As), Beryllium (Be), Cadmium (Cd), Chromium (Cr), Cobalt (Co), Lead (Pb), Manganese (Mn), Mercury (Hg), Nickel (Ni), Selenium (Se), Tin (Sn), and Vanadium (V).

4.6 Other Monitoring Results

4.6.1 Gas Flow Data - No.6 Kiln Stack

Stack discharge characteristics in the No.6 Kiln Stack are monitored continuously, with data recorded at 5-minute intervals. These discharge characteristics include gas flow rate, temperature, moisture content, and oxygen and carbon dioxide percentages.

Data from the 2012 and 2013 years has been analysed for this report, for the purpose of identifying the typical range of the discharge characteristics which are relevant to dispersion modelling – in particular gas flow rate, temperature, and the calculated gas velocity at the stack exit. The data was filtered to remove periods where the kiln was not operating at steady state (feed rate to kiln at least 250 tph).

Data from 2014 was not included in this analysis, as the 2014 calendar year was not complete at the time this analysis was started.

The range of data values (1-hour average) measured for gas flow rate, temperature, and gas velocity are shown in Table 15, Figure 5 and Figure 6.

The gas flow rates and velocities assessed from the continuous monitoring are higher than that reported in the annual stack tests (as per Table 10). The data from the continuous monitoring was used to determine emission rates for dispersion modelling in this report, as this flow data is higher (and therefore the emission rates are higher because the emission rates are the product of flow multiplied by concentration). It is possible however that the emission rates have been over-stated using this approach.

Table 15: Summary of No.6 Kiln Stack discharge parameters, from 2012 and 2013 continuous emissions monitoring data (1-hour average calculated from 5-minute raw data)

Statistic	Stack gas temperature (°C)	Gas velocity at stack operating conditions (m/s)*	Gas flow rate corrected to 10% O ₂	
			Nm ³ /min &	Nm ³ /s &
Mean	103	38.8	11189	186
50 th percentile	102	38.7	11367	189
75 th percentile	104	39.4	11733	196
90 th percentile	109	40.8	11999	200
95 th percentile	116	42.5	12165	203
98 th percentile	120	43.9	12457	208
99 th percentile	122	44.5	12642	211
99.9 th percentile	139	45.6	13555	226
Maximum	142	50.2	15404	257

* Calculated from raw data provided at standard temperature and pressure, by adjusting for actual temperature and pressure.

& All Nm³ = dry gas, standard temperature and pressure - 0°C or 273K, and 101.3kPa, 10% O₂.

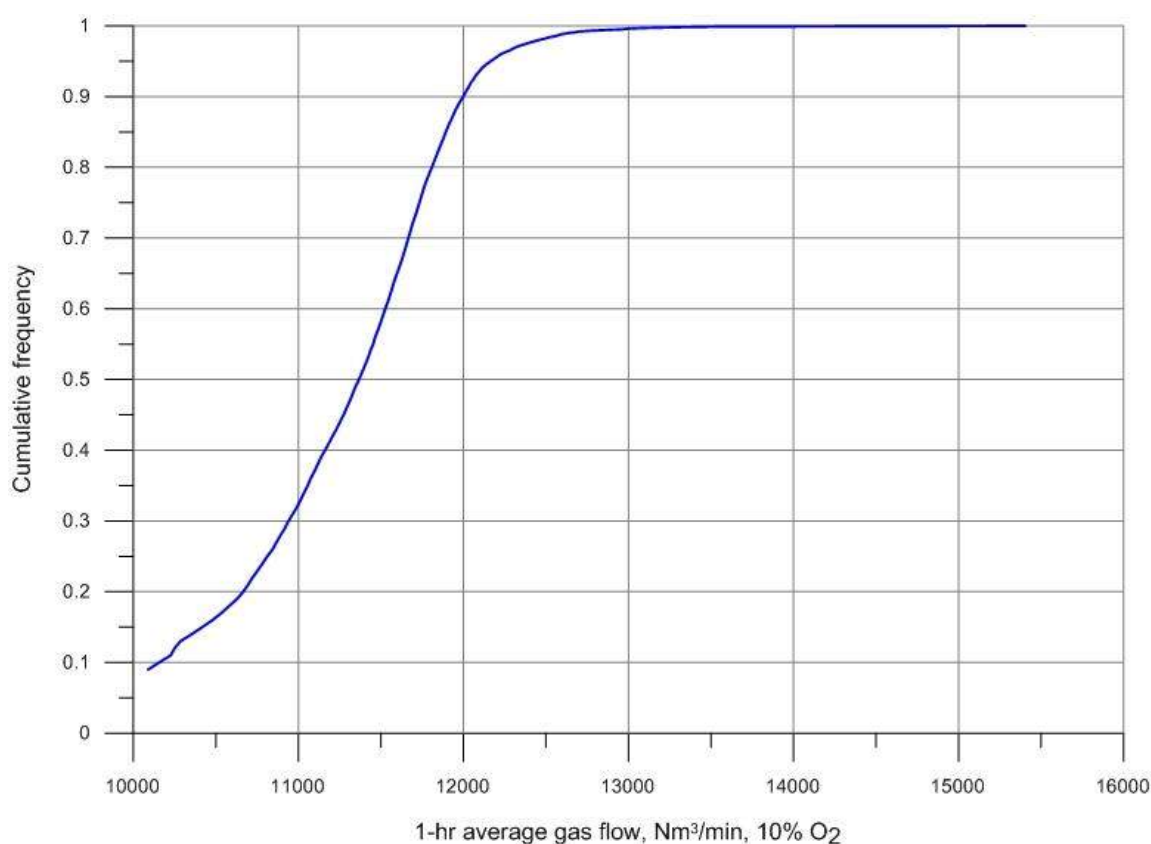


Figure 5: Cumulative frequency of No.6 Kiln stack gas flow rates, 0°C, dry, 10% O₂. Compiled from 1-hour average data with feed rate of at least 250tph, collected continuously over 2012 and 2013.

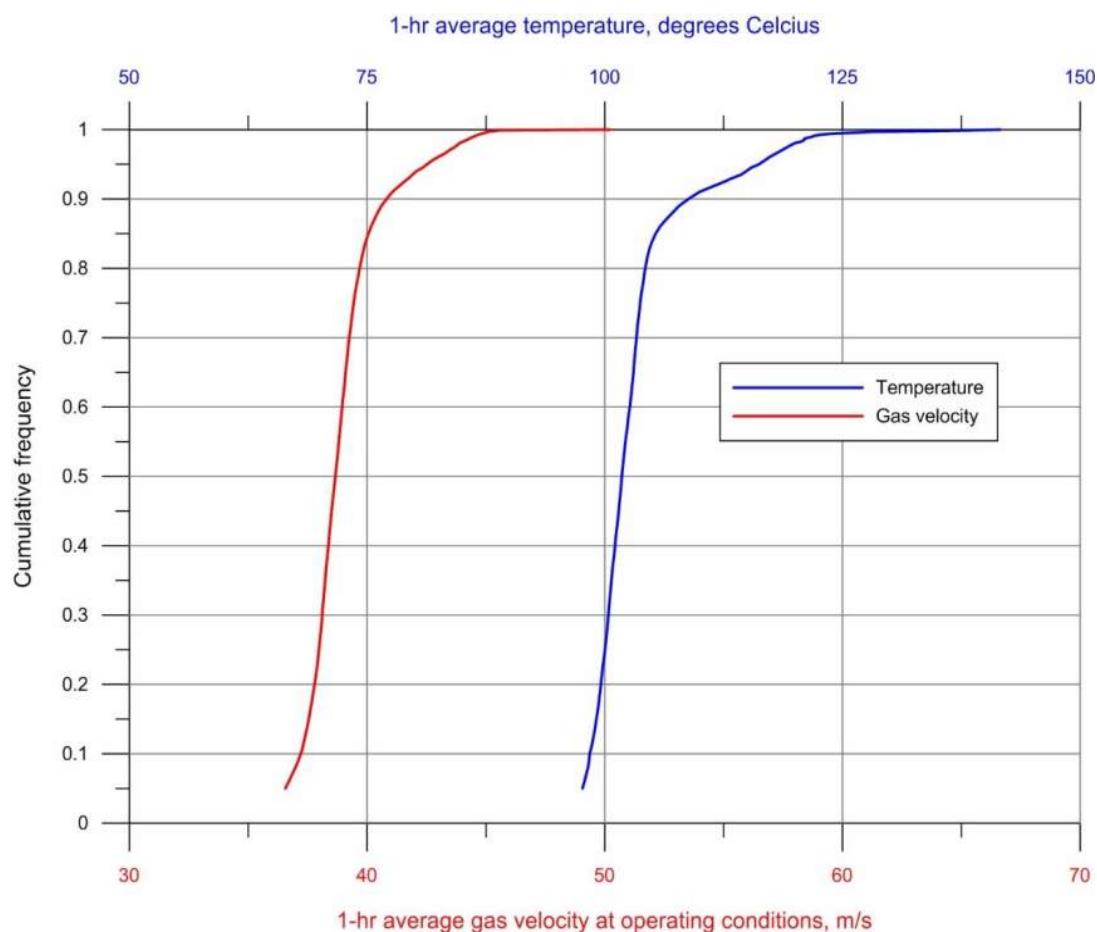


Figure 6: Cumulative frequency of No.6 Kiln stack gas velocities and temperatures at stack conditions. Velocity was calculated from records of gas flow at STP. Compiled from 1-hour average data with feed rate of at least 250tph, collected continuously over 2012 and 2013.

4.6.2 No.6 Kiln Stack Measurements from Voluntary Annual Stack Testing

Test results from the monitoring of PM₁₀ and PM_{2.5} in the No.6 Kiln Stack discharge are summarised in Table 16. In the EPL, PM₁₀ and PM_{2.5} monitoring is not required and the data is collected voluntarily by Boral Cement. This table also shows the TSP data collected at the same time as the PM₁₀ and PM_{2.5} data (and previously reported in Table 11), for comparison. Each data reported in the table is the arithmetic mean of two individual samples.

Table 16: Measurements of emissions of TSP, PM₁₀ and PM_{2.5} from No.6 Kiln Stack, from annual monitoring campaigns

Pollutant	Mass emission rates, kg/hr			
	2011	2012	2013	2014
TSP*	8.8	9.5	27.9	7.6
PM ₁₀	6.5	N/A**	19.4	4.7
PM ₁₀ as proportion of TSP	74%		70%	61%
PM _{2.5}	Not tested	N/A**	8.3	2.5
PM _{2.5} as proportion of TSP			30%	33%

* Duplicate of the same data previously reported in Table 11, provided here for comparison to the PM₁₀ data. TSP and PM₁₀ data was collected concurrently on each occasion. TSP and PM₁₀ data for each year is arithmetic mean of two individual samples.

** Results not reported

Concentrations and mass emission rates for SO₂ and VOCs from the No.6 Kiln Stack measured in 2011-2014 are summarised in Table 17 and Table 18.

Table 17: Measurements of emissions of SO₂ from No.6 Kiln Stack, from annual monitoring campaigns

Pollutant	Concentrations, mg/Nm ³ corrected to 10% O ₂				Mass emission rates, kg/hr			
	2011	2012	2013	2014	2011	2012	2013	2014
SO ₂	nd	nd	0.64	nd	nd	nd	0.31	nd

Table 18: Measurements of emissions of VOCs from No.6 Kiln Stack, from annual monitoring campaigns

Pollutant	Concentrations, ppm ** corrected to 10% O ₂ except where indicated				Mass emission rates, kg/hr			
	2011 [#]	2012	2013	2014	2011	2012	2013	2014
NMHCs*	58	12	13	18	44.3	9.5	11.2-22.4%	19.0

* Non methane hydrocarbons, reported as C₃ in 2011 and 2012, and as n-propane in 2014.

% Range depends on average molecular weight assumed; test method in 2013 reports concentration as "C3-C6".

** Reported as ppm for consistency with EPL and test method.

[#] 2013 data used different test method (USEPA Method 18 rather than USEPA Method 25A which was used for 2011, 2012 and 2014).

The existing levels and variability of NMHCs are not related to Non-Standard Fuels as none are being burnt at the Works; these originate from raw materials and therefore constitute a "base" level.

Concentrations and mass emission rates for heavy metals, PAHs, dioxins, halides, sulfuric acid mist/sulfur trioxide and hexavalent chromium from the No.6 Kiln Stack measured in 2011-2014 are summarised in Table 19 to Table 23.

In these tables of results, the following abbreviations apply across all tables:

- MDL = method detection limit for the specific test method
- nd = not detected (below MDL)
- Half MDL = half the value of the MDL
- nt = not tested

Table 19 and Table 20 both show test results for heavy metals. The first of the two table shows results as reported, with “nd” for any concentrations that were below detectable levels. The second table shows the same set of data results, but with a value equal to half of the MDL for the metal used in place of “nd”.

Table 21 shows similar treatment of data for measurements of hexavalent chromium. In each year, the testing for hexavalent chromium was carried out on a different day to the total chromium test, so the results cannot be directly compared.

Table 19: Measurements of emissions of heavy metals from No.6 Kiln Stack, from annual monitoring campaigns. Any concentrations below method detection limit reported as “not detected”.

Pollutant	Concentrations, mg/dscm corrected to 10% O ₂					Mass emission rates, kg/hr				
	2011	2012	2013	2014	Average	2011	2012	2013	2014	Average
Arsenic	nd	nd	nd	0.00054	0.00054	nd	nd	nd	0.00030	0.00030
Beryllium	nd	nd	nd	nd		nd	nd	nd	nd	
Cadmium	nd	nd	0.0059	0.0091	0.0075	nd	nd	0.0028	0.0050	0.0039
Cobalt	nd	nd	nd	nd		nd	nd	nd	nd	
Chromium	0.0021	nd	nd	0.004	0.0030	0.0011	nd	nd	0.0022	0.0017
Copper	0.0017	0.013	0.0023	0.0074	0.0061	0.00091	0.0058	0.0012	0.0040	0.0029
Mercury	0.0076	0.0039	0.012	0.01	0.0084	0.0041	0.0018	0.0058	0.0054	0.0043
Manganese	0.016	0.041	0.071	0.05	0.044	0.0084	0.019	0.035	0.027	0.022
Nickel	0.0025	nd	0.0014	0.0078	0.0039	0.0013	nd	0.00065	0.0043	0.0021
Lead	0.0028	nd	0.0022	0.0043	0.0031	0.0015	nd	0.0010	0.0024	0.0016
Antimony	nd	nd	nd	nd		nd	nd	nd	nd	
Selenium	nd	0.0009	nd	0.0029	0.0019		0.00043		0.0016	0.0010
Thallium	0.0032	0.031	0.0036	0.022	0.015	0.0017	0.014	0.0017	0.012	0.0075
Vanadium	nd	nd	0.0018	0.0024	0.0021	nd	nd	0.00086	0.0013	0.0011
Tin	nd	nd	nd	nd		nd	nd	nd	nd	
Total Haz. Substances Aggregate**	0.031	0.046	0.094	0.091	0.066	0.016	0.021	0.046	0.050	0.033

** Sum of all metals in table except copper and thallium

Table 20: Measurements of emissions of heavy metals from No.6 Kiln Stack, from annual monitoring campaigns.
Any concentrations below method detection limit reported as half of the method detection limit

Pollutant	Concentrations, mg/dscm corrected to 10% O ₂ , incl half MDL for any measured as "nd"					Mass emission rates, kg/hr, incl half MDL for any measured as "nd"				
	2011	2012	2013	2014	Average	2011	2012	2013	2014	Average
Arsenic	0.0003	0.00033	0.0006	0.00054	0.00044	0.00016	0.00015	0.00029	0.00029	0.00022
Beryllium	0.0003	0.00033	0.0006	0.00022	0.00036	0.00016	0.00015	0.00029	0.00012	0.00018
Cadmium	0.0003	0.00065	0.0059	0.0091	0.0040	0.00016	0.00030	0.0028	0.0050	0.0020
Cobalt	0.0003	0.0015	0.0006	0.0015	0.00098	0.00016	0.00070	0.00029	0.00084	0.00050
Chromium	0.0021	0.00033	0.0006	0.004	0.0018	0.0011	0.00015	0.00029	0.0022	0.00094
Copper	0.0017	0.013	0.0023	0.0074	0.0061	0.00091	0.0058	0.0011	0.0040	0.0029
Mercury	0.0076	0.0039	0.012	0.01	0.0084	0.0041	0.0018	0.0058	0.0054	0.0043
Manganese	0.016	0.041	0.071	0.05	0.044	0.0084	0.019	0.035	0.027	0.022
Nickel	0.0025	0.003	0.0014	0.0078	0.0037	0.0013	0.0014	0.00065	0.0043	0.0019
Lead	0.0028	0.006	0.0022	0.0043	0.0038	0.0015	0.0028	0.0010	0.0024	0.0019
Antimony	0.0003	0.015	0.0006	0.00022	0.0040	0.00016	0.0070	0.00029	0.00012	0.0019
Selenium	0.0003	0.0009	0.0006	0.0029	0.0012	0.00016	0.00043	0.00029	0.0016	0.00062
Thallium	0.0032	0.031	0.0036	0.022	0.015	0.0017	0.014	0.0017	0.012	0.0075
Vanadium	0.00046	0.0017	0.0018	0.0024	0.0016	0.00024	0.00079	0.00086	0.0013	0.00081
Tin	0.0003	0.006	0.0006	0.00022	0.0018	0.00016	0.00015	0.00029	0.00030	0.00022
Total Haz. Substances Aggregate**	0.034	0.081	0.099	0.093	0.076	0.018	0.035	0.047	0.051	0.038

** Sum of all metals in table except copper and thallium

Table 21: Measurements of emissions of hexavalent chromium from No.6 Kiln Stack, from annual monitoring campaigns

Pollutant	Concentrations, mg/Nm ³ corrected to 10% O ₂					Mass emission rates, kg/hr				
	2011*	2012*	2013*	2014*	Average	2011*	2012*	2013*	2014*	Average
Cr (6+)	0.00022	nd	0.0025	nd	0.0014	0.00010	nd	0.0013	nd	0.00070
Cr (6+) including half MDL if "nd"	0.00022	0.00010	0.0025	0.0012	0.0010	0.00010	0.00008	0.0013	0.00052	0.00050

* Sampled on a different day to total chromium in table above so results cannot be directly compared.

Table 22: Measurements of emissions of halides and sulfuric acid mist/sulfur trioxide from No.6 Kiln Stack, from annual monitoring campaigns

Pollutant	Concentrations, mg/Nm ³ corrected to 10% O ₂					Mass emission rates, kg/hr				
	2011	2012	2013	2014	Average	2011	2012	2013	2014	Average
Total fluoride (reported as hydrogen fluoride)	0.28	1.2	0.72	0.41	0.65	0.14	0.58	0.36	0.22	0.32
Hydrogen chloride	0.26*	0.24	nd (MDL 0.22)	0.25	0.25	0.10	0.11	nd	0.12	0.11
Chlorine	0.32	0.22	nd (MDL 0.18)	nd (MDL 0.19)	0.27	0.18	0.10	nd	nd	0.14
Sulfuric acid mist/sulfur trioxide	nd (MDL 1.2)	nd (MDL 0.05)	nd (MDL 1)	1.5	<1.5	nd	nd	nd	0.83	<0.83

* Not corrected to 10% O₂ (correction not reported)

Table 23: Measurements of emissions of PAHs and Dioxins from No.6 Kiln Stack, from annual monitoring campaigns

Pollutant	Concentrations, ng/Nm ³ corrected to 10% O ₂					Mass emission rates, mg/hr (note: 1 mg/hr = one millionth of 1 kg/hr)				
	2011	2012	2013	2014	Average	2011	2012	2013	2014	Average
Dioxins/ Furans**	0.00027	0.0011	0.00018	0.0012	0.00069	0.132	0.504	0.097	0.612	0.336
TEQ PAHs*	0.22	6.8	0.25	6.4	3.4	108	3240	126	3096	1462

* PAHs with toxicity equivalent quotient (TEQ) contribution, expressed as Benzo(a)pyrene including half of MDL values for compounds that were less than detection levels.

** As I-TEQ, sum of all dioxin and furan congeners, including half of MDL values for compounds that were less than detection levels.

4.6.3 No.6 Kiln Stack Measurements from Continuous Emission Monitoring – Concentration Data

Emission data from the continuous emission monitoring programme for 2012 and 2013 (which is voluntary except for TSP which is required by the EPL during burning of standard fuels) has been analysed in a similar manner to the discharge parameter data described in Section 4.6.1.

The range of data values measured for average emission concentrations of NO, NO₂, SO₂, particulate (TSP), and non-methane hydrocarbons are shown in Table 24 for 1-hour averages. Data is also provided in Table 25 for calculated 24-hour averages for comparison purposes. Calculated emissions of NO_x are also shown in the tables; these were calculated from the 1-hour NO and NO₂ data⁵.

⁵ By multiplying NO by the molar weight ratio of NO₂:NO (46/30), then adding the NO₂ value.

The 1-hour data is calculated from the original filtered 5-minute data (filtered for high O₂, low temperature indicated kiln not operating), provided that there was at least one valid 5-minute data reading within that hour. The 1-hour data was also filtered to remove all data occurring at a kiln feed throughput of less than 250 tonnes per hour – this represents the threshold for onset of steady state conditions which is required for the burning of NSF.

The 24-hour data was calculated from valid 1-hour data at a kiln feed throughput of at least 250 tonnes per hour, with the 24-hour average only being calculated if there were at least 12 individual hourly-average readings with the previous 24-hour period. The 24-hour average was calculated as a midday-to-midday average.

Table 24: Summary of No.6 Kiln Stack emission concentrations (mg/Nm³ at 10% O₂), 1-hour averages calculated from 2012 and 2013 continuous emissions monitoring data. Minimum kiln feed throughput 250 tph.

Pollutant ^α 1-hr average *	NO	NO ₂	NO _x (as NO ₂)	SO ₂	TSP	NMHC%
Mean	424	2.9	652	1.2	34	22
50 th percentile	421	2.8	649	0.5	32	21
75 th percentile	460	3.3	709	0.7	41	24
90 th percentile	497	3.8	766	1.4	48	29
99.9 th percentile	688	6.9	1063	43	115	121
Maximum	746	17.5	1150	68	181	126

* All units reported as mg/Nm³ corrected to 10% O₂.

^α All pollutants use steady state data only (minimum kiln feed throughput 250 tph).

% Converted from ppm to mg/Nm³ assuming molecular weight of 36 g/mol (equivalent to C₃). Current levels reflect the NMHC emissions arising from raw materials used in the kiln.

Table 25: Summary of No.6 Kiln Stack emission concentrations (mg/Nm³ at 10% O₂), 24-hour midday-midday averages calculated from 2012 and 2013 continuous emissions monitoring data. Minimum kiln feed throughput 250 tph.

Pollutant ^α 24-hr average [§] *	NO	NO ₂	NO _x (as NO ₂)	SO ₂	TSP	NMHC%
Mean	423	2.9	652	1.2	34	22
50 th percentile	422	2.9	649	0.6	32	21
75 th percentile	455	3.2	701	1.0	41	24
90 th percentile	487	3.7	750	2.5	48	28
99.9 th percentile	619	5.4	955	25	75	114
Maximum	623	5.4	960	34	77	114

* All units reported as mg/Nm³ corrected to 10% O₂.

^α All pollutants use steady state data only (minimum kiln feed throughput 250 tph).

% Converted from ppm to mg/Nm³ assuming molecular weight of 36 g/mol (equivalent to C₃). Current levels reflect the NMHC emissions arising from raw materials used in the kiln.

[§] Midday-to-midday 24-hour average from 1-hour data with minimum hourly average kiln feed throughput 250 tph. Minimum number of hourly values used to calculate 24-hour average = 12.

4.6.4 No.6 Kiln Stack Measurements from Continuous Emission Monitoring – Mass Emission Rate Data

The range of data values measured for mass emission rates of NO, NO₂, SO₂, particulate (TSP), and non-methane hydrocarbons are shown in Table 26 for 1-hour averages and in Table 27 for 24-hour averages.

The 1-hour and 24-hour data was calculated using the same assumptions as those described in Section 4.6.3 above.

Table 26: Summary of No.6 Kiln Stack mass emission rates (g/s), 1-hour averages calculated from 2012 and 2013 continuous emissions monitoring data. Minimum kiln feed throughput 250 tph.

Pollutant ^α 1-hr average *	NO	NO ₂	NO _x (as NO ₂)	SO ₂	TSP	NMHC%
Mean	79	0.54	121	0.22	6.3	4.1
50 th percentile	78	0.53	121	0.10	5.8	3.8
75 th percentile	84	0.60	130	0.13	7.5	4.6
90 th percentile	91	0.68	140	0.25	8.9	5.6
95 th percentile	95	0.75	147	0.75	9.5	6.7
98 th percentile	104	0.89	160	2.16	11	18
99 th percentile	114	1.00	175	3.20	13	20
99.5 th percentile	120	1.07	185	4.21	14	22
99.9 th percentile	125	1.23	192	8.13	22	24
Maximum	147	2.95	227	12.6	33	25

* All units reported as g/s.

^α All pollutants use steady state data only (minimum kiln feed throughput 250 tph).

% Current levels reflect the NMHC emissions arising from raw materials used in the kiln.

Table 27: Summary of No.6 Kiln Stack mass emission rates (g/s), 24-hour midday-midday averages calculated from 2012 and 2013 continuous emissions monitoring data. Minimum kiln feed throughput 250 tph.

Pollutant ^α 1-hr average [§] *	NO	NO ₂	NO _x (as NO ₂)	SO ₂	TSP	NMHC%
Mean	79	0.54	121	0.22	6.3	4.2
50 th percentile	78	0.53	121	0.12	5.7	3.8
75 th percentile	84	0.60	129	0.18	7.6	4.6
90 th percentile	88	0.67	136	0.46	8.9	5.5
99.9 th percentile	121	1.06	187	4.47	14	22
Maximum	122	1.08	187	4.79	15	22

* All units reported as g/s.

^α All pollutants use steady state data only (minimum kiln feed throughput 250 tph).

% Current levels reflect the NMHC emissions arising from raw materials used in the kiln.

[§] Midday-to-midday 24-hour average from 1-hour data with minimum hourly average kiln feed throughput 250 tph. Minimum number of hourly values used to calculate 24-hour average = 12.

4.6.5 1-hour versus 24-hour data (Peak to Mean)

A “peak-to-mean” ratio represents the ratio of any single value within a dataset to the average of all values in the dataset. An analysis of peak-to-mean ratios for 1-hour averages compared with corresponding 24-hour averages has been carried out to investigate the variability of 1-hour average data compared to the longer term mean.

For example, in the data for TSP in 24-hour TSP data in Table 26 and Table 27, there were 475 individual 24-hour average data records that met the criteria of having a minimum of 12 1-hour data records during the midday-midday 24-hour period at a kiln throughput of 250 tph. There were 10,606 individual 1-hour data records that contributed to those 24-hour averages. Therefore 10,606 peak-to-mean ratios can be calculated.

Table 28 and Table 29 show the range of peak-to-mean values calculated based on concentration data and mass emission rate data respectively. This analysis shows that:

- The peak-to-mean ratios for each substance are very similar regardless of whether the peak-to-mean calculation is based on concentration or mass emission rate.
- Emissions are consistent from hour to hour with little variability around the 24-hour mean (as demonstrated by most of the P:M ratios being close to unity).
- SO₂ concentrations tend to fluctuate more than other substances – as shown by the higher P:M ratios in the >95th percentile bracket.

For substances other than SO₂, a very small number of elevated peak-to-mean ratios were noted, as shown in the >99.9th percentile and “maximum” rows in Table 28 and Table 29. Retrospective analysis of 5-minute average raw data that contributed to these peak-to-mean ratios showed that these peak-to-means tended to be caused by a very brief (10-15 minute) period of elevated concentration readings, that may or may not be real. These very small number of elevated peak-to-mean ratios are not considered to be significant in the context of potential health impacts at downwind sensitive receptors.

Table 28: Peak-to-mean (1-hour:24-hour) based on concentration data.

Pollutant ^a	NO	NO ₂	NO _x	SO ₂	TSP	NMHC
50 th percentile	1.00	1.00	1.00	0.94	0.99	1.00
75 th percentile	1.04	1.06	1.04	1.05	1.03	1.05
90 th percentile	1.08	1.15	1.08	1.36	1.09	1.12
95 th percentile	1.12	1.22	1.12	1.98	1.16	1.18
99.0 th percentile	1.20	1.39	1.20	5.24	1.37	1.37
99.5 th percentile	1.24	1.49	1.24	6.95	1.54	1.53
99.9 th percentile	1.41	1.92	1.41	10.7	2.37	3.75
99.95 th percentile	1.50	2.15	1.50	11.9	2.60	6.39
99.99 th percentile	1.51	2.65	1.52	13.4	3.01	7.72
Maximum	1.53	4.38	1.53	24.0	3.87	10.5

Table 29: Peak-to-mean (1-hour:24-hour) based on mass emission rate data.

Pollutant ^a	NO	NO ₂	NO _x	SO ₂	TSP	NMHC
50 th percentile	1.00	1.00	1.00	0.94	1.00	1.00
75 th percentile	1.04	1.07	1.04	1.05	1.03	1.06
90 th percentile	1.08	1.14	1.08	1.35	1.08	1.14
95 th percentile	1.11	1.20	1.11	1.97	1.14	1.20
99.0 th percentile	1.19	1.35	1.19	5.03	1.33	1.41
99.5 th percentile	1.22	1.41	1.22	6.77	1.49	1.51
99.9 th percentile	1.33	1.87	1.34	10.4	2.40	3.69
99.95 th percentile	1.37	2.02	1.37	10.9	2.62	6.26
99.99 th percentile	1.53	2.38	1.53	13.2	2.94	7.82
Maximum	1.62	4.29	1.62	24.0	3.80	10.5

4.7 Emission Rates During NSF Combustion

A trial of burning of NSF was carried out at the Berrima Works in 2003 accompanied by emission testing of pollutants discharged from the Kiln 6 stack.

Trials were carried out firstly with the co-firing of just Hi Cal 50 alone. Next, the kiln was operated with the co-firing of Hi Cal 50 and AKF-1 together. Finally, the kiln was operated using Hi Cal 50, AKF-1 and AKF-5 (tyres). Refer to Section 1 for an overview of these NSF materials.

The emissions measured for each of these firing conditions are presented in Table 30. This table is sourced from Table 7.1, page 30, of the Statement of Environmental Effects for use of Alternative Fuels and Materials in Berrima Kiln 6 prepared by Blue Circle Southern Cement Ltd (now Boral Cement) in 2003 (BCSC, 2003). The table also shows the current EPL limits for each of these pollutants to allow interpretation of the results in context.

The original test reports from the emission testing carried out during these trials are not available. It is not known if the test results reported for each day are the average of several individual test samples, or a single test run.

The test results for TSP, NO_x and VOCs exceeded the current EPL limits, for all trials including the baseline with no NSF. There may have been a small increase in TSP and VOC emissions when burning NSF, however it is difficult to tell if the variation in results between each test run is within the normal expected variability for these pollutants.

The test results for sulfur oxides, halides, and heavy metals showed no changes considered to be significant between test runs with the exception of hydrogen chloride (HCl). All of the test results including HCl were well below the current EPL limits for burning NSF.

Test results for dioxins and PAHs show higher concentrations when burning all of the three NSF together than with the other trials. Again, it is difficult to tell if the test results shown are significantly higher than

normal expected variations. The maximum measured dioxin concentration was still an order of magnitude lower than the concentration allowed in the EPL.

These trials were carried out prior to the upgrading of the Kiln 6 preheater capacity and the construction of the precalciner. Those upgrades increase the ability of the kiln system to reduce formation of dioxins, and improve the combustion efficiency thus leading to the expectation that emissions of many of the pollutants should be lower if the trials were repeated in 2015.

Table 30: Results of emission testing during NSF burning trials in 2003 (Source: BCSC, 2003).

Pollutant	Units	Baseline (no NSF)	Hi Cal 50	Hi Cal 50 + AKF-1	Hi Cal 50 + AKF-1 + AKF-5	Current EPL Limits for NSF (2015)
Date of Trial (in 2003)		8 August	9 August	14 October	14 October	
TSP	mg/m ³	39	40	44	51	30
Nitrogen oxides (as NO _x)	mg/m ³	1700	1200	1100	1200	800
Sulfur oxides (as H ₂ SO ₄)	mg/m ³	13	11	8.8	9.2	100
Chlorine	mg/m ³	< 1	< 1	< 1	< 1	200
Hydrogen chloride (HCl)	mg/m ³	< 1	< 1	1.8	1.2	10
Hydrogen fluoride (HF)	mg/m ³	< 1	< 1	< 1	< 1	1
Mercury	mg/m ³	0.011	0.0091	0.0039	0.0028	0.05
Cadmium	mg/m ³	< 0.002	0.015	0.002	0.0024	0.05 with thallium
Hazardous Substances**	mg/m ³	0.20	0.22	0.19	0.21	0.5
VOCs	mg/m ³	32 (8.3ppm)	51 (13.3ppm)	61 (15.9ppm)	55 (14.3ppm)	20 ppm
Dioxins and Furans (as TEQ)	ng/m ³	0.0034	0.0049	Not tested	0.013	0.1
PAHs (not stated as BaP- TEQ)	µg/m ³	6.9	5.8	Not tested	21	Not listed

** Aggregate of Sb, As, Be, Cd, Cr, Co, Pb, Mn, Hg, Ni, Se, Sn and V

4.8 Emission Rates Used In Dispersion Model

4.8.1 Emission Rates for Kiln 6 Stack, Based on Emission Limits Specified on a 24-Hour Average Concentration

Due to the introduction of the Energy from Waste Policy in NSW in 2013, Boral Cement has proposed the following variations to maximum emission concentrations in the EPL for the burning of NSF to align the licence limits with current NSW regulations (all concentrations expressed as dry, standard temperature and pressure, and 10% O₂):

- TSP: 50 mg/Nm³, calculated over a midday-to-midday 24-hour basis
- NO_x: 1000 mg/Nm³, calculated over a midday-to-midday 24-hour basis
- VOC (as NMHC): 40 ppm, calculated over a midday-to-midday 24-hour basis

No changes are proposed to other emission limits in the EPL for NSF, as listed earlier in Table 7.

The remainder of this report presents an assessment of potential air quality impacts due to emissions at these emission concentrations, and compares those predicted impacts with the impact assessment criteria published by NSW EPA.

Dispersion models use 1-hour average emissions as input data. Therefore for the emissions of TSP, NO_x and NMHC it was necessary to assume an associated 1-hour average emission concentration for each substance that represents the 24-hour average. This assumed representative 1-hour average concentration needs to be high enough to cover near-worst case peak 1-hour emission rates, yet not so high that the probability of the assumed concentration actually occurring is very remote.

The consideration of an appropriate representative 1-hour average concentration was based on the peak-to-mean ratio analysis in Section 4.6.5, and the 99.0th percentile of peak-to-mean ratios for each substance was selected to represent the near-worst case peak 1-hour emission rate. It was considered that selecting a higher percentile peak-to-mean ratio than the 99.0th percentile would result in an assumed emission rate which was unrealistically high with a very low probability of coinciding with atmospheric conditions that produce the greatest ground level concentrations.

It was also necessary to define emission rates for NO and NO₂ that represent a 24-hour average NO_x emission concentration of 1000 mg/Nm³. Using the NO:NO₂ molar ratio of 30:46, a NO_x emission concentration of 1000 mg/Nm³ is equivalent to a NO emission concentration of 652 mg/Nm³. As shown in Table 24, NO₂ emission concentrations are typically less than 1% of NO emission concentrations, and therefore an NO₂ emission concentration of 6.5 mg/m³ was assumed. This assumed emission concentration was greater than the 99.8th percentile of the measured NO₂ emission concentrations and is therefore considered to be conservative. The NO emission concentration was then reduced to 648 mg/Nm³ so that the total NO (as NO₂) + NO₂ concentration did not exceed 1000 mg/Nm³.

Dispersion models use mass emission rates as input data, rather than concentrations. Therefore a representative but conservative gas flow rate must be assumed. Based on the analysis of stack gas flow rate in Section 4.6.1, the emission concentrations defined for the model scenarios were multiplied by the 90th percentile stack gas flow rate of 200 Nm³/s (10% O₂). The 90th percentile was considered to represent a compromise between overstating the emission rates (due to using a flow rate which is very high) and

understating the potential peak ground level concentrations in the unlikely event that the maximum emission rate coincides with worst case meteorology. It is noted that even selecting the 99th percentile flow rate of 211 Nm³/s (10% O₂) would have made only a 5% difference to the calculated emission rates.

The specified NMHC concentration of 40 ppm needed to be converted to a mass basis for the dispersion model. A concentration of 40 ppm at standard temperature and pressure is equivalent to 64.3 mg/Nm³ assuming a molar weight of 36 g/mol (C₃).

The resultant 1-hour emission rates used in the dispersion model for the No.6 Kiln Stack for TSP, NO_x and NMHC are listed in Table 31. These emission rates were assumed to apply continuously, i.e. 365 days per year, 24 hours per day.

When comparing Table 31 with earlier Table 26, it is apparent that this method of assuming a near-worst case 1-hour emission concentration and a near-worst case gas flow rate results in very conservative estimates of 1-hour emission rates. For NO, the assumed 1-hour emission rate exceeds the actual maximum measured 1-hour emission rate. For NO₂, TSP and NMHC, the assumed 1-hour emission rate exceeds the actual 99.98th, 99.2nd, and 97.5th percentile measured emission rates respectively.

Table 31: Calculated No.6 Kiln Stack mass emission rates for dispersion model for NO_x, TSP and NMHC, based on concentrations specified as a 24-hour average. Emissions assumed to occur continuously, every hour of the year.

	Units	NO	NO ₂	TSP	NMHC
Specified emission concentration	24-hour average, mg/Nm ³ at 10% O ₂	648	6.5	50	64.3
Peak-to-mean ratio to calculate equivalent near worst-case 1-hour average for dispersion model		1.20	1.39	1.37	1.37
Representative emission concentration, 1-hour basis	1-hour average, mg/Nm ³ at 10% O ₂	778	8.9	68.5	88.1
Gas flow rate	Nm ³ /s 10% O ₂	200	200	200	200
Mass emission rate	g/s	156	1.78	13.7	17.6

4.8.2 Other Emission Rates for Kiln 6 Stack

Emission rates for other pollutants potentially discharged from the Kiln 6 stack were calculated based on the emission concentration limits in the current EPL. No changes to these limits are proposed by Boral Cement. The emission concentrations were multiplied by the assumed constant gas flow rate of 200 Nm³/s (10% O₂). The resultant mass emission rates are summarised in Table 32. These emission rates were assumed to apply continuously, i.e. 365 days per year, 24 hours per day.

For the heavy metals, assumptions about individual emission rates were necessary because the EPL specifies only cumulative metal emission limits whereas an air quality impact assessment requires individual emissions. For cadmium and thallium, for which the cumulative emission limit in the EPL is 0.05 mg/Nm³, each metal was assumed to have an emission concentration of 0.025 mg/Nm³. For all other metals defined in the "hazardous substances" list, for which the cumulative emission limit in the EPL is 0.5 mg/Nm³, each was assumed to have an emission concentration of ten times the maximum concentration measured over

2011-2014 as shown in Table 20. This assumption was also applied to emissions of copper, and hexavalent chromium.

For PAH emissions, there is no current EPL emission limit. The PAH emission concentration for dispersion modelling was therefore assumed to be ten times the maximum concentration measured over 2011-2014 as shown in Table 23.

The calculated mass emission rate for SO₂ for the dispersion modelling is 10 g/s. This is higher than the 99.9th percentile highest measured concentration from the continuous monitoring data shown in Table 26.

Table 32: Assumed emission rates for dispersion model for heavy metals and other trace pollutants in Kiln 6 Stack. Emissions assumed to occur continuously, every hour of the year.

Contaminant	Assumed emission concentration for dispersion model, mg/Nm ³ (10% O ₂)	Calculated emission rate (g/s) with gas flow rate of 200 Nm ³ /s (10% O ₂)
Sulfur dioxide	50	10
Sulfuric acid mist and/or sulfur trioxide	100	20
Arsenic	0.006	0.0012
Beryllium	0.006	0.0012
Cadmium	0.025	0.005
Cobalt	0.015	0.003
Chromium	0.04	0.008
Copper	0.13	0.026
Mercury	0.05	0.01
Manganese	0.71	0.142
Nickel	0.078	0.0156
Lead	0.06	0.012
Antimony	0.15	0.03
Selenium	0.029	0.0058
Thallium	0.025	0.005
Vanadium	0.024	0.0048
Tin	0.06	0.012
Hexavalent chromium	0.025	0.005
Chlorine	200	40
Hydrogen chloride	10	2
Hydrogen fluoride	1	0.2
PAHs as BaP-TEQ	0.000068 (68 ng/Nm ³)	1.36 x 10 ⁻⁵
Dioxins and Furans as I-TEQ	0.0000001 (0.1 ng/Nm ³)	2 x 10 ⁻⁸

4.8.3 TSP Emission Rates for Other Stacks

The TSP emission rates assumed for the Kiln 6 Cooler stack and the two Cement Mills were not based on the concentration limits in the EPL because this would have grossly overestimated TSP emissions from the Kiln 6 Cooler stack and the vent from Cement Mill 6. Instead, for those two sources a TSP concentration of ten times the maximum measurement concentration from 2011-2014 was assumed (excluding the single outlier concentration measured in the Cooler stack in 2014). For the vent from Cement Mill 7, the more conservative EPL limit concentration of 20 mg/Nm³ was assumed.

These assumed concentrations were multiplied by the average gas flow rates measured in the annual testing campaigns in 2011-2014 to calculate a mass emission rate. These calculations are shown in Table 33.

The emission rates were assumed to apply continuously, i.e. 365 days per year, 24 hours per day.

Table 33: Assumed TSP emission rates for Cooler Stack and Cement Mills. Emissions assumed to occur continuously, every hour of the year.

Source	Assumed TSP emission concentration for dispersion model, mg/Nm ³ (see text for explanation of basis of assumptions)	Average flow rate from annual campaign testing, Nm ³ /min	Calculated TSP emission rate (g/s)
Kiln 6 Cooler	39	2562	1.7
Cement Mill 6	42	1314	0.92
Cement Mill 7	20	815	0.27

4.8.4 PM₁₀ and PM_{2.5} Emissions

Emission rates of PM₁₀ and PM_{2.5} for the dispersion model were determined by multiplying an assumed composition percentage by the total TSP emission rate for each of the four TSP discharge sources. For the Kiln 6 stack, the assumed composition percentages for both PM₁₀ and PM_{2.5} were based on the measured data reported in Table 16; PM₁₀ emissions were assumed to be 70% of TSP, and PM_{2.5} emissions were assumed to be 33% of TSP.

For the Kiln 6 cooler stack, PM₁₀ and PM_{2.5} emissions were assumed to be 76% and 40% of TSP respectively, based on the AP42 data described in Section 3.2.2. No test data from the Berrima Works is available for comparison.

For the two cement mill vents, PM₁₀ emissions were assumed to be 100% of TSP in the absence of any test data or AP42 data. PM_{2.5} emissions were assumed arbitrarily to be 40% of PM₁₀ emissions.

PM₁₀ and PM_{2.5} emission rates are summarised in Table 34. These emission rates were assumed to apply continuously, i.e. 365 days per year, 24 hours per day.

It is noted that the assumed PM₁₀ and PM_{2.5} emission rates for the Kiln 6 Stack are significantly higher than emission rates measured in the annual campaign testing in 2011-2014 (refer Table 16).

Table 34: Assumed PM₁₀ and PM_{2.5} emission rates for all stacks. Emissions assumed to occur continuously, every hour of the year.

Source	TSP emission rate, g/s	Percent of TSP that is PM ₁₀	Percent of TSP that is PM _{2.5}	PM ₁₀ emission rate, g/s	PM _{2.5} emission rate, g/s
Kiln 6 Stack	13.7	70%	33%	9.6 (35 kg/hr)	4.5 (16 kg/hr)
Kiln 6 Cooler	1.7	76%	40%	1.3	0.68
Cement Mill 6	0.92	100%	40%	0.92	0.37
Cement Mill 7	0.27	100%	40%	0.27	0.11

5 Emission Rates and Discharge Parameters – Fugitive Sources

5.1 Odour

The magnitude of the odour emission is expected to be minor based on advice provided to Boral Cement by other cement manufacturers already using SWDF, such as Adelaide Brighton Cement in South Australia (refer correspondence detailed provided in Section 8.11).

Boral has advised that the ventilation design of the storage building will be to have one door in the building open at a time, with passive ventilation only (no mechanical fans). If there is any odour in the building air, that odour may escape through the open door or from any other openings within the building. Odour is therefore considered to be a fugitive source.

No data on likely odour concentrations and emission rates from the building is available. Therefore a preliminary estimate of odour emission rate was developed by assuming a building odour concentration and a ventilation rate.

TOU (2013) provides an assessment of fugitive odour emissions expected from a waste-to-energy facility. The reference provides information on odour concentrations measured in waste transfer stations. Data is provided for a naturally ventilated waste transfer station (WTS) in the Perth Metropolitan Area that described as *“accepts both municipal solid waste and commercial/industrial waste streams from council trucks and the public at a volume of up to 55,000 tonnes per annum”*. This mass of influent waste is about half of the total wood waste, AKF5 and RDF waste proposed to be used at the Works (up to 100,000 tpa, see Table 2). TOU (2013) describes that the Perth WTS is naturally ventilated on all four sides allowing a constant flow of ambient wind which strips the odours from the tipping floor. Odour concentrations measured in 2009 at a downwind opened doorway on nine separate occasions ranged from 69 OU to 256 OU.

A second WTS example is also provided in TOU (2013). The second dataset represents an extremely large WTS in Metropolitan NSW. This WTS is described as *“accepts up to 400,000 tonnes per annum of MSW with at least 300 tonnes of waste remaining on the WTS floor daily. The waste is delivered via council rubbish collection and other commercial waste streams. It is stored inside the WTS where it is loaded into outgoing semi-trailers for landfill. The NSW tipping floor is under forced ventilation extraction.”* Reported measured concentrations in the extracted air were in the range of 320 – 2400 OU, with most measurements <1000 OU.

Neither the Perth nor the NSW WTS example precisely reflect the ventilation arrangement anticipated in the new SWDF storage building at the Works site. However based on these examples an assumed odour concentration somewhere in the range from 100 to 1000 OU seems reasonable.

The building air leakage rate has been estimated by assuming an air flow of 0.2 m/s from a doorway opening of 16 m² (4m x 4m) giving an air flow of 3.2 m³/s. For a building of size 50 x 33 x 13m, this represents an air flow of 1.9 building air exchanges per hour based on an empty building volume, or higher air exchanges per hour if only the free air space in the building is used for the calculation. These are exchange rates are considered to be of the correct order for a passively ventilated building.

These parameters are preliminary estimates and are not based on specific building design data, however they suit the purpose of estimating a conservative odour emission rate that can be used in the dispersion model to check the potential for off-site odour impacts and whether further investigation of emission rates is required.

At a concentration of 1000 OU and a flow rate of 3.2 m³/s, the odour emission rate from the storage building would be 3200 OU.m³/s. This is equivalent to the odour emission from a pond of 320m² containing municipal wastewater that is in anoxic or anaerobic condition (i.e. at an odour emission rate of about 10 OU.m³/m²/s). In real terms, odour from the SWDF storage building is not anticipated to be as odorous as such as pond. Thus the odour emission rate of 3200 OU.m³/s would appear to be a conservative estimate of likely odour emission rates from the storage building.

The emission from the storage building was assumed to be located at the position of the orange cross symbol shown on Figure 7. The dispersion model is not sensitive to small changes in this position.

5.2 Dust

5.2.1 Sources and methodology for emission rate development

Fugitive dust emission rates were determined individually for each of the following activity categories:

- Stockpiles of bulk dry materials, unpaved roads and dusty surfaces in stockpile areas and quarry
- Loaders generating dust from vehicle tracks
- Movement and dumping of materials
- Crushing and mixing of materials prior to kiln processing

Particulate fractions that may be discharged from these fugitive dust sources are mainly TSP and PM₁₀, although some PM_{2.5} can also be discharged.

The NPI Guide for Mining 2012 (NPI, 2012) states that PM_{2.5} is only reportable for combustion sources and other potential sources including stockpiles and road surfaces are excluded, and therefore there are no emission factors for PM_{2.5} in NPI (2012). However, the United States EPA does recommend emission factors for PM_{2.5} from such fugitive dust sources, with a nominal emission factor of 15% of PM₁₀ for material handling and wind erosion and 10% of PM₁₀ for vehicle tracked emissions (USEPA 2006a, 2006b, 2006c, 2006d). PM_{2.5} emission rates for fugitive sources were determined based on the PM_{2.5}:PM₁₀ ratios described above.

For each activity category, preliminary TSP and PM₁₀ emission rates were determined based on the assumptions and methods described below. The model results from these preliminary emission estimates were then compared with TSP and PM₁₀ concentrations measured at the Berrima AQMS under similar wind conditions, and the source emission rates were scaled as necessary so that the model was calibrated to the measured ambient air quality data. Only scaling of wind erosion emission rates was required.

5.2.2 Stockpiles and Dusty Surfaces

Dust emissions from stockpiles and dusty surfaces were allocated in proportion with the cube of the wind speed. Assumptions and method of calculation were as follows:

- Stockpile areas determined from aerial photograph on nearmap dated 22 May 2014 and Surfer program from Golden Software, combined with observations from AirQP site visit on 19 March 2015. Areas designated as stockpiles, dusty surfaces, and major unsealed roads are identified in Figure 7 and listed in Table 35.
- Annual average dust emission rates for each of the areas were calculated by assuming the default emission factors from NPI (2012):
 - Stockpiles have an average TSP emission rate of 0.4 kg/ha/hr and PM₁₀ emission rate of 0.2 kg/ha/hr. To be conservative, no control efficiency due to wind sheltering or watering is applied.
 - Dusty flat surfaces also have the same average TSP and PM₁₀ emission rates, but are reduced by a control efficiency of 30% due to some wind sheltering due to stockpiles and trees plus some sweeping and water spraying.
 - Stockpiles covered by tarpaulins have no dust emission rate.
- Dust emissions on an hourly basis were then assigned in proportion to the cube of the wind speed so that the total for the year equated to the annual average dust emission rate.
- Each area was then assigned to one of six sources for the dispersion model also shown on Figure 7 as black polygons labelled S1 to S6, and the emissions from each area included within each source was summed for each hour. Geometric areas of each of the six sources are summarised in Table 36.
- Dust emissions from the southern half of the quarry (below the area marked “15” on Figure 7) were assumed to be either negligible compared with other dust sources due to the deep pit and the infrequent operation of the quarry (approximately once per week), or included within the conservatism applied to the calculation of other dust emissions.
- Rainfall was not assumed to reduce dust emissions.
- After comparison of the preliminary fugitive dust model result for TSP, it was concluded that TSP emissions from wind erosion sourced needed to be increased by a factor of 8 so that the model was calibrated against the Berrima AQMS data. This is discussed in Section 8.3.2.
- After comparison of the preliminary fugitive dust model result for PM₁₀, it was concluded that PM₁₀ emissions from wind erosion sourced needed to be increased by a factor of 1.9 so that the model was calibrated against the Berrima AQMS data. This is also discussed in Section 8.4.2.



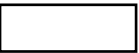
	Stockpile area mixing/crushing		Location of fugitive dust emission from
	Dusty surface but not stockpile storage		Location of fugitive odour emission from SWDF
	Stockpile covered with tarpaulin		Location of fugitive dust transfer point
	Source for dispersion model		

Figure 7: Location of fugitive dust and odour sources used in dispersion model

Table 35: List of areas defined as fugitive dust sources for dispersion model (refer also Figure 7)

Area label	Description	Geometric area (m ²)
1	Stockpile	2,372
2	Stockpile	5,712
3	Stockpile	3,875
4	Stockpile	3,045
5	Stockpile	2,298
6	Stockpile	952
7	Stockpile	3,652
8	Stockpile	2,488
9	Stockpile	7,976
10	Stockpile	6,842
11	Stockpile	3,944
12	Stockpile	5,686
13	Stockpile	2,862
14	Dusty flat surface (not stockpile)	48,401 total, less stockpiles
15	Dusty flat surface (not stockpile)	59,923 total, less stockpiles
16	Dusty flat surface (not stockpile)	13,369 total, less stockpiles
17	Dusty flat surface (not stockpile)	18,695 total, less stockpiles
18	Stockpile covered in tarpaulin	2,665
19	Stockpile covered in tarpaulin	646

Table 36: List of areas defined as fugitive dust sources for dispersion model (refer also Figure 7)

Source name	Geometric area, m ²	Percentage of total area S1-S6
S1	29,750	24%
S2	38,931	31%
S3	22,380	18%
S4	12,266	10%
S5	3,944	3%
S6	17,874	14%

5.2.3 Vehicle-Generated Tracked Dust

Data for vehicles generated tracked dust was provided by Boral from the site dust inventory reported to NSW EPA in 2013. Vehicle-tracked dust emissions were assumed to be independent of wind speed, in accordance with NPI (2012). Assumptions and method of calculation were as follows:

- Dust is generated by 2 loaders. One tractor also operates although the hours of operation are minor. Other vehicles are insignificant in comparison. In the 2013 dust inventory prepared by Boral, loader 972H worked 3020 hours in the 2013 year, loader 980H worked 2080 hours, and the tractor worked 288 hours.

- One loader (972H) works 24 hours per day, the other loader (980H) only works between 6am and 6pm (i.e. two loaders during the day, and one loader during the night). Vehicles are assumed for the model to operate continuously within these hours, although this is not the case in reality. Due to the conservatism in this assumption, the tractor was not assumed to operate for the dispersion model.
- Emission factor for TSP uses default values from NPI (2012) of 4.23 kg/VKT (vehicle kilometre travelled). Default emission factor for PM₁₀ is 1.25 kg/VKT.
- Average travel distance per hour for each loader was assumed to be arbitrarily 1 km. There is some uncertainty in this assumption, so an alternative scenario with the average travel distance being 5 km per hour per vehicle was also tested. However the latter scenario provided high TSP concentrations at the Berrima AQMS that are not matched by monitoring data, so that scenario was concluded to be invalid.
- To be conservative, no reduction in dust emissions for surface sweeping, tanker watering, or rainfall was applied.
- The total emission rate per hour was divided between the six fugitive sources for the model in proportion with surface area (as listed in Table 36).

5.2.4 Movement and Dumping of Materials

Data for dust generated by movement of materials was provided by Boral from the site dust inventory reported to NSW EPA in 2013. Vehicle-tracked dust emissions were assumed to be independent of wind speed, in accordance with NPI (2012). Assumptions and method of calculation were as follows:

- Transfer points refer to fugitive emissions from galleries and towers, and total emissions equate to 2,801 kg/yr for TSP and 1,313 kg/yr for PM₁₀. This includes a 70% applied control efficiency since the transfer points are enclosed. To derive an average hourly emission rate, these transfer points were assumed to operate for 90% of the time giving emission rates of 0.355 kg/hr for TSP, and 0.167 kg/hr for PM₁₀. These emissions were then assumed to be divided evenly between two separate fugitive volume sources as shown by the blue crosses on Figure 7. For the dispersion model, these sources were assumed to operate for 100% of the time. Dimensions for the sources were based on the two transfer points shown in Figure 8.
- Dust from excavators/shovels/front-end loaders on material and dumping was estimated by Boral to equate to 32,894 kg/yr for TSP and 14,132 kg/yr for PM₁₀. These total figures were divided by the total hours of operation of the front end loaders and tractor, being 5388 hours in 2013, to give a typical hourly emission rate of 6.11 kg/hr for TSP and 2.62 kg/hr for PM₁₀. Two vehicles were assumed to be operating during the hours of 6am to 6pm, each at this discharge rate, and one vehicle outside those hours. The total emission rate per hour was finally divided between the six fugitive sources for the model in proportion with surface area.

Loading of clinker and cement onto trains and trucks is carried out in an enclosure with dust control, and Boral has estimated residual fugitive dust emissions to be negligible.



Figure 8: Location of two transfer point sources included in the dispersion model (with the emission from these two sources representing the emissions from all transfer points).

5.2.5 Crushing

Crushing of raw materials is carried out in an enclosed building with emissions control. Residual fugitive dust emissions are estimated by Boral Cement to be 897 kg/yr for TSP, and 90 kg/yr for PM₁₀. To derive an average hourly emission rate, crushing was assumed to operate for 90% of the time giving emission rates of 0.11 kg/hr for TSP, and 0.011 kg/hr for PM₁₀. These emissions were then assumed to be discharged from a single fugitive volume source as shown by the yellow cross on Figure 7. For the dispersion model, this source was assumed to operate for 100% of the time.

6 Description of Local Environment

6.1 Topography

Topographical elevation data over the region around Berrima is shown. The Berrima region is flanked by hills on all sides within about 10-20km of the Works. These hills rise to an elevation of about 60-130m above local ground level at the cement works (which is about 675m above mean sea level). The Australian coastline is 50km to the east of the Works.

The Works site itself is flat, and the immediate surrounding area is characterised by gently rolling shallow hills and valleys with some flat areas.



Figure 9: Topographical map of region around Berrima Works.

6.2 Land Use

The property owned by Boral Cement around the Berrima Works is shown in Figure 10.



Figure 10: Land owned by Boral Cement around Berrima Works, March 2015.

Figure 11 shows the land use zonings around the Berrima Works site⁶ with the properties owned by Boral Cement indicated. The Works site is zoned “Heavy Industrial” and “General Industrial” and is adjoined by other land zoned “General Industrial”, “Rural Landscape” and “Environmental Management”. The closest residential zone is located in New Berrima, with the boundary of the residential zone being about 650m north from the No.6 Kiln Stack at the closest point. Residential zones are also located in Berrima, at least 2150m north of the No.6 Kiln Stack.

The Berrima sewage treatment plant is located to the west of New Berrima, on property adjacent to that owned by Boral Cement as marked on Figure 11.

The New Berrima residential zones are flanked to the south and east by “Private Recreation” zones. The Private Recreation zone to the south of New Berrima is on the south side of the main road, Taylor Avenue, and is owned by Boral Cement. The land is landscaped with grass and mature trees which screen the works from the road. This land is not considered to be sensitive to air quality impacts from the Works.

⁶ From, Wingecarribee Local Environment Plan 2010, Land Zoning Maps LZN_007B and LZN_007C. Downloaded from <http://www.wsc.nsw.gov.au/development/local-environmental-plans/wingecarribee-local-environmental-plan-2010/index-of-wlep-2010-maps/land-zoning-minimum-lot-size-maps>, 29 Feb 2012.

The explanation of land uses allowed in the Private Recreation zone with or without development consent, according to the Wingecarribee Local Environment Plan 2010 (Part 2, Land Use Table), is as follows:

Zone RE2 Private Recreation

1 Objectives of zone

- To enable land to be used for private open space or recreational purposes.
- To provide a range of recreational settings and activities and compatible land uses.
- To protect and enhance the natural environment for recreational purposes.

2 Permitted without consent

Environmental protection works; Extensive agriculture; Home-based child care; Home occupations

3 Permitted with consent

Airstrips; Aquaculture; Camping grounds; Caravan parks; Cellar door premises; Child care centres; Community facilities; Educational establishments; Entertainment facilities; Environmental facilities; Farm buildings; Flood mitigation works; Food and drink premises; Function centres; Helipads; Kiosks; Markets; Places of public worship; Recreation areas; Recreation facilities (indoor); Recreation facilities (outdoor); Registered clubs; Respite day care centres; Roads; Roadside stalls; Signage; Tourist and visitor accommodation; Water storage facilities

4 Prohibited

Any development not specified in item 2 or 3

It is taken therefore that persons could carry out recreational activities within the “Private Recreation” zone to the east of New Berrima, but it is assumed for the purposes of the air impact assessment in this report that people would not carry out residential dwelling and sleeping activities in this zone.

The circles on Figure 12 are not purported to be an exhaustive inventory of dwelling and non-residential/industrial site locations – nevertheless they are representative of the spread of dwellings and potentially sensitive locations around the Berrima Works site. These locations were used as “discrete receptor” locations for dispersion model predictions (further information provided in Section 7.5.1).

It is noted that a number of houses are present in the General Industrial Zone between the Berrima Works and Mossvale (which is at the southeast corner of Figure 12).

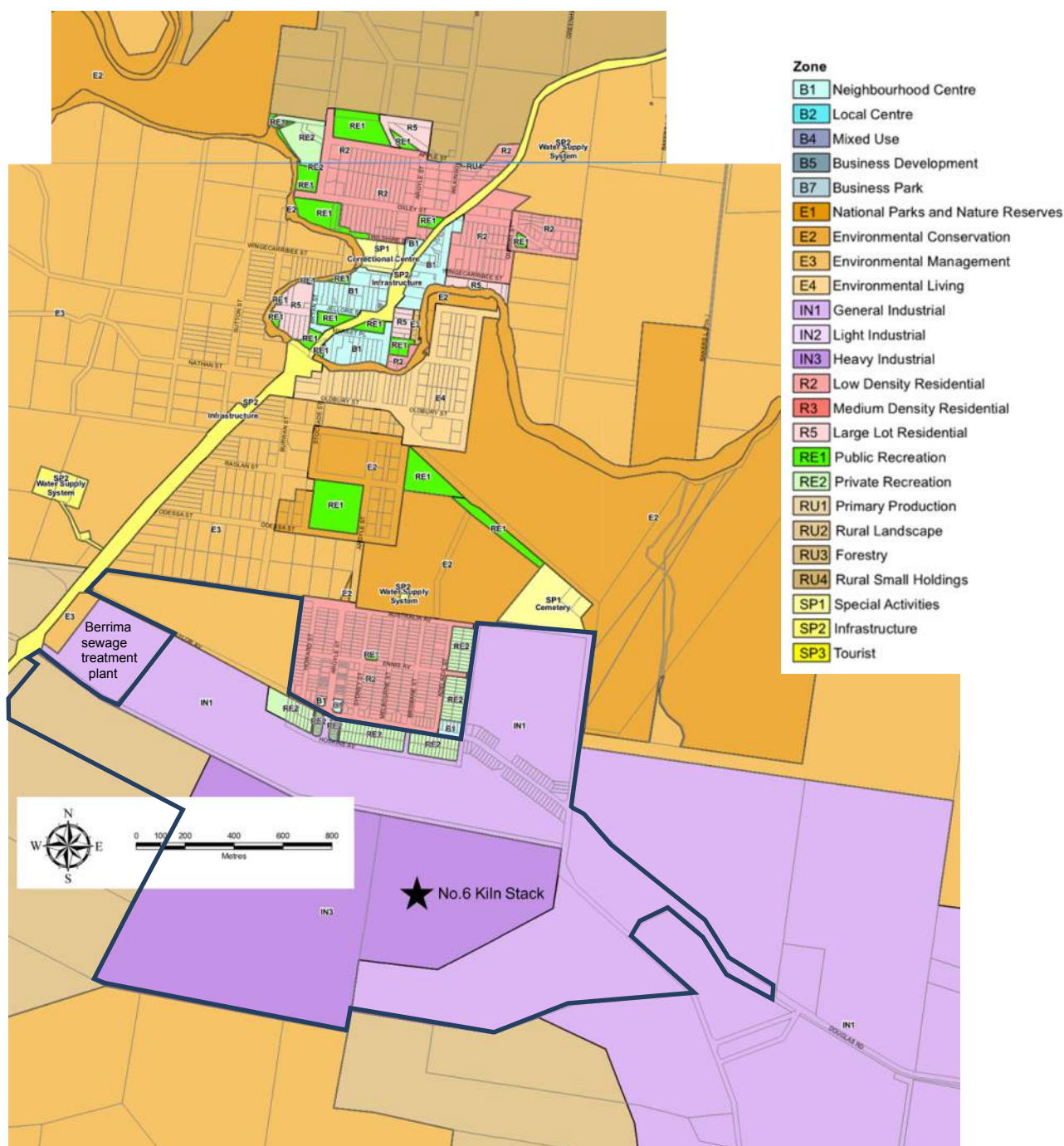


Figure 11: Land Use Zones around Berrima Works. Heavy blue line shows boundary of land owned by Boral Cement (as of March 2015).

Figure 12 shows the location of the Works, relevant land use zones, nearby houses and non-residential developments. The aerial image is from nearmap, dated 22 May 2014.

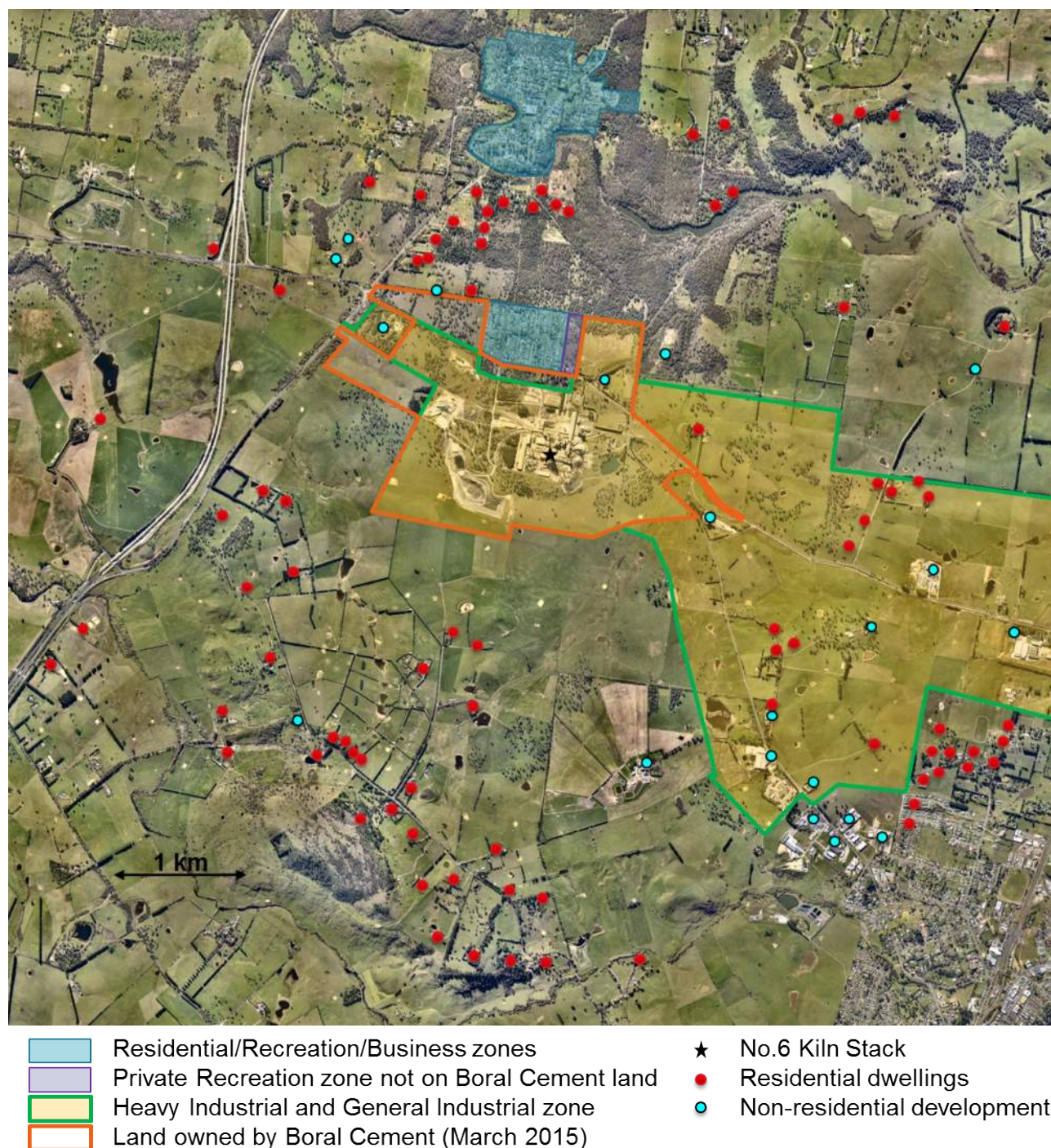


Figure 12: Berrima Works location and surrounding dwelling locations (red circle = dwelling or building where use and occupancy is unclear; yellow circle = non-residential development). Image from nearmap, aerial flown 22 May 2014.

6.3 Meteorology

Boral Cement operates an ambient air quality monitoring station (AQMS) beyond the site boundary. Meteorological data is recorded continuously, and TSP, PM₁₀ and heavy metals are recorded on a “one-day-in-six” basis. The meteorological data is described in this section. The ambient monitoring results for air quality are described in the following section.

The monitoring station is located 790m to the east of the No.6 Kiln Stack, in pasture land. The location is shown in Figure 13, and the station itself is shown in Figure 14.



Figure 13: Location of ambient monitoring site. Image from nearmap.



Figure 14: Ambient air quality monitoring station (AQMS). Photo taken 19 March 2015.

A windrose of wind speeds and directions from the monitoring site for January 2010 - December 2014 is shown in Figure 15. The windrose features a prevalence of winds from the west and west-northwest direction, and also from the north-northeast and southwest directions. The site also shows a relatively frequent occurrence of calm or very light winds. Windroses for individual years 2010 – 2014 are attached in Appendix 1 along with a graphical comparison of wind speed frequencies for each year.

Each of the Berrima windroses is annotated with a statistic for “missing or calm” data. It was not possible to distinguish between missing data records and calm data records. This problem was most pronounced in 2011 and 2012 when 27% and 32% respectively of the hourly data records were “missing or calm”, and least pronounced in 2013 and 2014 when only 8% and 4% respectively of the data was thus affected.

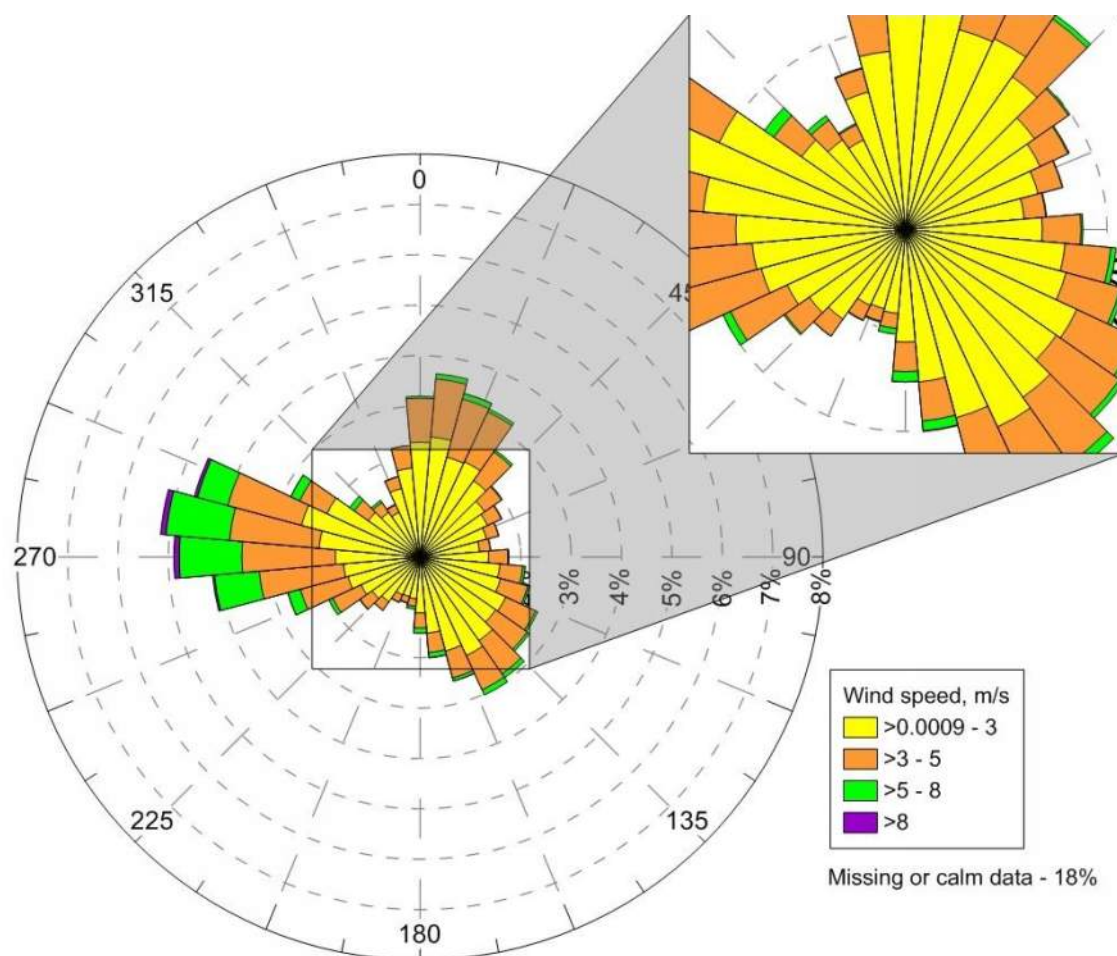


Figure 15: Windrose of meteorological monitoring data for Berrima site; January 2010 – December 2014, data recorded at 1-hour frequency.

6.4 Ambient Monitoring Data from AQMS

TSP, PM₁₀ and heavy metal concentrations contained within particulate are measured at the AQMS on a one-day-in-six basis. The measured concentrations of particulate include fine particulate matter naturally-occurring or generated from other industrial/agricultural/residential sources and bushfires, as well as particulate from both point and fugitive sources cement works.

6.4.1 Annual Average PM₁₀ and TSP

Annual average concentrations of PM₁₀ and TSP calculated from the 1-day-in-6 measured 24-hour average Berrima data are shown in Table 37. The annual average concentrations of TSP are less than half of the goal level of 90 µg/m³ set by NSW EPA (refer Section 7.6.2). The annual average concentrations of PM₁₀ are also less than (or equal to) half of the NSW EPA goal level of 30 µg/m³ (refer Section 7.6.1).

Table 37: Annual average PM₁₀ and TSP concentrations at Berrima monitoring site (calculated from 24-hour average data measured on a 1-day-in-6 basis).

Year	Annual average, PM ₁₀ µg/m ³	Annual average, TSP µg/m ³
2011	13.2	35.3
2012	13.7	42.1
2013	15.1	42.8
2014	11.0	37.6

6.4.2 24-hour Average PM₁₀ and TSP

Figure 16 shows the monitoring results for 24-hour TSP and PM₁₀ measured over the four year period from January 2011 to December 2014.

For most of the time, the measured 24-hour PM₁₀ concentrations (fraction of potential health significance) were below the national air quality standard for PM₁₀ which is 50 µg/m³ averaged over 24 hours. Figure 17 shows the cumulative distribution of measured concentrations. The graph shows that, for example, 80% of measured PM₁₀ concentrations were less than 20 µg/m³, and 96% of measured PM₁₀ concentrations were less than 36 µg/m³.

However there were a few occasions when the 24-hour average PM₁₀ concentration approached or exceeded the national standard – 18/10/13 (56 µg/m³), 24/9/13 (52 µg/m³), 30/8/12 (52 µg/m³), 10/12/11 (48 µg/m³), and 30/12/14 (46 µg/m³). The relative contribution of PM₁₀ discharges from the cement works versus other emission sources (industrial/agricultural/residential) cannot be determined from the ambient monitoring data alone. The figures in Appendix 3 show windroses for each of these five days (midnight to midnight) overlaid on an aerial photograph and centred on the AQMS location.

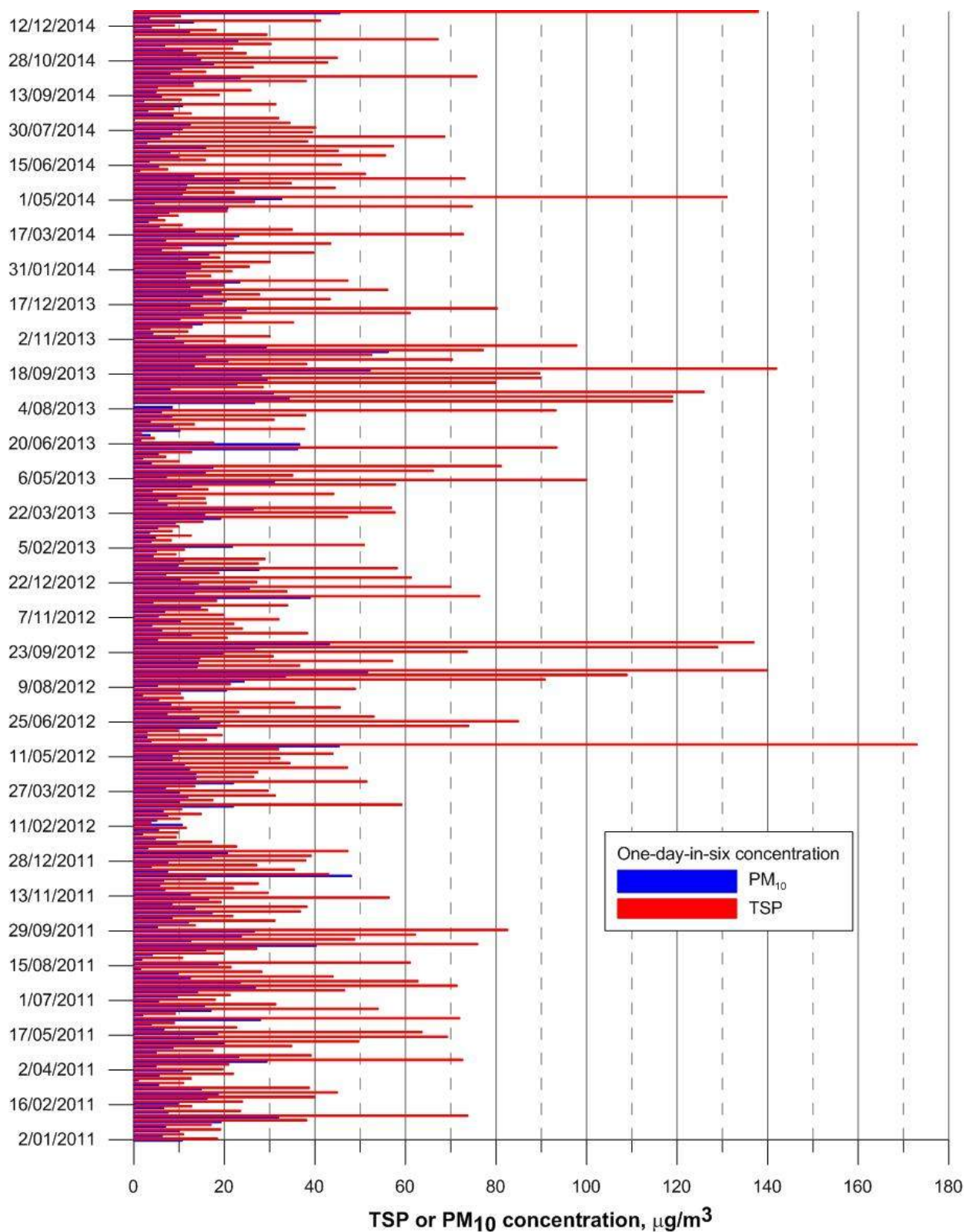


Figure 16: TSP and PM₁₀ ambient monitoring data (24-hour average, 1-day-in-6 sampling), from Berrima ambient monitoring station; 2 January 2011 to 30 December 2014.

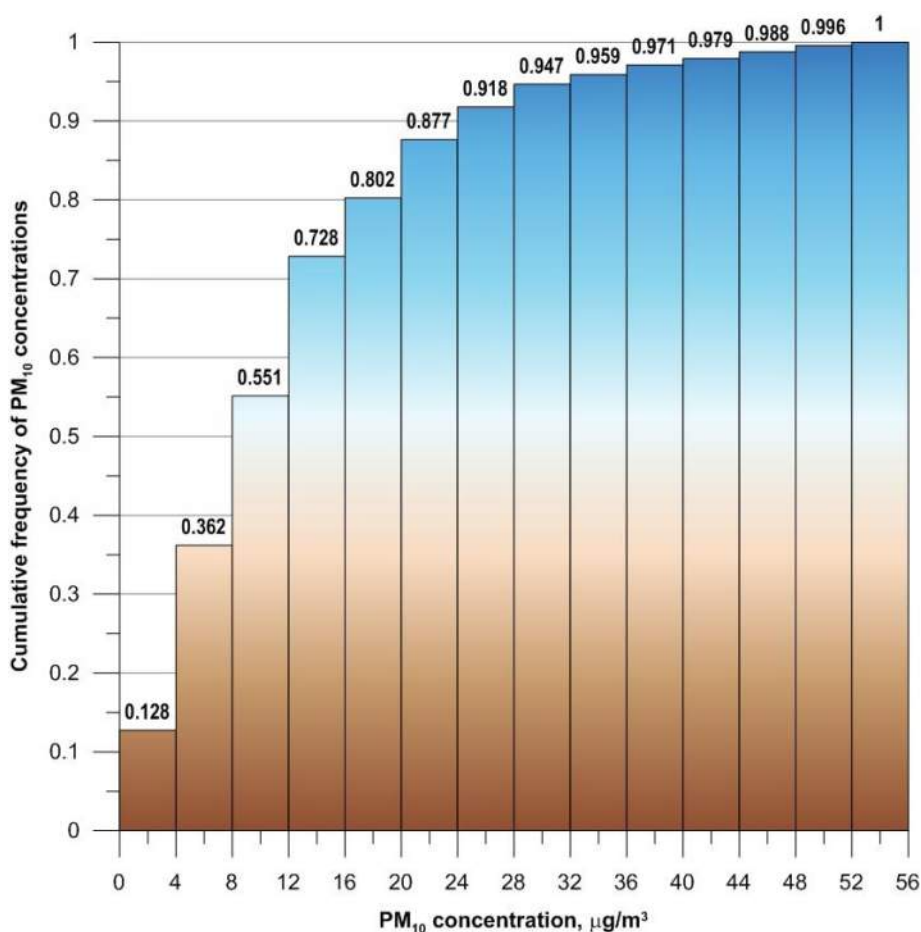


Figure 17: Cumulative frequency of PM₁₀ ambient monitoring data (24-hour average, 1-day-in-6 sampling), from Berrima ambient monitoring station; 2 January 2011 to 30 December 2014.

On two of these days (18/10/13 and 10/12/11) the wind was blowing consistently from the north-northeast and northeast or light and highly variable, and therefore it is very unlikely that the cement works was the main cause of PM₁₀ concentrations measured on those two days. Alternative sources of PM₁₀ are likely to have occurred. For example, there was a very large bushfire near Balmoral between the 17 and 20 of October 2013, just 20-30km from Berrima⁷. This is considered very likely to be the cause of the PM₁₀ concentration of 56 µg/m³ measured on that day. No data on bushfire activity on an around 10 December 2011 is currently available for a similar analysis.

On the other three days, the wind was blowing generally from the direction of the Works, with hourly average wind speeds in the 5-8 m/s bracket occurring. TSP concentrations were also elevated on those days, in the order of 140 µg/m³ on each occasion. It is considered likely that fugitive dust emissions from the Works would have contributed to the PM₁₀ and TSP concentrations measured on those days, with the wind speeds being favourable for fugitive dust pickup and transport. It is not known if activities with the potential to generate fugitive dust were operating normally at the Works on these days, or whether some factor related to these activities at the site contributed to the magnitude of dust emissions.

⁷ Bureau of Meteorology Annual Climate Summary Statement NSW for 2013.
<http://www.bom.gov.au/climate/current/annual/nsw/archive/2013.summary.shtml>

The 24-hour concentration data for TSP and PM₁₀ was broken down further to analyse the particulate concentrations as a function of wind direction and wind speed. The concentration data is reported only as a 24-hour average, so it is not possible to analyse direct correlations between concentration and wind speed and direction on a contemporaneous hourly basis. However, it is still possible to filter the concentration data for 24-hour average wind speed, and number of hours in the day when the wind was blowing from the direction of the Works (defined for the purpose of this analysis as winds in a direction from 240 degrees to 300 degrees).

Figure 18 and Figure 19 show the measured 24-hour average TSP and PM₁₀ concentrations over 2011-2014 graphed as a function of daily average wind speed when the Works was upwind of the AQMS for some or most of the day. The daily average wind speed was calculated from the 24 readings of hourly average wind speed recorded by the AQMS. In these two figures, only data recorded on days when at least 11 readings of hourly wind direction vector were blowing from the direction of the Works. The selection of 11 as the minimum number of hours per day when the Works was upwind of the AQMS was arbitrary, but the graph was insensitive to small variations to this number.

The figures show a general correlation between increasing particulate concentration (either TSP or PM₁₀) and increasing average wind speed. However there are some exceptions to this rule. It is noted that this analysis does not take into account site activities occurring on the day (and whether the Works was operating), dust mitigation activities (such as road sweeping or tank watering), and recent rainfall.

Figure 20 and Figure 21 show the measured 24-hour average TSP and PM₁₀ concentrations over 2011-2014 graphed as a function of daily average wind speed when the Works was not upwind of the AQMS for most of the day. The daily average wind speed was calculated from the 24 readings of hourly average wind speed recorded by the AQMS. In these two figures, only data recorded on days when 4 or less readings of hourly wind direction vector were blowing from the direction of the Works. The selection of 4 as the maximum number of hours per day when the Works was upwind of the AQMS was arbitrary, but again the graph was insensitive to small variations to this number.

This second pair of graphs shows an absence of correlation between increasing particulate concentration and increasing wind speed, indicating sources of particulate that are not associated with wind-blown dust. The graphs also show that whilst 24-hour average PM₁₀ concentrations occur to about the same magnitude whether the Works is upwind of the AQMS or not, the TSP concentrations are lower when the Works is not upwind of the AQMS.

Finally, Figure 22 and Figure 23 show the ratio of PM₁₀ to TSP concentration measured on days when the Works was upwind of the AQMS for some or most of the day, and on days when the Works was not upwind of the AQMS for most of the day. There is a marked relationship when the Works is upwind of the AQMS, with the PM₁₀ concentration being typically 20-40% of TSP and with no apparent correlation with average daily wind speed. However when the Works is not upwind of the AQMS, the PM₁₀:TSP ratio is highly variable ranging typically from 10% to 70%.

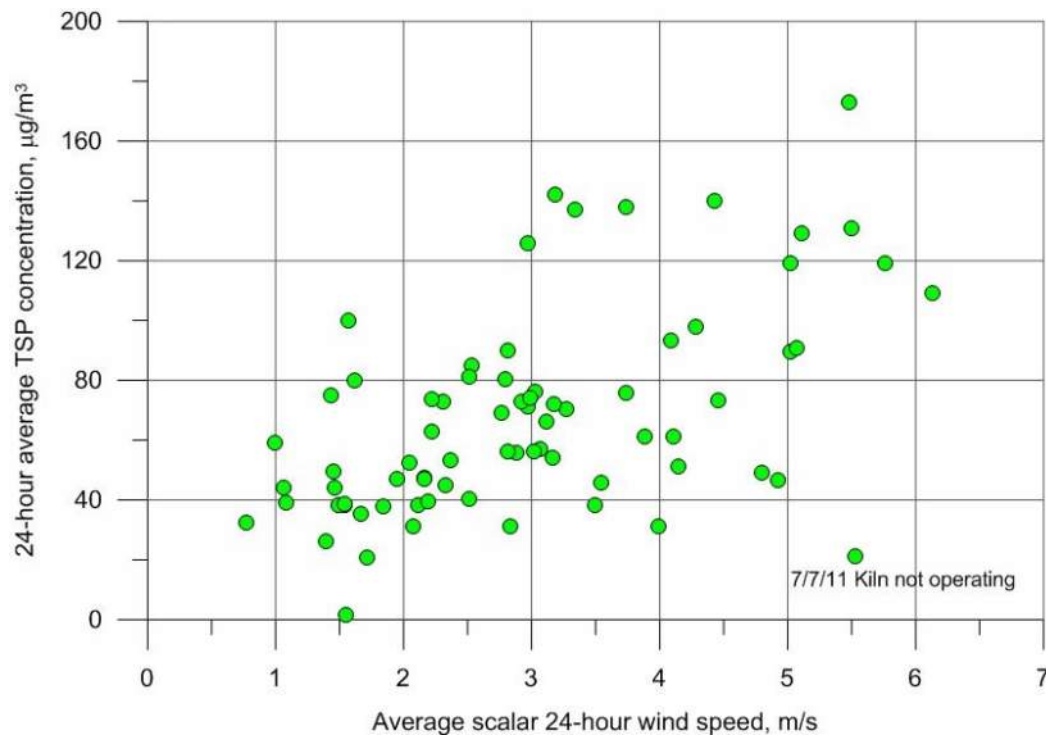


Figure 18: 24-hour average TSP concentration measured at AQMS (1-day-in-6 basis) as a function of daily average wind speed. Showing only days where the wind was blowing from the direction of the Works for at least 11 out of the 24 hours – i.e. Works upwind of AQMS for some or most of the day.

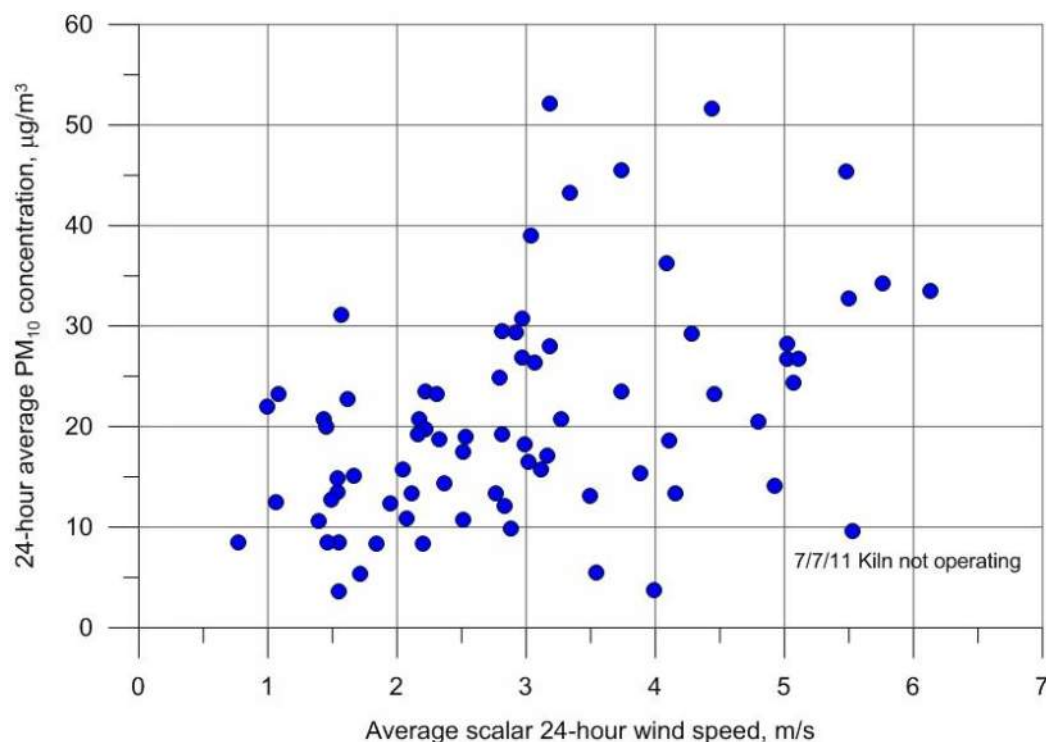


Figure 19: 24-hour average PM_{10} concentration measured at AQMS (1-day-in-6 basis) as a function of daily average wind speed. Showing only days where the wind was blowing from the direction of the Works for at least 11 out of the 24 hours – i.e. Works upwind of AQMS for some or most of the day.

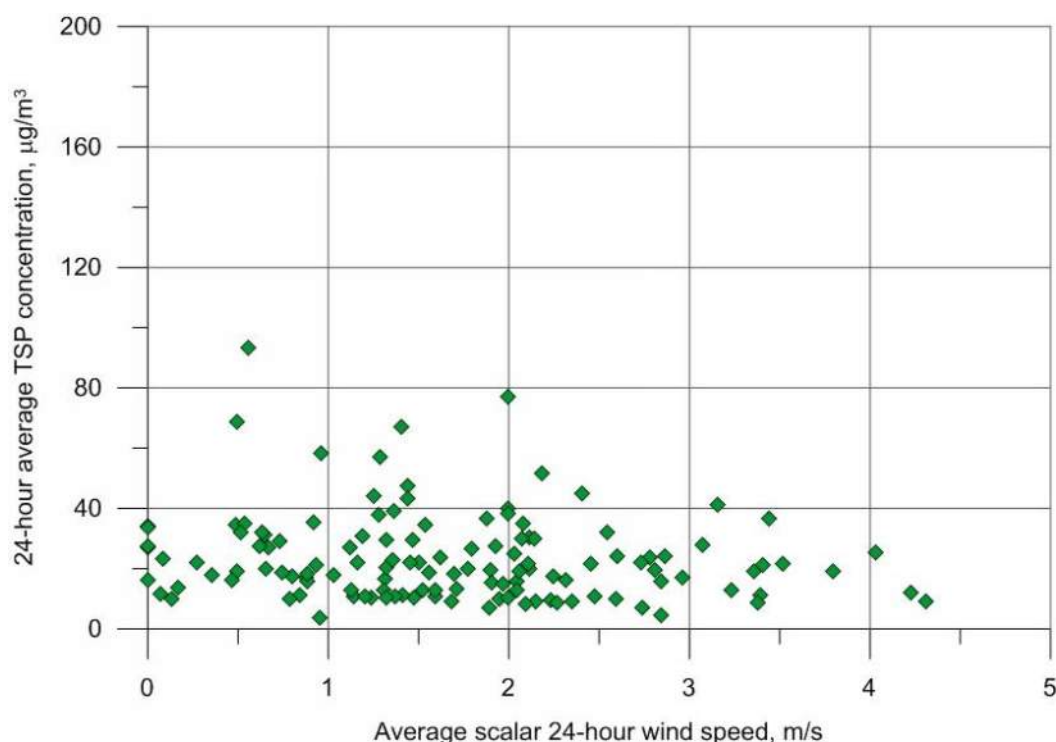


Figure 20: 24-hour average TSP concentration measured at AQMS (1-day-in-6 basis) as a function of daily average wind speed. Showing only days where the wind was blowing from the direction of the Works for no more than 4 out of the 24 hours – i.e. Works not upwind of AQMS for most of the day.

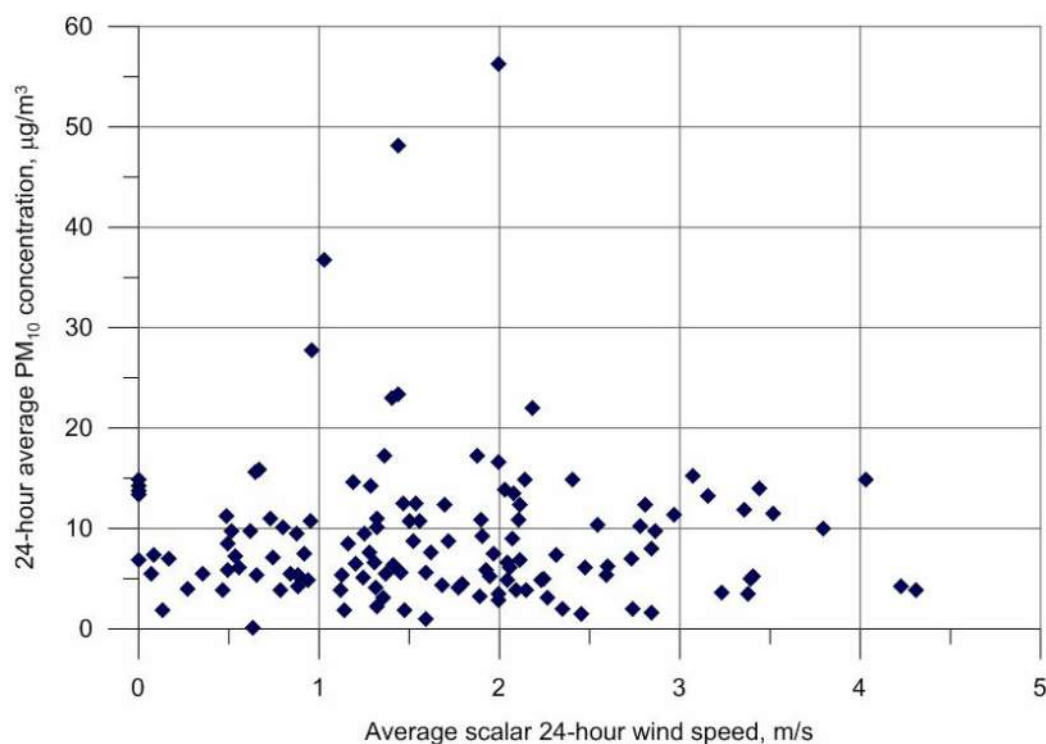


Figure 21: 24-hour average PM_{10} concentration measured at AQMS (1-day-in-6 basis) as a function of daily average wind speed. Showing only days where the wind was blowing from the direction of the Works for no more than 4 out of the 24 hours – i.e. Works not upwind of AQMS for most of the day.

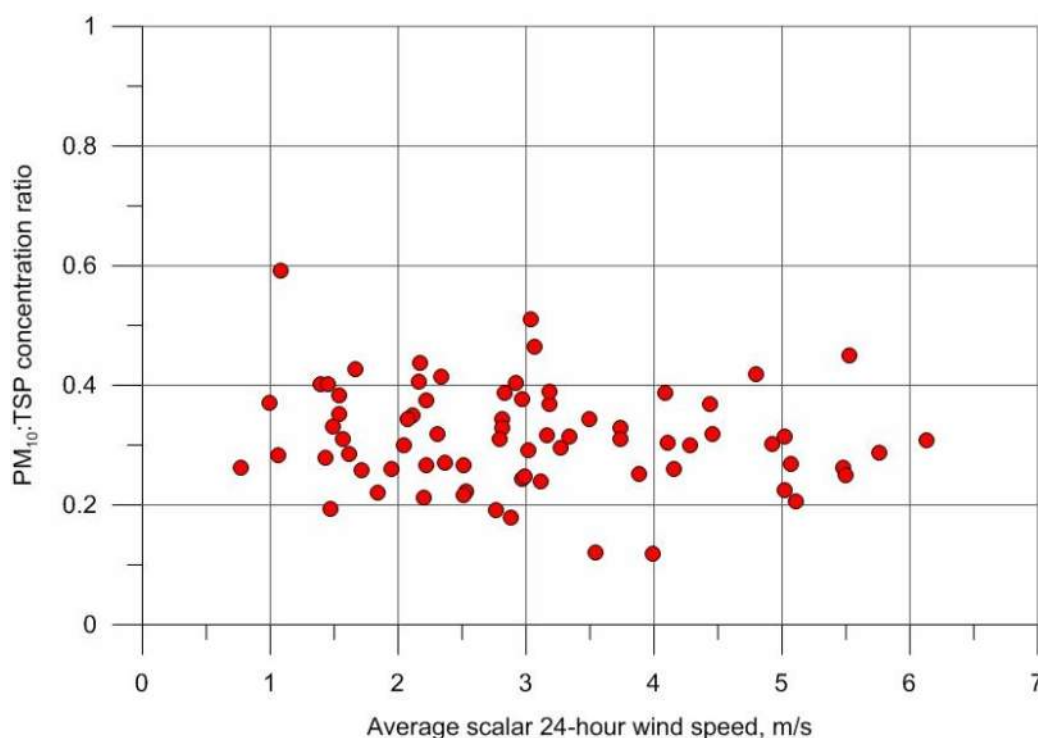


Figure 22: Ratio of PM₁₀ to TSP 24-hour average concentration measured at AQMS (1-day-in-6 basis) as a function of daily average wind speed. Showing only days where the wind was blowing from the direction of the Works for at least 11 out of the 24 hours – i.e. Works upwind of AQMS for some or most of the day.

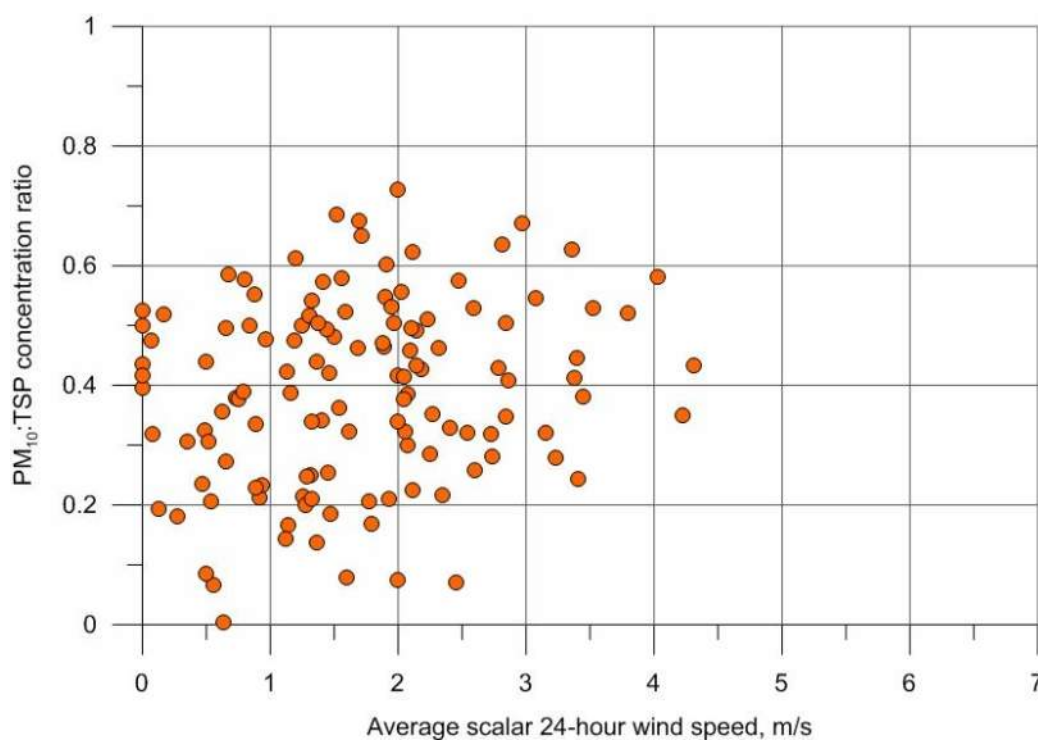


Figure 23: Ratio of PM₁₀ to TSP 24-hour average concentration measured at AQMS (1-day-in-6 basis) as a function of daily average wind speed. Showing only days where the wind was blowing from the direction of the Works for no more than 4 out of the 24 hours – i.e. Works not upwind of AQMS for most of the day.

6.4.3 Heavy Metals

The results of analysis of heavy metals within the particulate measured during the 1-day-in-6 AQMS monitoring programme are shown in Table 38. More discussion on the air quality threshold criteria sources listed in the table footnotes are provided in Section 7.6.5.

The test results were always well below the applicable air quality threshold criteria. In the case of arsenic, beryllium, cadmium, cobalt, nickel, selenium and mercury, the test results were always less than the method detection limit.

Table 38: Summary of results of heavy metal testing at AQMS, 2011-2014. 24-hour average concentrations measured in particulate during 1-day-in-6 testing programme.

Metal	Total number of tests, 2011-2014	Number of times the test result was higher than MDL	Concentrations when test result is higher than MDL ($\mu\text{g}/\text{m}^3$)			Air Quality Threshold Criteria
			Minimum measured concentration [§]	Maximum measured concentration [§]	Average concentration	
Antimony	243	16	0.007**	0.104	0.025	9 ²
Arsenic	243	0	<0.007	<0.01	n/a*	0.09 ²
Beryllium	243	0	<0.004	<0.01	n/a*	0.004 ²
Cadmium	243	0	<0.004	<0.005	n/a*	0.018 ²
Chromium Total	243	98	0.004**	0.021	0.0055	9 ²
Cobalt	243	0	<0.004	<0.01	n/a*	nd [%]
Copper	243	103	0.004**	0.026	0.0053	18 ^{2,3}
Manganese	243	240	0.004**	0.147	0.029	18 ²
Nickel	243	0	<0.004	<0.01	n/a*	0.18 ²
Thallium	243	3	0.004**	0.005	0.0047	Nd [%]
Tin	243	7	0.009**	0.027	0.015	Nd [%]
Zinc	243	243	0.005**	0.779	0.034	90 ^{2,4}
Vanadium	243	39	0.004**	0.012	0.0063	30 ^{5,6,7}
Lead	243	5	0.008**	0.019	0.013	0.50 ^{1,2}
Selenium	243	0	<0.007	<0.01	n/a*	20 ^{6,8}
Mercury	243	0	<0.00015	<0.0005	n/a*	1.8 ²
Chromium VI	243	1	0.008**	0.008	0.008	0.09 ²

1 Air NEPM (1998), annual average

2 NSW EPA Approved Methods (2005) Impact Assessment Criteria, 1-hour average

3 Dust-associated copper

4 Zinc oxide fume

5 Vanadium pentoxide

6 Office of Environmental Health Hazard Assessment (OEHHHA) California Reference Exposure Level (REL)

7 Acute OEHHHA REL, 1-hour average

8 Chronic OEHHHA REL, annual average

* Not calculated – all results less than method detection level (MDL)

** Excludes any test data <MDL

§ Pink font = test data <MDL

% No data – no standards or guidelines provided in NSW Approved Methods (2005), OEHHHA RELs, or Air NEPM

7 Dispersion Model Methodology

7.1 Dispersion Model Selection

The air impact assessment has employed a “Level 2” dispersion modelling methodology as defined in Sections 2.1 and 4.1 of the “Approved Methods” guideline.

A commonly used dispersion model in Australia is AUSPLUME, and this is recognised in the “Approved Methods” guideline. However AUSPLUME does not simulate dispersion of stack discharges well in a number of circumstances which may be significant for the Berrima Works site, such as periods of frequent low wind speeds, and handling of strongly buoyant plumes (due to temperature and/or velocity of the discharge) that may interact with vertical mixing layers.

The “Approved Methods” guideline notes the following: *“AUSPLUME v. 6.0 is the approved dispersion model for use in most applications in NSW. However it is not approved in some applications where other more advanced dispersion models, such as CALPUFF and TAPM, may be more appropriate.”* The use of CALPUFF is also encouraged where appropriate in other parts of the guideline. In the years since this guideline was published, CALPUFF has gained much wider popularity due to its enhanced simulation of dispersion due to plume buoyancy, plume path memory, simulation of inversion penetration, and incorporation of the PRIME building downwash algorithm. CALPUFF was therefore selected for the air impact assessment for the Berrima Works.

The CALPUFF model also requires meteorological input data to simulate dispersion. The meteorology was prepared using TAPM and CALMET (in NO-OBS mode), following the guidelines in OEH (2011).

7.2 Selection of Representative Year of Meteorology

The 2013 year was chosen as a suitably representative year for the air quality impact assessment. A recent year was preferable so that ambient air quality monitoring data from the AQMS could also be utilised - earlier years would not have been representative of current Works operations. The 2014 year was not considered because that calendar year was not complete when the air quality assessment work commenced.

Meteorological data was supplied by Bureau of Meteorology (BoM) for the nearest BoM site at Mossvale. Comparative windroses and wind speed distribution plots for Mossvale for 2013 versus the most recent 10-year and 5-year periods are shown in Appendix 2. The windroses and graph in Appendix 2 show variations in wind speed and direction distributions from year to year at Mossvale, with an overall prevalence of winds from the west and the north-northeast sectors. This overall prevalence is also shown in the 2013 windrose.

In 2011, 2012 and 2013, wind speed frequencies were higher in the “>7m/s” category and lower in the “<6m/s” category than in other years since 2005. However this is not expected to affect dispersion model results because the interpretation of model results is based on worst case percentiles and 99.9th percentiles. Using a year with a greater proportion of higher wind speeds compared to the average is also conservative for assessment of fugitive dust, as the higher wind speeds are necessary for dust pickup and transport.

The 2013 year can also be compared to the other data from the 5-year period 2010-2014 for the Berrima site, shown in Appendix 1. The windrose for the 2013 is very similar to the full 2010-2014 windrose, and the wind speed distribution shown on the bar graph is typical of most years.

The 2013 year was concluded to be a suitably representative year, meteorologically speaking, to form the basis of the air quality impact assessment.

It is noted that wind speed distributions between Mossvale and Berrima should not be directly compared, because the Mossvale data is based on 10-minute averaging times, and the Berrima data is based on 60-minute averaging times.

7.3 TAPM Model

The TAPM model was run for the 2013 calendar year. TAPM version 4.0.5⁸ was used for the simulation, run with the basic set-up specification described in Section 4.5 of the “Approved Methods” guideline.

A windrose of TAPM predictions for 2013 at the Berrima monitoring site was compared with measured data from Boral Cement to benchmark the suitability of the TAPM model results. The comparison is shown in Appendix 4. At the Berrima monitoring site, the TAPM model simulation of wind frequencies shows a reasonably similar distribution of wind directions and wind speeds.

It was concluded that the TAPM simulation of wind speeds is suitable for the Berrima site, and the predictions are suitable to generate an “initial guess” file for the first coarse CALMET simulation.

7.4 CALMET Model

The CALMET model setup was as follows:

- Full 2010 year, one-hour time step
- UTM Map Projection, zone 56S
- Two nested grids
 - coarse grid spacing 1.0km with 57 grid cells in x-direction and 47 grid cells in y-direction (57km x 47km grid extent)
 - fine grid spacing 0.32km with 63 grid cells in each direction (20km square grid extent)
- 10 vertical levels used, with cell face heights from 20m to 5000m
- Geophysical data –
 - Terrain elevation data supplied by Department of Trade and Investment, NSW Geological Survey Branch, at 80m x 80m mesh/resolution originally sourced from Shuttle Radar Topography Mission (SRTM) gridded data.
 - Land use data extracted from TAPM database

⁸ Model executable files version 4.0.5, graphical user interface version 4.0.4.

- All geophysical data plotted over actual map images to assess accuracy of data and land use data modified accordingly.
- TAPM output used as initial guess field for CALMET coarse grid, converted using “CALTAPM2” processor.
- CALMET coarse grid output used as initial guess field for CALMET fine grid.
- Radius of influence of terrain features (TERRAD) – 10km.

A windrose for the Berrima Works site for 2013, extracted from the completed CALMET model, is shown in Figure 24. This compares well with the measured Berrima data, also shown in the figure.

7.5 CALPUFF Model

7.5.1 Receptors and Terrain

Concentrations were modelled over a 11km x 11km (W-E by S-N) grid at 160m spacing, plus additional receptors at 80m spacing for the centre 6km x 8km grid closest to the stack. The receptors were defined as discrete receptors at terrain elevations as per the geophysical data supplied for the CALMET model. The total grid of 11km x 11km was found to be necessary to capture the ground level impacts from the stack plume.

The computational grid was set to be 3km larger than the modelled grid in each direction, to allow for plume recirculation.

Additional discrete receptors that are potentially sensitive to air pollutants were identified from the dwelling and non-residential buildings shown previously in Figure 12. A total of 87 discrete receptors were positioned on the grid to represent these locations. These discrete receptors are shown in Figure 25. The “white” coloured receptors represent residential dwellings. The “yellow” coloured receptors represent non-residential buildings.

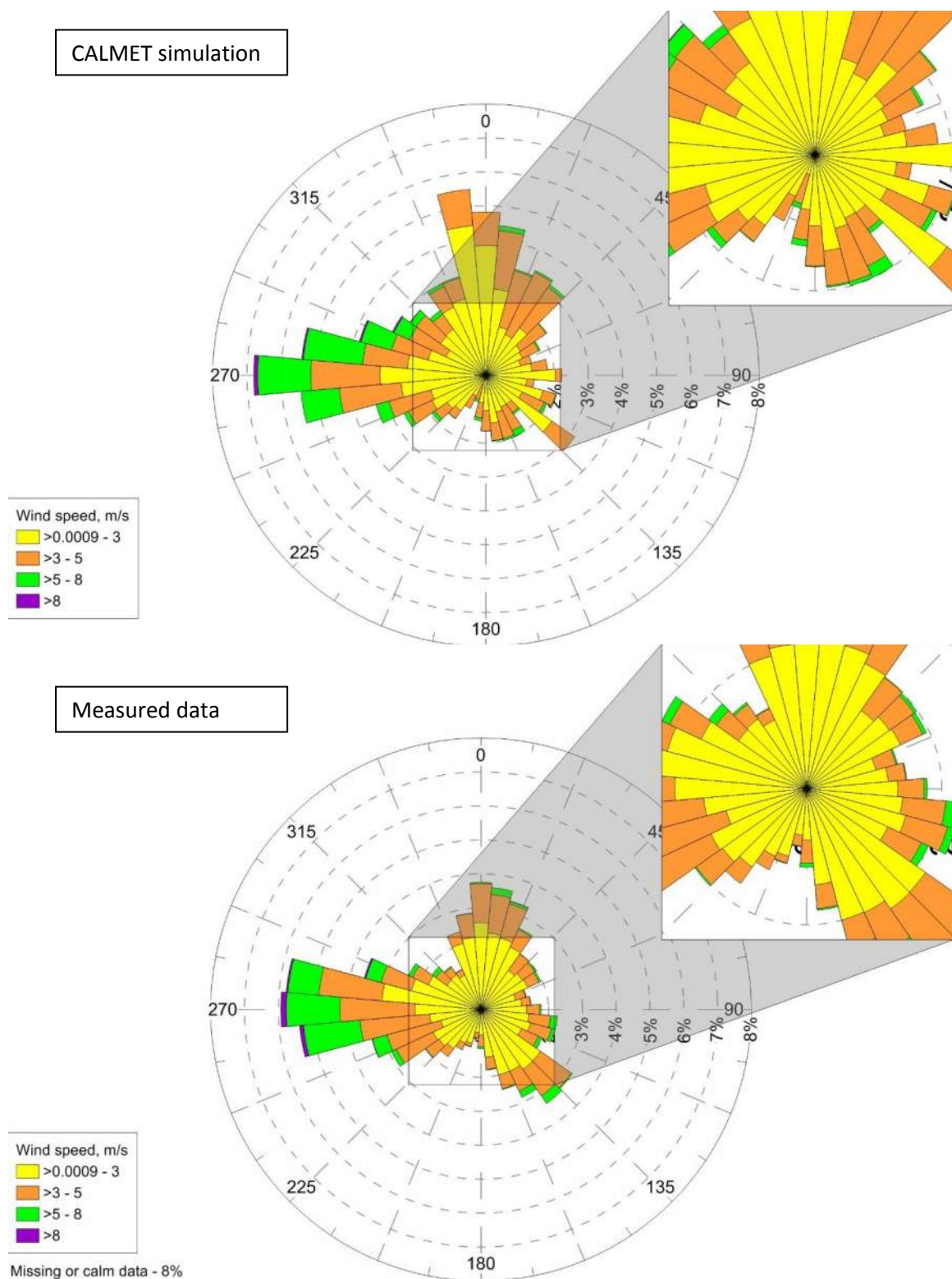


Figure 24: Windrose of meteorological data for Berrima site 2013.
Top – CALMET simulation using fine grid. Bottom – measured data.

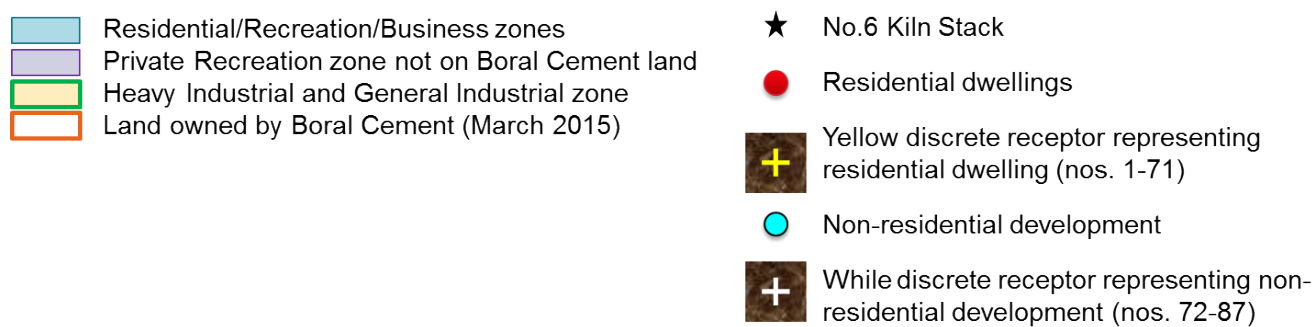
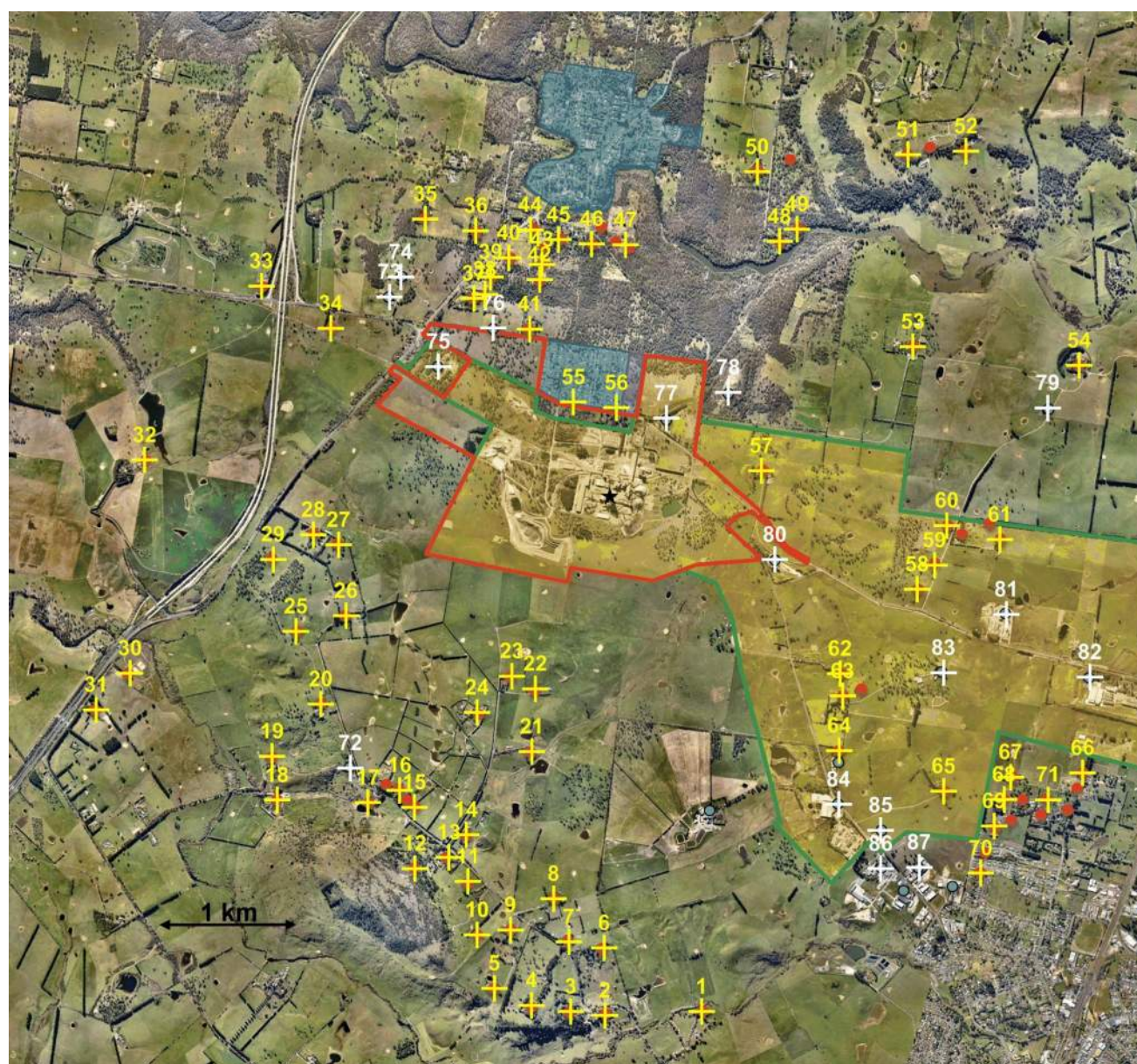


Figure 25: Discrete receptors representing potentially sensitive locations.

7.5.2 Point Source Inputs

Building downwash from the multiple structures around the Works site was incorporated using the PRIME downwash algorithm. A diagram summarising the building dimensions and heights used in the model is provided in Figure 26.

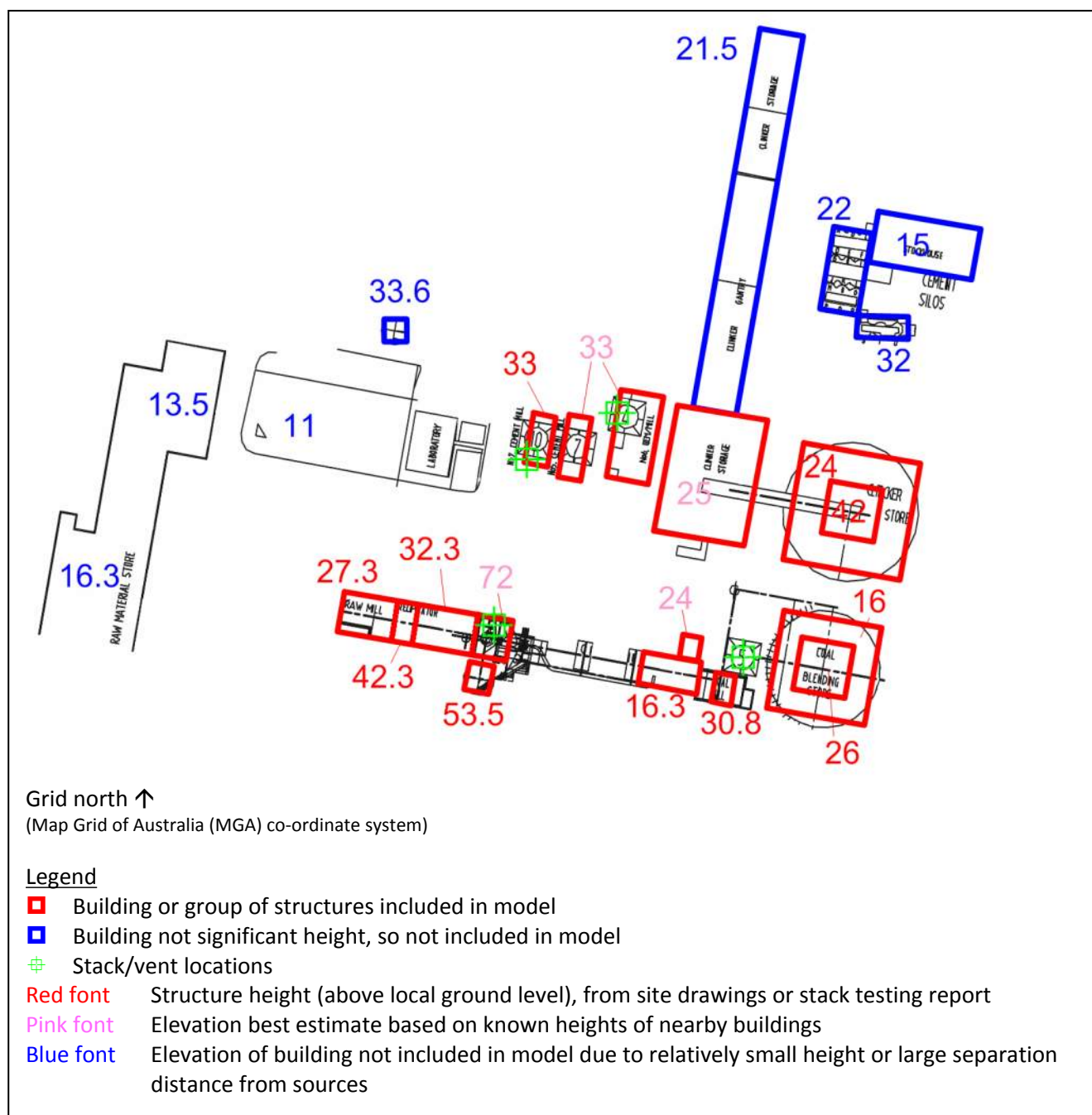


Figure 26: Summary of building dimension data for dispersion model inputs.

The dispersion parameters used for each of the three relatively minor particulate emission point sources in the dispersion model are drawn from the 2011-2014 annual test data provided in Table 10 earlier. The parameters used in the model are summarised in Table 39. Emission rates for TSP, PM₁₀ and PM_{2.5} were summarised earlier in Table 33 and Table 34.

Table 39: Discharge parameters for Kiln Cooler Stack and No.6 and No.7 Cement Mills

Parameter	Kiln Cooler Stack	No.6 Cement Mill	No.7 Cement Mill
Height	37 m	17 m	8 m
Stack tip diameter	2.4 m	1.75 m	1.91 m
Exit velocity	14 m/s	13 m/s	3.7 m/s (vertical component only)
Momentum flux (0 = horizontal discharge)	1	0	1
Exit temperature	87°C	84°C	102°C

The dispersion parameters used for No.6 Kiln Stack are drawn from the CEM data (refer Table 15). The parameters used in the model are summarised in Table 40. Emission rates assumed for the No.6 Kiln Stack are listed earlier in Table 31.

Table 40: Discharge parameters for No.6 Kiln Stack

Parameter	No.6 Kiln Stack
Height	85 m
Stack tip diameter	3.0 m
Exit velocity	38 m/s
Exit temperature	103°C

7.5.3 Area Source Inputs

Each of the six area sources representing fugitive dust emissions from open areas was entered into the model using an hourly varying emissions data file with the following assigned parameters:

- Effective height of the emissions: 2m above ground (assumed average of stockpiles, dumping, loading and wind erosion activities)
- Temperature: ambient temperature for each hour in the model using temperature timeseries extracted from Calmet for Berrima AQMS location. Using ambient temperature avoids buoyancy-enhanced dispersion which would not be appropriate. Effective rise velocity and effective radius for rise calculation therefore also set to zero.
- Initial vertical spread: set arbitrarily to 0.2m. In a sensitivity model run, this assumption was checked with an alternative initial vertical spread of 3m (representing elevation above ground for dumping and loading activities as well as vehicle-tracked emissions). However this input modification made no difference to model results outside the immediate vicinity of the stockpiles.

7.5.4 Volume Source Inputs

The volume source parameters assumed for the odour discharge, the discharge from mixing, and the discharges from transfer points, are summarised in Table 41. Using standard conventions, the initial sigma y and sigma z for the sources were set at one quarter of the building width and height respectively.

Due to the distance from the sources to the nearest sensitive receptors, the dispersion model results will be insensitive to moderate changes to the assumptions about the initial sigma values and effective height for each of these sources.

For the two transfer point sources, the building dimensions were approximated based on the two transfer point sources shown earlier in Figure 8. Whilst there are also other transfer point sources, the model was not considered to be sensitive to further breakdown of the transfer emission amongst other source locations due to the magnitude of the dust emission compared with other dust sources.

Table 41: Summary of assumed dimensions for volume sources in the dispersion model.

Source	Effective release height (m)	Initial sigma y	Initial sigma z	Comment
Odour from SDWF storage building	2	12	3	Building dimensions are 33m long, 50m wide and 13m high. Majority of emission assumed to be released through open doorway.
Crushing	4	2	1	Emission assumed from some kind of gantry or tower with an opening about 4m above the ground.
Transfer point A	8	1.25	2.5	Building approx. 10m high, 5x5m footprint
Transfer point B	6	1	2	Building approx. 8m high, 4x4m footprint

7.5.5 Other Inputs

Other model settings for CALPUFF were as follows:

- Terrain adjustment by partial plume path method.
- Plume element modelled as “PUFF”, with “dispersion coefficients computed from internal micrometeorology” setting. “PDF” method enabled.
- Transitional plume rise and partial penetration of inversions modelled.
- Minimum threshold defining calm wind = 0.2m/s.

These settings are in accordance with standard modelling practice, and the recommendations in the OEH (2011) guideline for CALPUFF modelling.

7.6 Assessment Criteria

7.6.1 Assessment Criteria for PM₁₀, PM_{2.5}, SO₂, NO₂, Lead and Hydrogen Fluoride

Assessment criteria for PM₁₀, NO₂, SO₂, lead and hydrogen fluoride for comparing against model results are defined in Chapter 7.1 of the “Approved Methods” guidelines. From these guidelines, the impact assessment criteria relevant to the Berrima Works site are listed in Table 42. Assessment criteria for PM_{2.5} were based on the advisory reporting criteria specified in the NEPM (1998)⁹, as recommended by NSW EPA¹⁰.

Table 42: Impact assessment criteria for PM₁₀, PM_{2.5}, NO₂, SO₂, lead and hydrogen fluoride

Pollutant	Averaging period	Ambient Air Concentration (µg/m ³)	
PM ₁₀	24 hours	50	
	Annual	30	
PM _{2.5}	24 hours	25	
	Annual	8	
NO ₂	1 hour	246	
	Annual	62	
SO ₂	1 hour	570	
	24 hours	228	
	Annual	60	
Lead	Annual	0.5	
Hydrogen fluoride	24 hours	2.9 ^a	1.5 ^b
	7 days	1.7 ^a	0.8 ^b
	30 days	0.84 ^a	0.4 ^b
	90 days	0.5 ^a	0.25 ^b

a General land use, which includes all areas other than specialised land use

b Specialised land use, which includes all areas with vegetation sensitive to fluoride, such as grape vines and stone fruits

NSW EPA requires the assessment criteria in Chapter 7.1 of the “Approved Methods” guidelines to be applied as follows:

- At the nearest existing or likely future off-site sensitive receptor.
- Background concentrations must be included.
- Results must be reported for both incremental concentrations (ie caused by the sources alone) and cumulative concentrations (sources plus background).
- The total or cumulative impact (including background) must be reported at the maximum (100th percentile) for each of the averaging periods.

It is understood that the assessment criteria for PM_{2.5} are to be applied in the same manner.

⁹ National Environment Protection (Ambient Air Quality) Measure (1998), as varied in 2003.

¹⁰ Pers. comm. Tracy Freeman (Air Quality Professionals) with Janelle Pickup (NSW EPA), 23 March 2015

7.6.2 Assessment Criteria for TSP

Chapter 7.1 of the “Approved Methods” guidelines provides an impact assessment criteria for TSP. The criteria is an annual average concentration of 90 $\mu\text{g}/\text{m}^3$. No 24-hour average concentration is specified.

Model results are assessed using the same methodology criteria as listed above in Section 7.6.1.

7.6.3 Assessment Criteria for NMHCs

As NMHC represents a wide collection of organic compounds there is no single generic representative assessment threshold. An indicative breakdown of organic compounds in emissions from Portland cement kilns is provided in USEPA (1995). In this breakdown, a large proportion of the organic emission is comprised of benzene and benzoic acid, with smaller amounts of other constituents. This breakdown is shown in Table 43. Further breakdown of NMHC constituents is not considered to be useful unless chemical composition data is collected at the Berrima site.

Applicable impact assessment criteria from NSW EPA (2005) and the Texas Commission on Environmental Quality Effects Screening Levels (ESLs) for these components are also listed in Table 43. It was necessary to refer to the ESLs because not all of the listed pollutants are included in the ambient air quality assessment threshold lists specified by NSW EPA.

ESLs are used to evaluate potential for effects to occur as a result of exposure to concentrations of constituents in the ambient air. ESLs are based on data concerning health effects, odour/nuisance potential, and effects on vegetation. They are not ambient air quality standards. If predicted or measured airborne levels of a constituent do not exceed the screening level, adverse health or welfare would not be expected to result. If predicted concentrations of constituents in ambient air exceed the screening level, it does not necessarily indicate a problem, but a more in-depth review is conducted.

The chemical species naphthalene, phenanthrene and acenaphthylene in Table 43 are included in the analysis of PAHs measured at the Works, and will be assessed as components of total PAHs rather than as NMHCs.

Assessment for NMHCs has been carried out using a Level 2 impact assessment methodology as defined in the “Approved Methods” guidelines. The NSW EPA requires the assessment criteria for NMHCs (grouped under the category of “individual toxic air pollutants”), as defined in Section 7.2.2 of NSW EPA (2005), to be applied as follows:

- At and beyond the boundary of the facility.
- The incremental impact (predicted impacts due to the pollutant source alone) for an averaging period of 1 hour and as the 99.9th percentile of dispersion model predictions.

Table 43: Assumed breakdown of composition of organic pollutants present in kiln stack discharge and relevant air quality criteria

Pollutant	Mass proportion of organic compounds as per USEPA (1995) ^{&}	Applicable ambient air quality assessment threshold in NSW EPA (2005), $\mu\text{g}/\text{m}^3$	ESL*, $\mu\text{g}/\text{m}^3$	
			Short term (1-hour average)	Long term (annual average)
acenaphthylene [#]	1.2%		1	0.1
acetone	3.7%	22000	7800	4800
benzene	31.4%	29	170	4.5
benzoic acid	35.3%		50	5
carbon disulfide	1.1%		30	3
chloromethane (methyl chloride)	3.7%	1900	1030	103
formaldehyde	4.5%	20	15	3.3
methylene chloride	4.9%	3200	3600	350
naphthalene [#]	2.2%		200	50
phenanthrene [#]	3.9%		0.5	0.05
toluene	2.0%		3500	1200
xylene	1.3%		350	180
others	4.7%			

* Texas Commission on Environmental Quality Effects Screening Levels, March 2014.

http://www.tceq.texas.gov/toxicology/esl/list_main.html#esl_1.

& Data in USEPA (1995) expressed as kg per tonne of clinker produced. Converted to a mass percentage of total organic constituent emission from USEPA (1995).

Included in PAHs expressed as total BaP-TEQ in this report rather than in NMHC assessment

7.6.4 Assessment Criteria for Odour

Chapter 7.5.1 of the “Approved Methods” guidelines provides impact assessment criteria for odours. In a Level 2 odour dispersion assessment, model results should be compared with the impact assessment criteria listed in Table 44.

The dispersion model produces one-hour average concentrations of odour. However the odour impact assessment criteria in Table 44 are applied to peak (approximately 1 second) concentrations. The prediction of peak concentrations from 1-hour averages can be obtained using “peak-to-mean” ratios published in Section 6 of the “Approved Methods” guideline. For the odour source at the Works, the appropriate peak-to-mean ratio is a factor of 2.3. Therefore the last column in Table 44 provides the equivalent 1-hour average odour impact assessment criteria for comparison with the dispersion model results.

The applicable odour impact assessment criteria for New Berrima is assumed to be that of a population of about 500 people. The applicable odour impact assessment criteria for other rural residences was assumed to be that of a population of about 10 people, given that many of these rural residences occur in small clusters.

Table 44: Odour assessment criteria from “Approved Methods” guidelines

Population of affected community	Impact assessment criteria for odour, 1-second average (OU)	Impact assessment criteria for odour, 1-hour average applying peak to mean ratio of 2.3 (OU).
Urban ($\geq \sim 2000$) and/or schools and hospitals	2.0	0.87
~500	3.0	1.3
~125	4.0	1.7
~30	5.0	2.2
~10	6.0	2.6
Single rural residence ($\leq \sim 2$)	7.0	3.0

The “Approved Methods” guideline requires that the impact assessment criteria for odours must be applied as follows:

- At the nearest existing or likely future off-site sensitive receptor.
- The impact (predicted impact due to the pollutant source alone) must be reported as the 99th percentile of dispersion model predictions for Level 2 impact assessments.

7.6.5 Assessment Criteria for Other Contaminants

Assessment criteria for other pollutants discharged in small quantities from the No.6 Kiln Stack, are also defined in Chapter 7.2 of the “Approved Methods” guidelines. From these guidelines, the impact assessment criteria relevant to the Berrima Works site are listed in Table 45.

Assessment for these pollutants has been carried out using a Level 2 impact assessment methodology as defined in the “Approved Methods” guidelines. As for NMHCs, the NSW EPA requires the assessment criteria for these pollutants to be applied as follows:

- At and beyond the boundary of the facility.
- The incremental impact (predicted impacts due to the pollutant source alone) for an averaging period of 1 hour and as the 99.9th percentile of dispersion model predictions.

Table 45: Impact assessment criteria for trace pollutants

Pollutant	Threshold ambient air concentration specified by NSW EPA ($\mu\text{g}/\text{m}^3$) or elsewhere*
Heavy metals[^]	
Arsenic	0.09
Beryllium	Not listed in "Approved Methods". ESL = $0.02 \mu\text{g}/\text{m}^3$ for "beryllium – particulate" **
Cadmium	0.018
Chromium (III)	9
Chromium (VI)	0.09
Cobalt	Not listed in "Approved Methods". ESL = $0.2 \mu\text{g}/\text{m}^3$ for "cobalt and inorganic compounds" **
Copper dust	18
Mercury (inorganic)	1.8
Manganese	18
Nickel	0.18
Antimony	9
Selenium	Not listed in "Approved Methods". ESL = $2 \mu\text{g}/\text{m}^3$ for "selenium and compounds" **
Thallium	Not listed in "Approved Methods". ESL = $1 \mu\text{g}/\text{m}^3$ for "thallium and compounds" **
Vanadium	Not listed in "Approved Methods". ESL = $0.5 \mu\text{g}/\text{m}^3$ ** WHO ambient air goal (24-hour average) = $1 \mu\text{g}/\text{m}^3$ §
Tin	Not listed in "Approved Methods". ESL = $20 \mu\text{g}/\text{m}^3$ for "tin compounds: metal, oxide, and inorganic" **
Other pollutants	
Dioxins	0.000002 ($2 \text{ ng}/\text{m}^3$)
PAHs as B(a)P	0.4
Hydrogen chloride	140
Chlorine	50
Sulfuric acid mist and/or sulfur trioxide	18 (for sulfuric acid)

* All 1-hr averaging period except where specified for Vanadium

** Texas ESLs, refer explanation in Section 7.6.3.

§ World Health Organisation Ambient Air Quality Guidelines for Europe, as reported in NSW EPA (2002) and independently confirmed via WHO website on 14 April 2015,
http://www.euro.who.int/_data/assets/pdf_file/0005/74732/E71922.pdf .

[^] Lead is not included in this table as it is included earlier in Table 42.

7.7 Background Concentrations

7.7.1 Representative Monitoring Sites

Chapter 5.1 of the “Approved Methods” guideline specifies appropriate methods of accounting for background concentrations. Two methods are given:

Level 1: *At the maximum exposed off-site receptor, add the maximum background concentration and the 100th percentile dispersion model prediction to obtain the total impact for each averaging period.*

Level 2: *At each receptor, add each individual dispersion model prediction to corresponding contemporaneous measured background concentrations to obtain hourly predictions of total impact.*

The modelling carried out has used a “Level 2” assessment for modelling and meteorological data. An assessment of available background data was carried out. Measured PM₁₀ data from the Berrima air quality monitoring station cannot be used as representative background data as the data is only a 1-day-in-6 24-hour average value, so site contributions cannot be filtered out from the true background data. In addition, as data is only measured on one out of every six days, the sample size of the data from the Berrima station was not considered to be adequate for attempting to define background concentrations.

Alternative monitoring sites maintained by Office of Environment and Heritage (OEH) were investigated to identify a suitable proxy site where statistical data could be used to identify a representative maximum background concentrations. The OEH monitoring sites to the south of Sydney are shown in Figure 27. The three sites near Wollongong (to the east of Boral Berrima near the coast) were not considered to be suitable due to the high contribution of industry emissions to the local airshed. Using 24-hour averaging period datasets downloaded from the OEH website, mean and peak statistics for concentrations of ozone, NO₂, SO₂ and PM₁₀ at monitoring stations at Bringelly, Bargo, MacArthur/Campbelltown West, Camden and Oakdale were compared for the five-year period 1/1/2010 to 31/12/2014. Data at the Macarthur and Campbelltown West sites was combined for the purpose of this analysis, as the latter site has replaced the former. These statistics are shown in Table 46. Camden data was included as this is the nearest and most representative PM_{2.5} monitoring station¹¹, but data was only available from October 2012 when the site was established.

The Macarthur/Campbelltown West site was not considered to be a suitable proxy site due to displaying higher trends than the other sites for NO₂ (and SO₂, although this was not a significant factor for consideration). The Oakdale site was also not considered to be suitable due to displaying lower trends than the other sites for NO₂, higher concentrations of ozone, and slightly lower concentrations of PM₁₀ in most statistics categories.

Compared to Bargo, the Bringelly and Camden sites showed higher PM₁₀ concentrations in the median to 99th percentile bracket, but overall similar statistics to Bargo, so the Bringelly, Camden and Bargo sites were considered to be potentially suitable. The very high maximum PM₁₀ measured at Bargo was caused by a major bushfire and is considered to be an outlier. The Camden site showed lower NO₂ concentrations than the other two sites.

As Bringelly and Camden are further from the Boral Berrima site, Bargo was selected as the site most likely to be suitable as a proxy for ambient background data at Berrima with the exception of PM_{2.5} for which Camden had the only available data. The Bargo site was considered likely to represent the best available

¹¹ Pers. comm. Tracy Freeman (Air Quality Professionals) with Janelle Pickup (NSW EPA), 23 March 2015

option for a small town population in a largely rural area without major industrial contributions. Even though the Bargo site is about 32km (in a direct line) from Berrima, the distance is not a very significant factor as the background analysis only requires statistically representative data rather than real-time data.

Hourly measurements of ozone, NO, NO₂, SO₂ and PM₁₀ for Bargo were purchased from the NSW EPA for 2013 for this assessment. Hourly measurements of ozone, NO, NO₂, PM_{2.5} and PM₁₀ were also purchased for Camden for 2013. Detailed analysis of data as presented in the following sections included data from both sites where available.



Figure 27: OEHL Air Quality Monitoring Sites to the south of Sydney (additional sites at Bathurst, Albury and Wagga Wagga not shown due to scale of map).

Table 46: 24-hour average ambient air quality monitoring data statistics for OEH sites at Bringelly, Bargo, Macarthur and Oakdale for NO₂, SO₂, ozone, PM₁₀ and PM_{2.5} – 1 January 2010 to 31 December 2014

	Bringelly	Bargo	Macarthur/ Campbelltown West	Oakdale	Camden (from Oct 2012 only)
NO₂ 24-hour average (pphm)					
Mean	0.48	0.51	0.90	0.18	0.44
Median	0.5	0.5	0.9	0.1	0.4
75 th percentile	0.6	0.7	1.2	0.3	0.6
90 th percentile	0.8	1.0	1.5	0.4	0.8
95 th percentile	0.9	1.2	1.7	0.4	0.9
98 th percentile	1.0	1.3	1.9	0.5	0.9
99 th percentile	1.1	1.5	2.0	0.6	1.0
99.5 th percentile	1.2	1.6	2.0	0.6	1.1
99.9 th percentile	1.5	1.8	2.3	0.7	1.2
Maximum	1.6	2.4	2.8	0.8	1.2
SO₂ 24-hour average (pphm)					
Mean	0.02	0.02	0.04		
Median	0	0	0		
75 th percentile	0	0	0.1		
90 th percentile	0.1	0.1	0.1		
95 th percentile	0.1	0.1	0.1		
98 th percentile	0.1	0.1	0.2		
99 th percentile	0.2	0.1	0.2		
99.5 th percentile	0.2	0.2	0.2		
99.9 th percentile	0.2	0.2	0.3		
Maximum	0.3	0.3	0.4		
PM₁₀ 24-hour average (µg/m³)					
Mean	16.14	13.98	14.92	11.94	15.90
Median	14.8	12.6	13.7	10.3	14.5
75 th percentile	19.7	17.2	18.3	14.7	19.8
90 th percentile	25.5	22.6	23.9	20.5	25.7
95 th percentile	29.1	26.4	27.9	24.3	29.5
98 th percentile	33.8	30.5	31.6	28.9	32.6
99 th percentile	37.9	35.5	35.3	31.7	35.6
99.5 th percentile	41.8	42.5	37.1	36.6	40.5
99.9 th percentile	76.3	62.5	51.3	80.8	61.8
Maximum	97.2	208.9 (2 nd highest 89.7)	58.7	99.0	97.5
PM_{2.5} 24-hour average (µg/m³)					
Mean					6.52
Median					5.8
75 th percentile					8.3
90 th percentile					10.9
95 th percentile					12.7
98 th percentile					14.8
99 th percentile					18.2
99.5 th percentile					20.7
99.9 th percentile					39.7
Maximum					61.9

	Bringelly	Bargo	Macarthur/ Campbelltown West	Oakdale	Camden (from Oct 2012 only)
Ozone 24-hour average (pphm)					
Mean	1.71	2.00	1.66	2.51	1.94
Median	1.7	2	1.6	2.5	1.9
75 th percentile	2.1	2.4	2.0	2.8	2.4
90 th percentile	2.5	2.8	2.4	3.2	2.8
95 th percentile	2.7	3	2.7	3.6	3.1
98 th percentile	3.2	3.4	3.1	4.0	3.4
99 th percentile	3.3	3.6	3.4	4.3	3.6
99.5 th percentile	3.7	3.8	3.7	4.6	3.9
99.9 th percentile	4.5	4.2	4.4	4.8	4.7
Maximum	5.0	4.7	5.2	4.9	4.8

7.7.2 Annual Average Data for NO₂, PM₁₀, PM_{2.5} and TSP

Annual average concentrations of NO₂ and PM₁₀ measured at Bargo, as reported on the NSW EPA website (<http://www.environment.nsw.gov.au/AQMS/search.htm> accessed 6/4/2015) are summarised in Table 47. These annual averages are assumed to include data from high PM₁₀ events during bushfires, which may explain the higher annual average concentrations reported for 2012 and 2013. Annual average PM_{2.5} and PM₁₀ data from Camden for 2013 and 2014 (first years of Camden operation) is also provided in the table.

Table 47: Annual average concentrations of NO₂ and PM₁₀ at Bargo and PM_{2.5} at Camden (source, NSW EPA website)

Year (ending 31 December)	NO ₂ annual average concentration at Bargo, µg/m ³ *%	PM ₁₀ annual average concentration at Bargo or Camden, µg/m ³ *	PM _{2.5} annual average concentration at Camden, µg/m ³ *
2010	8.8	12.9	
2011	8.8	12.9	
2012	8.8	14.3	
2013	8.8	15.7 Bargo 15.4 Camden	6.5
2014	8.8	14.4 Bargo 15.6 Camden	6.3

* NSW EPA website states that these averages are derived from 1-hour average data.

% Data reported on NSW EPA website in units of “parts per hundred million”, same value of 0.5pphm reported for each of the four years in the table. Data converted to µg/m³ for this report assuming constant temperature and pressure of 20°C and 94 kPa (pressure appropriate for Berrima elevation) – conversion rate is 1 pphm = 17.7 mg/m³.

A cumulative impact assessment for annual average TSP using background concentrations is not directly possible because the OEH monitoring sites discussed in Section 5.6.1 do not measure TSP (as opposed to PM₁₀). However, the calculated annual average concentrations of TSP at the Berrima monitoring site (Table 37) over the last four years are 35-43 µg/m³, less than half of the annual average criteria for TSP of 90 µg/m³ in the “Approved Methods” guidelines. These measured concentrations include both background TSP and contributions from the Boral Berrima site (including fugitive dust sources in addition to the stack sources).

7.7.3 PM₁₀ and PM_{2.5} 24-hour Average Data

Figure 28 shows the daily variation in 24-hour average PM₁₀ concentrations at the Bargo and Camden monitoring sites, prepared from the data reported on the OEH website. Significant “spikes” in daily average concentration are assumed to be related to regional bushfire or “controlled burn” activity. For example, NSW EPA states in the NSW Air Quality Statement for 2013 that the maximum daily average PM₁₀ concentration across the entire NSW monitoring network in the 2013 calendar year was 208.9 µg/m³, at Bargo on 17 October during the September–November 2013 bushfire emergency period¹², and as mentioned earlier in Section 6.4.2 there was a very large bushfire near Balmoral between the 17 and 20 of October 2013. Depending on wind directions, smoke from that bushfire could impact both the Bargo and Camden monitoring sites. AirQP is also aware that the summer of 2012/2013 was very hot, and featured a number of bushfires in southern NSW. However it is not clear how many of the PM₁₀ “spikes” in the graph in Figure 28 are due to fire smoke or dust storm events.

The Camden and Bargo data in Figure 28 appear to follow similar timeseries trends. This is reinforced by the scatter plots in Figure 29 and Figure 30 which show contemporaneous Camden and Bargo data. With the exception of some outliers, there is reasonable consistency between the two sites although the Camden data can be 5-10 µg/m³ higher or lower than the Bargo data on any given day.

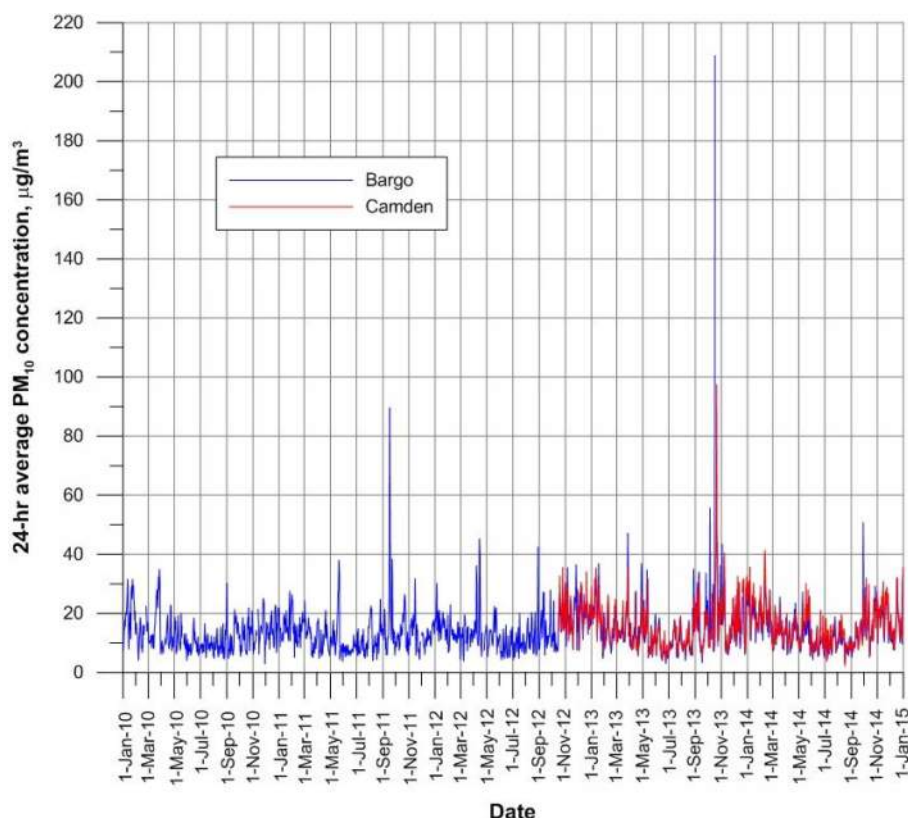


Figure 28: Daily variation in 24-hour average PM₁₀ concentration at Bargo and Camden monitoring sites, from 1 January 2010 to 31 December 2014. Data source: OEH website.

¹² “New South Wales Air Quality Statement 2013”, NSW EPA

<http://www.environment.nsw.gov.au/resources/aqms/140057nswairqual13.pdf>, page 3

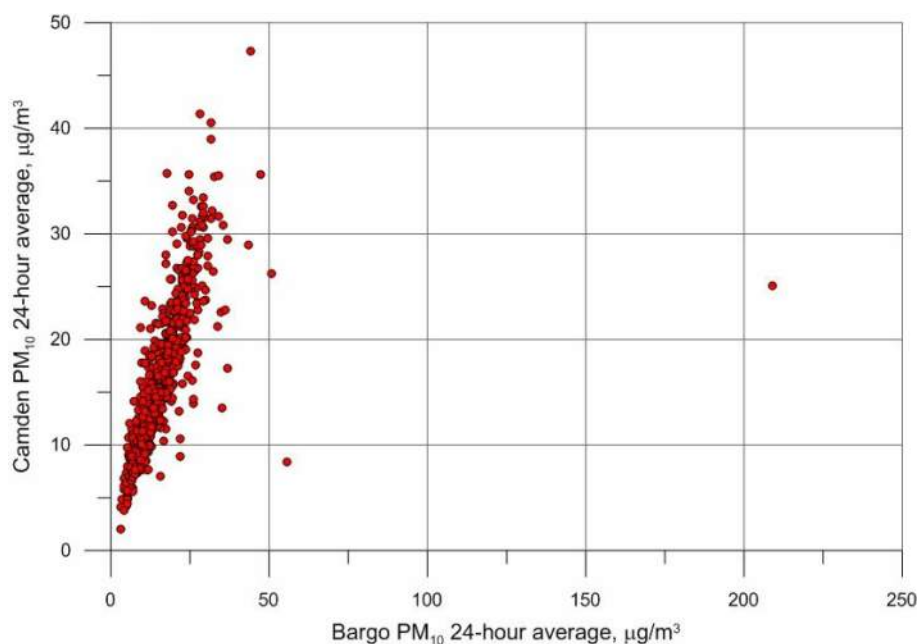


Figure 29: Scatter plot showing contemporaneous Bargo and Camden PM₁₀ data (24-hour average, October 2012 to December 2014).

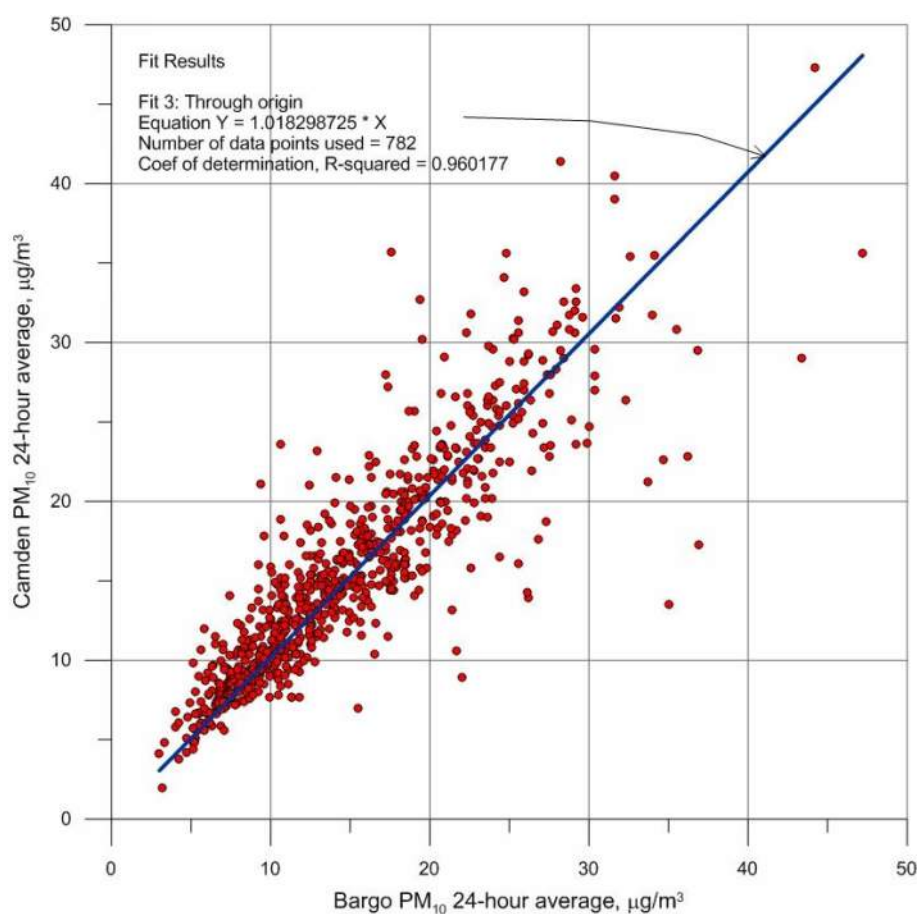


Figure 30: Scatter plot showing contemporaneous Bargo and Camden PM₁₀ data (24-hour average, October 2012 to December 2014), showing only Bargo data <50 µg/m³.

A cumulative frequency plot of the Bargo and Camden daily PM₁₀ concentrations is compared with a similar plot for PM₁₀ measured on a 1-day-in-6 basis at Berrima, in Figure 31. The data for the Berrima site contains only a sixth of the data records. This may influence the comparison of data. Notwithstanding this limitation, the graph shows that the Berrima data exceeds the Bargo and Camden data above the 75th percentile, as also shown in Table 48. The Berrima data exceeds the Camden data above the 90th percentile, although the smaller period of data capture at Camden may influence this comparison. The maximum at Berrima is much lower than the maximum at Bargo, due to the smoke event as noted earlier.

The differences between the Bargo/Camden and Berrima sites at the high cumulative percentiles may be partly due to contributions from the Boral Berrima site, but may also be influenced by the smaller frequency of data capture at Berrima and also local smoke or background dust issues. Nevertheless, it is considered that either the Bargo site or the Camden site would be a suitable proxy site for background PM₁₀ data at Berrima. This conclusion provides confidence that using the Camden site as the source of background PM_{2.5} data for Berrima is also appropriate.

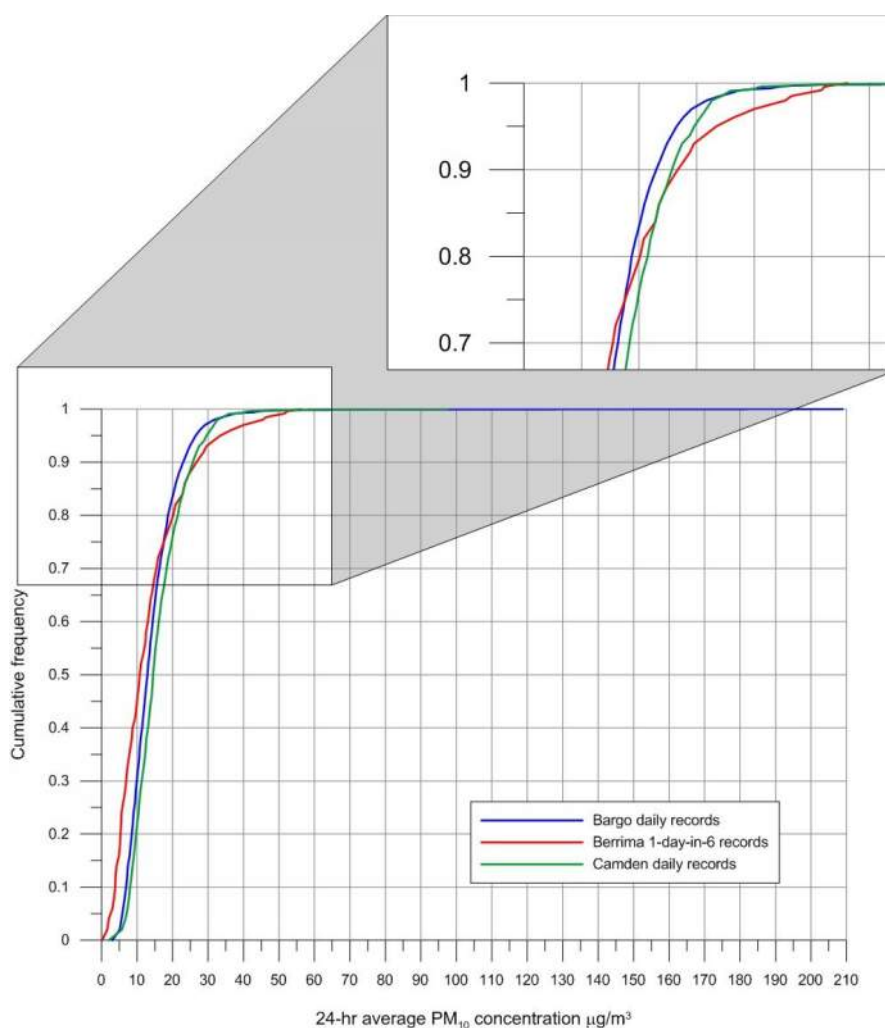


Figure 31: Comparison of cumulative frequency of PM₁₀ ambient monitoring data at Berrima (24-hour average, 1-day-in-6 sampling) and Bargo and Camden (daily sampling); January 2011 to December 2014 (Berrima and Bargo); October 2012 to December 2014 (Camden).

Table 48: Comparison of 24-hour average ambient air quality monitoring data statistics for OEH sites at Bargo and Camden, and Berrima AQMS site operated by Boral – January 2011 to December 2014

	Berrima 1-day-in-6 data	Bargo daily data*	Camden daily data**
75 th percentile	17.4	17.5	19.8
90 th percentile	26.7	23.0	25.7
95 th percentile	33.4	26.5	29.5
98 th percentile	45.4	31.7	32.6
99 th percentile	50.2	36.7	35.6
99.5 th percentile	52.1	43.6	40.5
99.9 th percentile	55.2	74.6	61.8
Maximum	56.2	208.9	97.5

* This data is slightly different to the list of data in Table 46 because the earlier table includes data from 2010.

** From October 2012 only.

The question arose of what PM₁₀ concentration from Bargo to assume as the “maximum background concentration” for any preliminary “Level 1” dispersion modelling. A strict interpretation of the definition of a “Level 1” treatment of background, as quoted earlier at the start of Section 7.7.1, would require a PM₁₀ background concentration of 209 µg/m³ to be used. This is, of course, inappropriate because that particular maximum concentration occurred during a significant bushfire smoke event and is already more than four times higher than the NSW EPA assessment criteria of 50 µg/m³.

Chapter 5.1.3 of the “Approved Methods” guideline recognises that *“in some locations, existing ambient air pollutant concentrations may exceed the impact assessment criteria from time to time”*. The recommended approach in such situations is as follows:

In such circumstances, a licensee must demonstrate that no additional exceedances of the impact assessment criteria will occur as a result of the proposed activity and that best management practices will be implemented to minimise emissions of air pollutants as far as is practical.

The highest five 24-hour average PM₁₀ concentrations measured in Bargo each year are summarised in Table 49. This data was obtained by downloading 24-hour average data records from the NSW EPA website. There were no exceedances of 50 µg/m³ in 2010 and 2012, one exceedance in 2011 and 2014, and two exceedances in 2013. These concentrations and exceedances can be compared to the National Environment Protection (Ambient Air Quality) Measure 1998 (“NEPM”) for PM₁₀, which specifies a 24-hour PM₁₀ concentration standard of 50 µg/m³ with 5 exceedances allowed annually¹³. The number of exceedances measured at Bargo each year are below that permitted by the NEPM.

Due to the complex nature of background data for PM₁₀, no “Level 1” impact assessment was carried out. The assessment instead focussed on a “Level 2” approach with contemporaneous background data.

¹³ The NEPM for Air Quality (1998) is currently under review by the federal government. The review may result in a change to the PM₁₀ standard. Submissions closed on the proposed amendments on 10 October 2014. As at 1 April 2015, no new NEPM for Air Quality has been finalised and no policy for retrospective application of any revised NEPM concentrations to existing industrial sites has been released by NSW EPA. Therefore, only the existing NEPM for Air Quality (released in 1998) is referred to in this report.

The data in Table 49 will be referenced in the consideration of cumulative impact assessment for PM₁₀, following the presentation of the incremental PM₁₀ dispersion model results.

Table 49: Five highest daily average PM₁₀ concentrations measured in Bargo for each of the calendar years 2010-2014

Rank	2010	2011	2012	2013	2014
1 st	34.9	89.7	45.2	208.9	50.8
2 nd	32.4	43.6	42.5	55.7	34.1
3 rd	31.6	38.4	39.8	47.2	31.9
4 th	31.6	38.0	36.5	44.2	31.6
5 th	30.5	33.4	36.1	43.4	30.0

A similar assessment was also carried out for treatment of background for PM_{2.5} dispersion modelling. The highest five 24-hour average PM_{2.5} concentrations measured in Camden for the two full calendar years since monitoring started are summarised in Table 50. The NEPM specifies a reporting criteria of 25 µg/m³ for PM_{2.5}. In 2013, there were three exceedances of the reporting criteria, and none in 2014. Due to the magnitude of the background data, the assessment focussed only on a “Level 2” approach rather than carrying out the preliminary “Level 1” assessment as well.

Table 50: Five highest daily average PM_{2.5} concentrations measured in Camden for each of the calendar years 2013 and 2014

Rank	2013	2014
1 st	61.9	18.5
2 nd	34.1	18.2
3 rd	27.5	17.3
4 th	24.7	15.3
5 th	20.7	14.8

7.7.4 Odour

Background concentrations of odour in the area around the Berrima Works will be a mixture of normal odours that occur in a rural/residential area. A potential additional source of odour is the wastewater treatment plant located just to the west of the Works, however AirQP is not aware of any odour issues associated with this plant.

Background odours that could act cumulatively with odour of the type that have the potential to be discharged from the SWDF storage building are therefore assumed to be negligible.

7.7.5 Dioxins, Organics, PAHs, and Heavy Metals - Background Data

The NSW EPA conducted an ambient air quality study across a comprehensive range of hazardous air pollutants in urban areas and some regional centres across NSW from early 1996 till August 2001. The pollutants included dioxins, organics, polycyclic aromatic hydrocarbons (PAHs), and heavy metals (NSW EPA, 2002).

Incorporation of these background concentrations with dispersion model results is not required for a Level 2 impact assessment approach in the “Approved Methods” guidelines except for lead. However, the background concentrations measured in the NSW EPA study are summarised below to assist with understanding the context of predicted concentrations from the Works emissions.

7.7.5.1 Dioxins

Dioxin concentrations were measured at a rural background site (Siding Spring in central-western NSW), a site representative of conditions in an urban area in western Sydney (Westmead); and an urban site near a known industrial source of dioxins (Warrawong in Wollongong).

The results were reported as femtograms per cubic metre (fg/m³). One femtogram is 1×10^{-15} grams or 0.000000000000001 g. One femtogram is also equal to one millionth of a nanogram (i.e. 1 fg = 0.000001 ng).

To put this extremely small measure in perspective, 1 fg is to a gram as 1 milligram is to one million tonnes.

At both Warrawong and Westmead, higher concentrations were observed in winter than in summer. This was considered in NSW EPA (2002) to probably be due to a number of factors, including poor dispersion because of the effects of inversion layers and possibly increased inputs from domestic heating.

Table 51 shows the results obtained from the three monitored areas, expressed as I-TEQs. Samples were measured over 12 days at Warrawong and Westmead, and 24 days at Siding Spring.

The measured data from Warrawong is assumed to be applicable to the Berrima area due to the potential for domestic home heating emissions in the area. However the NSW EPA assessment criteria for dioxins applies to 1-hour average dioxin concentrations, and therefore the concentrations in Table 51 cannot be directly compared. The corresponding 1-hour average concentration will be higher than the 12-day average concentration.

However it is noted that the very low concentrations measured during the NSW EPA study are negligible compared with the dioxin assessment criteria in the “Approved Methods” guideline, which is 2×10^{-9} mg/m³ or 2,000 fg/m³.

Table 51: Dioxins measured in NSW EPA ambient monitoring programme (NSW EPA, 2002)

Site	Dioxin concentration in total I-TEQ (fg/m ³) (12 or 24 day averaging period)		
	Minimum	Average	Maximum
Siding Spring	0.2	0.64	2.4
Warrawong	3	10	20
Westmead	2.3	14	53

7.7.5.2 Organics

Measurements of organics were made at 5 sites in the Sydney–Newcastle–Wollongong area, plus smaller sampling campaigns at supplementary sites in the Newcastle and Wollongong areas. The study measured the ambient or airborne concentrations of 41 volatile organic compounds, including 1,3-butadiene. The list of compounds tested is provided in Figure 32 (reproduced from NSW EPA (2004a)).

Aromatic hydrocarbons	Alkenes and halogenated alkenes	Halogenated alkanes
benzene	vinyl chloride	bromomethane
ethylbenzene	1,1-dichloroethene	chloromethane
toluene	<i>cis</i> -1,2-dichloroethene	dichloromethane
4-ethyltoluene	trichloroethylene	chloroform
<i>o</i> -xylene	tetrachloroethylene	carbon tetrachloride
(<i>p+m</i>)-xylene	3-chloropropene	chloroethane
1,3,5-trimethylbenzene	<i>cis</i> -1,3-dichloropropene	1,1-dichloroethane
1,2,4-trimethylbenzene	<i>trans</i> -1,3-dichloropropene	1,2-dichloroethane
styrene	1,3-butadiene	1,2-dibromoethane
Halogenated aromatics	hexachloro-1,3-butadiene	1,1,1-trichloroethane
chlorobenzene	Chlorofluorocarbons	1,1,2-trichloroethane
1,2-dichlorobenzene	Freon 11	1,1,2,2-tetrachloroethane
1,3-dichlorobenzene	Freon 12	1,2-dichloropropane
1,4-dichlorobenzene	Freon 113	
1,2,4-trichlorobenzene	Freon 114	

Figure 32: List of organic compounds tested in NSW EPA ambient air quality study (NSW EPA, 2004a).

The annual average concentrations of organic air toxics measured in the study, which were regarded as generally representative of urban parts of the Sydney–Newcastle–Wollongong area, were very low. Many of the commonly recognised organic air toxics were not detected in any samples.

Most of the detected compounds were primarily generated by motor vehicles, especially benzene and 1,3-butadiene. Therefore results from these tests should be interpreted with care in the context of the Berrima air quality assessment, as traffic volumes (and particularly traffic congestion) will be significantly higher at the Sydney–Newcastle–Wollongong urban area sites.

Nevertheless, 24-hour average data from the testing programme for Wollongong is provided in Figure 33 (reproduced from NSW EPA, 2004a). The Wollongong site was considered to be the closest representation of Berrima air quality. The overall average and maximum 24-hour average for each of the compounds detected at Wollongong are also listed in Table 52.

It is noted that the limit of detection for these tests was 0.2ppb prior to January 2000, and then revised to 0.1ppb for 27 of the tested species from January 2000 onwards. Results below the method detection limit (MDL) were reported as being at a concentration of half of the MDL – i.e. 0.1ppb or 0.05ppb depending on method and species. For a number of the species listed in Table 52, the maximum and/or overall average concentrations are 0.1 ppb, indicating that these species were not found in detectable quantities. Other species listed in Figure 32 that are not listed in Table 52 were also assumed to have not been found in detectable quantities.

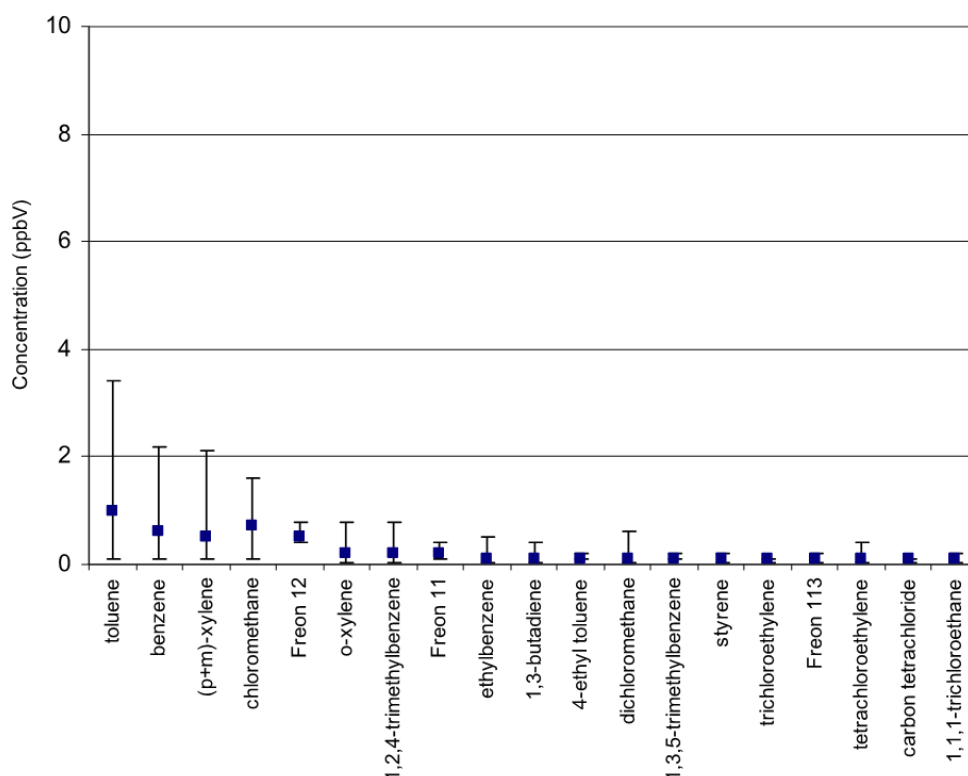


Figure 33: Overall average, minimum 24-hour average and maximum 24-hour average concentrations of organics measured in Wollongong, 1997-2001 (from NSW EPA, 2004a).

Table 52: Overall average and maximum 24-hour average concentrations of organics measured in Wollongong, 1997-2001 (from NSW EPA, 2004a).

Organic species	Overall average concentration, ppb	Max 24-hr average concentration, ppb	Organic species	Overall average concentration, ppb	Max 24-hr average concentration, ppb
1,1,1-trichloroethane	0.1	0.2	chloromethane	0.7	1.6
1,1-dichloroethane	0.1	0.1	dichloromethane	0.1	0.6
1,2,4-trichlorobenzene	0.1	0.1	ethylbenzene	0.1	0.5
1,2,4-trimethylbenzene	0.2	0.8	Freon 11	0.2	0.4
1,2-dichloroethane	0.1	0.1	Freon 113	0.1	0.2
1,3,5-trimethylbenzene	0.1	0.2	Freon 12	0.5	0.8
1,3-butadiene	0.1	0.4	hexachloro-1,3-butadiene	0.1	0.1
1,3-dichlorobenzene	0.1	0.1	o-xylene	0.2	0.8
3-chloropropene	0.1	0.1	(p+m)-xylene	0.5	2.1
4-ethyltoluene	0.1	0.2	styrene	0.1	0.2
benzene	0.6	2.2	tetrachloroethylene	0.1	0.4
bromomethane	0.1	0.1	toluene	1	3.4
cis-1,2-dichloroethene	0.1	0.8	trichloroethylene	0.1	0.1
carbon tetrachloride	0.1	0.1	vinyl chloride	0.1	0.1
chloroform	0.1	0.1			

7.7.5.3 PAHs

Samples were collected at over 24-hour periods at 22 sites covering the urban Sydney–Newcastle–Wollongong areas, as well as sites in a number of regional centres. The sites in the regional centres were selected because of the likely impacts of smoke from domestic solid fuel heaters in winter.

The study found that there was significant variation in concentrations between regions in winter, with the regional sites showing significantly higher winter averages. This was attributed to the greater use of solid fuels for heating in these regions.

Figure 34, reproduced from NSW EPA (2004b), summarises the average 24-hour PAH concentrations reported by site and season. The PAH concentrations are expressed as BaP-TEQ. Whilst none of the test sites are considered to be directly applicable to the Berrima area, it is considered that indicative sites could be those of Cooma or Tumut, for which the average 24-hour PAH concentration is interpreted as 1.5 ng/m³ as BaP-TEQ. The Lithgow site is unusual as coal is a prevalent and cheap source of home heating fuel in the area, and is not considered applicable to Berrima.

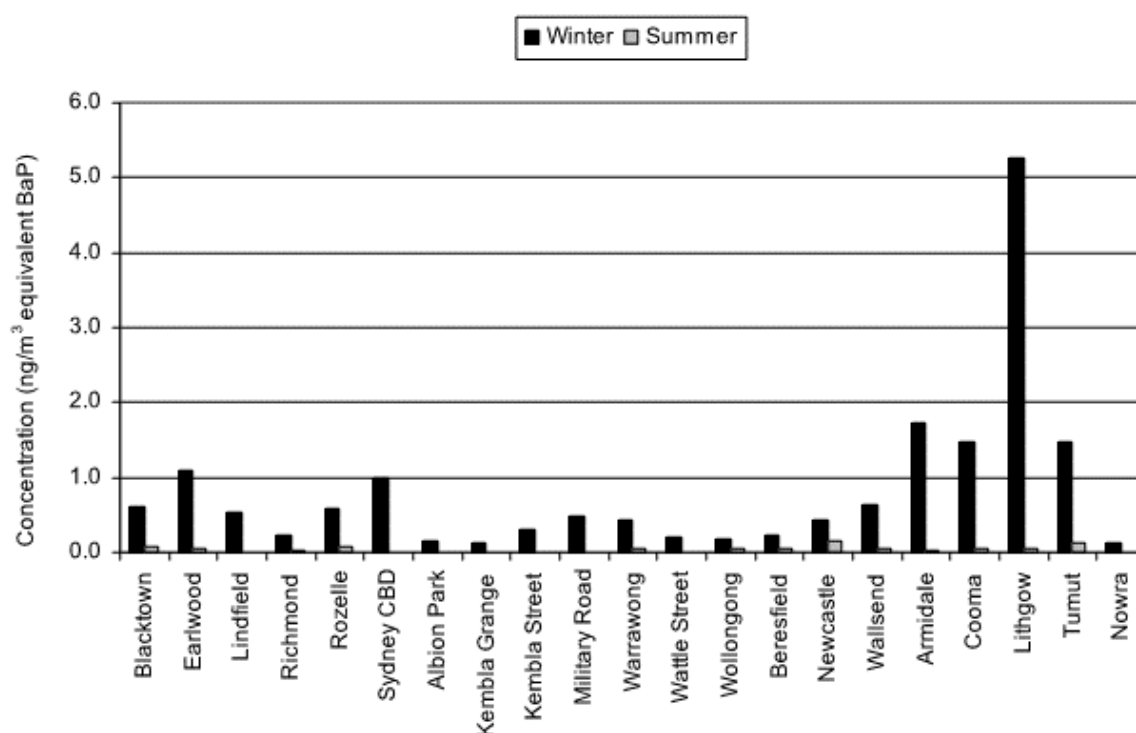


Figure 34: Average 24-hour PAH concentrations reported in NSW EPA (2004b) by site and season. Concentrations expressed as BaP-TEQ.

Individual sample results were reported only as total PAHs (not converted to BaP-TEQ), or BaP alone. Therefore maximum PAH (as BaP-TEQ) concentrations cannot be isolated. However the study found that BaP concentrations dominated the total PAH (as BaP-TEQ), and for both Cooma and Tumut the maximum BaP concentration measured was 2.7 times the average BaP concentration. It is assumed therefore for the Berrima air quality impact assessment that the maximum PAH (as BaP-TEQ) concentration is also 2.7 times the mean PAH (as BaP-TEQ) concentration.

This yields a maximum winter time 24-hour average PAH (as BaP-TEQ) concentration of 4 ng/m³ (or 0.004 µg/m³).

The NSW EPA assessment criteria for PAH requires concentrations to be calculated on a 1-hour average BaP-TEQ basis, and therefore the 24-hour concentration above cannot be directly compared. The applicable 1-hour average concentration will be somewhat higher than the 24-hour average concentration.

7.7.5.4 Heavy Metals

Twelve heavy metals were analysed during the NSW EPA ambient monitoring programme:

■ antimony	■ arsenic	■ beryllium
■ cadmium	■ cobalt	■ copper
■ lead	■ manganese	■ nickel
■ selenium	■ vanadium	■ zinc

The sampling programme is described in NSW EPA (2002) as limited study designed to determine regional concentrations of these metals and to indicate if any further work is warranted. Samples were collected over 24-hour periods for a total of four days from mid-August to early September 2000, when concentrations were expected to be high because of the still weather conditions. Particles up to 10 micrometres in diameter (i.e. PM₁₀) were collected and analysed. There were eight measuring sites in the Sydney–Newcastle–Wollongong area.

Within the limited scope of this study, the measured levels of all metals were low. The results showed that:

- Beryllium was below the limit of detection at all sites.
- Cadmium, cobalt and selenium were detected at 1 ng/m³ or less at all sites.
- Antimony and arsenic were detected at less than 5 ng/m³ at all sites.
- The remaining six metals - copper, lead, manganese, nickel, vanadium and zinc - accounted for over 95% of the total metal concentration at any site.

The results are listed in Table 53. The concentrations are reported in nanograms (1 ng = 0.000001 mg). NSW EPA (2002) commented that the mean 24-hour results were likely to be high readings for these heavy metals because the data collected for the study was sampled during winter when regional concentrations of air-borne heavy metals are thought to be elevated.

It is also noted however that the heavy metal analysis focussed only on heavy metals associated with fine particulate. As discussed in Section 3.2.7, some of the metals that were tested are semi-volatile (specifically antimony, cadmium, lead, selenium, and zinc), and therefore may not have been completely accounted for in the limited study carried out by NSW EPA.

Table 53: Heavy metals measured in ambient air by NSW EPA (2002)

Metal	Mean of samples (24-hour average), ng/m ³	Range of samples (24-hour average), ng/m ³
Antimony	1.2	0.04-4.6
Arsenic	0.6	0.1-2.5
Beryllium	Not detected	Not detected
Cadmium	0.18	0.03-1.0
Cobalt	0.19	0.1-0.39
Copper	8.2	2.4-28
Lead	29.9	3.4-99
Manganese	18.0	4.4-119
Nickel	3.6	1-20
Selenium	0.2	0.10-0.65
Vanadium	2.6	0.16-49
Zinc	32.6	11-71

Other heavy metals included in the dispersion model that were not measured in the NSW EPA (2002) campaign include chromium (both trivalent and hexavalent), mercury, thallium, and zinc. Information about ambient air quality levels of these metals is scarce, however a few comments are provided below.

Chromium

Some ambient air quality total chromium data is reported in WHO (2000): *“The following chromium concentrations have also been reported: 0.7 ng/m³ in the Shetland Islands and Norway, 0.6 ng/m³ in northwest Canada, 1–140 ng/m³ in continental Europe, 20–70 ng/m³ in Japan, and 45–67 ng/m³ in Hawaii. Monitoring of the ambient air during the period 1977–1980 in many urban and rural areas of the United States of America showed chromium concentrations to range from 5.2 ng/m³ (24-hour background level) to 156.8 ng/m³ (urban annual average); the maximum concentration determined in the United States in any one measurement was about 684 ng/m³ (24-hour average). Ranges of chromium levels in Member States of the European Union were given in a recent survey as follows: remote areas 0–3 ng/m³; urban areas: 4–70 ng/m³, and industrial areas 5–200 ng/m³”.*

Mercury

A small comment on ambient levels of mercury in air is also provided in WHO (2000): *“Current levels of mercury in outdoor air, except for regional “hot spots”, are typically in the order of 0.005–0.010 µg/m³ [5-10 ng/m³] and thus are marginal compared to exposure from dental amalgam. The exposure to mercury from outdoor air at these air levels is not expected to have direct effects on human health.”*

Thallium

The Agency for Toxic Substances and Disease Registry (ATSDR)¹⁴ reports that data on thallium levels in ambient air are sparse. ATSDR (1992) reports that *“in six United States cities, the thallium concentrations ranged from 0.02 to 0.1 ng/m³, with a typical concentration of 0.04 ng/m³. Concentrations of thallium in Chadron, Nebraska reportedly ranged from 0.04 to 0.48 ng/m³, and geometric mean concentrations measured during 1985-1986 in Genoa, Italy were about 0.015 µg/m³ [15 ng/m³].”* Averaging periods for the data are not stated. The reported Italian data is higher than the USA data and it is not stated whether the Italian data is background ambient data or data near an industrial source of thallium (such as a coal-burning power plant).

Zinc

ATSDR (2005) reports that *“In a survey by the National Air Surveillance Network, the mean concentration of zinc in the air in the United States in 1977–1979 was 0.02–0.16 µg/m³ for urban air compared to 0.01–0.05 µg/m³ for rural air. The concentrations of zinc in the air of remote areas range from <0.003 to 0.027 µg/m³.”*

7.7.6 Hydrogen Fluoride

Background concentrations for hydrogen fluoride were assumed to be negligible.

7.8 NO_x to NO₂ Oxidation Calculations

Emission data for both NO and NO₂ discharged from the No.6 Kiln Stack is available. To calculate ambient concentrations of NO₂ that could occur as a result of these discharges, it is necessary to estimate the oxidation of NO into NO₂ in the atmosphere after discharge from the stack.

For the calculation of NO₂ dynamics, in order to compare the model results to the assessment criteria in Table 42, an assessment of NO-to-NO₂ conversion is required. Several options for calculating this conversion are provided in the “Approved Methods” guidelines. Methods 1, 2 and 3 specified in the guidelines were all used to test the sensitivity of the results to the method selected.

As will be shown in Section 8.1, Method 1 was found to be unsuitable for the assessment, but Methods 2 and 3 both showed that the predicted cumulative NO₂ concentrations were within the NSW EPA assessment criteria.

¹⁴ The ATSDR, based in Atlanta, Georgia, is a federal public health agency of the U.S. Department of Health and Human Services.

8 Dispersion Model Results

8.1 NO_x and NO₂

All NO_x and NO₂ model results discussed in this section assume a constant NO_x emission concentration of 1000 mg/Nm³ which is the proposed 24-hour average maximum emission concentration to be included in the EPL for the burning of NSF.

As explained in Section 4.8.1, this 24-hour average emission concentration was converted into a very conservative equivalent 1-hour NO_x concentration for use in the dispersion model that accounts for peak 1-hour concentrations that could occur within the 24-hour period. The model was run using that peak 1-hour concentration as the constant emission rate for 365 days per year, 24 hours per day.

The model results are presented in the following subsections.

8.1.1 Model Output – one hour average

Figure A5a in Appendix 5 shows the model results for 100th percentile, incremental 1-hour average NO concentrations from the No.6 Kiln stack. The Kiln stack is the only source of NO emissions at the site.

Figure A5b in Appendix 5 shows the model results for 100th percentile, incremental 1-hour average NO₂ concentrations from the No.6 Kiln stack, for the NO₂ discharged from the stack in NO₂ form (i.e. at 1.78 g/s as per Table 31). This figure does not show any NO₂ calculated from atmospheric conversion of NO to NO₂.

Calculation of the cumulative NO₂ concentrations was carried out at each of the 87 discrete receptor locations shown in Figure 25 using the three methods in the “Approved Methods” guidelines as discussed below.

8.1.2 NO-to-NO₂ conversion using Method 1

“Method 1” for NO-to-NO₂ conversion specified in the “Approved Methods” guidelines requires the assumption that 100% of the NO_x emitted is converted to NO₂. This is a highly simplistic and conservative method. Using this method, incremental NO₂ concentrations (i.e. without adding background concentrations) exceeded the NSW EPA assessment criteria at 55 out of the 87 receptors. Therefore, Method 1 was deemed to be unsuitable for this assessment, and a more refined assessment was undertaken using both Methods 2 and 3.

8.1.3 NO-to-NO₂ conversion using Method 2 - “Ozone Limiting Method”

Method 2 for NO-to-NO₂ conversion specified in the “Approved Methods” guidelines requires the assumption that all the available ozone in the atmosphere will react with NO in the plume until either all the ozone or all the NO is used up. This approach assumes that the atmospheric reaction is instant, whereas in reality the reaction takes place over a number of hours. Therefore this method, called the “ozone limiting method” or “OLM”, is also a conservative method that is likely to overestimate NO₂ concentrations.

Method 2 was applied to each of the 87 discrete receptors by the following procedure:

1. Assume that 100% of the NO emitted from the stack is converted into NO₂
2. Assume that ozone data measured at Bargo can be used contemporaneously for hour-by-hour OLM conversions
3. Calculate converted NO₂ concentration as minimum of either incremental NO₂ concentration or (46/48 × ozone) concentration.
4. Add modelled incremental NO₂ concentration from kiln discharge.
5. Add contemporaneous background NO₂ from Bargo¹⁵, converted from ppmh to ug/m³ using Berrima temperature and pressure data.
6. As a sensitivity check, the total NO₂ concentration was also calculated using contemporaneous background NO₂ data from Camden.

This procedure is slightly different to the equation specified in the “Approved Methods” guidelines, because here the actual NO₂ stack discharge has been added to the NO₂ concentration from converted NO. In the “Approved Methods” guidelines, an assumption is made that 10% of the discharged NO_x is in the NO₂ form, which is an appropriate assumption only if emission rates of actual NO₂ are not available.

The maximum incremental concentrations (i.e. no background NO₂ contributions) of 1-hour NO₂ using the ozone limiting method at each of the discrete receptors 1-87 are listed in Table 54. This data includes the relatively minor contribution of NO₂ discharged as NO₂ from the kiln stack. The maximum off-site incremental concentration of 1-hour average NO₂ beyond the site boundary at an existing or likely future off-site sensitive receptor using Method 2 is 180 µg/m³ at receptor 68.

The maximum 1-hour concentrations shown in Table 54 are illustrated in Figure 35, which also shows the 99.9th percentile 1-hour incremental concentrations, and the NSW EPA criteria for 1-hour NO₂ of 246 µg/m³.

The maximum cumulative concentrations of 1-hour NO₂ using the Bargo or Camden contemporaneous background concentrations are listed in Table 55. The table also shows the calculated cumulative NO₂ concentrations after editing the Bargo data file to remove peak NO₂ concentrations occurring over the period 17-21 October 2013, and editing the Camden data file to remove peak NO₂ concentrations occurring on 20 October 2013. Timeseries concentration data at the two sites is shown in Figure 36, with the peak in late October clearly visible in the Bargo data, but less pronounced in the Camden data. These dates coincided with the large Balmoral bushfire referred to earlier in this report, and were not considered to be representative of normal background.

Using the Bargo background data including the October peak records, the maximum off-site cumulative (incremental + background) concentration of 1-hour average NO₂ beyond the site boundary at an existing or likely future off-site sensitive receptor using Method 2 is 210 µg/m³, occurring at both receptors 59 and 60. This cumulative concentration is less than the NSW EPA criteria of 246 µg/m³. When the peak background data is removed, the maximum off-site cumulative concentration at those two receptors is approximately halved, and the new maximum is 180 µg/m³ at receptor 68¹⁶.

¹⁵ Any missing records in the Bargo dataset were replaced with interpolated data from hours before and after the missing data if only 1 or 2 records were missing, or replaced with Camden data if a greater number of sequential hours were missing. Similar approach applied to the Camden data set using Bargo data as replacement dataset.

¹⁶ The actual cumulative concentration would be a little higher (likely in the order of 2-10 µg/m³ higher based on typical data values for hour 17 in the Bargo datafile) than this as this concentration occurred during hour 17 on 20 October 2013, when valid background data was not available and the background was therefore assumed to be zero.

Using the Camden background data, the maximum off-site cumulative (incremental + background) concentration of 1-hour average NO₂ beyond the site boundary at an existing or likely future off-site sensitive receptor using Method 2 is 209 µg/m³, occurring at receptor 68. This cumulative concentration is less than the NSW EPA criteria of 246 µg/m³. The Camden concentration data shown in the table is unaffected by removed the peak background concentration that occurred in Camden on 20 October 2013.

Table 54: 1-hour average incremental ground level concentration of NO₂ at potentially sensitive discrete receptors. NO-to-NO₂ conversion using Method 2 (ozone-limiting method). Excludes background concentrations.

Receptor no.	Max 1-hr avg NO ₂ (µg/m ³)	Receptor no.	Max 1-hr avg NO ₂ (µg/m ³)	Receptor no.	Max 1-hr avg NO ₂ (µg/m ³)
1	110	30	80	59	100
2	140	31	78	60	119
3	119	32	80	61	100
4	150	33	76	62	142
5	136	34	76	63	148
6	167	35	87	64	133
7	119	36	87	65	158
8	131	37	104	66	78
9	153	38	104	67	139
10	141	39	96	68	180
11	115	40	87	69	164
12	127	41	93	70	83
13	127	42	77	71	125
14	128	43	77	72	119
15	127	44	72	73	91
16	119	45	77	74	89
17	120	46	78	75	104
18	104	47	68	76	104
19	112	48	74	77	127
20	112	49	69	78	127
21	173	50	64	79	76
22	159	51	62	80	108
23	159	52	63	81	83
24	143	53	80	82	86
25	108	54	72	83	127
26	108	55	106	84	127
27	82	56	106	85	127
28	80	57	160	86	127
29	80	58	98	87	127

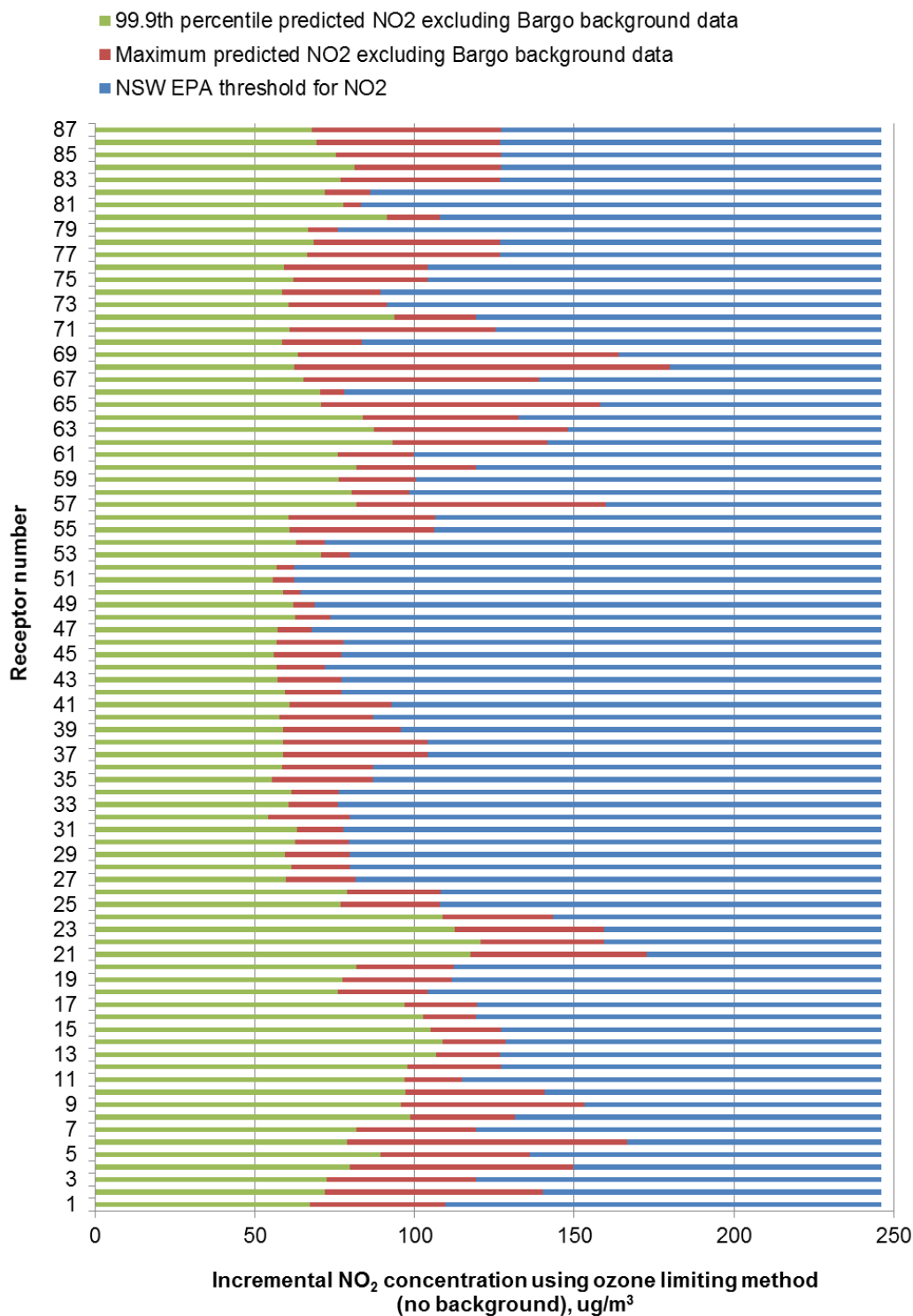


Figure 35: Incremental NO₂ concentrations in ambient air predicted at each discrete receptor using ozone limiting method; 1-hr average, both maximum and 99.9th percentile values shown compared to NSW EPA ambient air quality assessment threshold for NO₂.

Data excludes background contribution of NO₂ but includes NO₂ emissions from stack plus NO₂ converted from NO after discharge from stack using Method 2 (ozone limiting method).

Table 55: 1-hour average cumulative ground level concentrations of NO₂ at potentially sensitive discrete receptors. NO-to-NO₂ conversion using Method 2 (ozone-limiting method). Includes contemporaneous background concentrations from Bargo and Camden.

Receptor no.	1-hr avg NO ₂ (µg/m ³)	1-hr avg NO ₂ (µg/m ³)	1-hr avg NO ₂ (µg/m ³)	1-hr avg NO ₂ (µg/m ³)
	Bargo background data	Bargo data excl. 17-21 Oct peaks	Camden background data	Camden data excl. 20 Oct peak
1	122	113	122	122
2	152	152	163	163
3	125	125	126	126
4	160	160	167	167
5	150	150	155	155
6	179	179	189	189
7	125	125	129	129
8	141	141	147	147
9	167	167	172	172
10	155	155	160	160
11	127	127	127	127
12	132	132	136	136
13	132	132	135	135
14	134	134	139	139
15	132	132	136	136
16	125	125	127	127
17	125	125	127	127
18	122	110	115	115
19	122	119	121	121
20	122	119	121	121
21	180	180	188	188
22	164	164	172	172
23	164	164	170	170
24	148	148	154	154
25	122	115	115	115
26	122	115	117	117
27	122	86	88	88
28	122	86	88	88
29	122	83	84	84
30	122	83	90	90
31	122	83	90	90
32	122	88	83	83
33	122	78	85	85
34	122	78	85	85
35	122	89	92	92
36	122	89	92	92
37	126	104	111	111
38	126	104	111	111
39	122	96	103	103
40	122	89	92	92
41	122	93	100	100
42	122	79	82	82
43	122	79	83	83
44	122	77	79	79
45	122	79	83	83
46	122	80	83	83
47	122	77	73	73
48	122	79	77	77
49	122	77	72	72

Receptor no.	1-hr avg NO ₂ (µg/m ³)	1-hr avg NO ₂ (µg/m ³)	1-hr avg NO ₂ (µg/m ³)	1-hr avg NO ₂ (µg/m ³)
	Bargo background data	Bargo data excl. 17-21 Oct peaks	Camden background data	Camden data excl. 20 Oct peak
50	122	77	66	66
51	122	77	64	64
52	122	77	64	64
53	122	83	89	89
54	122	77	83	83
55	122	113	111	111
56	122	113	112	112
57	167	167	180	180
58	162	105	114	114
59	210	100	107	107
60	210	119	121	121
61	201	106	113	113
62	166	142	171	171
63	172	148	177	177
64	145	145	153	153
65	182	158	188	188
66	122	80	95	95
67	163	139	168	168
68	204	180	209	209
69	188	164	193	193
70	122	94	101	101
71	150	125	155	155
72	125	125	126	126
73	122	91	99	99
74	122	89	97	97
75	126	104	112	112
76	126	104	111	111
77	134	134	137	137
78	134	134	137	137
79	122	81	82	82
80	131	112	117	117
81	143	96	104	104
82	122	96	102	102
83	137	127	149	149
84	144	144	148	148
85	144	144	148	148
86	144	144	148	148
87	144	144	148	148

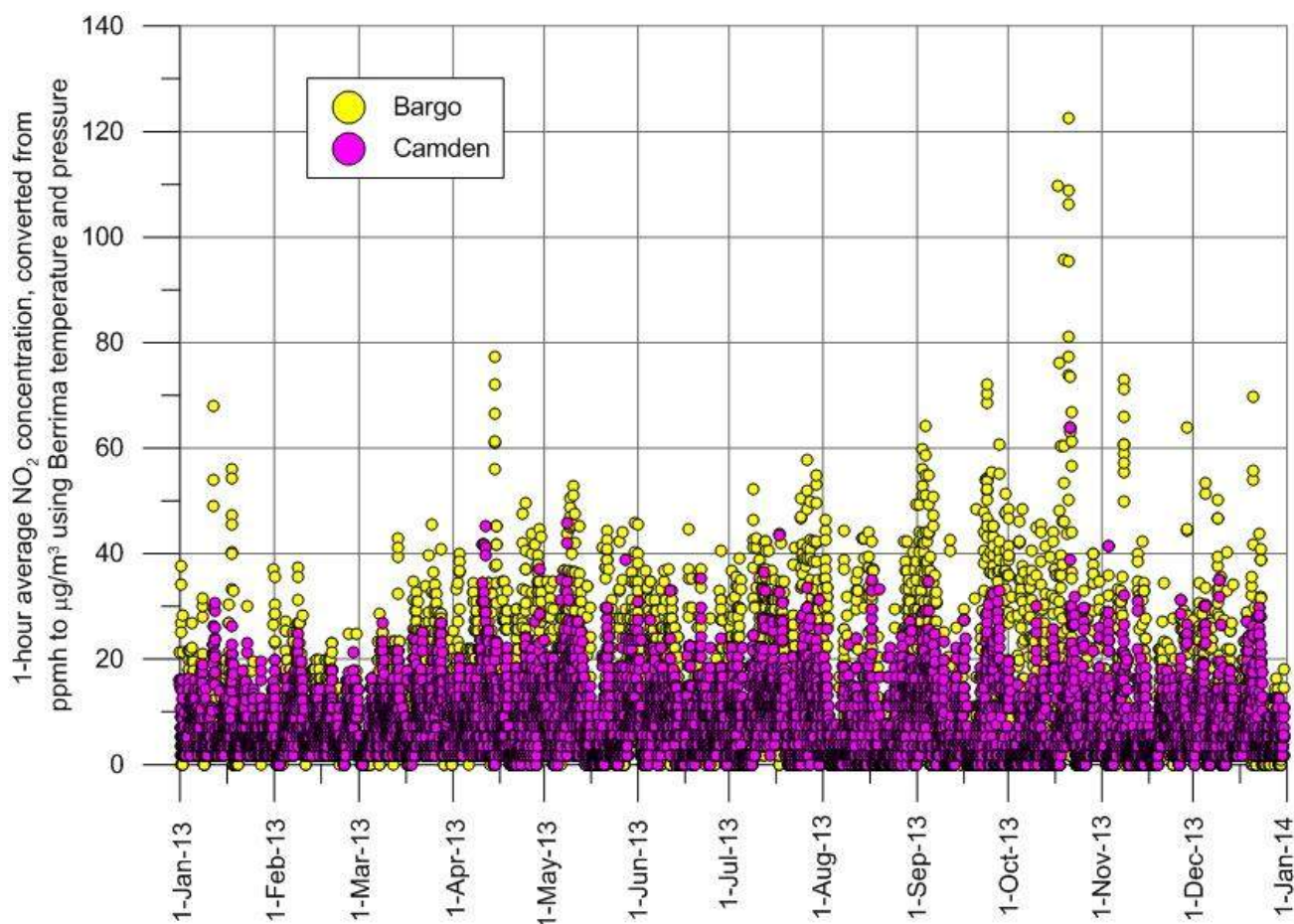


Figure 36: Bargo and Camden 1-hour average NO₂ concentration data used for contemporaneous background assessment.

The 1-hour cumulative concentrations shown in Table 55 are illustrated in Figure 37, Figure 38, and Figure 39, which also show the 99.9th percentile 1-hour cumulative concentrations and the NSW EPA criteria for 1-hour NO₂ of 246 µg/m³.

Finally, the 1-hour cumulative data is plotted on an aerial map showing spatial distribution of the predicted concentrations in Figure 40 to Figure 42. The higher predicted concentrations generally occur to the south and southeast of the Works.

The model results show some elevated concentrations of NO₂ near Mossvale, well to the southeast of the Works (receptors 65 to 71). This is largely due to the coincidence of high concentrations of ozone in the Bargo ozone data at the same time as maximum GLCs of NO occur at those receptors.

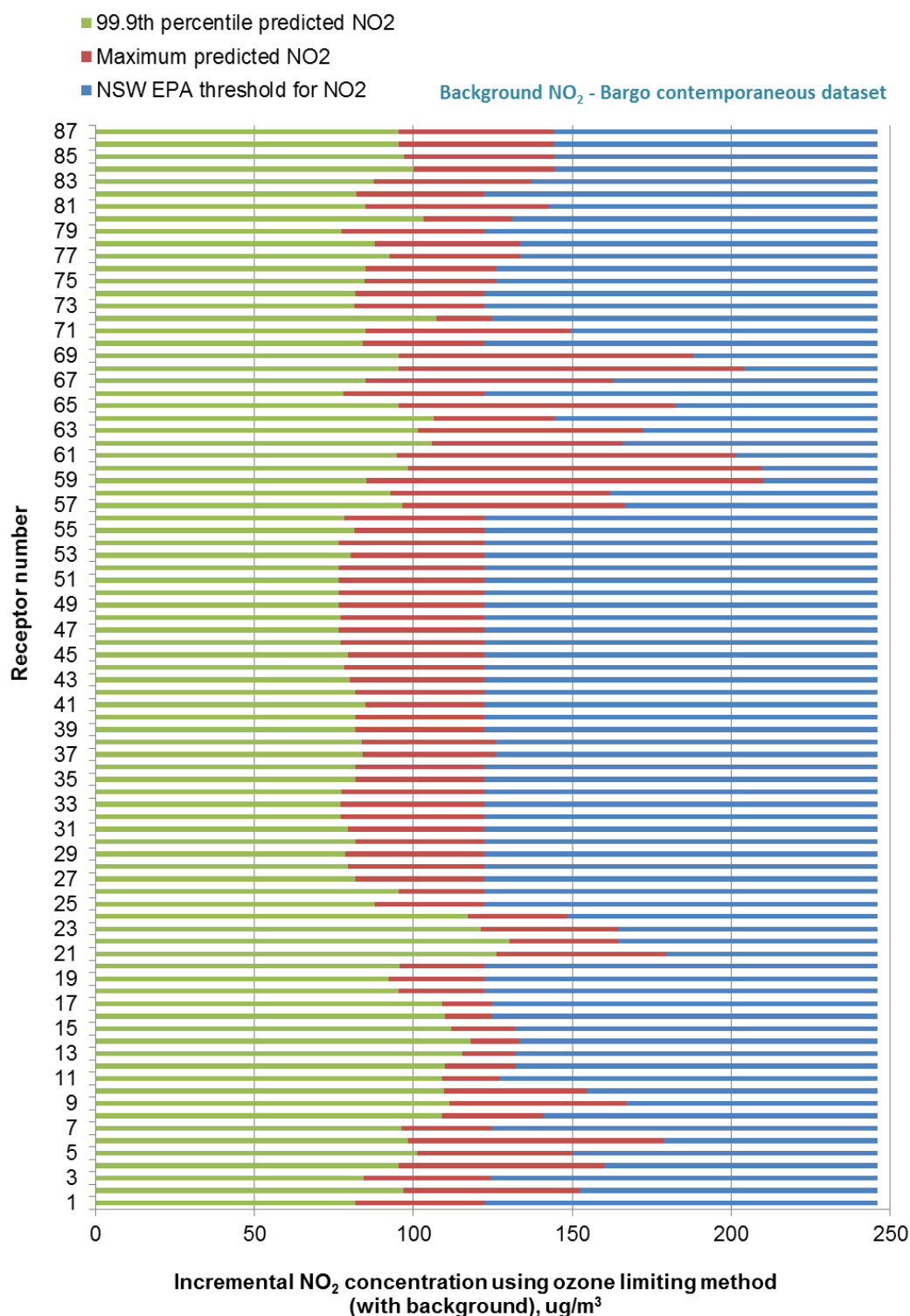


Figure 37: Cumulative NO₂ concentrations in ambient air predicted at each discrete receptor using ozone limiting method; 1-hr average, both maximum and 99.9th percentile values shown compared to NSW EPA ambient air quality assessment threshold for NO₂.

Data includes background contribution of NO₂ using contemporaneous hourly data from Bargo.

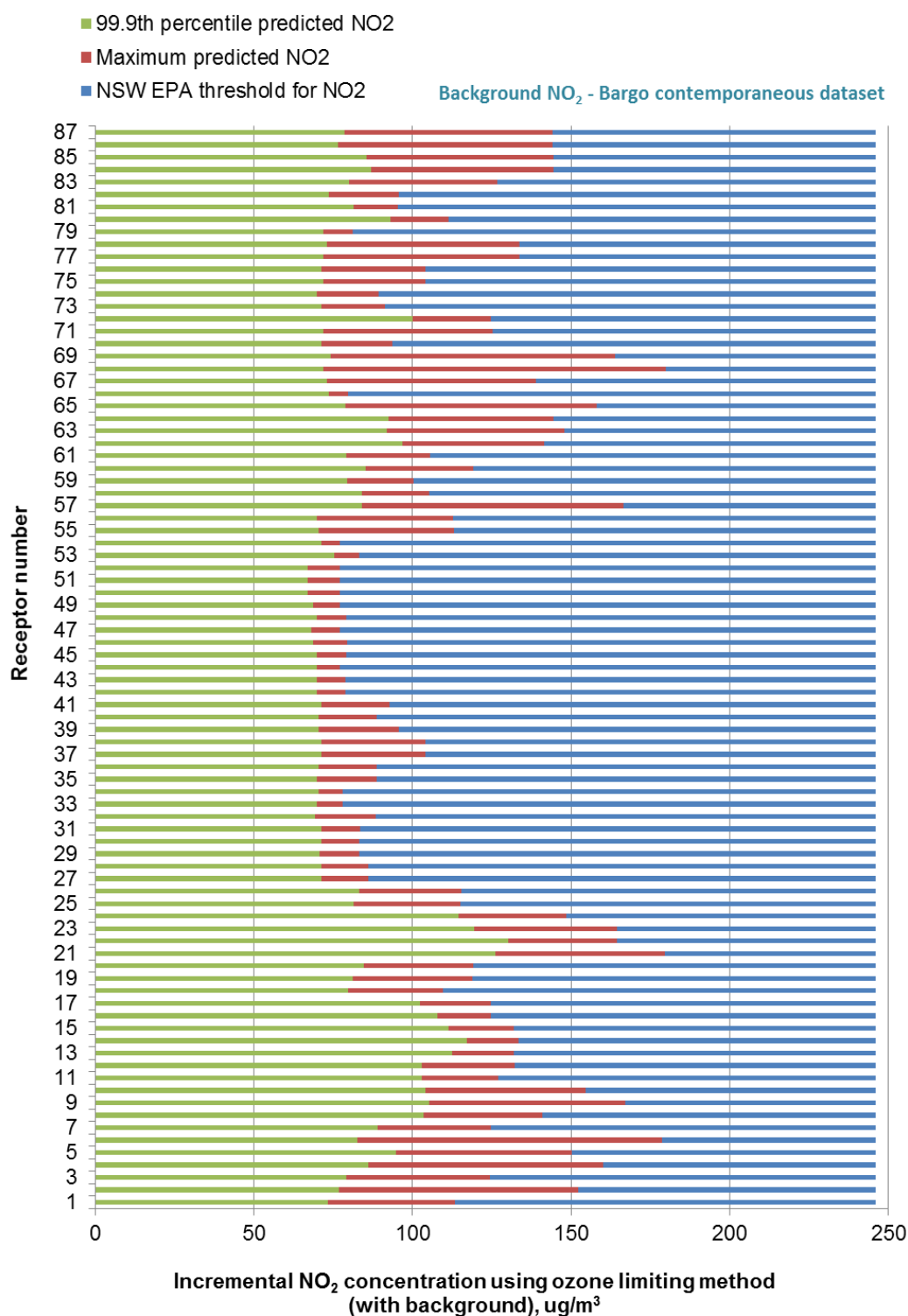


Figure 38: Cumulative NO₂ concentrations in ambient air predicted at each discrete receptor using ozone limiting method; 1-hr average, both maximum and 99.9th percentile values shown compared to NSW EPA ambient air quality assessment threshold for NO₂.

Data includes background contribution of NO₂ using contemporaneous hourly data from Bargo but with peak background concentrations occurring on 17-21 October removed.

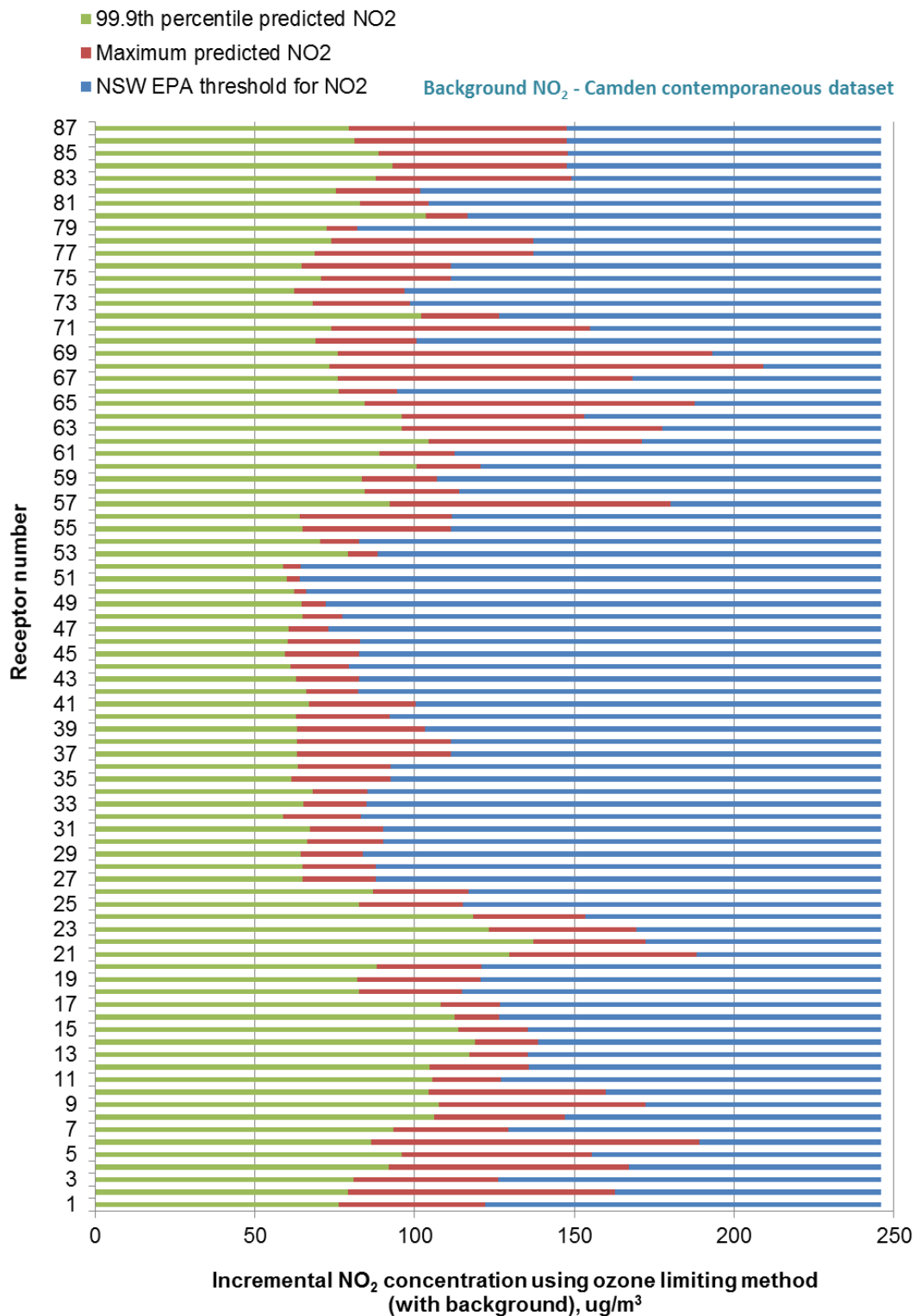
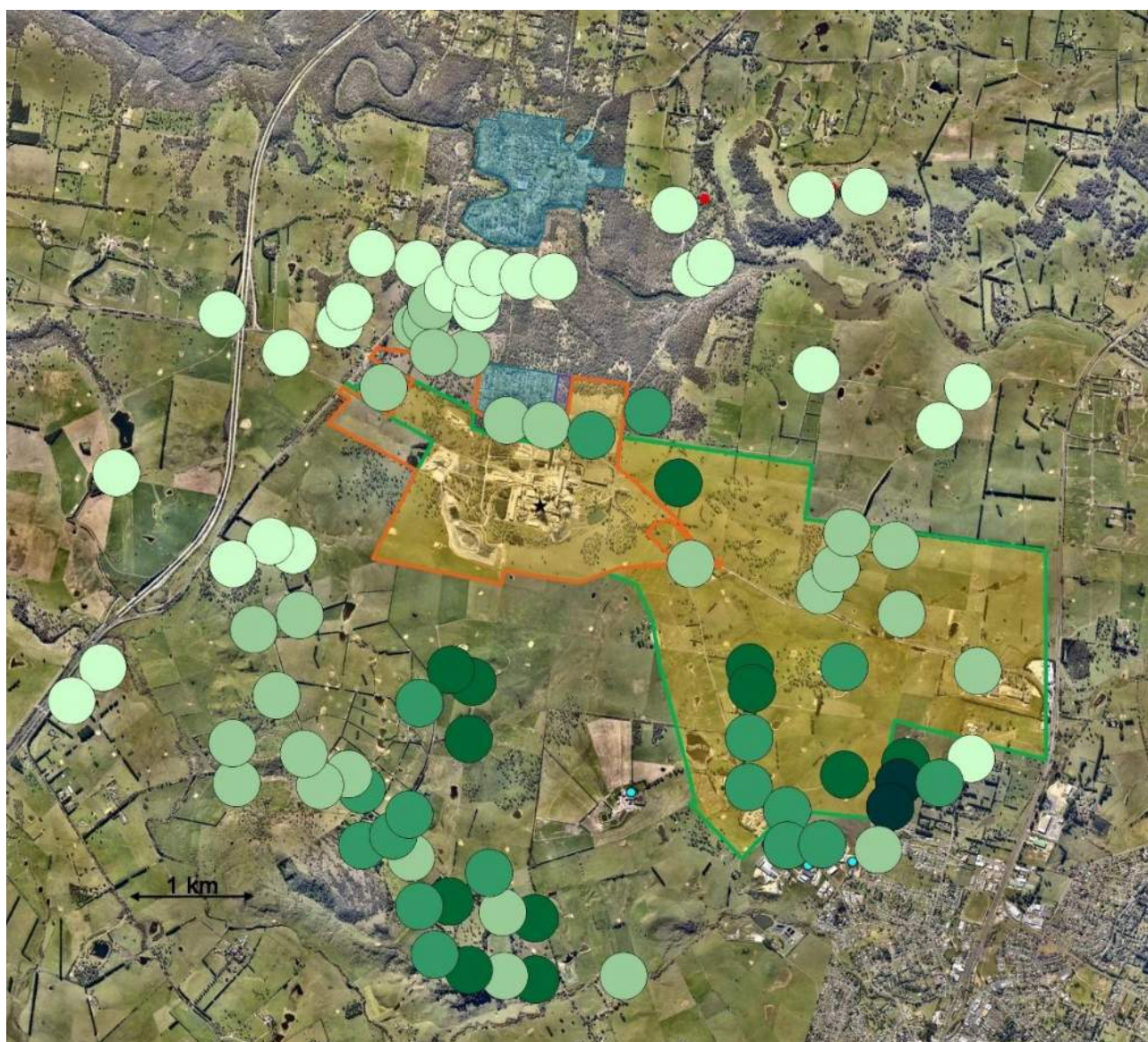


Figure 39: Cumulative NO₂ concentrations in ambient air predicted at each discrete receptor using ozone limiting method; 1-hr average, both maximum and 99.9th percentile values shown compared to NSW EPA ambient air quality assessment threshold for NO₂.

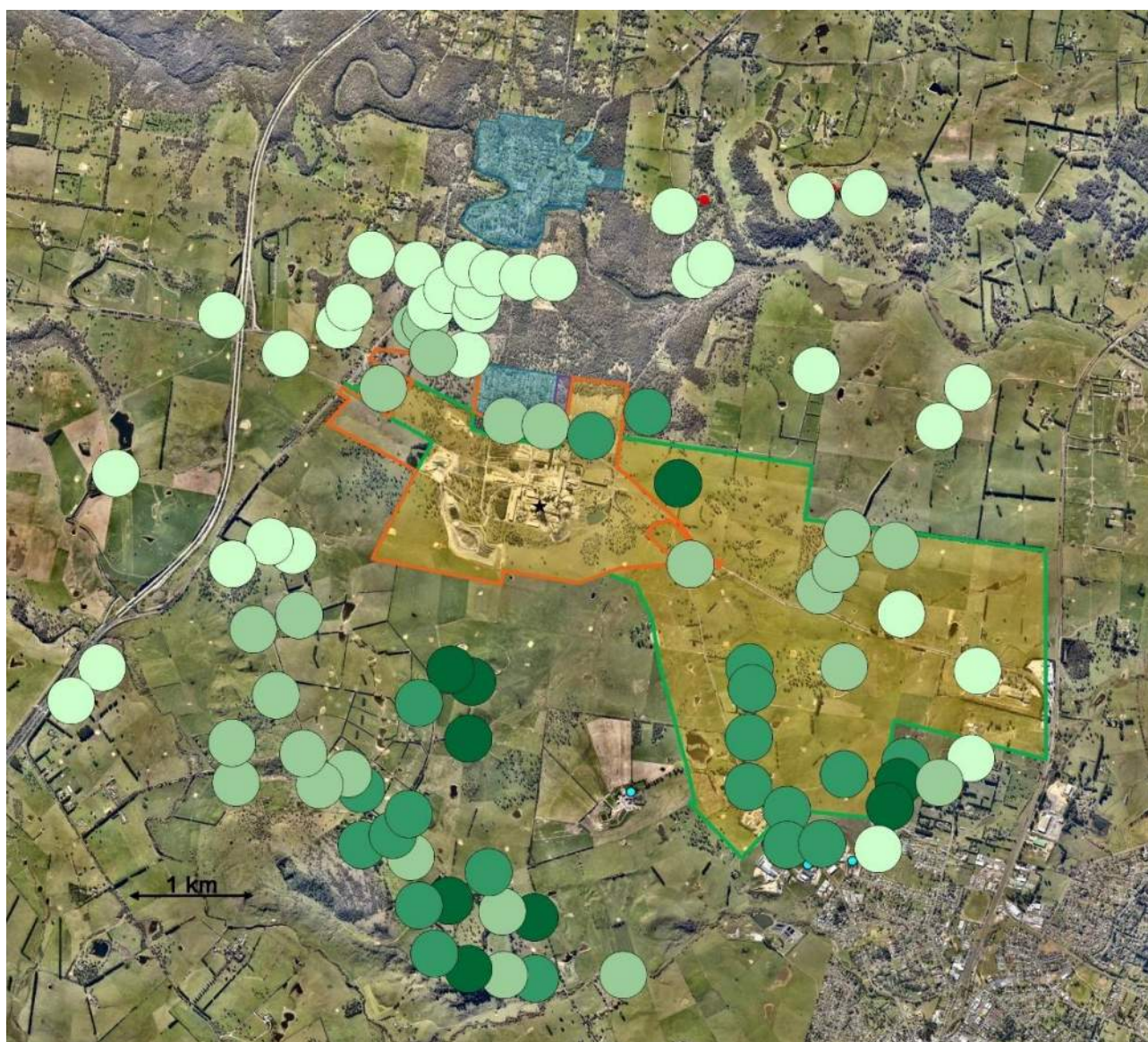
Data includes background contribution of NO₂ using contemporaneous hourly data from Camden.



Concentration, $\mu\text{g}/\text{m}^3$

- 60 to 100
- 100 to 130
- 130 to 160
- 160 to 190
- 190 to 210

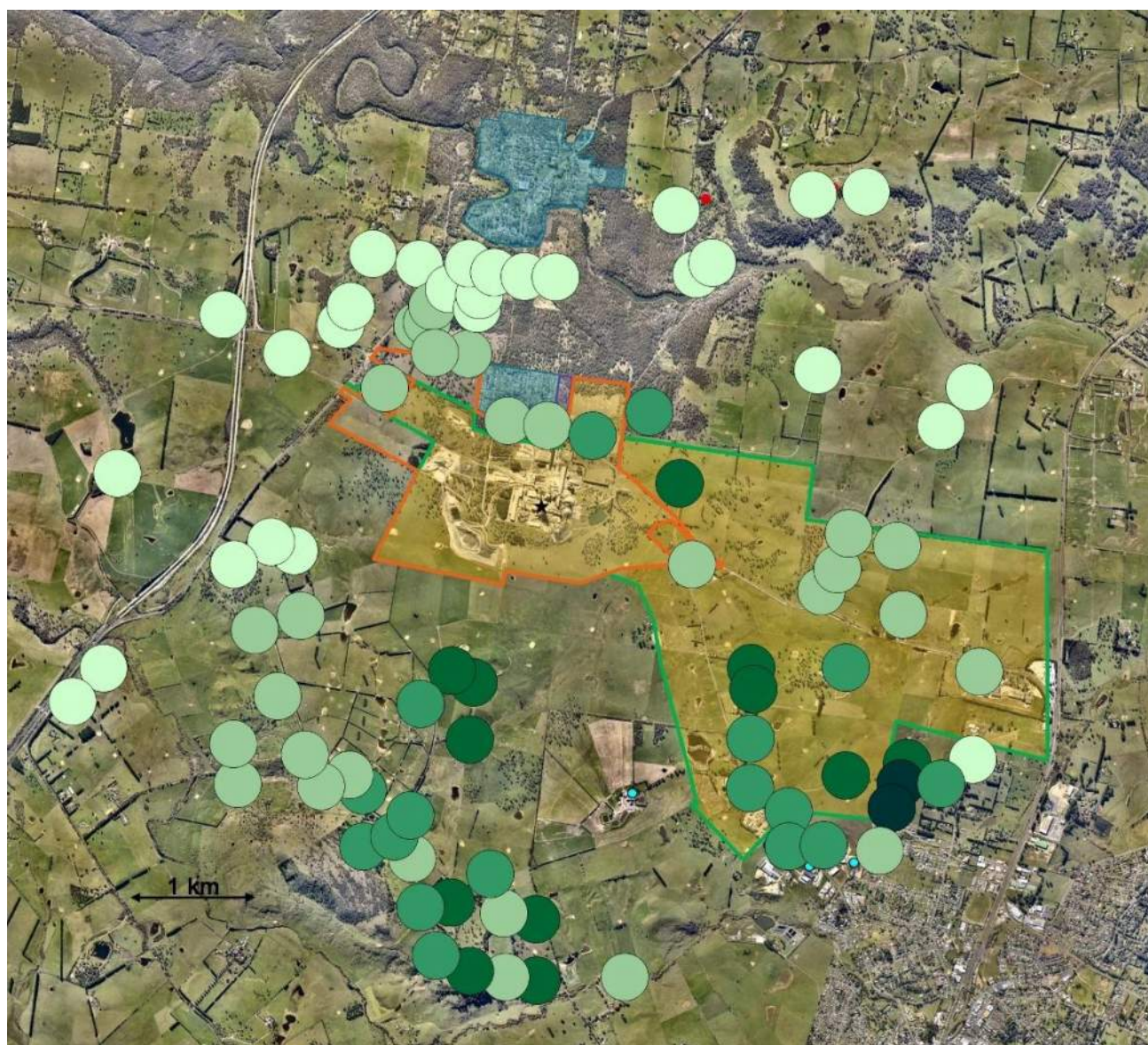
Figure 40: Spatial distribution of cumulative NO_2 concentrations in ambient air using ozone limiting method; 1-hr average, including contemporaneous background data contribution from Bargo (including background data measured 17-21 October 2013).



Concentration, $\mu\text{g}/\text{m}^3$

- 60 to 100
- 100 to 130
- 130 to 160
- 160 to 190
- 190 to 210

Figure 41: Spatial distribution of cumulative NO_2 concentrations in ambient air using ozone limiting method; 1-hr average, including contemporaneous background data contribution from Bargo (excluding background data measured 17-21 October 2013).



Concentration, $\mu\text{g}/\text{m}^3$

- 60 to 100
- 100 to 130
- 130 to 160
- 160 to 190
- 190 to 210

Figure 42: Spatial distribution of cumulative NO_2 concentrations in ambient air using ozone limiting method; 1-hr average, including contemporaneous background data contribution from Camden.

8.1.4 NO-to-NO₂ conversion using Method 3 - “Janssen Method”

Method 3 in the “Approved Methods” guideline is known as the “Janssen method”.

The Janssen method takes the form of an empirical equation for estimating the oxidation rate of NO, initially derived for power plant plumes. The equation is dependent on distance downwind from the source and two parameters “A” and “α”, and has the following form (page 43, “Approved Methods”):

$$\text{NO}_2 / \text{NO}_x = A(1 - \exp(-\alpha x))$$

where:

x = the distance from the source

A and α are classified according to O₃ concentration, wind speed and season (Janssen et al. (1988) provides values for A and α).

For determining the factors of A and α for the Janssen equation, hourly measurements of background ozone concentrations from the Bargo site, converted from the format supplied by NSW EPA of ppmh to µg/m³ using Berrima temperature and pressure, were applied to the raw data from the dispersion model on an hour-by-hour basis. It was assumed that the applicable range of wind speeds at plume height is 5-15m/s.

The Janssen equation was applied to a number of selected receptor locations which represented potentially sensitive or maximum impacted locations within the receiving environment. The method used to assess cumulative NO₂ concentrations at each of these locations was as follows:

1. Extract time series (hourly estimates) of NO concentrations and NO₂ concentrations (due to discharge of NO and NO₂ from No.6 Kiln Stack and without allowance for atmospheric conversions) at each location.
2. Assign values for the factors A and α for the Janssen equation, based on ozone background concentrations for the same hour, and the season when the concentration occurred (summer assumed to be December to March, winter assumed to be June to August).
3. Calculate NO_x:NO₂ ratio for each receptor.
4. Convert NO concentrations in the time series to NO_x and then multiply by the NO_x:NO₂ ratio to get NO₂ contribution from NO emissions.
5. Add NO₂ contribution due to NO₂ discharged from No.6 Kiln Stack for that hour, plus corresponding background NO₂ from Bargo or Camden for that hour. For the Bargo data, only the data file with the peak records for 17-21 October 2013 removed was used.

The maximum incremental concentrations of 1-hour NO₂ using the Janssen method at each of the discrete receptors 1-87 are listed in Table 56. This data includes the relatively minor contribution of NO₂ discharged as NO₂ from the kiln stack. The maximum off-site incremental concentration of 1-hour average NO₂ beyond the site boundary at an existing or likely future off-site sensitive receptor using the Janssen method is 124 µg/m³ at receptor 82.

The maximum 1-hour concentrations shown in Table 56 are illustrated in Figure 43, which also shows the 99.9th percentile 1-hour incremental concentrations, and the NSW EPA criteria for 1-hour NO₂ of 246 µg/m³.

Table 56: 1-hour average incremental ground level concentration of NO₂ at potentially sensitive discrete receptors. NO-to-NO₂ conversion using Method 3 (Janssen method). Excludes background concentrations.

Receptor no.	Max 1-hr avg NO ₂ (µg/m ³)	Receptor no.	Max 1-hr avg NO ₂ (µg/m ³)	Receptor no.	Max 1-hr avg NO ₂ (µg/m ³)
1	57	30	64	59	79
2	91	31	60	60	69
3	79	32	67	61	67
4	117	33	41	62	68
5	87	34	42	63	76
6	102	35	46	64	80
7	83	36	33	65	95
8	99	37	47	66	67
9	94	38	36	67	87
10	93	39	44	68	121
11	102	40	33	69	105
12	114	41	27	70	56
13	87	42	22	71	83
14	98	43	24	72	80
15	88	44	24	73	33
16	86	45	32	74	33
17	88	46	36	75	33
18	93	47	32	76	29
19	61	48	24	77	29
20	73	49	24	78	38
21	99	50	38	79	43
22	75	51	71	80	41
23	74	52	98	81	82
24	84	53	58	82	124
25	74	54	55	83	69
26	69	55	27	84	100
27	48	56	24	85	108
28	40	57	56	86	88
29	48	58	77	87	98

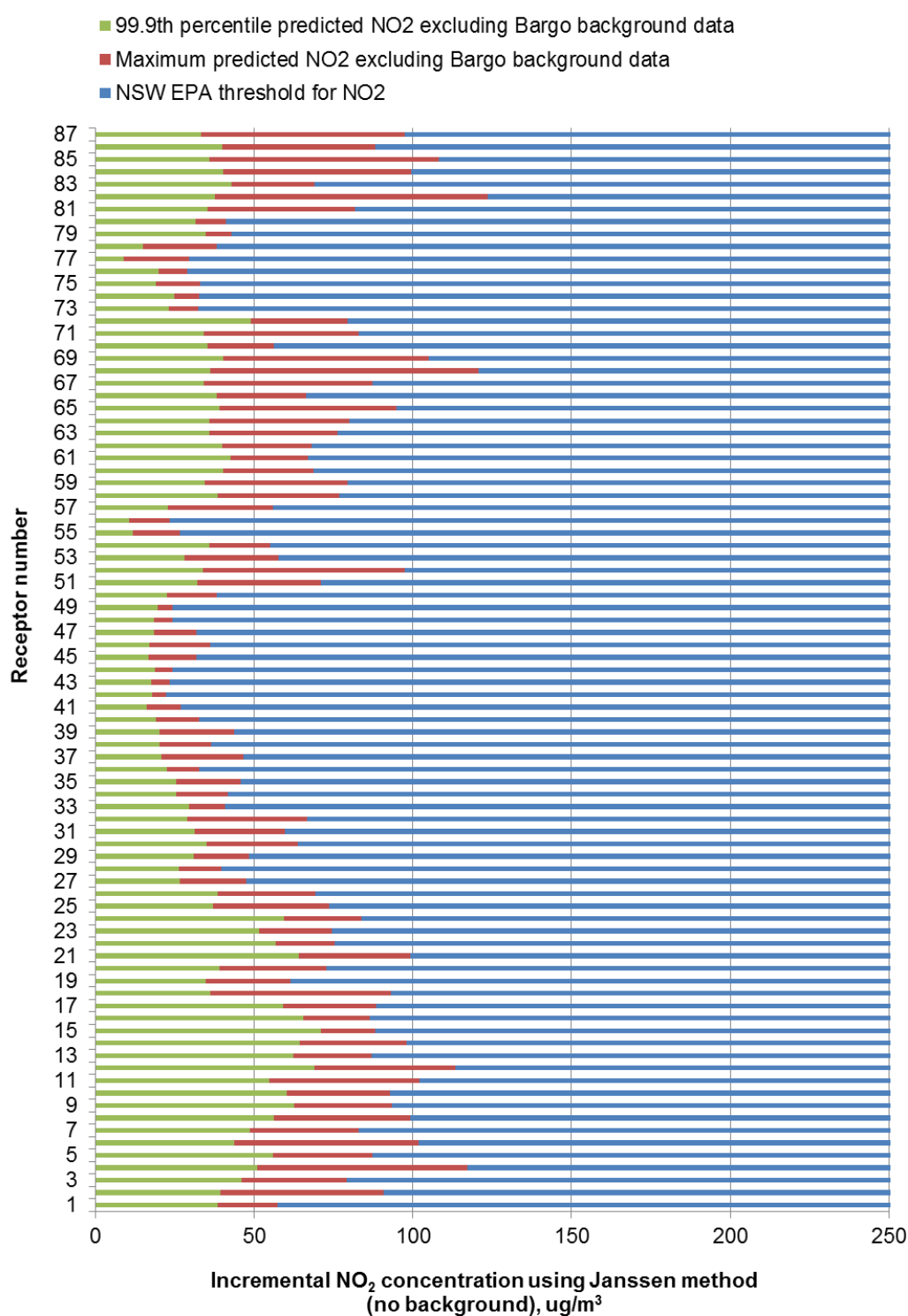


Figure 43: Incremental NO₂ concentrations in ambient air predicted at each discrete receptor using Method 3 (Janssen method); 1-hr average, both maximum and 99.9th percentile values shown compared to NSW EPA ambient air quality assessment threshold for NO₂.

Data excludes background contribution of NO₂ but includes NO₂ emissions from stack plus NO₂ converted from NO after discharge from stack using Method 3.

The maximum cumulative concentrations of 1-hour NO₂ using the Janssen method and either contemporaneous Bargo (excluding 17-21 October peak data) or Camden background data are listed in Table 57.

The 1-hour cumulative concentrations shown in Table 57 are illustrated in Figure 44 and Figure 45, which also show the 99.9th percentile 1-hour cumulative concentrations and the NSW EPA criteria for 1-hour NO₂ of 246 µg/m³.

Using the Bargo background data excluding the October peak records, the maximum off-site cumulative (incremental + background) concentration of 1-hour average NO₂ beyond the site boundary at an existing or likely future off-site sensitive receptor using Method 3 is 128 µg/m³, occurring at receptor 4. This cumulative concentration is just over 50% of the NSW EPA criteria of 246 µg/m³.

Using the Camden background data, the maximum off-site cumulative (incremental + background) concentration of 1-hour average NO₂ beyond the site boundary at an existing or likely future off-site sensitive receptor using Method 3 is 150 µg/m³, occurring at receptor 68. This cumulative concentration is 61% of the NSW EPA criteria of 246 µg/m³.

Lastly, the 1-hour cumulative data is plotted on an aerial map showing spatial distribution of the predicted concentrations in Figure 46 and Figure 47. As with the Method 2 analysis, the higher predicted concentrations generally occur to the south and southeast of the Works. However the predicted concentrations overall are lower than those predicted using Method 2.

As with the predicted concentrations using Method 2, the model results show some elevated concentrations of NO₂ near Mossvale, well to the southeast of the Works (receptors 65 to 71). This is largely due to the coincidence of high concentrations of ozone in the Bargo ozone data at the same time as maximum GLCs of NO occur at those receptors. In addition, the larger distance between the Works and the receptors increases the percentage conversion of NO to NO₂ compared with receptors closer to the Works.

Table 57: 1-hour average cumulative ground level concentrations of NO₂ at potentially sensitive discrete receptors. NO-to-NO₂ conversion using Method 3 (Janssen method). Includes contemporaneous background concentrations from Bargo and Camden (Bargo data excluding peak values recorded 17-21 October 2013).

Receptor no.	1-hr avg NO ₂ (µg/m ³)	1-hr avg NO ₂ (µg/m ³)	Receptor no.	1-hr avg NO ₂ (µg/m ³)	1-hr avg NO ₂ (µg/m ³)
	Bargo background data	Camden background data		Bargo background data	Camden background data
1	77	70	45	77	46
2	103	113	46	77	46
3	84	86	47	77	46
4	128	135	48	77	46
5	101	106	49	77	46
6	114	125	50	77	46
7	88	90	51	77	78
8	104	113	52	112	109
9	106	111	53	77	80
10	100	105	54	77	66
11	109	111	55	77	46
12	116	121	56	77	46
13	94	96	57	77	71
14	105	107	58	79	86
15	95	99	59	88	90
16	93	97	60	77	69
17	94	96	61	84	86
18	98	100	62	77	95
19	77	70	63	77	100
20	80	82	64	94	100
21	106	115	65	95	124
22	80	84	66	77	70
23	81	83	67	87	117
24	91	91	68	121	150
25	77	77	69	105	134
26	77	71	70	78	73
27	77	49	71	85	112
28	77	46	72	85	87
29	77	50	73	77	46
30	77	67	74	77	46
31	77	63	75	77	46
32	77	76	76	77	49
33	77	50	77	77	46
34	77	51	78	77	49
35	77	66	79	77	63
36	77	53	80	77	53
37	77	67	81	84	91
38	77	57	82	125	132
39	77	64	83	77	92
40	77	53	84	117	120
41	77	47	85	125	129
42	77	46	86	105	109
43	77	46	87	115	118
44	77	46			

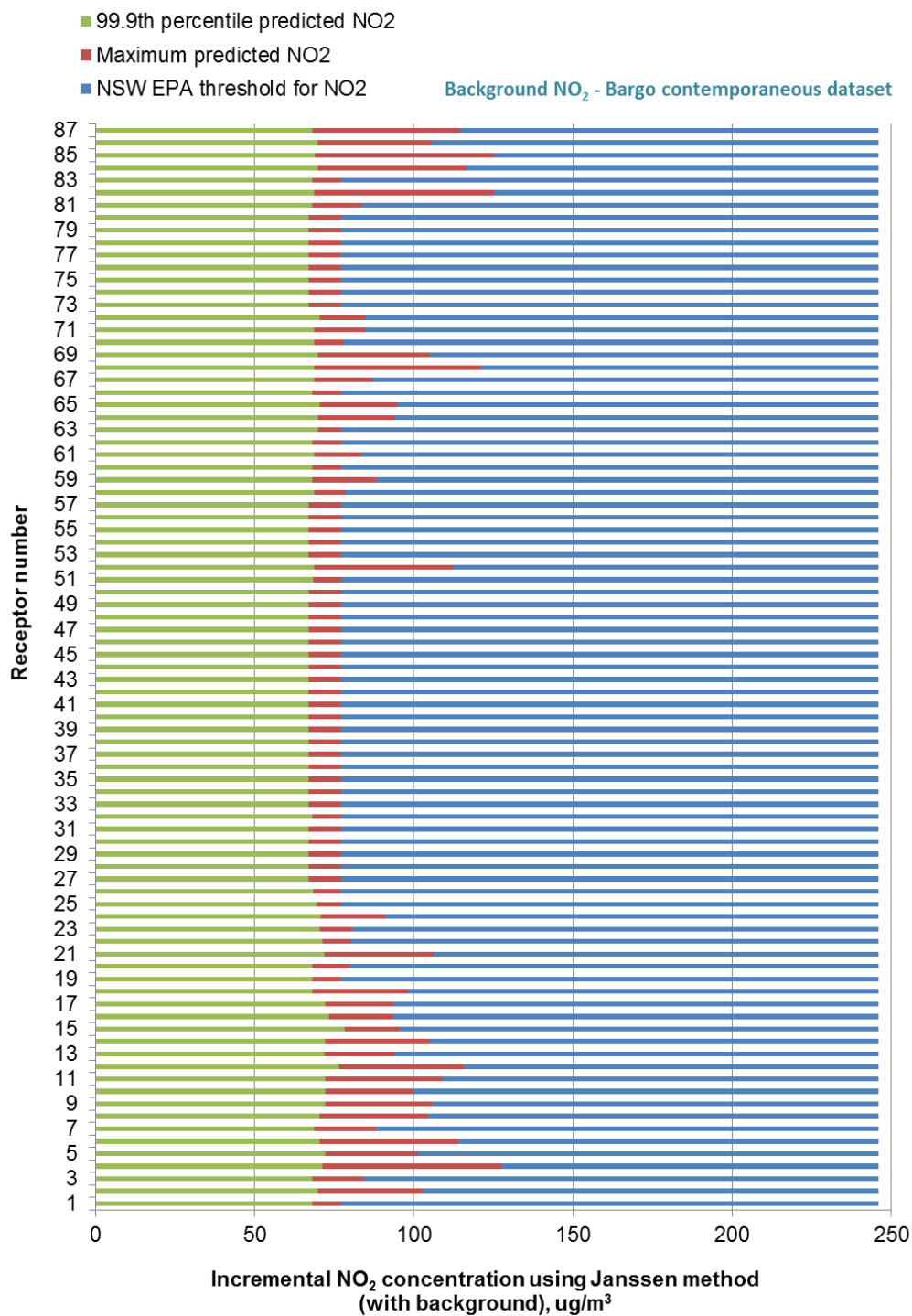


Figure 44: Cumulative NO₂ concentrations in ambient air predicted at each discrete receptor using Janssen method; 1-hr average, both maximum and 99.9th percentile values shown compared to NSW EPA ambient air quality assessment threshold for NO₂.

Data includes background contribution of NO₂ using contemporaneous hourly data from Bargo but with peak background concentrations occurring on 17-21 October removed.

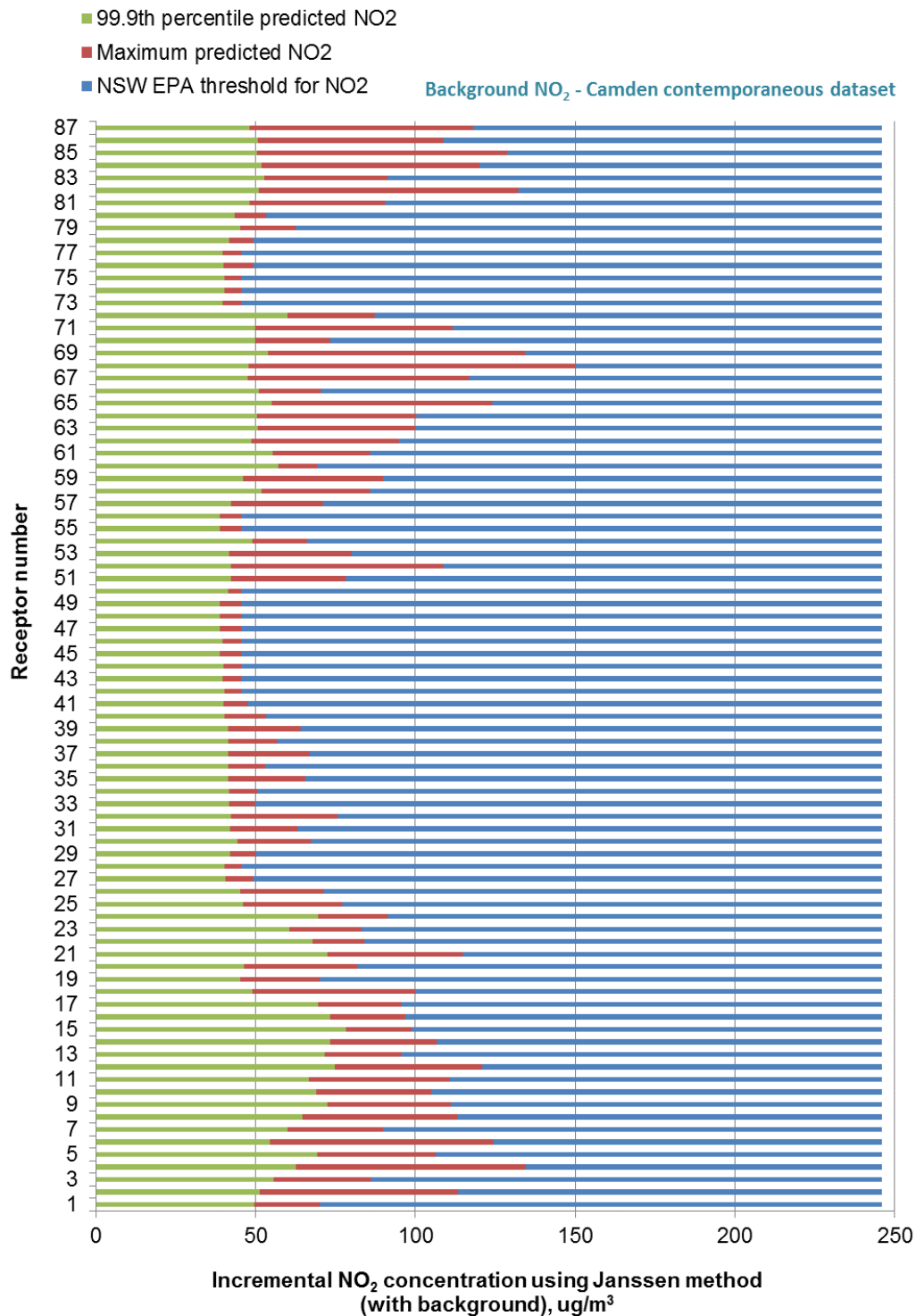


Figure 45: Cumulative NO₂ concentrations in ambient air predicted at each discrete receptor using ozone limiting method; 1-hr average, both maximum and 99.9th percentile values shown compared to NSW EPA ambient air quality assessment threshold for NO₂.

Data includes background contribution of NO₂ using contemporaneous hourly data from Camden.

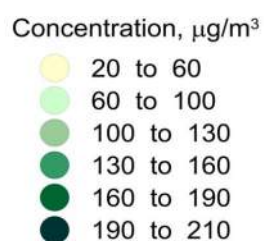
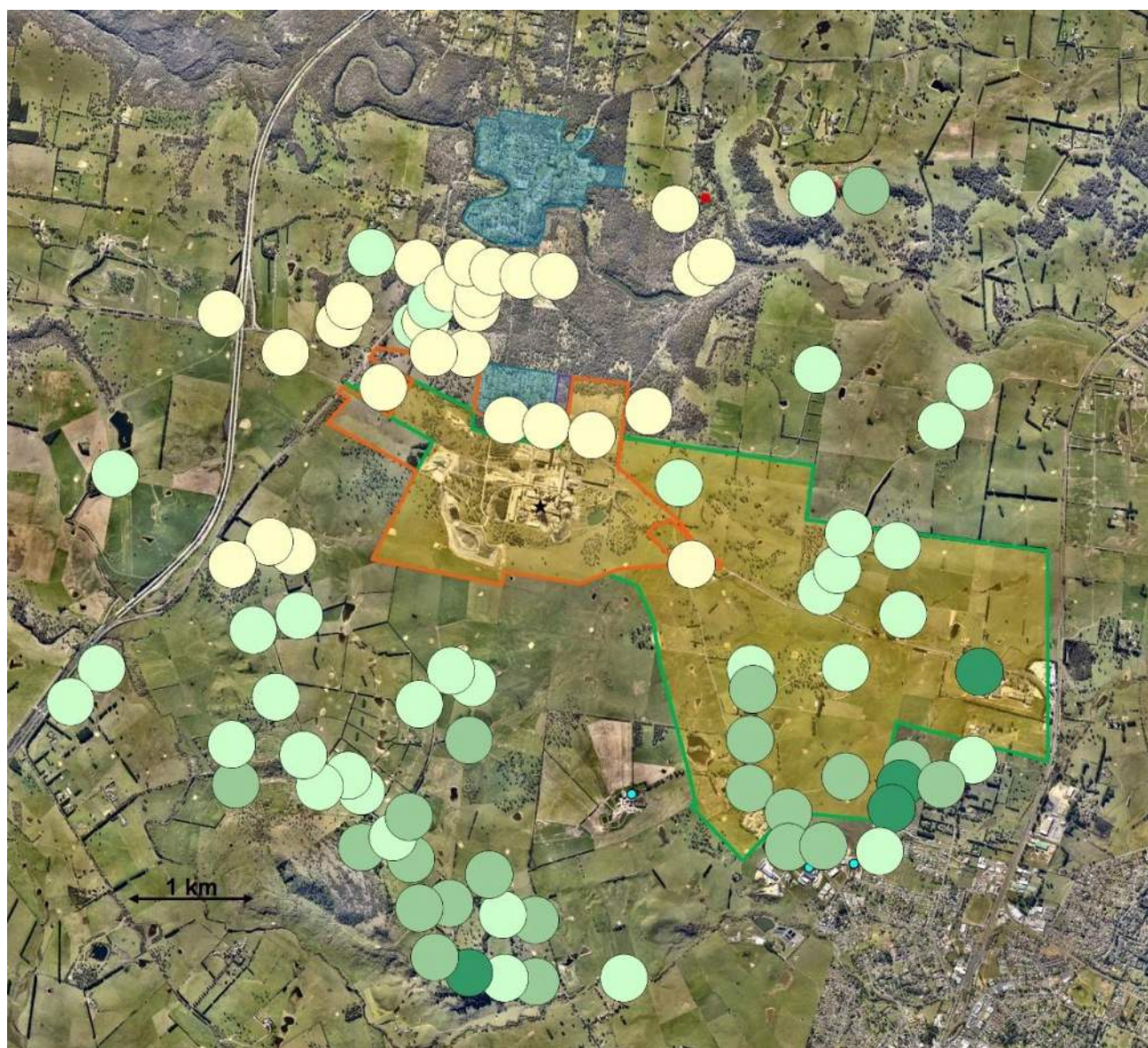


Figure 46: Spatial distribution of cumulative NO_2 concentrations in ambient air using Janssen method; 1-hr average, including contemporaneous background data contribution from Bargo (excluding background data measured 17-21 October 2013).



Concentration, $\mu\text{g}/\text{m}^3$

- 20 to 60
- 60 to 100
- 100 to 130
- 130 to 160
- 160 to 190
- 190 to 210

Figure 47: Spatial distribution of cumulative NO_2 concentrations in ambient air using Janssen method; 1-hr average, including contemporaneous background data contribution from Camden.

8.1.5 Annual Average

The incremental annual average NO₂ at each discrete receptor was calculated by taking the mean of the timeseries of incremental 1-hour concentrations at each receptor determined from either NO-to-NO₂ conversion Method 2 or Method 3.

The annual average incremental NO₂ concentrations predicted at each receptor using Methods 2 and 3 are shown in Table 58.

The maximum off-site incremental concentration of annual average NO₂ at the discrete receptors is 3.34 µg/m³ (receptor 60) using Method 2, and 0.98 µg/m³ (receptor 38) using Method 3. These incremental concentrations are very small compared to the NSW EPA criteria of 62 µg/m³.

The annual average cumulative (incremental + background) NO₂ concentrations predicted at each receptor using Methods 2 and 3 are shown in Table 59. The annual average was calculated using the cumulative hourly average data at each receptor which included contemporaneous background data from either Bargo or Camden.

The maximum off-site cumulative concentration of annual average NO₂ at the discrete receptors is summarised as follows:

<i>NO-to-NO₂ calculation method</i>	<i>Source of contemporaneous background data</i>	<i>Maximum predicted annual concentration</i>	<i>Discrete receptor where this concentration occurs</i>
Method 2	Bargo (excluding peaks 17-21 October 2013)	13.1 µg/m ³	60
	Camden	11.3 µg/m ³	60
Method 3	Bargo (excluding peaks 17-21 October 2013)	10.7 µg/m ³	12, 60, 61
	Camden	8.9 µg/m ³	12, 60, 61

The maximum off-site cumulative annual average concentration of NO₂ predicted using any of the methods and background data is 13.1 µg/m³ (receptor 38) using Method 2. This cumulative concentration is only 21% of the NSW EPA criteria of 62 µg/m³.

Table 58: Annual average incremental ground level concentrations of NO₂ at potentially sensitive discrete receptors. NO-to-NO₂ conversion using either Method 2 (ozone limiting method) or Method 3 (Janssen method).

Receptor no.	Incremental annual avg NO ₂ (µg/m ³)	Incremental annual avg NO ₂ (µg/m ³)	Receptor no.	Incremental annual avg NO ₂ (µg/m ³)	Incremental annual avg NO ₂ (µg/m ³)
	Method 2	Method 3		Method 2	Method 3
1	1.22	0.51	45	1.02	0.21
2	1.51	0.63	46	1.03	0.21
3	1.56	0.68	47	1.06	0.23
4	1.57	0.72	48	1.06	0.24
5	1.50	0.64	49	1.04	0.24
6	1.70	0.69	50	1.02	0.25
7	1.75	0.73	51	0.93	0.29
8	1.89	0.76	52	0.91	0.30
9	1.70	0.69	53	1.86	0.52
10	1.63	0.67	54	1.99	0.71
11	1.80	0.73	55	0.79	0.09
12	1.96	0.91	56	0.83	0.08
13	1.92	0.80	57	2.27	0.29
14	1.97	0.78	58	2.79	0.81
15	2.04	0.86	59	2.94	0.83
16	1.97	0.80	60	3.34	1.00
17	1.76	0.73	61	3.10	0.97
18	1.18	0.45	62	1.88	0.52
19	1.07	0.40	63	1.72	0.51
20	1.19	0.42	64	1.50	0.49
21	2.21	0.74	65	1.36	0.48
22	2.25	0.66	66	1.47	0.57
23	2.16	0.60	67	1.45	0.54
24	2.17	0.70	68	1.33	0.51
25	1.00	0.33	69	1.22	0.46
26	1.07	0.32	70	1.07	0.42
27	0.87	0.29	71	1.35	0.54
28	0.84	0.29	72	1.55	0.60
29	0.85	0.35	73	0.96	0.25
30	0.77	0.29	74	0.93	0.25
31	0.73	0.27	75	0.97	0.20
32	0.62	0.22	76	0.97	0.18
33	0.97	0.33	77	0.91	0.08
34	1.01	0.30	78	1.18	0.16
35	1.00	0.29	79	2.42	0.77
36	1.03	0.25	80	2.41	0.45
37	0.97	0.21	81	2.37	0.75
38	0.98	0.21	82	1.87	0.67
39	1.01	0.21	83	2.11	0.70
40	0.98	0.21	84	1.42	0.50
41	0.93	0.16	85	1.30	0.48
42	0.99	0.20	86	1.24	0.48
43	1.01	0.21	87	1.18	0.45
44	1.01	0.22			

Table 59: Annual average cumulative (incremental plus background) ground level concentrations of NO₂ at potentially sensitive discrete receptors. NO-to-NO₂ conversion using Method 2 (ozone limiting method) or Method 3 (Janssen method) and either Bargo or Camden contemporaneous hourly background data (Bargo data excluding peaks 17-21 October 2013).

Receptor no.	Annual avg NO ₂ (µg/m ³)		Annual avg NO ₂ (µg/m ³)	
	Method 2		Method 3	
	Bargo data excl. 17-21 Oct peaks	Bargo data excl. 17-21 Oct peaks	Camden background data	Camden background data
1	11.0	10.3	9.2	8.4
2	11.3	10.4	9.5	8.6
3	11.3	10.4	9.5	8.6
4	11.3	10.5	9.5	8.7
5	11.3	10.4	9.4	8.6
6	11.5	10.4	9.6	8.6
7	11.5	10.5	9.7	8.7
8	11.6	10.5	9.8	8.7
9	11.5	10.4	9.6	8.6
10	11.4	10.4	9.6	8.6
11	11.5	10.5	9.7	8.7
12	11.7	10.7	9.9	8.9
13	11.7	10.5	9.9	8.7
14	11.7	10.5	9.9	8.7
15	11.8	10.6	10.0	8.8
16	11.7	10.6	9.9	8.7
17	11.5	10.5	9.7	8.7
18	10.9	10.2	9.1	8.4
19	10.8	10.2	9.0	8.3
20	10.9	10.2	9.1	8.4
21	12.0	10.5	10.2	8.7
22	12.0	10.4	10.2	8.6
23	11.9	10.3	10.1	8.5
24	11.9	10.5	10.1	8.6
25	10.7	10.1	8.9	8.3
26	10.8	10.1	9.0	8.3
27	10.6	10.0	8.8	8.2
28	10.6	10.0	8.8	8.2
29	10.6	10.1	8.8	8.3
30	10.5	10.0	8.7	8.2
31	10.5	10.0	8.7	8.2
32	10.4	10.0	8.6	8.2
33	10.7	10.1	8.9	8.3
34	10.8	10.1	9.0	8.2
35	10.7	10.0	8.9	8.2
36	10.8	10.0	9.0	8.2
37	10.7	10.0	8.9	8.2
38	10.7	10.0	8.9	8.1
39	10.8	10.0	9.0	8.2
40	10.7	10.0	8.9	8.2
41	10.7	9.9	8.9	8.1
42	10.7	10.0	8.9	8.1
43	10.8	10.0	8.9	8.1

Receptor no.	Annual avg NO ₂ (µg/m ³)		Annual avg NO ₂ (µg/m ³)	
	Method 2		Method 3	
	Bargo data excl. 17-21 Oct peaks	Bargo data excl. 17-21 Oct peaks	Camden background data	Camden background data
44	10.8	10.0	8.9	8.2
45	10.8	10.0	9.0	8.2
46	10.8	10.0	9.0	8.2
47	10.8	10.0	9.0	8.2
48	10.8	10.0	9.0	8.2
49	10.8	10.0	9.0	8.2
50	10.8	10.0	9.0	8.2
51	10.7	10.0	8.9	8.2
52	10.7	10.1	8.8	8.2
53	11.6	10.3	9.8	8.5
54	11.7	10.5	9.9	8.6
55	10.5	9.8	8.7	8.0
56	10.6	9.8	8.8	8.0
57	12.0	10.0	10.2	8.2
58	12.5	10.6	10.7	8.8
59	12.7	10.6	10.9	8.8
60	13.1	10.7	11.3	8.9
61	12.9	10.7	11.0	8.9
62	11.6	10.3	9.8	8.5
63	11.5	10.3	9.7	8.4
64	11.3	10.2	9.4	8.4
65	11.1	10.2	9.3	8.4
66	11.2	10.3	9.4	8.5
67	11.2	10.3	9.4	8.5
68	11.1	10.3	9.3	8.5
69	11.0	10.2	9.2	8.4
70	10.8	10.2	9.0	8.4
71	11.1	10.3	9.3	8.5
72	11.3	10.4	9.5	8.5
73	10.7	10.0	8.9	8.2
74	10.7	10.0	8.9	8.2
75	10.7	10.0	8.9	8.1
76	10.7	9.9	8.9	8.1
77	10.7	9.8	8.8	8.0
78	10.9	9.9	9.1	8.1
79	12.2	10.5	10.4	8.7
80	12.2	10.2	10.4	8.4
81	12.1	10.5	10.3	8.7
82	11.6	10.4	9.8	8.6
83	11.9	10.5	10.0	8.6
84	11.2	10.3	9.4	8.4
85	11.1	10.2	9.2	8.4
86	11.0	10.2	9.2	8.4
87	10.9	10.2	9.1	8.4

8.1.6 Summary

The dispersion model results for both 1-hour average and annual average cumulative concentrations of NO₂ are much less than the criteria concentrations specified by NSW EPA in the “Approved Methods” Guidelines.

In the case of 1-hour concentrations calculated using Method 3, the “Janssen” method, maximum predicted cumulative concentrations at potential sensitive receptors are 61% of the NSW EPA criteria. Maximum impacts occur to the south and southeast of the Works, with very low impacts occurring in New Berrima and Berrima.

In the case of annual concentrations, maximum predicted cumulative concentrations at potential sensitive receptors are 17% of the NSW EPA criteria using Method 3, and 21% of the NSW EPA criteria using the more conservative Method 2.

The model results and calculated cumulative concentrations are considered to be robust as two sources of background contemporaneous data were used (Bargo and Camden), with the resultant cumulative concentrations being insignificantly different in the context of comparison to the NSW EPA criteria.

Further, the model results and calculated cumulative GLCs are very conservative as model was run using a constant (365 days per year, 24 hours per day) 1-hour average emission concentration that represents the peak 1-hour average concentration that might occur within the maximum 24-hour average concentration proposed in the EPL modification for the burning of NSF.

Therefore, it is concluded that the NO_x assessment has robustly demonstrated that there is minimal risk that the EPA’s 1-hour average NO₂ impact assessment criteria will be exceeded at any time if the proposed 24-hour average emission concentration of 1000 mg/Nm³ during burning of NSF is incorporated into the EPL.

8.2 SO₂

8.2.1 Incremental concentrations

Figure A6a-c in Appendix 6 show the model results for 100th percentile, incremental 1-hour, 24-hour and annual average SO₂ concentrations from the No.6 Kiln stack. The Kiln stack is the only significant source of SO₂ emissions at the site.

The maximum incremental concentrations (i.e. no background SO₂ contributions) of 1-hour, 24-hour and annual average SO₂ at each of the discrete receptors 1-87 are listed in Table 54. The maximum off-site incremental concentration of 1-hour average SO₂ beyond the site boundary at an existing or likely future off-site sensitive receptor is 29 µg/m³ at receptor 57. The maximum off-site incremental concentration of 24-hour average SO₂ beyond the site boundary at an existing or likely future off-site sensitive receptor is 3.8 µg/m³ at receptor 12. The maximum off-site incremental concentration of annual-average SO₂ beyond the site boundary at an existing or likely future off-site sensitive receptor is 0.23 µg/m³ at receptor 60.

8.2.2 Cumulative concentrations

Figure A6d-f in Appendix 6 shows the model results for 100th percentile, cumulative 1-hour average SO₂ concentrations from the No.6 Kiln stack using contemporaneous background data from Bargo.

The maximum cumulative concentrations of 1-hour, 24-hour and annual average SO₂ at each of the discrete receptors 1-87 are listed in Table 54. The maximum off-site cumulative concentrations compare with the NSW EPA assessment criteria as follows:

<i>Averaging period</i>	<i>NSW EPA Criteria</i>	<i>Cumulative concentration</i>	<i>Discrete receptor where this concentration occurs</i>
1-hour	570 µg/m ³	34.7 µg/m ³	59
24-hour	228 µg/m ³	10.6 µg/m ³	18
Annual	60 µg/m ³	0.84 µg/m ³	60

8.2.3 Summary

The dispersion model results for 1-hour, 24-hour and annual average cumulative concentrations of NO₂ are all less than a tenth of the criteria concentrations specified by NSW EPA in the “Approved Methods” Guidelines.

Table 60: Incremental ground level concentrations of SO₂ at potentially sensitive discrete receptors.

Receptor no.	SO ₂ (µg/m ³) Incremental 1-hour average	SO ₂ (µg/m ³) Incremental 24-hour average	SO ₂ (µg/m ³) Incremental Annual average
1	11.5	1.2	0.08
2	10.7	1.5	0.09
3	9.6	1.8	0.10
4	10.0	2.0	0.10
5	11.9	1.3	0.08
6	10.4	1.8	0.11
7	8.3	2.0	0.11
8	8.5	2.1	0.12
9	9.7	1.4	0.10
10	10.5	1.6	0.09
11	9.6	2.7	0.11
12	28.7	3.8	0.15
13	16.8	2.6	0.14
14	14.3	2.4	0.13
15	20.6	2.2	0.15
16	10.4	2.3	0.14
17	13.1	2.1	0.12
18	13.8	2.2	0.07
19	12.5	2.0	0.07
20	9.6	2.2	0.09
21	9.4	2.2	0.14
22	9.0	2.2	0.15
23	11.2	2.2	0.14
24	14.4	2.5	0.15
25	18.1	2.2	0.07
26	18.8	2.4	0.08
27	9.0	2.5	0.09
28	9.0	2.5	0.08
29	9.9	2.7	0.09
30	8.5	1.4	0.05
31	7.8	1.2	0.04
32	14.5	1.7	0.04
33	8.6	2.1	0.07
34	8.4	1.9	0.08
35	12.5	3.1	0.08
36	12.0	2.2	0.07
37	20.6	2.2	0.07
38	16.3	1.9	0.07
39	18.8	1.9	0.07
40	13.7	1.8	0.07
41	14.9	1.6	0.07
42	10.3	1.4	0.07
43	8.7	1.4	0.07
44	7.9	1.4	0.07
45	10.6	1.2	0.07
46	12.4	1.6	0.07
47	11.0	2.5	0.08

Receptor no.	SO ₂ (µg/m ³) Incremental 1-hour average	SO ₂ (µg/m ³) Incremental 24-hour average	SO ₂ (µg/m ³) Incremental Annual average
48	7.7	1.5	0.07
49	7.0	1.4	0.06
50	9.0	1.3	0.06
51	13.7	1.5	0.06
52	20.3	1.7	0.06
53	17.4	1.9	0.13
54	13.5	1.9	0.13
55	21.6	1.5	0.06
56	16.4	1.6	0.06
57	29.1	1.7	0.12
58	22.0	2.7	0.20
59	10.3	2.6	0.20
60	11.8	2.5	0.23
61	16.2	2.2	0.20
62	8.1	2.2	0.12
63	8.4	2.3	0.11
64	10.7	1.6	0.10
65	11.9	1.8	0.08
66	11.0	1.9	0.09
67	9.3	1.7	0.09
68	9.2	1.9	0.09
69	9.1	1.6	0.07
70	15.9	1.2	0.07
71	9.9	1.6	0.09
72	10.6	2.4	0.11
73	9.7	1.9	0.07
74	8.7	1.7	0.07
75	11.0	1.4	0.08
76	14.7	2.1	0.07
77	12.9	1.1	0.05
78	15.6	1.7	0.07
79	10.0	2.2	0.15
80	10.5	2.1	0.16
81	18.9	2.0	0.15
82	23.8	1.9	0.11
83	9.1	3.1	0.14
84	16.1	1.9	0.09
85	13.3	1.6	0.08
86	15.8	1.6	0.08
87	8.8	1.7	0.08

Table 61: Cumulative ground level concentrations of SO₂ at potentially sensitive discrete receptors.

Receptor no.	SO ₂ (µg/m ³) Cumulative 1-hour average	SO ₂ (µg/m ³) Cumulative 24-hour average	SO ₂ (µg/m ³) Cumulative Annual average
1	33.2	9.1	0.68
2	33.2	9.1	0.70
3	33.2	9.3	0.70
4	33.2	9.7	0.71
5	33.2	9.1	0.69
6	33.2	9.1	0.71
7	33.2	9.5	0.72
8	33.2	9.7	0.73
9	33.2	9.1	0.70
10	33.2	9.1	0.70
11	33.2	9.2	0.72
12	33.2	9.6	0.76
13	33.2	9.4	0.74
14	33.2	9.3	0.74
15	33.2	9.9	0.75
16	33.2	9.9	0.74
17	33.2	10.0	0.73
18	33.2	10.6	0.68
19	33.2	10.3	0.68
20	33.2	10.1	0.69
21	33.2	9.3	0.74
22	33.2	9.2	0.75
23	33.2	9.5	0.75
24	33.2	9.7	0.75
25	33.2	9.1	0.68
26	33.2	9.1	0.68
27	33.2	9.1	0.69
28	33.2	9.1	0.69
29	33.2	9.1	0.69
30	33.2	9.1	0.65
31	33.2	9.1	0.65
32	33.2	9.1	0.65
33	33.2	9.1	0.68
34	33.2	9.1	0.69
35	33.2	9.1	0.68
36	33.2	9.1	0.68
37	33.2	9.1	0.68
38	33.2	9.1	0.68
39	33.2	9.1	0.67
40	33.2	9.1	0.67
41	33.2	9.1	0.67
42	33.2	9.1	0.67
43	33.2	9.1	0.67
44	33.2	9.1	0.67
45	33.2	9.1	0.67
46	33.2	9.1	0.68

Receptor no.	SO ₂ (µg/m ³) Cumulative 1-hour average	SO ₂ (µg/m ³) Cumulative 24-hour average	SO ₂ (µg/m ³) Cumulative Annual average
47	33.2	9.1	0.68
48	33.2	9.1	0.67
49	33.2	9.1	0.67
50	33.2	9.1	0.67
51	33.2	9.1	0.66
52	33.2	9.1	0.66
53	33.2	9.1	0.73
54	33.2	9.1	0.74
55	33.2	9.1	0.67
56	33.2	9.1	0.67
57	33.2	9.1	0.73
58	34.6	9.1	0.80
59	34.7	9.1	0.80
60	33.2	9.1	0.84
61	33.2	9.1	0.81
62	33.2	9.1	0.73
63	33.2	9.1	0.72
64	33.2	9.1	0.70
65	33.2	9.1	0.69
66	33.2	9.1	0.70
67	33.2	9.1	0.70
68	33.2	9.1	0.69
69	33.2	9.1	0.68
70	33.2	9.1	0.67
71	33.2	9.1	0.69
72	33.2	10.4	0.71
73	33.2	9.1	0.68
74	33.2	9.1	0.67
75	33.2	9.1	0.68
76	33.2	9.1	0.68
77	33.2	9.1	0.66
78	33.2	9.1	0.68
79	33.2	9.1	0.76
80	33.6	9.1	0.76
81	33.2	9.1	0.76
82	33.2	9.1	0.72
83	33.2	9.1	0.75
84	33.2	9.1	0.70
85	33.2	9.1	0.69
86	33.2	9.1	0.69
87	33.2	9.1	0.68

8.3 TSP

All TSP model results discussed in this section assume a constant TSP emission concentration of 50 mg/Nm³ which is the proposed 24-hour average maximum emission concentration to be included in the EPL for the burning of NSF.

As explained in Section 4.8.1, this 24-hour average emission concentration was converted into a very conservative equivalent 1-hour TSP concentration for use in the dispersion model that accounts for peak 1-hour concentrations that could occur within the 24-hour period. The model was run using that peak 1-hour concentration as the constant emission rate for 365 days per year, 24 hours per day.

The model results are presented in the following subsections.

8.3.1 Model Output – Point Sources

Appendix 7 shows the model results for 100th percentile, incremental TSP concentrations for the various point sources of particulate. Only annual averages are shown, as this is the only averaging period for TSP specified in the “Approved Methods” guidelines. The plots contained in the appendix are as follows:

- TSP annual averaging period
 - Figure A7a: Kiln 6 stack alone
 - Figure A7b: Cement mills 6 and 7 and cooler stack combined (no Kiln 6 stack).
 - Figure A7c: Kiln 6 plus cement mills 6 and 7 and cooler stack

The maximum off-site incremental concentrations of annual average TSP at each of the discrete receptors 1-87 are listed in Table 62.

The maximum off-site incremental concentration of annual average TSP for all four point sources combined, beyond the site boundary at an existing or likely future off-site sensitive receptor, is 1.35 µg/m³ at receptor 57. This is a conservative concentration because it assumes that the kiln and mills operate 24 hours per day, 365 days per year at steady state and at the maximum assumed emission limit, with no rain and no reduction in TSP through gravitational settling and vegetation screening.

Table 62: Annual average incremental ground level concentration of TSP at potentially sensitive discrete receptors, point sources only. Kiln and mills are assumed to operate 24 hours per day, 365 days per year at steady state.

Receptor no.	Annual average TSP ($\mu\text{g}/\text{m}^3$) Incremental	Annual average TSP ($\mu\text{g}/\text{m}^3$) Incremental	Annual average TSP ($\mu\text{g}/\text{m}^3$) Incremental
	Kiln 6 stack only	Cement mills and cooler stack only	Kiln 6 stack, cement mills and cooler stack
1	0.10	0.10	0.20
2	0.12	0.13	0.26
3	0.13	0.20	0.34
4	0.14	0.25	0.39
5	0.11	0.21	0.33
6	0.15	0.19	0.33
7	0.15	0.22	0.37
8	0.16	0.24	0.41
9	0.13	0.22	0.35
10	0.13	0.23	0.36
11	0.15	0.25	0.41
12	0.21	0.33	0.54
13	0.19	0.28	0.46
14	0.18	0.29	0.47
15	0.20	0.28	0.48
16	0.19	0.26	0.44
17	0.17	0.21	0.38
18	0.10	0.11	0.21
19	0.10	0.10	0.19
20	0.12	0.15	0.27
21	0.19	0.38	0.56
22	0.20	0.58	0.79
23	0.20	0.57	0.77
24	0.20	0.41	0.61
25	0.10	0.12	0.22
26	0.11	0.14	0.25
27	0.12	0.14	0.26
28	0.11	0.12	0.23
29	0.12	0.11	0.23
30	0.07	0.06	0.12
31	0.06	0.06	0.11
32	0.06	0.05	0.11
33	0.10	0.07	0.17
34	0.11	0.09	0.20
35	0.10	0.13	0.23
36	0.09	0.16	0.25
37	0.10	0.16	0.25
38	0.10	0.17	0.27
39	0.09	0.18	0.28
40	0.09	0.17	0.27
41	0.09	0.26	0.35
42	0.09	0.19	0.28
43	0.09	0.17	0.26
44	0.09	0.14	0.23

Receptor no.	Annual average TSP ($\mu\text{g}/\text{m}^3$) Incremental	Annual average TSP ($\mu\text{g}/\text{m}^3$) Incremental	Annual average TSP ($\mu\text{g}/\text{m}^3$) Incremental
	Kiln 6 stack only	Cement mills and cooler stack only	Kiln 6 stack, cement mills and cooler stack
45	0.09	0.13	0.22
46	0.09	0.13	0.22
47	0.11	0.12	0.22
48	0.09	0.10	0.19
49	0.09	0.10	0.18
50	0.08	0.11	0.19
51	0.08	0.14	0.22
52	0.08	0.13	0.21
53	0.17	0.19	0.37
54	0.18	0.22	0.40
55	0.09	0.55	0.64
56	0.08	0.48	0.56
57	0.17	1.19	1.35
58	0.27	0.28	0.54
59	0.27	0.28	0.55
60	0.32	0.34	0.66
61	0.28	0.27	0.55
62	0.17	0.21	0.37
63	0.15	0.19	0.35
64	0.14	0.16	0.30
65	0.12	0.12	0.23
66	0.12	0.10	0.22
67	0.13	0.10	0.23
68	0.12	0.10	0.22
69	0.10	0.10	0.20
70	0.09	0.08	0.17
71	0.12	0.10	0.22
72	0.15	0.19	0.34
73	0.10	0.09	0.19
74	0.09	0.08	0.18
75	0.10	0.19	0.29
76	0.10	0.20	0.29
77	0.07	0.50	0.57
78	0.10	0.35	0.45
79	0.21	0.32	0.53
80	0.22	0.47	0.69
81	0.21	0.17	0.37
82	0.16	0.11	0.27
83	0.20	0.19	0.38
84	0.13	0.13	0.26
85	0.12	0.12	0.23
86	0.11	0.10	0.21
87	0.10	0.10	0.20

8.3.2 Fugitive Emissions Sensitivity Tests

Appendix 8 shows the preliminary sensitivity test model results for fugitive emissions. These results were processed as 100th percentile 24-hour averages so that the results could be compared with data from the Berrima AQMS. Therefore these results are for model test purposes only and should not be compared with the NSW EPA criteria for TSP.

The schedule of plots contained in this appendix is as follows:

- TSP 24-hour averaging period for sensitivity tests:
 - Figure A8a: Crushing and transfer points emissions
 - Figure A8b: Vehicle-tracked emissions from vehicles travelling at 1 km per hour of operation
 - Figure A8c: Vehicle-tracked emissions from vehicles travelling at 5 km per hour of operation
 - Figure A8d: Emissions from vehicles handling material
 - Figure A8e: Emissions from open sources subject to wind erosion (stockpiles and surfaces) at preliminary calculated emission rate
 - Figure A8f: Emissions from open sources subject to wind erosion (stockpiles and surfaces) at eight times the preliminary emission rate
 - Figure A8g: All fugitive sources:
 - Emissions from open sources subject to wind erosion (stockpiles and surfaces) at **one** times the preliminary emission rate,
 - Vehicle-tracked emissions from vehicles travelling at **1 km per hour** of operation,
 - Emissions from vehicles handling material,
 - Crushing and transfer point emissions.
 - Figure A8h: All fugitive sources:
 - Emissions from open sources subject to wind erosion (stockpiles and surfaces) at **one** times the preliminary emission rate,
 - Vehicle-tracked emissions from vehicles travelling at **5 km per hour** of operation,
 - Emissions from vehicles handling material,
 - Crushing and transfer point emissions.
 - Figure A8i: All fugitive sources:
 - Emissions from open sources subject to wind erosion (stockpiles and surfaces) at **eight** times the preliminary emission rate,
 - Vehicle-tracked emissions from vehicles travelling at **1 km per hour** of operation,
 - Emissions from vehicles handling material,
 - Crushing and transfer point emissions.

The following findings were noted from these sensitivity tests:

- The emissions from crushing and transfer points are very minor compared to the other fugitive sources.
- Maximum GLCs for vehicle-tracked emissions and vehicles handling material occur during days when wind speeds are low (1-2m/s). This is because the equations used to derive those emissions are not wind speed dependent, so GLCs are higher when wind speeds are lower. However this trend does not match the analysis of wind conditions on days when the Berrima AQMS is predominantly downwind of the Works and high TSP and PM₁₀ 24-hour average concentrations are measured (see Section 6.4.2). On such days, wind speeds in the 5-8 m/s category are recorded. Emissions on such days are likely to come from sources subject to wind erosion.
- The emissions from vehicle-tracked emissions and vehicles handling material are very significant, particularly in low wind speed conditions. The emission factor estimates used to derive the emission rates for these sources are based on published data from NPI (2012) and have not been calibrated or confirmed for local conditions. This is a source of uncertainty in the model results.
- The models assume full operation of vehicles and processes for the available time – i.e. 24 hours per day, 365 days per year except for one of the loaders which is assumed to operate for 12 hours per day. This will overstate 24-hour and annual average GLCs if actual hours of operation per day are less than this.
- Maximum GLCs at the Berrima AQMS resulting from open sources subject to wind erosion at the preliminary calculated emission rate occurred on a day when the Berrima AQMS is predominantly downwind of the Works and wind speeds in the 5-8 m/s bracket were recorded for a large period of the day. This is consistent with the monitoring results from the Berrima AQMS, which validates the modelling approach. However, the magnitude of the GLCs is too small, indicating that emission rates during high wind speeds have been underestimated or that other sources of dust may be present during high wind speeds (such as a component of wind speed dependence to emissions from vehicles handling material or driving on unsealed surfaces, or emissions from the quarry). It was assumed that background concentrations of TSP from upwind of the Works (i.e. the area to the southwest and west of the Works) during these conditions were minor compared to Works sources of TSP. It was also found that other fugitive dust sources such as vehicle-related emissions and point sources were minor contributors to the total GLCs under these wind conditions.
- Through trial and error, it was found that increasing the preliminary emission rates for wind erosion sources by a factor of 8 resulted in maximum 24-hour GLCs at the Berrima AQMS location that were similar to the maximum measured air quality in similar wind conditions.
- Although this scaling factor of 8 is considered appropriate at higher wind speeds, it may not apply across lower wind speeds as well. Some publications recommend applying a minimum wind speed threshold below which wind erosion emissions are zero. This layer of complexity has not yet been added to the fugitive dust model here, but the contribution from various sources could be investigated at individual discrete receptors if necessary.
- Similarly, no account of suspended dust scavenging through gravitational settling or capture by vegetation around the site has been made yet due to the complexity inherent in those assumptions and a lack of available data on TSP particulate size distribution in the fugitive dust.

- If the model results indicate potential issues with dust or fine particulate concentrations beyond the site boundary, then it is recommended that the dust model could be updated to test the sensitivity to these additional factors.

8.3.3 Model Output – Point Source and Fugitive Source Emissions

Appendix 9 shows incremental annual average TSP concentrations for combined point source and fugitive emissions. No additional background data contribution is assumed as the dispersion model is calibrated against measured ambient air quality at the Berrima AQMS during wind conditions where the Works is upwind of the AQMS site.

The schedule of plots contained in this appendix is as follows:

- TSP annual averaging period:
 - Figure A9a: All fugitive sources (with 8x-scaled emission rates for open sources subject to wind erosion).
 - Figure A9b: All fugitive sources plus all point sources.

The two plots are very similar. The maximum cumulative GLCs of annual average TSP at each of the discrete receptors 1-87 for these two source groups are listed in Table 63. An additional discrete receptor is also shown, numbered 88. This location is also shown on the Figures A9a and A9b. This represents the house at the corner of Howard Street and Taylor Avenue at the southwest corner of New Berrima. This location is shown on the aerial photo in Figure 48. This house was under construction at the time the aerial photo was taken (22 May 2014).

It is clear from both the plots in Appendix 9 and the tabulated GLCs that there is little difference between the GLCs for the fugitive sources alone, and when the point sources are added to the fugitive sources. This was expected from the relative magnitude of annual average TSP GLCs for the point sources alone (as per Table 62) versus the “fugitive sources alone” column in Table 63.

This indicates that the TSP concentrations occurring beyond the site boundary due to emissions from the Works are very insensitive to changes in TSP emission rates from the Kiln 6 stack.

The maximum off-site annual-average concentration of TSP at any potentially sensitive receptor is $15.2 \mu\text{g}/\text{m}^3$. This predicted worst case concentration is much less than the TSP impact assessment criteria of $90 \mu\text{g}/\text{m}^3$ specified in the “Approved Methods” guidelines by NSW EPA.

So far, the discussion of TSP concentrations has assumed that background concentrations (i.e. contributed by sources other than the Works site) are zero. However there will be background contributions to ambient TSP from other sources such as domestic fires or farming activities. As discussed in Section 7.7.2, the annual average TSP concentrations measured at the Berrima air quality monitoring site are the only available estimates of background concentrations of TSP, even though concentrations measured at the Berrima site include contributions from the Works.

The annual average concentrations of TSP measured at the Berrima AQMS over 2011, 2012 and 2013 ranged from $35.3 \mu\text{g}/\text{m}^3$ to $42.8 \mu\text{g}/\text{m}^3$. The GLC for annual average TSP at this location predicted by the model is about $19 \mu\text{g}/\text{m}^3$ which is higher than any of the discrete receptor concentrations. Therefore it can be

assumed that annual average concentrations of TSP including background at each of the discrete receptors 1-88 will be less than that measured at the Berrima AQMS; this is well below the Approved Methods assessment criteria of $90 \mu\text{g}/\text{m}^3$.



Figure 48: Location of receptor 88. Photo from nearmap, date of imagery 22 May 2014.

8.3.4 Summary

Cumulative annual average concentrations of TSP from both fugitive and point sources at the Works, and including background concentrations, are well below the Approved Methods assessment criteria of $90 \mu\text{g}/\text{m}^3$ at each of the discrete receptors.

In addition, TSP concentrations occurring beyond the site boundary due to emissions from the Works are very insensitive to changes in TSP emission rates from the Kiln 6 stack.

The model results and calculated cumulative GLCs are very conservative as the model was run using a constant (365 days per year, 24 hours per day) 1-hour average emission concentration that represents the peak 1-hour average concentration that might occur within the maximum 24-hour average concentration proposed in the EPL modification for the burning of NSF.

Therefore it is concluded that adverse air quality impacts will not arise due to TSP emissions due to the Project.

Table 63: Annual average ground level concentrations of TSP at potentially sensitive discrete receptors, all fugitive and point sources. Kiln, and mills and material handling are assumed to operate 24 hours per day, 365 days per year at steady state. Background concentration contributions from outside the Works are assumed to be nil.

Receptor no.	Annual average TSP ($\mu\text{g}/\text{m}^3$)	Annual average TSP ($\mu\text{g}/\text{m}^3$)	Receptor no.	Annual average TSP ($\mu\text{g}/\text{m}^3$)	Annual average TSP ($\mu\text{g}/\text{m}^3$)
	Fugitive sources only	Fugitive sources plus point sources		Fugitive sources only	Fugitive sources plus point sources
1	0.8	1.0	45	2.1	2.4
2	1.0	1.2	46	1.4	1.6
3	1.0	1.4	47	0.9	1.2
4	1.2	1.6	48	0.9	1.1
5	1.3	1.7	49	0.9	1.1
6	1.3	1.6	50	0.5	0.7
7	1.4	1.8	51	0.6	0.8
8	1.8	2.2	52	0.6	0.8
9	1.7	2.0	53	2.6	3.0
10	1.8	2.1	54	2.3	2.7
11	2.3	2.8	55	9.5	10.2
12	3.0	3.5	56	8.3	8.8
13	2.9	3.3	57	11.2	12.6
14	3.0	3.5	58	3.5	4.1
15	4.3	4.8	59	3.9	4.4
16	4.7	5.2	60	4.1	4.8
17	4.3	4.7	61	3.3	3.8
18	2.5	2.7	62	2.8	3.1
19	2.5	2.7	63	2.5	2.9
20	4.5	4.8	64	2.1	2.4
21	3.9	4.5	65	1.3	1.5
22	6.8	7.6	66	0.9	1.1
23	7.9	8.7	67	1.0	1.2
24	6.1	6.7	68	1.0	1.2
25	4.9	5.1	69	1.0	1.2
26	7.6	7.9	70	0.9	1.0
27	7.8	8.1	71	0.9	1.1
28	5.9	6.2	72	4.8	5.1
29	4.8	5.0	73	6.4	6.6
30	1.3	1.4	74	6.1	6.3
31	1.2	1.3	75	14.9	15.2
32	2.0	2.1	76	8.4	8.7
33	2.8	2.9	77	9.4	10.0
34	4.8	5.0	78	5.6	6.1
35	4.4	4.6	79	3.0	3.5
36	4.3	4.5	80	9.1	9.8
37	6.9	7.2	81	2.3	2.7
38	6.4	6.6	82	1.4	1.7
39	5.1	5.3	83	1.9	2.3
40	3.7	4.0	84	1.6	1.9
41	6.2	6.5	85	1.4	1.6
42	3.5	3.8	86	1.1	1.4
43	3.0	3.2	87	1.1	1.3
44	2.4	2.6	88	12.3	12.7

8.4 PM₁₀

All PM₁₀ model results for the Kiln 6 stack discussed in this section assume a constant PM₁₀ emission concentration which is calculated from a constant TSP concentration of 50 mg/Nm³ (which is the proposed 24-hour average maximum emission concentration to be included in the EPL for the burning of NSF) and a constant PM₁₀ fraction of 70% of TSP.

Using the same approach as for TSP emissions, the calculated maximum PM₁₀ 24-hour average emission concentration was converted into a very conservative equivalent 1-hour PM₁₀ concentration for use in the dispersion model that accounts for peak 1-hour concentrations that could occur within the 24-hour period. The model was run using that peak 1-hour concentration as the constant emission rate for 365 days per year, 24 hours per day.

The model results are presented in the following subsections.

8.4.1 Model Output – Point Sources

Appendix 10 shows the model results for 100th percentile, incremental PM₁₀ concentrations for the four point sources of particulate. A schedule of plots contained in this appendix is as follows:

- 24-hour averaging period
 - Figure A10a: Kiln 6 stack alone
 - Figure A10b: Cement mills 6 and 7 and cooler stack combined (no Kiln 6 stack).
 - Figure A10c: Kiln 6 plus cement mills 6 and 7 and cooler stack
- Annual averaging period
 - Figure A10d: Kiln 6 stack alone
 - Figure A10e: Cement mills 6 and 7 and cooler stack combined (no Kiln 6 stack).
 - Figure A10f: Kiln 6 plus cement mills 6 and 7 and cooler stack

The maximum off-site incremental concentrations of 24-hour and annual average PM₁₀ at each of the discrete receptors 1-88 are listed in Table 64 and Table 65. Receptor 88 was introduced in Section 8.3.3 and will be used in the analysis of all particulate model results. The maximum concentrations are summarised as follows:

<i>Averaging period</i>	<i>Emission sources</i>	<i>Maximum predicted concentration at a discrete receptor</i>	<i>Discrete receptor where this concentration occurs</i>
24-hours	Kiln 6 stack only	3.7 µg/m ³	12
	All point sources	12.6 µg/m ³	55
Annual	Kiln 6 stack only	0.22 µg/m ³	60
	All point sources	1.2 µg/m ³	57

The maximum predicted incremental 24-hour PM_{10} concentration at existing or likely future sensitive receptors due to stack sources at the Works is $12.6 \mu\text{g}/\text{m}^3$. This predicted PM_{10} concentration is only 25% of the NSW EPA ambient air quality assessment threshold criteria of $50 \mu\text{g}/\text{m}^3$, but does not yet include fugitive emissions of PM_{10} and background concentrations. This is discussed in the following sections.

The maximum off-site incremental concentration of annual average PM_{10} for all four point sources combined, beyond the site boundary at an the existing or likely future off-site sensitive receptor, is $1.2 \mu\text{g}/\text{m}^3$. This is a conservative concentration because it assumes that the kiln and mills operate 24 hours per day, 365 days per year at steady state and at the maximum assumed emission limit. In addition, 100% of the TSP discharge from the two cement mill vents is assumed to be in the PM_{10} range. Despite this degree of conservatism, the maximum predicted incremental concentration is only 4% of the NSW EPA assessment criteria of $30 \mu\text{g}/\text{m}^3$.

Table 64: 24-hour average incremental ground level concentration of PM₁₀ at potentially sensitive discrete receptors, point sources only.

Receptor no.	24-hr avg incremental PM ₁₀ (µg/m ³)	24-hr avg incremental PM ₁₀ (µg/m ³)	Receptor no.	24-hr avg incremental PM ₁₀ (µg/m ³)	24-hr avg incremental PM ₁₀ (µg/m ³)
	Kiln 6 stack only	All 4 point sources		Kiln 6 stack only	All 4 point sources
1	1.2	2.3	45	1.1	2.8
2	1.5	3.0	46	1.5	3.2
3	1.7	4.3	47	2.4	4.1
4	1.9	3.5	48	1.4	2.7
5	1.3	3.2	49	1.4	2.5
6	1.7	4.1	50	1.3	3.3
7	1.9	4.2	51	1.4	4.1
8	2.1	3.8	52	1.6	3.2
9	1.4	3.2	53	1.8	4.8
10	1.6	2.7	54	1.8	5.0
11	2.6	4.2	55	1.4	12.6
12	3.7	6.1	56	1.5	10.5
13	2.5	4.8	57	1.6	10.1
14	2.3	4.7	58	2.6	6.3
15	2.2	4.2	59	2.5	7.4
16	2.2	3.6	60	2.4	7.3
17	2.0	3.5	61	2.1	6.1
18	2.1	3.0	62	2.1	3.7
19	2.0	3.6	63	2.2	3.3
20	2.1	4.2	64	1.6	3.4
21	2.1	4.2	65	1.7	2.5
22	2.1	5.7	66	1.9	3.2
23	2.1	6.6	67	1.6	2.6
24	2.4	5.4	68	1.8	3.1
25	2.1	3.0	69	1.5	2.5
26	2.3	3.3	70	1.2	1.6
27	2.4	4.6	71	1.6	2.6
28	2.4	4.7	72	2.3	3.6
29	2.6	4.6	73	1.9	2.8
30	1.4	2.1	74	1.6	3.0
31	1.2	1.7	75	1.3	7.5
32	1.6	2.2	76	2.0	6.3
33	2.1	4.2	77	1.1	6.9
34	1.8	4.5	78	1.6	7.0
35	3.0	6.5	79	2.1	5.2
36	2.1	4.4	80	2.1	7.1
37	2.1	5.8	81	1.9	4.3
38	1.8	6.2	82	1.8	3.2
39	1.9	5.2	83	2.9	5.0
40	1.8	3.8	84	1.8	2.9
41	1.5	6.2	85	1.6	3.1
42	1.4	5.3	86	1.5	2.3
43	1.3	4.6	87	1.6	2.9
44	1.3	3.8	88	1.2	7.6

Table 65: Annual average incremental ground level concentration of PM₁₀ at potentially sensitive discrete receptors, point sources only.

Receptor no.	Annual avg incremental PM ₁₀ (µg/m ³)	Annual avg incremental PM ₁₀ (µg/m ³)	Receptor no.	Annual avg incremental PM ₁₀ (µg/m ³)	Annual avg incremental PM ₁₀ (µg/m ³)
	Kiln 6 stack only	All 4 point sources		Kiln 6 stack only	All 4 point sources
1	0.072	0.165	45	0.064	0.184
2	0.087	0.212	46	0.066	0.179
3	0.094	0.277	47	0.075	0.180
4	0.097	0.321	48	0.064	0.154
5	0.080	0.279	49	0.061	0.148
6	0.103	0.275	50	0.058	0.154
7	0.107	0.309	51	0.056	0.178
8	0.115	0.343	52	0.053	0.167
9	0.093	0.302	53	0.122	0.303
10	0.088	0.306	54	0.127	0.325
11	0.108	0.348	55	0.060	0.570
12	0.147	0.444	56	0.059	0.504
13	0.130	0.390	57	0.117	1.199
14	0.128	0.398	58	0.188	0.437
15	0.140	0.401	59	0.187	0.443
16	0.131	0.375	60	0.224	0.537
17	0.116	0.316	61	0.194	0.440
18	0.071	0.171	62	0.116	0.308
19	0.068	0.159	63	0.107	0.288
20	0.083	0.222	64	0.095	0.245
21	0.130	0.486	65	0.081	0.189
22	0.142	0.690	66	0.086	0.175
23	0.139	0.677	67	0.089	0.183
24	0.143	0.526	68	0.082	0.173
25	0.069	0.187	69	0.071	0.158
26	0.075	0.211	70	0.065	0.140
27	0.083	0.213	71	0.084	0.174
28	0.079	0.189	72	0.104	0.288
29	0.084	0.190	73	0.069	0.153
30	0.047	0.099	74	0.066	0.142
31	0.040	0.093	75	0.072	0.242
32	0.042	0.085	76	0.067	0.245
33	0.071	0.134	77	0.051	0.508
34	0.077	0.159	78	0.070	0.394
35	0.073	0.189	79	0.145	0.437
36	0.066	0.211	80	0.152	0.582
37	0.067	0.210	81	0.144	0.295
38	0.067	0.225	82	0.109	0.210
39	0.065	0.230	83	0.138	0.308
40	0.064	0.222	84	0.089	0.213
41	0.062	0.300	85	0.081	0.191
42	0.066	0.238	86	0.077	0.173
43	0.066	0.218	87	0.072	0.165
44	0.063	0.186	88	0.055	0.360

8.4.2 Handling of Fugitive Emissions

Fugitive PM₁₀ emissions were modelled in the same manner as described for TSP. The magnitude of emissions from wind erosion sources was scaled so that the 24-hour average model results at the location of the AQMS matched measured data during windy days, i.e. about 50 µg/m³. A contribution of about 7 µg/m³ from background PM₁₀ was assumed, as this was the 24-hour concentration occurring in the Bargo dataset on 23 August 2013, a day of consistent high wind speeds (>5m/s) and westerly winds.

Through trial and error it was found that applying a scaling factor of 3.8 to the preliminary PM₁₀ estimate for open sources subject to wind erosion, when combined with the other PM₁₀ emissions from fugitive sources and the point sources, yielded a predicted 24-hour PM₁₀ concentration at the AQMS site of about 42 µg/m³ (with the background contribution to be added to that). This scaling factor was used in all subsequent cumulative PM₁₀ assessments.

8.4.3 Fugitive and Point Sources Combined

Appendix 10 shows incremental 24-hour average PM₁₀ concentrations for combined point source and fugitive emissions. The following figures are provided:

- 24-hour annual averaging period
 - Figure A10g: All fugitive sources (with 3.8x-scaled emission rates for open sources subject to wind erosion).
 - Figure A10h: All fugitive sources plus all point sources.
 - Figure A10i: All fugitive sources plus all point sources, with Kiln 6 emission rate increased by 50%
 - Figure A10j: Overlay comparison of Figure A10g, A10h and A10i.

The purpose of providing Figure A10i is to demonstrate the insensitivity of the model to changes in the Kiln 6 PM₁₀ emission rate. As highlighted in Figure A10j, the three figures are almost identical, even when all point source emissions are switched off (i.e. Figure A10g).

Appendix 10 also shows incremental annual average PM₁₀ concentrations for combined point source and fugitive emissions. The following figures are provided:

- Annual averaging period
 - Figure A10k: All fugitive sources (with 3.8x-scaled emission rates for open sources subject to wind erosion).
 - Figure A10l: All fugitive sources plus all point sources.
 - Figure A10m: All fugitive sources plus all point sources, with Kiln 6 emission rate increased by 50%
 - Figure A10n: Overlay comparison of Figure A10k, A10l and A10m.

As highlighted in Figure A10n, the three figures for annual average are almost identical, even when all point source emissions are switched off (i.e. Figure A10k), especially within a kilometre of the site boundary where the GLCs are highest.

This indicates that significant changes can be made to the Kiln 6 emissions of PM₁₀, such as a 50% increase over and above the emission rate used in this report, without impacting on the maximum PM₁₀ impacts occurring beyond the site boundary.

The 24-hour concentrations occurring at each discrete receptor for the model shown in Figure A10h (all PM₁₀ emission sources) are listed in Table 66. The annual average concentrations occurring at each discrete receptor for the same model are listed in Table 67.

Table 66: 24-hour average incremental ground level concentration of PM₁₀ at potentially sensitive discrete receptors, fugitive and point sources combined (Kiln 6 stack emissions at proposed Licence limit).

Receptor no.	Max 24-hr avg PM ₁₀ (µg/m ³)	Receptor no.	Max 24-hr avg PM ₁₀ (µg/m ³)	Receptor no.	Max 24-hr avg PM ₁₀ (µg/m ³)
1	3.8	30	6.2	59	18.2
2	4.6	31	6.4	60	21.8
3	6.0	32	10.9	61	20.4
4	6.4	33	20.0	62	12.6
5	6.5	34	24.9	63	10.7
6	5.8	35	25.1	64	9.2
7	6.6	36	20.0	65	7.1
8	8.4	37	31.2	66	7.1
9	8.4	38	26.4	67	7.0
10	7.2	39	22.5	68	6.1
11	8.3	40	21.5	69	5.9
12	11.4	41	32.3	70	4.3
13	10.6	42	20.8	71	6.5
14	11.3	43	17.9	72	11.7
15	15.4	44	17.4	73	40.2
16	12.2	45	13.3	74	32.1
17	8.9	46	8.5	75	64.6
18	8.5	47	6.4	76	33.2
19	7.5	48	6.9	77	25.9
20	12.6	49	6.7	78	16.8
21	10.8	50	4.2	79	15.8
22	17.0	51	5.4	80	26.4
23	27.0	52	5.9	81	13.7
24	22.1	53	13.0	82	11.3
25	19.6	54	12.5	83	14.2
26	23.8	55	27.8	84	8.9
27	29.0	56	21.7	85	7.6
28	28.7	57	28.0	86	7.2
29	23.6	58	18.8	87	5.6
				88	52.5

Table 67: Annual average incremental ground level concentration of PM₁₀ at potentially sensitive discrete receptors, fugitive and point sources combined (Kiln 6 stack emissions at proposed Licence limit).

Receptor no.	Annual avg PM ₁₀ (µg/m ³)	Receptor no.	Annual avg PM ₁₀ (µg/m ³)	Receptor no.	Annual avg PM ₁₀ (µg/m ³)
1	0.40	30	0.51	59	1.51
2	0.51	31	0.49	60	1.68
3	0.60	32	0.78	61	1.34
4	0.68	33	1.04	62	1.14
5	0.69	34	1.77	63	1.05
6	0.67	35	1.63	64	0.89
7	0.75	36	1.63	65	0.57
8	0.90	37	2.50	66	0.44
9	0.82	38	2.33	67	0.48
10	0.84	39	1.91	68	0.46
11	1.06	40	1.45	69	0.45
12	1.33	41	2.28	70	0.40
13	1.25	42	1.36	71	0.43
14	1.32	43	1.17	72	1.73
15	1.68	44	0.96	73	2.29
16	1.80	45	0.87	74	2.16
17	1.61	46	0.63	75	5.25
18	0.94	47	0.48	76	3.01
19	0.93	48	0.46	77	3.46
20	1.64	49	0.44	78	2.17
21	1.72	50	0.32	79	1.29
22	2.83	51	0.36	80	3.22
23	3.13	52	0.35	81	0.94
24	2.38	53	1.09	82	0.60
25	1.77	54	1.00	83	0.85
26	2.68	55	3.59	84	0.72
27	2.88	56	3.11	85	0.62
28	2.22	57	4.54	86	0.53
29	1.81	58	1.42	87	0.49
				88	4.27

8.4.4 Annual Average PM₁₀ Cumulative Assessment and Comparison with Ambient Air Quality Assessment Threshold Criteria

The maximum off-site incremental annual-average concentration of PM₁₀ at any potentially sensitive receptor is 5.2 µg/m³ occurring at receptor 75. This predicted worst case concentration is 17% of the PM₁₀ impact assessment criteria of 30 µg/m³ specified in the “Approved Methods” guidelines by NSW EPA.

To put this incremental concentration in perspective, the annual average background concentration from the nearest environmentally-comparable ambient monitoring station operated by NSW EPA, at Bargo has ranged from 12.9 µg/m³ to 15.7 µg/m³ for PM₁₀ over the last four years (2011 to 2014). Similarly, the annual average background concentrations from Berrima (calculated from 24-hour data measured on a 1-day-in-6 basis) over 2011 to 2014 ranged from 11.0 µg/m³ to 15.1 µg/m³. The annual average incremental PM₁₀ concentration of 5.2 µg/m³ generated by the activities at the Berrima Works is clearly minor in comparison, even with the conservative assumption that the Works operates continuously for 365 days per year.

When the worst case incremental concentration of 5.2 µg/m³ is added to the worst case annual average background concentration of 15.7 µg/m³, the total cumulative concentration of 20.9 µg/m³ is 70% of the impact assessment criteria of 30 µg/m³.

8.4.5 24-hour Average PM₁₀ Cumulative Assessment and Comparison with Ambient Air Quality Assessment Threshold Criteria

The model results in Figure A10g-i and resultant GLCs extracted from the model and listed in Table 66 indicate the potential for PM₁₀ incremental 24-hour concentrations to exceed NSW EPA criteria of 50 µg/m³ at the southwest edge of New Berrima (receptor 88) and on the Berrima sewage treatment plant site (receptor 75). These hypothetical PM₁₀ concentrations are caused by fugitive dust emissions on the site and are unaffected by emissions from the Kiln and the other three point sources at the Works.

As discussed earlier in Section 8.3, the modelling of fugitive emissions carried out in this report is conservative because of the following assumptions:

- The model assumes that there is no rain to dampen exposed dusty surface, and no reduction in particulate concentrations in the air as they travel downwind due to gravitational settling and vegetation screening.
- The model assumes full operation of vehicles and processes for the available time – i.e. 24 hours per day, 365 days per year except for one of the loaders which is assumed to operate for 12 hours per day. This will overstate 24-hour and annual average GLCs as actual hours of operation per day are less than this.
- Some publications recommend applying a minimum wind speed threshold below which wind erosion emissions are zero. This layer of complexity has not yet been added to the fugitive dust model.
- No account of suspended dust scavenging through gravitational settling or capture by vegetation around the site has been made yet due to the complexity inherent in those assumptions and a lack of available data on TSP particulate size distribution in the fugitive dust.

- The equations used to derive emissions from vehicles (tracked dust and material handling) are not wind speed dependent, which may overstate emissions rates in light wind speed conditions.
- The scaling factor applied to the open sources subject to wind erosion is appropriate at higher wind speeds, but may not apply across lower wind speeds as well.

Due to these assumptions, the predicted PM₁₀ GLCs shown in this section are considered to be over-estimates of actual maximum GLCs at receptors close to the site boundary.

Of more importance for the Boral proposal to modify the Licence limit for operation using NSF, is the finding that the model results are insensitive to large changes in Kiln 6 stack PM₁₀ emission rates and thus there will be no effective change to off-site air quality impacts of PM₁₀ due to the Project.

Despite the comments above about the conservative nature of predicted PM₁₀ GLCs close to the site boundary, a cumulative assessment of incremental GLCs with background air quality concentrations has been carried out. The methodology for this assessment was as follows:

- A timeseries of 1-hour average PM₁₀ concentrations at each of the 88 discrete receptors for each day in the year of modelled data was extracted from the “all fugitive plus point sources” model
- Contemporaneous background concentration data from Bargo for each hour was added to the hourly timeseries data for each receptor
- 24-hour averages (midnight to midnight) for each day of the year at each receptor were calculated
- The number of exceedances of the NSW EPA criteria of 50 µg/m³ was identified for each receptor and also for the background data by itself
- At receptors where the number of exceedances of the NSW EPA criteria is increased compared with the background data, the incremental GLCs and background contributions for each hour were identified.
- The process was then repeated using contemporaneous background concentration data from Camden instead of Bargo.

The Bargo background data file was compiled from raw 1-hour interval data provided by NSW EPA. That data file contained a lot of missing data over the period when the very high PM₁₀ concentrations were measured, 17-21 October. From hour 21:00 on 17 October to hour 13:00 on 21 October, only 16 hourly data records were available out of a total of 89. In the cumulative assessment carried out, missing data in this period (and elsewhere in the data file) was replaced with Camden data for the same dates and times. Negative readings were also replaced with zero. The Camden raw data was treated similarly, with missing data replaced with Bargo data.

Analysis of 24-hour average data calculated as midnight-to-midnight averages from the Bargo raw data file resulted in a different breakdown of highest-occurring concentrations compared to that calculated from 24-hour data downloaded from the NSW EPA website and reproduced earlier in Table 49. Three days of high PM₁₀ (over 100 µg/m³) have not been included in that list because no data is reported for the days 18-21 October. This is of no consequence for the cumulative assessment reported here, however the observation is acknowledged in case a comparison of Table 49 is made with the exceedance statistics discussed here for the cumulative GLCs.

In the Bargo background data file processed for use with the dispersion model, where missing data was replaced with Camden data, the 50 $\mu\text{g}/\text{m}^3$ criteria was exceeded on six days, occurring over the five day period from 17 October to 21 October (when the nearby bushfire occurred) plus 5 October. The criteria was nearly exceeded on another day, with 47.2 $\mu\text{g}/\text{m}^3$ measured on 27 March 2013.

In the Camden background data file, the 50 $\mu\text{g}/\text{m}^3$ criteria was exceeded on two days, being 20 and 21 October. The criteria was almost exceeded on 22 October with a concentration of 47.3 $\mu\text{g}/\text{m}^3$ recorded.

Table 68 lists the number of exceedances of the NSW EPA criteria at each discrete receptor found using the Bargo data file. Table 69 lists the number of exceedances of the NSW EPA criteria at each discrete receptor found using the Camden data file.

Table 68: Number of exceedances of NSW EPA criteria for 24-hour average PM_{10} (50 $\mu\text{g}/\text{m}^3$) at each discrete receptor – cumulative concentrations of PM_{10} from all fugitive and point sources plus contemporaneous background data from Bargo.

Highlighted in green: one additional exceedance compared to Bargo background data. This additional exceedance occurs on 27 March 2013 when background data was 47.2 $\mu\text{g}/\text{m}^3$

Highlighted in orange: more than one additional exceedance compared to Bargo background data.

Receptor no.	Number of exceedances	Receptor no.	Number of exceedances	Receptor no.	Number of exceedances
1	6	30	6	59	6
2	6	31	6	60	6
3	7	32	6	61	6
4	7	33	6	62	6
5	7	34	6	63	6
6	6	35	6	64	6
7	7	36	6	65	6
8	7	37	7	66	6
9	7	38	6	67	6
10	7	39	6	68	6
11	7	40	6	69	6
12	7	41	6	70	6
13	7	42	6	71	6
14	7	43	6	72	7
15	7	44	6	73	6
16	7	45	6	74	6
17	7	46	6	75	13
18	6	47	6	76	7
19	6	48	6	77	7
20	6	49	6	78	7
21	7	50	6	79	6
22	7	51	6	80	7
23	7	52	6	81	6
24	7	53	6	82	6
25	6	54	6	83	6
26	7	55	7	84	6
27	6	56	7	85	6
28	6	57	8	86	6
29	6	58	6	87	6
				88	11
Bargo background data file alone – 6 exceedances					

Table 69: Number of exceedances of NSW EPA criteria for 24-hour average PM₁₀ (50 µg/m³) at each discrete receptor – cumulative concentrations of PM₁₀ from all fugitive and point sources plus contemporaneous background data from Camden.

Highlighted in green: one additional exceedance compared to Camden background data. This additional exceedance occurs on 22 October 2013 when background data was 47.3 µg/m³

Highlighted in orange: more than one additional exceedance compared to Camden background data.

Receptor no.	Number of exceedances	Receptor no.	Number of exceedances	Receptor no.	Number of exceedances
1	2	30	2	59	2
2	2	31	2	60	2
3	2	32	2	61	2
4	2	33	2	62	2
5	2	34	2	63	2
6	2	35	2	64	2
7	2	36	2	65	2
8	2	37	2	66	2
9	2	38	2	67	2
10	2	39	2	68	2
11	2	40	2	69	2
12	2	41	2	70	2
13	2	42	2	71	2
14	2	43	2	72	3
15	3	44	2	73	2
16	3	45	2	74	2
17	3	46	2	75	9
18	2	47	2	76	2
19	2	48	2	77	3
20	2	49	2	78	3
21	3	50	2	79	2
22	3	51	2	80	2
23	4	52	2	81	2
24	3	53	2	82	2
25	2	54	2	83	2
26	2	55	3	84	2
27	2	56	3	85	2
28	2	57	3	86	2
29	2	58	2	87	2
				88	7
Camden background data file alone – 2 exceedances					

In the analysis based on Bargo background data, the only discrete receptors that have more than one exceedance over the background data are receptors 57, 75 and 88. Receptors showing only one additional exceedance have not been counted as this additional exceedance is due to a high background concentration that almost exceeds the threshold.

In the analysis based on Camden background data, the only discrete receptors that have more than one exceedance over the background data are receptors 23, 75 and 88. Again, receptors showing only one additional exceedance have not been counted as this additional exceedance is due to a high background concentration that almost exceeds the threshold.

A more detailed analysis of cumulative concentrations occurring at receptors 23, 57, 75 and 88 was carried out. Receptor 75 represents the Berrima Sewage Treatment Plant, and is not considered to be a very sensitive receptor due to low human occupation. However it has still been included in the analysis.

Table 70 summarises the cumulative 24-hour average GLCs that exceed $50 \mu\text{g}/\text{m}^3$ occurring at each of these four receptors in the 2013 year used in the model, and the background and incremental GLC contributions. The following comments are provided:

- **Receptor 23:** The highest incremental concentration at this receptor that causes a cumulative concentration to exceed $50 \mu\text{g}/\text{m}^3$ (excluding days where background exceeds $47 \mu\text{g}/\text{m}^3$) is $10.4 \mu\text{g}/\text{m}^3$. Therefore GLC exceedances at this receptor are highly dependent on background data.
- **Receptor 57:** The highest incremental concentration at this receptor that causes a cumulative concentration to exceed $50 \mu\text{g}/\text{m}^3$ (excluding days where background exceeds $47 \mu\text{g}/\text{m}^3$) is $17.2 \mu\text{g}/\text{m}^3$. The associated cumulative GLC only just breaches the $50 \mu\text{g}/\text{m}^3$ threshold. GLC exceedances at this receptor are highly dependent on background data, but also on the conservatism in the prediction of GLCs near the site boundary due to fugitive emissions.
- **Receptor 75:** At this receptor, incremental GLCs resulting in a cumulative GLC exceeding $50 \mu\text{g}/\text{m}^3$ (excluding days where background exceeds $47 \mu\text{g}/\text{m}^3$) range from 34.6 to $64.6 \mu\text{g}/\text{m}^3$. The conservative nature of these GLCs due to assumptions implicit in the fugitive dust modelling assessment are discussed above, at the start of this section. The number of cumulative GLCs exceeding $50 \mu\text{g}/\text{m}^3$ at this receptor is highly dependent on the modelled incremental concentrations, and therefore highly dependent on the magnitude of the fugitive dust concentrations. The number of cumulative GLCs exceeding $50 \mu\text{g}/\text{m}^3$ at this receptor is not dependent on the PM_{10} emission rate from the Kiln 6 stack at the emission rates proposed by Boral Cement.
- **Receptor 88:** At this receptor, incremental GLCs resulting in a cumulative GLC exceeding $50 \mu\text{g}/\text{m}^3$ (excluding days where background exceeds $47 \mu\text{g}/\text{m}^3$) range from 17.3 to $52.5 \mu\text{g}/\text{m}^3$, with the majority of those incremental concentrations exceeding $44.4 \mu\text{g}/\text{m}^3$. The conservative nature of these GLCs due to assumptions implicit in the fugitive dust modelling assessment are discussed above, at the start of this section. The number of cumulative GLCs exceeding $50 \mu\text{g}/\text{m}^3$ at this receptor is highly dependent on the modelled incremental concentrations, and therefore highly dependent on the magnitude of the fugitive dust concentrations. The number of cumulative GLCs exceeding $50 \mu\text{g}/\text{m}^3$ at this receptor is not dependent on the PM_{10} emission rate from the Kiln 6 stack at the emission rates proposed by Boral Cement.

Table 70: Breakdown of highest occurring cumulative GLCs at receptors 23, 57, 75 and 88; and incremental and background contributions to the cumulative GLCs. Grey shading = background above 50 $\mu\text{g}/\text{m}^3$ or exceeding 47 $\mu\text{g}/\text{m}^3$

Rank of 24-hour cumulative GLC (1 = highest)	Analysis based on Bargo background data (all concentrations in $\mu\text{g}/\text{m}^3$)			Analysis based on Camden background data (all concentrations in $\mu\text{g}/\text{m}^3$)		
	Cumulative concentration	Incremental concentration	Background concentration	Cumulative concentration	Incremental concentration	Background concentration
Receptor 23						
1	177.6	0.1	177.5	94.1	8.7	85.3
2	133.2	8.7	124.4	58.6	6.2	52.4
3	94.1	6.8	87.3	51.4	4.1	47.3
4	74.6	2.6	72.0	51.2	10.4	40.7
5	58.6	6.2	52.4			
6	55.5	1.9	53.7			
7	52.6	5.4	47.2			
Receptor 57						
1	185.5	8.0	177.5	85.3	0.0	85.3
2	124.4	0.0	124.4	52.4	0.0	52.4
3	87.3	0.0	87.3	50.1	2.8	47.3
4	75.2	3.2	72.0			
5	54.0	0.3	53.7			
6	53.7	10.2	43.5			
7	52.4	0.0	52.4			
8	50.9	17.2	33.7			
Receptor 75						
1	177.5	0.0	177.5	85.3	0.0	85.3
2	124.4	0.0	124.4	69.7	64.6	5.1
3	87.3	0.0	87.3	63.6	49.6	14.1
4	73.4	1.3	72.0	57.7	48.2	9.5
5	69.9	64.6	5.3	54.1	34.6	19.4
6	57.9	48.2	9.7	53.1	43.4	9.7
7	57.0	49.6	7.4	53.1	5.8	47.3
8	55.5	34.6	20.8	52.4	0.0	52.4
9	53.7	0.0	53.7	51.4	34.6	16.8
10	52.5	43.4	9.2			
11	52.4	0.0	52.4			
12	51.2	34.6	16.6			
Receptor 88						
1	178.0	0.5	177.5	85.3	0.0	85.3
2	124.4	0.0	124.4	63.5	52.5	11.1
3	87.3	0.0	87.3	56.3	44.6	11.7
4	78.3	6.3	72.0	54.7	44.4	10.4
5	63.0	52.5	10.5	53.5	44.9	8.6
6	60.8	17.3	43.5	52.4	0.0	52.4
7	56.0	44.4	11.7	51.4	4.1	47.3
8	55.5	44.6	10.8			
9	53.7	0.0	53.7			
10	53.3	44.9	8.4			
11	52.4	0.0	52.4			

8.4.6 Peak Incremental Annual Average GLCs at any Off-Site Receptor

Identification of peak incremental annual average GLCs of PM₁₀ occurring at any off-site receptor is not required in the “Approved Methods” guidelines by NSW EPA (i.e. including receptors that are not potentially sensitive to PM₁₀ as defined in the “Approved Methods” guidelines), but was requested for the health-risk assessment for the Project being carried out by SLR Consulting.

The maximum incremental annual average concentrations occurring off-site (i.e. at or beyond the orange boundary on Figures A10d, A10f, A10l, and A10m in Appendix 10) are listed in Table 71. The location of these maximum concentrations was just outside a small section of the western boundary of the site and not in an area of habitation.

Table 71: Maximum incremental annual average concentrations of PM₁₀ occurring off-site

Source group	Maximum off-site incremental concentration of PM ₁₀ (µg/m ³)
Kiln stack only	0.26
All point sources	1.5
Point sources plus fugitive sources	18
Point sources plus fugitive sources plus Kiln 6 emission rate increased by 50%	18

8.4.7 Summary

Annual average

Cumulative annual average concentrations of PM₁₀ from both fugitive and point sources at the Works, including background concentrations, are below the Approved Methods assessment criteria of 90 µg/m³ at each of the discrete receptors even with the conservative assumption that the Works operates continuously for 365 days per year.

Therefore it is concluded that adverse air quality impacts will not arise from annual average PM₁₀ concentrations due to the Project.

24-Hour average

For most of the discrete receptors, no additional exceedances of the 24-hour average PM₁₀ air quality criteria are generated due to PM₁₀ emissions from the Works. However a small number of discrete receptors near the site boundary do show some possible additional exceedances. For receptors 23 and 57, GLC exceedances are highly dependent on background data. For receptors 75 and 88, and to an extent receptor 57 as well, the number of cumulative GLCs exceeding 50 µg/m³ is highly dependent on the modelled incremental concentrations, and therefore highly dependent on the magnitude of the fugitive dust concentrations. Those fugitive dust concentrations are considered to be over-estimates of actual maximum incremental GLCs at receptors close to the site boundary because of the assumptions required for the fugitive dust dispersion analysis. In most cases, the cumulative GLCs that exceed 50 µg/m³ are only 10-20% greater than that threshold concentration, so overestimates of fugitive dust concentrations will play a large role in the number of predicted exceedances.

Of more importance for the Boral proposal to modify the Licence limit for operation using NSF, is the finding that the model results are insensitive to large changes in Kiln 6 stack PM₁₀ emission rates and thus there will be no effective change to off-site local air quality impacts of PM₁₀ due to the Project.

8.5 PM_{2.5}

All PM_{2.5} model results for the Kiln 6 stack discussed in this section assume a constant PM_{2.5} emission concentration which is calculated from a constant TSP concentration of 50 mg/Nm³ (which is the proposed 24-hour average maximum emission concentration to be included in the EPL for the burning of NSF) and a constant PM_{2.5} fraction of 33% of TSP.

Using the same approach as for TSP emissions, the calculated maximum PM_{2.5} 24-hour average emission concentration was converted into a very conservative equivalent 1-hour PM_{2.5} concentration for use in the dispersion model that accounts for peak 1-hour concentrations that could occur within the 24-hour period. The model was run using that peak 1-hour concentration as the constant emission rate for 365 days per year, 24 hours per day.

The model results are presented in the following subsections.

8.5.1 Model Output – Point Sources

Appendix 11 shows the model results for 100th percentile, incremental PM_{2.5} concentrations for the four point sources of particulate. A schedule of plots contained in this appendix is as follows:

- 24-hour averaging period
 - Figure A11a: Kiln 6 stack alone
 - Figure A11b: Cement mills 6 and 7 and cooler stack combined (no Kiln 6 stack).
 - Figure A11c: Kiln 6 plus cement mills 6 and 7 and cooler stack
- Annual averaging period
 - Figure A11d: Kiln 6 stack alone
 - Figure A11e: Cement mills 6 and 7 and cooler stack combined (no Kiln 6 stack).
 - Figure A11f: Kiln 6 plus cement mills 6 and 7 and cooler stack

The maximum off-site incremental concentrations of 24-hour and annual average PM_{2.5} at each of the discrete receptors 1-88 are listed in Table 72 and Table 73. The maximum concentrations are as follows:

<i>Averaging period</i>	<i>Emission sources</i>	<i>Maximum predicted concentration at a discrete receptor</i>	<i>Discrete receptor where this concentration occurs</i>
24-hours	Kiln 6 stack only	1.7 µg/m ³	12
	All point sources	5.6 µg/m ³	55
Annual	Kiln 6 stack only	0.11 µg/m ³	60
	All point sources	0.53 µg/m ³	57

Table 72: 24-hour average incremental ground level concentration of PM_{2.5} at potentially sensitive discrete receptors, point sources only.

Receptor no.	24-hr avg incremental PM _{2.5} (µg/m ³)	24-hr avg incremental PM _{2.5} (µg/m ³)	Receptor no.	24-hr avg incremental PM _{2.5} (µg/m ³)	24-hr avg incremental PM _{2.5} (µg/m ³)
	Kiln 6 stack only	All 4 point sources		Kiln 6 stack only	All 4 point sources
1	0.034	0.073	45	0.030	0.083
2	0.041	0.094	46	0.031	0.081
3	0.044	0.125	47	0.035	0.082
4	0.046	0.146	48	0.030	0.070
5	0.038	0.123	49	0.029	0.067
6	0.049	0.123	50	0.027	0.070
7	0.050	0.138	51	0.026	0.083
8	0.054	0.152	52	0.025	0.077
9	0.043	0.132	53	0.057	0.135
10	0.041	0.135	54	0.059	0.147
11	0.051	0.153	55	0.028	0.251
12	0.069	0.200	56	0.028	0.219
13	0.061	0.173	57	0.055	0.532
14	0.060	0.176	58	0.088	0.199
15	0.066	0.177	59	0.088	0.201
16	0.062	0.165	60	0.105	0.242
17	0.054	0.139	61	0.091	0.199
18	0.033	0.076	62	0.055	0.137
19	0.032	0.071	63	0.050	0.129
20	0.039	0.098	64	0.044	0.109
21	0.061	0.212	65	0.038	0.085
22	0.066	0.302	66	0.040	0.079
23	0.065	0.295	67	0.042	0.083
24	0.067	0.230	68	0.039	0.078
25	0.032	0.082	69	0.033	0.072
26	0.035	0.093	70	0.030	0.062
27	0.039	0.095	71	0.039	0.079
28	0.037	0.084	72	0.049	0.126
29	0.039	0.085	73	0.032	0.069
30	0.022	0.044	74	0.031	0.064
31	0.019	0.041	75	0.034	0.109
32	0.020	0.038	76	0.031	0.110
33	0.033	0.061	77	0.024	0.224
34	0.036	0.073	78	0.033	0.173
35	0.034	0.086	79	0.068	0.198
36	0.031	0.095	80	0.071	0.260
37	0.032	0.095	81	0.067	0.134
38	0.031	0.101	82	0.051	0.096
39	0.031	0.104	83	0.064	0.140
40	0.030	0.100	84	0.042	0.095
41	0.029	0.135	85	0.038	0.085
42	0.031	0.107	86	0.036	0.078
43	0.031	0.098	87	0.034	0.074
44	0.030	0.084	88	0.026	0.160

Table 73: Annual average incremental ground level concentration of PM_{2.5} at potentially sensitive discrete receptors, point sources only.

Receptor no.	Annual avg incremental PM _{2.5} (µg/m ³)	Annual avg incremental PM _{2.5} (µg/m ³)	Receptor no.	Annual avg incremental PM _{2.5} (µg/m ³)	Annual avg incremental PM _{2.5} (µg/m ³)
	Kiln 6 stack only	All 4 point sources		Kiln 6 stack only	All 4 point sources
1	0.55	1.00	45	0.53	1.23
2	0.69	1.37	46	0.70	1.42
3	0.80	1.94	47	1.12	1.89
4	0.88	1.60	48	0.67	1.18
5	0.60	1.39	49	0.64	1.15
6	0.80	1.89	50	0.59	1.52
7	0.89	1.85	51	0.66	1.91
8	0.96	1.75	52	0.75	1.51
9	0.64	1.41	53	0.85	2.08
10	0.74	1.20	54	0.85	2.26
11	1.23	1.93	55	0.66	5.56
12	1.72	2.83	56	0.70	4.43
13	1.18	2.18	57	0.75	4.59
14	1.09	2.11	58	1.21	2.95
15	1.01	1.89	59	1.16	3.32
16	1.05	1.63	60	1.12	3.23
17	0.96	1.56	61	1.01	2.77
18	1.01	1.41	62	0.98	1.69
19	0.92	1.63	63	1.05	1.57
20	0.99	1.95	64	0.74	1.53
21	0.98	1.83	65	0.81	1.13
22	0.98	2.47	66	0.87	1.46
23	0.97	2.84	67	0.77	1.18
24	1.13	2.39	68	0.84	1.41
25	1.00	1.35	69	0.72	1.14
26	1.08	1.52	70	0.56	0.76
27	1.15	2.09	71	0.73	1.18
28	1.11	2.13	72	1.10	1.59
29	1.23	2.10	73	0.88	1.33
30	0.63	0.92	74	0.75	1.33
31	0.55	0.76	75	0.62	3.34
32	0.77	1.03	76	0.93	2.90
33	0.96	1.94	77	0.51	3.28
34	0.85	2.05	78	0.77	3.09
35	1.39	3.03	79	0.98	2.39
36	1.00	2.01	80	0.96	3.16
37	0.97	2.69	81	0.88	1.99
38	0.85	2.88	82	0.86	1.46
39	0.88	2.35	83	1.38	2.30
40	0.82	1.66	84	0.85	1.28
41	0.71	2.79	85	0.73	1.41
42	0.64	2.31	86	0.70	1.04
43	0.62	2.00	87	0.75	1.30
44	0.61	1.66	88	0.58	3.40

The maximum predicted incremental 24-hour PM_{2.5} concentration at existing or likely future sensitive receptors due to point sources at the Works is 5.6 µg/m³. This predicted PM_{2.5} concentration is only 22% of the NSW EPA ambient air quality assessment threshold criteria of 25 µg/m³, but does not yet include fugitive emissions of PM_{2.5} and background concentrations. This is discussed in the following sections.

The maximum off-site incremental concentration of annual average PM_{2.5} for all four point sources combined, beyond the site boundary at an the existing or likely future off-site sensitive receptor, is 0.53 µg/m³. This is a conservative concentration because it assumes that the kiln and mills operate 24 hours per day, 365 days per year at steady state and at the maximum assumed emission limit. Despite this degree of conservatism, the maximum predicted incremental concentration is only 7% of the NSW EPA assessment criteria of 8 µg/m³.

8.5.2 Handling of Fugitive Emissions

Fugitive PM_{2.5} emissions were modelled as outlined in Section 5.2.1, with PM_{2.5}:PM₁₀ ratios of 0.1 or 0.15 assigned to each source type.

In the case of PM_{2.5} emissions from wind erosion sources, the scaling factor of 3.8 applied to the PM₁₀ emissions was also applied to the PM_{2.5} emissions.

8.5.3 Fugitive and Point Sources Combined

Appendix 11 shows incremental 24-hour average PM_{2.5} concentrations for combined point source and fugitive emissions. The following figures are provided:

- 24-hour annual averaging period
 - Figure A11g: All fugitive sources.
 - Figure A11h: All fugitive sources plus all point sources.
 - Figure A11i: All fugitive sources plus all point sources, with Kiln 6 emission rate increased by 50%
 - Figure A11j: Overlay comparison of Figure A11g, A11h and A11i.

The purpose of providing Figure A11i is to demonstrate the insensitivity of the model to changes in the Kiln 6 PM_{2.5} emission rate. As highlighted in Figure A11j, the model contour plots for the two models with differing Kiln 6 emission rates (Figures A11h and A11i) are almost identical. However these two models differ a little from the model in Figure A11g which shows only fugitive sources. The difference is due to the assumed PM_{2.5} emission rates from the cement mills and the cooler stack.

Appendix 11 also shows incremental annual average PM_{2.5} concentrations for combined point source and fugitive emissions. The following figures are provided:

- Annual averaging period
 - Figure A11k: All fugitive sources.
 - Figure A11l: All fugitive sources plus all point sources.

- Figure A11m: All fugitive sources plus all point sources, with Kiln 6 emission rate increased by 50%
- Figure A11n: Overlay comparison of Figure A11k, A11l and A11m.

As highlighted in Figure A11n, the three figures for annual average exhibit the same comparative trends as described above for the 24-hour averages – i.e. the model for fugitive sources alone showing slightly lower concentration contours than the models with point sources included, but with the models being insensitive to emission rate of PM_{2.5} from Kiln 6.

The 24-hour concentrations occurring at each discrete receptor for the model shown in Figure A11h (all PM₁₀ emission sources) are listed in Table 74. The annual average concentrations occurring at each discrete receptor for the same model are listed in Table 75.

Table 74: 24-hour average incremental ground level concentration of PM_{2.5} at potentially sensitive discrete receptors, fugitive and point sources combined.

Receptor no.	Max 24-hr avg PM _{2.5} (µg/m ³)	Receptor no.	Max 24-hr avg PM _{2.5} (µg/m ³)	Receptor no.	Max 24-hr avg PM _{2.5} (µg/m ³)
1	1.1	30	1.4	59	4.9
2	1.5	31	1.2	60	5.4
3	2.2	32	1.7	61	4.9
4	1.8	33	4.2	62	2.7
5	1.8	34	5.0	63	2.4
6	2.1	35	3.7	64	2.0
7	2.2	36	3.2	65	1.8
8	2.1	37	4.3	66	2.0
9	1.9	38	3.7	67	1.8
10	1.7	39	3.2	68	1.8
11	2.1	40	3.2	69	1.6
12	3.1	41	4.5	70	1.1
13	2.5	42	3.1	71	1.8
14	2.4	43	2.9	72	2.3
15	2.3	44	3.0	73	5.9
16	2.1	45	2.2	74	5.3
17	2.0	46	1.9	75	9.0
18	1.6	47	2.1	76	4.7
19	2.2	48	1.7	77	5.5
20	2.6	49	1.7	78	3.8
21	2.3	50	1.6	79	3.9
22	3.0	51	2.1	80	5.6
23	3.8	52	1.8	81	3.4
24	3.2	53	3.2	82	2.6
25	3.1	54	3.4	83	3.0
26	3.7	55	6.2	84	1.9
27	4.8	56	5.1	85	1.8
28	4.3	57	7.2	86	1.6
29	3.8	58	4.7	87	1.6
				88	7.6

Table 75: Annual average incremental ground level concentration of PM_{2.5} at potentially sensitive discrete receptors, fugitive and point sources combined.

Receptor no.	Annual avg PM _{2.5} (µg/m ³)	Receptor no.	Annual avg PM _{2.5} (µg/m ³)	Receptor no.	Annual avg PM _{2.5} (µg/m ³)
1	0.11	30	0.10	59	0.35
2	0.14	31	0.10	60	0.41
3	0.17	32	0.13	61	0.33
4	0.20	33	0.19	62	0.25
5	0.18	34	0.30	63	0.24
6	0.18	35	0.29	64	0.20
7	0.20	36	0.29	65	0.14
8	0.23	37	0.41	66	0.12
9	0.21	38	0.39	67	0.13
10	0.21	39	0.34	68	0.12
11	0.25	40	0.27	69	0.11
12	0.33	41	0.41	70	0.10
13	0.29	42	0.26	71	0.12
14	0.31	43	0.23	72	0.33
15	0.36	44	0.19	73	0.37
16	0.37	45	0.18	74	0.34
17	0.32	46	0.14	75	0.80
18	0.18	47	0.12	76	0.49
19	0.18	48	0.11	77	0.64
20	0.30	49	0.11	78	0.42
21	0.39	50	0.09	79	0.32
22	0.60	51	0.11	80	0.64
23	0.64	52	0.10	81	0.23
24	0.49	53	0.25	82	0.15
25	0.30	54	0.24	83	0.22
26	0.44	55	0.67	84	0.17
27	0.46	56	0.58	85	0.15
28	0.36	57	1.01	86	0.13
29	0.31	58	0.34	87	0.12
				88	0.71

8.5.4 Annual Average PM_{2.5} Cumulative Assessment and Comparison with Ambient Air Quality Assessment Threshold Criteria

From Table 75, the maximum off-site incremental annual-average concentration of PM_{2.5} at any potentially sensitive receptor is 1.0 µg/m³ occurring at receptor 57. This predicted worst case GLC is 13% of the PM_{2.5} impact assessment criteria of 8 µg/m³ specified in the “Approved Methods” guidelines by NSW EPA.

To put this incremental concentration in perspective, the annual average background PM_{2.5} concentration from the nearest environmentally-comparable ambient monitoring station operated by NSW EPA, at Camden has ranged from 6.3 µg/m³ to 6.5 µg/m³ for over the two years of operation to date (2013 and 2014). The maximum annual average incremental PM₁₀ concentration of 1.0 µg/m³ generated by the activities at the Berrima Works is clearly minor in comparison, even with the conservative assumption that the Works operates continuously for 365 days per year.

When the worst case incremental concentration of 1.0 µg/m³ is added to the worst case annual average background concentration of 6.5 µg/m³, the total cumulative concentration of 7.5 µg/m³ is below the impact assessment criteria of 8 µg/m³, although only just because of the magnitude of the background concentration.

8.5.5 24-Hour Average PM_{2.5} Cumulative Assessment and Comparison with Ambient Air Quality Assessment Threshold Criteria

A cumulative assessment of incremental PM_{2.5} GLCs with background air quality concentrations has been carried out using the same methodology as for PM₁₀. Only one set of background data is available, from the Camden site.

In the Camden PM_{2.5} background data file processed for use with the dispersion model, the 24-hour criteria of 25 µg/m³ criteria was exceeded on three days, occurring over the three day period from 20 October to 22 October (when the nearby bushfire occurred). The criteria was nearly exceeded on the previous day, with 24.7 µg/m³ measured on 19 October 2013.

Table 76 lists the number of exceedances of the NSW EPA criteria at each discrete receptor found using the Camden background data. A number of receptors show one additional exceedance compared to the background data (as shown in green highlighting), however that exceedance occurs on 19 October 2013 when the background was only 0.3 µg/m³ below the NSW EPA criteria.

In practical terms it is therefore concluded that no additional exceedances of the NSW EPA criteria arise from the cumulative assessment of PM_{2.5} emissions from the site combined with contemporaneous background data.

Table 76: Number of exceedances of NSW EPA criteria for 24-hour average PM_{2.5} (25 µg/m³) at each discrete receptor – cumulative concentrations of PM_{2.5} from all fugitive and point sources plus contemporaneous background data from Camden.

Highlighted in green: one additional exceedance compared to Camden background data. This additional exceedance occurs on 19 October 2013 when background data was 24.7 µg/m³

Receptor no.	Number of exceedances	Receptor no.	Number of exceedances	Receptor no.	Number of exceedances
1	3	30	3	59	3
2	3	31	3	60	3
3	4	32	3	61	3
4	4	33	3	62	3
5	4	34	3	63	3
6	3	35	3	64	3
7	4	36	3	65	3
8	4	37	3	66	3
9	4	38	3	67	3
10	4	39	3	68	3
11	4	40	3	69	3
12	4	41	3	70	3
13	4	42	3	71	3
14	4	43	3	72	4
15	4	44	3	73	3
16	4	45	3	74	3
17	4	46	3	75	3
18	4	47	3	76	3
19	4	48	3	77	3
20	4	49	3	78	3
21	4	50	3	79	3
22	4	51	3	80	3
23	4	52	3	81	3
24	4	53	3	82	3
25	3	54	3	83	3
26	4	55	3	84	3
27	3	56	3	85	3
28	3	57	3	86	3
29	3	58	3	87	3
				88	3
Camden background data file alone – 3 exceedances					

8.5.6 Peak Incremental Annual Average GLCs at any Off-Site Receptor

Identification of peak incremental annual average GLCs of PM_{2.5} occurring at any off-site receptor is not required in the “Approved Methods” guidelines by NSW EPA (i.e. including receptors that are not potentially sensitive to PM₁₀ as defined in the “Approved Methods” guidelines), but was requested for the health-risk assessment for the Project being carried out by SLR Consulting.

The maximum incremental annual average concentrations occurring off-site (i.e. at or beyond the orange boundary on Figures A11d, A11f, A11l, and A11m in Appendix 11) are listed in Table 77. The location of these maximum concentrations was just outside a small section of the western boundary of the site and not in an area of habitation.

Table 77: Maximum incremental concentrations of PM_{2.5} occurring off-site

Source group	Maximum off-site incremental concentration of PM _{2.5} (µg/m ³)
Kiln stack only	0.12
All point sources	0.6
Point sources plus fugitive sources	3
Point sources plus fugitive sources plus Kiln 6 emission rate increased by 50%	3

8.5.7 Summary

Annual average

Cumulative annual average concentrations of PM_{2.5} from both fugitive and point sources at the Works, including background concentrations, are below the Approved Methods assessment criteria of 8 µg/m³ at each of the discrete receptors even with the conservative assumption that the Works operates continuously for 365 days per year.

Therefore it is concluded that adverse air quality impacts will not arise from annual average PM_{2.5} concentrations due to the Project.

24-Hour average

No additional exceedances of the NSW EPA criteria arise from the cumulative assessment of PM_{2.5} emissions from the site combined with contemporaneous background data. (In making this conclusion, exceedances of the criteria occurring on 19 October 2013 when the background concentration was only 0.3 µg/m³ below the NSW EPA criteria have been discounted.)

Therefore it is concluded that adverse air quality impacts will not arise from 24-hour average PM_{2.5} concentrations due to the Project.

As concluded for PM₁₀, the model results are insensitive to large changes in Kiln 6 stack PM_{2.5} emission rates and thus there will be no effective change to off-site local air quality impacts of PM_{2.5} due to the Project.

8.6 NMHC

8.6.1 1-Hour Average GLCs

All NMHC model results discussed in this section assume a constant NMHC emission concentration of 40 ppm which is the proposed 24-hour average maximum emission concentration to be included in the EPL for the burning of NSF.

As explained in Section 4.8.1, this 24-hour average emission concentration was converted into a very conservative equivalent 1-hour NMHC concentration for use in the dispersion model that accounts for peak 1-hour concentrations that could occur within the 24-hour period. The model was run using that peak 1-hour concentration as the constant emission rate for 365 days per year, 24 hours per day.

For a Level 2 impact assessment of NMHCs, NSW EPA requires identification of maximum incremental concentrations occurring anywhere outside the plant boundary, expressed as a 1-hour average and at the 99.9th percentile of dispersion model predictions. Figure A12a in Appendix 12 shows the incremental model results for 99.9th percentile, incremental 1-hour average ground level NMHC concentrations. The highest 99.9th percentile GLC occurring beyond the site boundary is 21 µg/m³.

The 99.9th percentile incremental 1-hour GLCs of individual NMHCs using the assumed mass percentage breakdown from Table 43 and based on a maximum total NMHC concentration of 21 µg/m³ are provided in Table 78. The air quality criteria shown in the table are either the criteria in the “Approved Methods” guidelines specified by NSW EPA if available, or the Texas ESLs (see Section 7.6.3) if no threshold criteria is defined in the “Approved Methods” guidelines.

The applicable assessment criteria are not exceeded for any of the individual NMHC species.

Table 78: Incremental individual NMHC species GLCs, 99.9th percentile maximum concentration predicted outside Works boundary.

Individual NMHC species*	Mass percentage assumed in total NMHC	Incremental GLC calculated pro-rata from total GLC of 21 µg/m ³	Applicable assessment criteria [^]
acetone	3.7%	0.78	22000
benzene	31.4%	6.6	29
benzoic acid	35.3%	7.4	50
carbon disulfide	1.1%	0.23	30
chloromethane	3.7%	0.78	1900
formaldehyde	4.5%	0.95	20
methylene chloride	4.9%	1.0	3200
toluene	2.0%	0.42	3500
xylenes	1.3%	0.27	350

* Naphthalene, phenanthrene and acenaphthylene in Table 43 are included in the analysis of PAHs rather than as NMHCs and therefore are not included in this table.

[^] NSW EPA criteria or ESL as per Table 43

For the majority of the individual NMHCs, the predicted incremental GLCs are at least two orders of magnitude less than the applicable air quality criteria. These individual NMHCs include acetone, carbon disulphide, chloromethane, formaldehyde, methylene chloride, toluene, and xylene. For benzene and benzoic acid, the incremental GLCs are 23% and 15% of the assessment criteria respectively.

In Section 4.8.1, it was noted that the mass emission rate of NMHC developed for the dispersion model using the approach of multiplying the specified emission limit concentration by a peak-to-mean ratio (which yielded an emission rate of 17.6 g/s), was equivalent to the 97.5th emission rate measured in the continuous monitoring programme. An alternative and conservative method of selecting a mass emission rate for the model would be to simply use the maximum measured emission rate of 25 g/s. The predicted incremental GLCs for this higher emission rate can be adjusted in proportion with the change in emission rate, so the resultant GLCs for benzene and benzoic acid would be 9.7 and 10.5 $\mu\text{g}/\text{m}^3$ respectively. These incremental GLCs are 33% and 21% of the assessment criteria respectively.

Therefore even with the conservative assumption of an emission rate of NMHC equal to the highest 1-hour average concentration measured over 2012 and 2013, the resultant GLCs are well below the applicable air quality criteria.

It is concluded that cumulative concentrations of all of the NMHCs considered in this assessment will be well below the NSW EPA criteria, and therefore no adverse impacts due to these emissions are anticipated.

It is also concluded that the NMHC assessment has robustly demonstrated that there is minimal risk that the EPA's 1-hour average NMHC impact assessment criteria will be exceeded at any time if the proposed 24-hour average emission concentration of 40 ppm during burning of NSF is incorporated into the EPL.

8.6.2 Annual Average GLCs

Identification of incremental annual average GLCs of NMHCs is not required in the "Approved Methods" guidelines by NSW EPA, but was requested for the health-risk assessment for the Project being carried out by SLR Consulting.

Incremental annual average GLCs were calculated by multiplying the annual average GLC for lead (see Section 8.9.1) by the ratio of the specific NMHC emission rate divided by the lead emission rate. This calculation is possible because the Kiln 6 stack is the only source of these pollutants, and therefore the model results are proportional to the emission rate.

The maximum incremental annual average concentrations of NMHCs occurring off-site (i.e. at or beyond the orange boundary on the Figures in Appendix 12) are listed in Table 79. The pattern of dispersion for each NMHC is similar to that shown in Figure A15a in Appendix 15 for annual average concentrations of lead – i.e. the maximum occurs to the east of the Works in unoccupied land between the orange and green land boundaries.

Table 79: Maximum incremental annual average concentrations of NMHCs occurring off-site

Contaminant	Max incremental annual average ($\mu\text{g}/\text{m}^3$)
acetone	0.017908
benzene	0.151976
benzoic acid	0.170852
carbon disulfide	0.005324
chloromethane	0.017908
formaldehyde	0.02178
methylene chloride	0.023716
toluene	0.00968
xylenes	0.006292

8.7 Dioxins

Figure A13a in Appendix 13 shows the incremental model results for 99.9th percentile, incremental 1-hour average ground level dioxin concentrations; for a constant emission concentration at the maximum proposed EPL limit of 0.1 ng/Nm³ during burning of NSF.

The concentration contours are shown in nanograms per cubic metre, and the predicted GLCs are extremely small with the highest GLC beyond the site boundary being 0.000024 ng/m³ (24 fg/m³). This concentration is 83,000 times less than the NSW EPA criteria of 2 ng/m³, and therefore it is concluded that air quality impacts due to dioxin emissions at the proposed limits are negligible.

To put this very small predicted concentration in context, background dioxin concentrations were considered in Section 7.7.5.1. Relevant background concentrations in the order of 3-20 fg/m³ were measured over a 12-day averaging period. The peak 1-hour background concentration within these 12-day periods would have been quite a bit higher. Therefore incremental dioxin GLCs from the Works are likely to be lower than the local background concentrations by some margin.

8.8 PAHs

Figure A14a in Appendix 14 shows the incremental model results for 99.9th percentile, incremental 1-hour average ground level PAH concentrations for an assumed constant emission concentration of 68 ng/Nm³ which is ten times higher than the maximum concentration measured over 2011-2014.

The predicted GLCs are extremely small with the highest GLC beyond the site boundary being 0.000017 $\mu\text{g}/\text{m}^3$. This is only 0.004% of the NSW EPA air quality criteria of 0.4 $\mu\text{g}/\text{m}^3$.

To put this very small predicted concentration in context, background PAH concentrations were considered in Section 7.7.5.3. A maximum winter time 24-hour average PAH (as BaP-TEQ) concentration of $0.004 \mu\text{g}/\text{m}^3$ was identified. Even though this 24-hour background concentration is less than the corresponding 1-hour background concentration would be, the background concentration is still 235 times higher than the predicted incremental 99.9th percentile GLC.

Therefore it is concluded that air quality impacts due to PAH emissions at the proposed limits are negligible.

8.9 Heavy Metals

8.9.1 Lead

Lead emissions are assessed separately from other heavy metals due to the requirement for lead to be assessed as an annual averaging period. NSW EPA requires 100th percentile lead GLCs to be assessed at the nearest existing or likely future off-site sensitive receptor, and background concentrations must be included. A mean 24-hour background concentration for lead of $29.9 \text{ ng}/\text{m}^3$ ($0.0299 \mu\text{g}/\text{m}^3$) was identified in the NSW sampling campaign discussed in Section 7.7.5.4. The equivalent annual average background concentration is expected to be lower than this value, however for the purpose of this assessment this concentration of $0.0299 \mu\text{g}/\text{m}^3$ has been adopted as representing the background annual average as well.

Figure A15a in Appendix 15 shows the incremental annual average GLCs for lead for an assumed constant emission concentration of $0.06 \text{ mg}/\text{Nm}^3$ which is ten times higher than the maximum concentration measured over 2011-2014.

The highest incremental annual average GLCs occurring anywhere beyond the site boundary is $0.00033 \mu\text{g}/\text{m}^3$. This occurs in the industrial-zoned area to the east of the Works, and does not occur near one of the discrete receptors 1-87.

The maximum cumulative lead concentration of $0.030 \mu\text{g}/\text{m}^3$ (sum of maximum background plus maximum GLC) is only 6% of the NSW EPA criteria of $0.5 \mu\text{g}/\text{m}^3$. Therefore adverse impacts from discharges of lead from the Works are anticipated to be negligible.

8.9.2 1-Hour Average GLCs for Other Heavy Metals

Other heavy metals were also modelled at an emission rate equal to ten times the maximum concentration measured over 2011-2014. For cadmium and thallium, for which the cumulative emission limit in the EPL is $0.05 \text{ mg}/\text{Nm}^3$, each metal was assumed to have a constant maximum emission concentration of $0.025 \text{ mg}/\text{Nm}^3$.

These heavy metals were assessed as incremental 99.9th percentile 1-hour average concentrations at or beyond the site boundary in accordance with the "Approved Methods" guidelines Chapter 7.2.2. The maximum GLC for each of the heavy metals was calculated by adjusting the GLCs in proportion with emission rate relative to the maximum GLC for a unitary emission rate of $1 \text{ g}/\text{s}$. The resulting GLCs are provided in Table 80 along with the corresponding air quality assessment criteria.

The table shows that the heavy metal with a GLC closest to its applicable air quality assessment criteria is cadmium, with the GLC being 34% of the assessment criteria. This GLC was calculated with an assumed cadmium emission rate of 0.005 g/s. In reality, this is a conservative emission rate, as measured cadmium emission rates in 2013 and 2014 were 0.00078 and 0.0014 g/s respectively, and were below the method detection limit in 2011 and 2012 (i.e. below 0.00009 g/s in 2011, and below 0.00017 g/s in 2012) (refer Table 20 for measured data, noting that emission rates in that table are provided in kg/hr).

As the predicted maximum GLCs are well below the NSW EPA assessment criteria, it is concluded that adverse impacts due to discharges of heavy metals from the Kiln 6 stack will be negligible. This conclusion is supported by the measured heavy metals data at the Berrima AQMS reported in Section 6.4.3.

Table 80: Heavy metal GLCs and comparison to assessment criteria

Heavy metal	Highest 99.9 th percentile incremental GLC beyond site boundary, $\mu\text{g}/\text{m}^3$	Air quality assessment criteria, $\mu\text{g}/\text{m}^3$	Ratio of GLC to assessment criteria
Arsenic	0.0015	0.09	0.016
Beryllium	0.0015	0.02	0.073
Cadmium	0.0061	0.018	0.34
Cobalt	0.0036	0.2	0.018
Chromium	0.010	9	0.0011
Copper	0.031	18	0.0017
Mercury	0.012	1.8	0.0067
Manganese	0.17	18	0.010
Nickel	0.019	0.18	0.10
Antimony	0.036	9	0.0040
Selenium	0.0070	2	0.0035
Thallium	0.0061	1	0.0061
Vanadium	0.0058	0.5	0.012
Tin	0.015	20	0.00073
Hexavalent chromium	0.0061	0.09	0.067

8.9.3 Annual Average GLCs for Other Heavy Metals

Identification of incremental annual average GLCs of heavy metals other than lead is not required in the "Approved Methods" guidelines by NSW EPA, but was requested for the health-risk assessment for the Project being carried out by SLR Consulting.

Incremental annual average GLCs were calculated by multiplying the annual average GLC for lead by the ratio of the specific heavy metal emission rate divided by the lead emission rate. This calculation is possible because the Kiln 6 stack is the only source of these pollutants, and therefore the model results are proportional to the emission rate.

The maximum incremental annual average concentrations of heavy metals occurring off-site (i.e. at or beyond the orange boundary on the Figures in Appendix 12) are listed in Table 81. The pattern of dispersion for each heavy metal is similar to that shown in Figure A15a for annual average concentrations of lead – i.e. the maximum occurs to the east of the Works in unoccupied land between the orange and green land boundaries.

Table 81: Maximum incremental annual average concentrations of heavy metals occurring off-site

Contaminant	Max incremental annual average ($\mu\text{g}/\text{m}^3$)	Contaminant	Max incremental annual average ($\mu\text{g}/\text{m}^3$)
Arsenic	0.000033	Nickel	0.000429
Beryllium	0.000033	Lead	0.00033
Cadmium	0.0001375	Antimony	0.000825
Cobalt	0.0000825	Selenium	0.0001595
Chromium	0.00022	Thallium	0.0001375
Copper	0.000715	Vanadium	0.000132
Mercury	0.000275	Tin	0.00033
Manganese	0.003905	Hexavalent chromium	0.0001375

8.10 Halides and Other

Chlorine, hydrogen chloride and sulfuric acid mist/sulfur trioxide GLCs were assessed as incremental 99.9th percentile 1-hour average concentrations at or beyond the site boundary in accordance with the “Approved Methods” guidelines Chapter 7.2.2. For each of these species, the emission concentration used in the model was the maximum specified in the current EPL for burning of NSF – i.e. 200, 10, and 100 mg/Nm^3 for chlorine, hydrogen chloride and sulfuric acid mist/sulfur trioxide respectively.

The maximum GLC for each of these species was calculated by adjusting the GLCs in proportion with emission rate relative to the maximum GLC for a unitary emission rate of 1 g/s. The resulting GLCs are provided in Table 82 along with the corresponding air quality assessment criteria.

The GLC for emissions of sulfuric acid mist/sulfur trioxide exceeds the NSW EPA assessment criteria for sulfuric acid. This GLC was derived from an assumed discharge at the emission concentration limit specified in the EPL, which is 100 mg/Nm^3 (at 10% O_2) yielding a mass emission rate of 20 g/s. In reality, emissions of sulfuric acid mist/sulfur trioxide are much lower than this. Measured concentrations from the annual testing campaigns were provided in Table 22. From the four years of annual testing, sulfuric acid mist/sulfur trioxide has only been detected on one occasion, with an emission concentration of 1.5 mg/Nm^3 (at 10% O_2) and a mass emission rate of 0.23 g/s. If that emission rate was applied to the dispersion model, the maximum GLC beyond the site boundary would be 0.28 $\mu\text{g}/\text{m}^3$ which is 1.5% of the NSW EPA assessment criteria. The reason for the low acidic emissions is the nature of the cement kiln which acts as a large alkaline scrubber neutralising acid gases.

The GLC for emissions of chlorine at the EPL limit of 200 mg/Nm³ (at 10% O₂) is close to exceeding the NSW EPA assessment criteria. In reality, emissions of chlorine are much lower than this. Measured concentrations from the annual testing campaigns were provided in Table 22. From the four years of annual testing, chlorine has only been detected on two occasions, with a maximum emission concentration of 0.32 mg/Nm³ (at 10% O₂) and a mass emission rate of 0.18 g/s (compared to 40 g/s used in the model). If that emission rate was applied to the dispersion model, the maximum GLC beyond the site boundary would be 0.22 µg/m³ which is 0.4% of the NSW EPA assessment criteria. Chlorine is a carefully controlled operational parameter in the feed as it impacts clinker quality and marked increases in emission concentrations for this element are unlikely.

The GLC for hydrogen chloride is small compared to the NSW EPA assessment criteria. However the emission rate that this GLC is derived from is also large compared with measured results. Measured concentrations from the annual testing campaigns were provided in Table 22. From the four years of annual testing, hydrogen chloride was detected on all but one occasion, with a maximum emission concentration of 0.25 mg/Nm³ (at 10% O₂) and a mass emission rate of 0.12 g/s. If that emission rate was applied to the dispersion model, the maximum GLC beyond the site boundary would be 0.15 µg/m³ which is 0.1% of the NSW EPA assessment criteria.

Table 82: Halide and other chemical species GLCs, and comparison to assessment criteria

Chemical species	Highest 99.9 th percentile incremental GLC beyond site boundary, µg/m ³	Air quality assessment criteria, µg/m ³	Ratio of GLC to assessment criteria
Sulfuric acid mist and/or sulfur trioxide	24.2*	18	1.34*
Chlorine	48.4 [^]	50	0.97 [^]
Hydrogen chloride	2.4 ^{&}	140	0.017 ^{&}

* Assumes a mass emission rate which is almost 100 times higher than actual measured emission rates

[^] Assumes a mass emission rate which is over 200 times higher than actual measured emission rates

[&] Assumes a mass emission rate which is 83 times higher than actual measured emission rates

Hydrogen fluoride emissions were assessed separately due to the requirement for hydrogen fluoride to be assessed as a number of different averaging periods. NSW EPA requires 100th percentile hydrogen fluoride GLCs to be assessed at the nearest existing or likely future off-site sensitive receptor for averaging periods of 24 hours, 7 days, 30 days and 90 days. Background concentrations must be included, however in this case background concentrations are assumed to be zero.

Figure A16a in Appendix 16 shows incremental 24-hour average GLCs for hydrogen fluoride, for a constant emission concentration at the maximum proposed EPL limit of 1 mg/Nm³ during burning of NSF. The highest GLC occurring beyond the site boundary is 0.11 µg/m³. This concentration is much less than the NSW EPA assessment criteria for the 24-hour averaging period, and also less than the assessment criteria for all the other longer term averaging periods (noting that GLCs will decrease as the averaging period increases). Therefore, GLCs for averaging periods of 7 days, 30 days and 90 days have not been calculated.

8.11 Odour

The maximum incremental 1-hour average odour concentrations expressed as the 99th percentile at each of the discrete receptors 1-87 are listed in Table 83.

The spatial distribution of these predicted odour concentrations is shown in Figure 49.

The predicted odour concentrations are much less than the applicable NSW EPA threshold criteria (7.6.4) which are 1.3 OU for the New Berrima and Berrima residential areas and 2.6 OU for other areas:

Type of receptor	NSW EPA Criteria	Highest 99th percentile predicted concentration	Discrete receptor where this concentration occurs
New Berrima and Berrima residential area	1.3 OU	0.143	22
Other areas	2.6 OU	0.147	77

For both types of receptor, there is a large buffer of almost a factor of 10 between the highest 99th percentile predicted concentration and the NSW EPA Criteria. It is concluded therefore that:

1. The potential for odour emissions to carry beyond the site boundary at concentrations that could cause nuisance is very low. Nuisance impacts due to odour are therefore not expected to occur.
2. Although the odour emission rate used in the modelling assessment was calculated from a preliminary estimate of building air concentrations and potential air flow rates in the absence of actual emission data, the large buffer between predicted concentrations and NSW EPA Criteria allows for a large margin of safety in the event that odour emission rates have been underestimate.

The conclusions are supported by a comment provided to Boral Cement by Michael Jones, Technical Manager SA & NSW for Adelaide Brighton Cement on their experience with using waste-derived fuels. Adelaide Brighton Cement uses Processed Engineered Fuel (PEF) provided by ResourceCo (a joint venture of Adelaide Brighton Cement with Veolia) as a partial replacement of fossil fuels in their kiln in Adelaide¹⁷:

"We have been using very significant volumes of a PEF at our Birkenhead site for more than 10 years. The receipt and storage facility for this material is located on Victoria Road, which is the main access route for our plant and the local area. The residential area commences on the other side of this road so we are extremely close to the local community. We encourage feedback from the residents in this area through our environmental hotline and our ongoing community liaison group, and we have never had a complaint or comment about odour from the PEF. In actual fact the community has been supportive of the use of this material, as they see the environmental benefits of using a high biomass content fuel which would otherwise have been landfilled. As an added precaution, through our supplier we are careful to avoid the use of putrescible waste in the fuel and, as a result, the fuel does not generate unpleasant odour."

¹⁷ Email from Michael Jones (Adelaide Brighton Cement) to Aleksandra Wnorowski (Boral Cement) on 23/3/15.

Table 83: 1-hour average 99th percentile incremental ground level concentrations of odour at potentially sensitive discrete receptors.

Receptor no.	Odour concentration OU	Receptor no.	Odour concentration OU	Receptor no.	Odour concentration OU
1	0.014	30	0.019	59	0.028
2	0.016	31	0.017	60	0.026
3	0.017	32	0.027	61	0.020
4	0.020	33	0.034	62	0.033
5	0.024	34	0.060	63	0.034
6	0.021	35	0.027	64	0.029
7	0.025	36	0.021	65	0.017
8	0.036	37	0.036	66	0.008
9	0.034	38	0.032	67	0.010
10	0.035	39	0.025	68	0.011
11	0.047	40	0.020	69	0.014
12	0.037	41	0.028	70	0.014
13	0.052	42	0.018	71	0.008
14	0.063	43	0.016	72	0.028
15	0.038	44	0.013	73	0.058
16	0.033	45	0.012	74	0.050
17	0.027	46	0.011	75	0.098
18	0.018	47	0.012	76	0.040
19	0.020	48	0.034	77	0.147
20	0.046	49	0.036	78	0.113
21	0.116	50	0.018	79	0.022
22	0.143	51	0.019	80	0.102
23	0.084	52	0.015	81	0.016
24	0.056	53	0.035	82	0.010
25	0.054	54	0.018	83	0.015
26	0.072	55	0.067	84	0.020
27	0.069	56	0.063	85	0.018
28	0.059	57	0.138	86	0.015
29	0.044	58	0.026	87	0.015

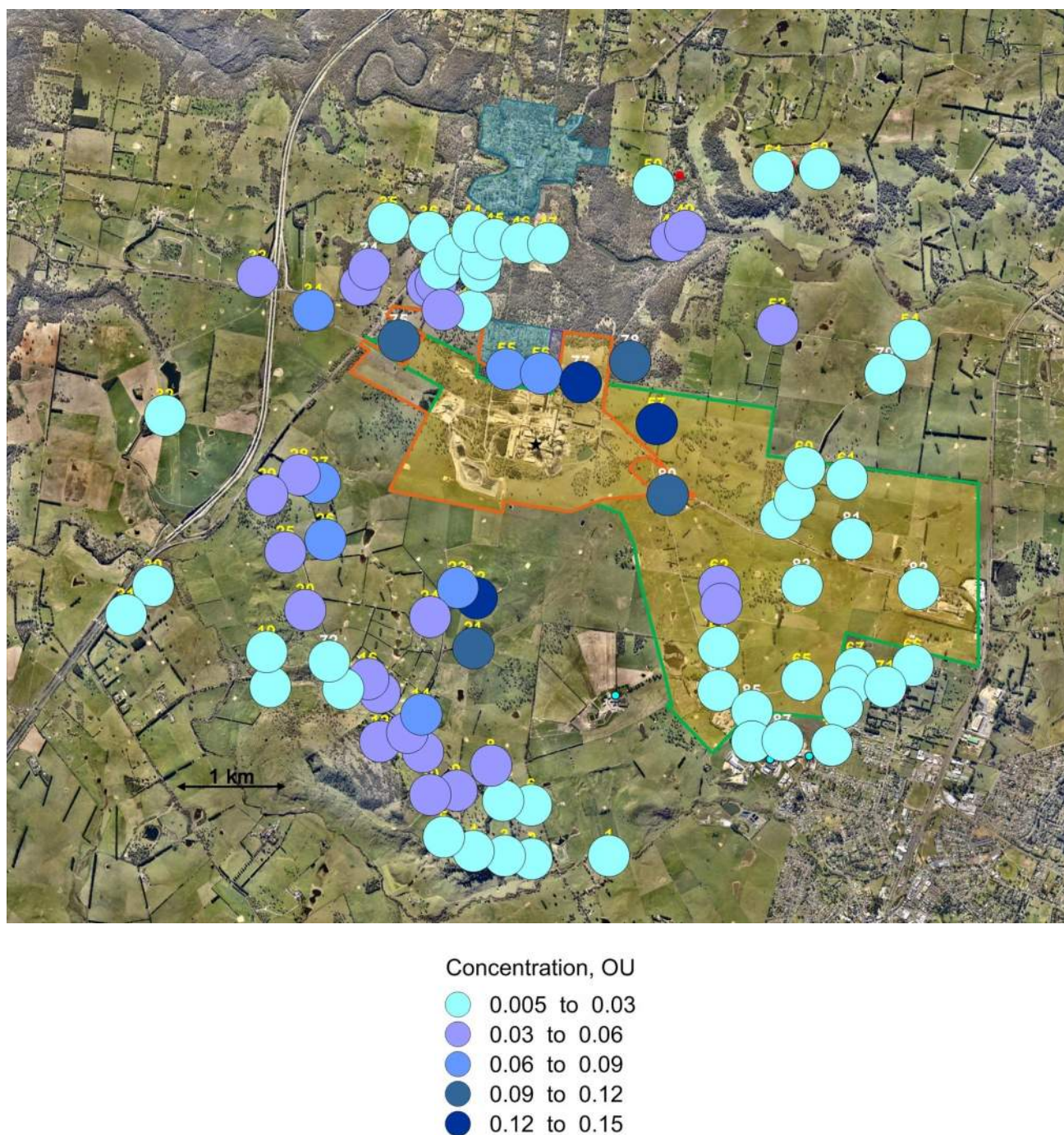


Figure 49: Spatial distribution of 99th percentile odour concentrations at discrete receptors.

9 Conclusion

This report provides an assessment of air quality impacts due to emissions of various pollutants to air from stack sources and fugitive dust and odour sources at the Berrima cement plant.

Due to the introduction of the Energy from Waste Policy in NSW in 2013, Boral Cement has proposed the following variations to maximum emission concentrations in the EPL for the burning of non standard fuels (NSF) to align the licence limits with current NSW regulations (all concentrations expressed as dry, standard temperature and pressure, and 10% O₂):

- TSP: 50 mg/Nm³, calculated over a midday-to-midday 24-hour basis
- NO_x: 1000 mg/Nm³, calculated over a midday-to-midday 24-hour basis
- VOC (as NMHC): 40 ppm, calculated over a midday-to-midday 24-hour basis

No changes are proposed to other emission limits in the EPL for NSF.

To demonstrate that the Works will meet the environmental outcomes adopted by the EPA as a result of discharges at these proposed emission limits during burning of NSF, dispersion modelling has been carried out to predict ambient concentrations of TSP, PM₁₀, PM_{2.5}, NO₂, SO₂, NMHC, dioxins, PAHs, heavy metals, halides, and sulfuric acid mist in the region around the Works site. Fugitive dust emissions from raw material stockpiling and handling were also modelled for TSP, PM₁₀ and PM_{2.5} emissions, as well as potential odour emissions from a proposed new storage building for solid waste derived fuel.

Model results were extracted for discrete receptor points in the environment around the Works site, representing the locations of residential dwellings, residential zones, and non-residential buildings.

The predicted concentrations were combined with background data and compared to assessment criteria specified by NSW Environment Protection Authority (EPA) in the 2005 Guideline publication "Approved Methods for the Modelling and Assessment of Air Pollutants in NSW". For some of the NMHC individual chemical species, no assessment criteria are specified by NSW EPA, so applicable assessment criteria were adopted from the United States.

The modelling found that with the exception of 24-hour average PM₁₀, for all pollutants the maximum applicable ground level concentrations were lower than the relevant ambient air assessment threshold limits, and therefore no adverse impacts are expected.

It was concluded that the NO_x and NMHC assessments robustly demonstrated that there is minimal risk that the EPA's 1-hour average NO₂ and NMHC impact assessment criteria will be exceeded at any time if the proposed 24-hour average emission concentrations for NO_x and NMHC during burning of NSF are incorporated into the EPL.

In regards to 24-hour average PM₁₀, for most of the discrete receptors, no additional exceedances of the 24-hour average PM₁₀ air quality criteria over and above current impacts are caused by the presence of the Works compared to the Works not being there at all. However a small number of discrete receptors near the site boundary do show some possible additional exceedances of the 24-hour PM₁₀ criteria compared with background levels, although this is dependent entirely on the magnitude of the fugitive dust concentrations. Those fugitive dust concentrations are considered to be over-estimates of actual maximum incremental GLCs at receptors close to the site boundary because of the assumptions required for the

fugitive dust dispersion analysis. The real-life long-term PM₁₀ measured data from the local ambient air quality monitoring station indicates that PM₁₀ levels at that location stay consistently below the NSW 24-hr and annual limits.

It was concluded that there would be no effective change to off-site local air quality impacts of PM₁₀ due to the Project as the model results are insensitive to Kiln 6 stack PM₁₀ emission rates at the equivalent TSP emission concentrations proposed during the burning of NSF.

10 References

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29 April 2016

Rod Wallace
Boral Property Group
Clunies Ross Street
Prospect NSW 2148

Dear Rod,

RE: Comments on enRiskS review letter dated 11 February 2016

Thank you for the opportunity to respond to comments made by Environmental Risk Sciences Pty Ltd (enRiskS) in relation to the Air Quality Impact Assessment (AQIA) carried out for the Boral Cement Berrima Works Use of Solid Waste Derived Fuels in Kiln 6 project.

I have not provided any comments on bullet points 4 and 6 in the enRiskS review letter, as I have discussed these with Craig Simpson and understand that these relate to the health risk assessment methodology rather than the AQIA.

With the exception of the first bullet point in the enRiskS review letter, regarding particulate matter which has been discussed separately with you, I respond to the remaining items raised in the enRiskS letter of 11 February 2016 in the following paragraphs.

1. Determination of annual average concentration of VOCs

In bullet point 2, enRiskS raises the following issue:

- **Air Toxics** – the determination of the annual average ground level concentration nor the actual value used in assessing the potential risks posed by the VOCs in the emissions is not provided in either the AQIA or the revised HHRA. Consequently, it is not possible to verify the values listed in Table 24. Working backwards from the listed benzene GLC, the annual average for total VOCs would have to be $0.48 \mu\text{g}/\text{m}^3$. This seems extraordinarily low. Further advice should be sought from the people reviewing the AQIA.

The calculation of incremental annual average concentrations of VOCs is discussed in Section 8.6.2 of the January 2016 version of the AQIA Report.



2. Determination of annual average concentration of VOCs

In bullet points 3 and 5, enRiskS raises queries relating to the determination of emission rates of VOC components in the stack discharge from Kiln 6. This refers to Section 7.6.3 and Table 43 of the AQIA Report. The following responses are noted:

- Some of the volatile chemicals listed in the AP42 document were not included in our assessment if they contributed a very small percentage of the total VOCs – nominally less than 1%. A full list of the calculations is provided in Attachment 1 to this letter. The excluded VOCs comprised a total of 4.7% of the summed emission factors, and are listed in Table 43 of the AQIA report under the category “others”.
- The chemical species naphthalene, phenanthrene and acenaphthylene were excluded from Table 43 of the AQIA because measured data for these species was available from the PAH emissions measured at the Works. It is always preferable to use measured emission rates if possible rather than AP42 approximations. Therefore, those species were assessed as components of total PAHs rather than as NMHCs. This is noted in the text explanation in Section 7.6.3. However, for the health risk assessment incremental annual average concentrations of these three chemical species have been requested. Emission rates for each of these three species were determined using the same method applied in the AQIA for PAHs: i.e. taking the average measured concentration from the annual testing reports for 2011, 2012, 2013 and 2014, multiplying this by a factor of ten for conservatism, and then converting this concentration to a mass emission rate by multiplying by the assumed gas flow rate of 200 Nm³/s (with all concentrations and flows standardised to 10% oxygen). Incremental annual average concentrations for these three chemical species were then calculated proportionally compared to the lead emission rates – as described in Section 8.6.2 of the January 2016 version of the AQIA Report for VOCs. The resultant emission rates and concentrations are as follows:

Contaminant	Assumed emission concentration for dispersion model, mg/Nm ³ (10% O ₂)*	Calculated emission rate (g/s) with gas flow rate of 200 Nm ³ /s (10% O ₂)	Maximum incremental annual average (µg/m ³) at any location beyond site boundary
naphthalene	2.445	0.489	0.013448
acenaphthalene	0.09375	0.01875	0.000516
phenanthrene	0.06875	0.01375	0.000378

* equals 10x average measured emission rate, as determined from annual test data 2011-2014

- To convert the emission factors from kg/tonne of clinker to ambient concentrations, the simple assumption was made that the mass proportions of VOCs listed in Table 43 corresponded to mass proportions of total VOCs measured in the discharge from the Kiln 6 stack. There are no undisclosed calculation steps in this process. For example, in the AP42 document, the emission factor for acetone is 3.7% of the total organic compounds emission factor, so was assumed to comprise 3.7% of the total dispersed ground level concentrations of VOCs.
- Air emissions from the kiln are split between electrostatic precipitator (ESP) and bagfilter control equipment. This is noted in the AQIA report, in Table 3. Boral advises that 60% of the kiln air flow passes through the ESP, and the remaining 40% passes through the bagfilter.
 - The only volatile chemicals in the AP42 document that have separate emission factors listed for ESP and bagfilter are benzene and naphthalene. If these emission factors are replaced in the calculation of percentage contributions from each VOC, the weighting of benzene increases from 31% to 65% (see Attachment 2).
 - However the average weighting of benzene for the total stack flow, attributing 40% to the bagfilter and 60% to the ESP, is $(0.4 \times 65\% + 0.6 \times 31\%) = 45\%$.
 - It is noted that benzoic acid, which has a similar emission factor to benzene for the ESP, does not have an emission factor listed separately for the bagfilter. If it is assumed that benzoic acid also increases by the same percentage with bagfilter treatment technology, then the average weighting of benzene would stay about the same as assumed in the AQIA.
 - Finally, it is noted that the emission factor data for benzene in the AP42 document are based on only two test results – sampling at one cement works in Maryland, USA in 1991 for the ESP data, and sampling at one cement works in California in 1990 for the bagfilter data (references 64 and 62 respectively in the AP42 document). No other data about the Kiln age and design (such as use of preheaters or precalciners), operating variables, and fuel and raw material quality is available. It is considered likely that the difference in emission factors for benzene between the ESP and bagfilter options is more of a function of the Kiln design and operation itself than the choice of pollution treatment equipment.
 - However, no other benzene emission data is available. Taking therefore the benzene emission factors listed in the AP42 document, and following the assessment procedure used in the AQIA:
 - For a single emission source, the groundlevel concentration is proportional to the emission rate. Therefore if an emission rate is doubled, the groundlevel concentration is also doubled.

- If the benzene emission weighting increases to 45%, which is effectively an increase in benzene emission rate of also 45% $[(45-31)/31]$, then each of the predicted groundlevel concentrations of benzene will also increase by 45%.
- The adjusted predicted groundlevel concentration for benzene is $9.6 \mu\text{g}/\text{m}^3$ for a 1-hour averaging period (compared with $6.6 \mu\text{g}/\text{m}^3$ in Table 78 of the AQIA report). This does not lead to any changes in conclusions about the significance of benzene air quality impacts based on comparison of the predicted groundlevel concentration with the NSW EPA assessment criteria of $29 \mu\text{g}/\text{m}^3$.
- The incremental annual average for benzene detailed in the AQIA report, Table 79, was $0.151976 \mu\text{g}/\text{m}^3$. A 45% increase in this concentration leads to an updated annual average concentration estimate of $0.220 \mu\text{g}/\text{m}^3$.

3. Dioxin calculations

In bullet point 7, enRiskS requests confirmation of the dioxin concentration units. The following responses are noted:

- Dioxin/furan emission concentrations used in the AQIA were based on annual test measurements carried out in 2011-2014, as summarised in Table 23 of the AQIA report. The annual test results ranged from 0.00018 to $0.0012 \text{ ng}/\text{Nm}^3$ (corrected to 10% O_2) with an average of $0.00069 \text{ ng}/\text{Nm}^3$ (corrected to 10% O_2). These concentrations were reported as I-TEQ, being the sum of all dioxin and furan congeners, including half of method detection limit values for compounds that were less than detection levels.
- The test results are quite a lot lower than the emission limit of $0.1 \text{ ng I-TEQ}/\text{Nm}^3$ (@10% O_2) specified in the UNEP Toolkit (2005) (refer Section 3.3.3 of AQIA report). However, Air Quality Professionals is not aware of any reason to doubt the validity of the test measurements conducted by ECS Stack Pty Ltd. Attention is also drawn to the test results reported in Section 4.7 of the AQIA, which discusses test results from a trial burning of non-standard fuels in 2005. Those test results and the discussion provided in that section support the magnitude of dioxin concentrations measured under normal operating conditions.
- Despite the very low measured dioxin concentrations, for the purpose of the AQIA the dioxin concentration during burning of solid-waste derived fuels was assumed to be $0.1 \text{ ng}/\text{Nm}^3$. This is $0.1 \times 10^{-9} \text{ g}/\text{Nm}^3$, or $0.1 \times 10^{-6} \text{ mg}/\text{Nm}^3$ ($0.000001 \text{ mg}/\text{Nm}^3$) as listed in Table 32 of the AQIA.
- The Kiln 6 stack provides excellent dilution and dispersion of stack gases prior to the gases reaching ground level outside the Works boundary. The highest incremental 1-hour average ground level concentrations of dioxins determined by the dispersion model were $0.000024 \text{ ng}/\text{m}^3$. This is a dilution factor of about 4100 compared to the concentration in the stack discharge. This dilution factor is reasonable for a stack of this size, temperature and air flow rate.

- As another example to validate these calculations, cadmium concentrations in the stack discharge were assumed to be 0.025 mg/Nm^3 (10% O_2), and the highest incremental 1-hour average ground level concentration of cadmium determined by the dispersion model outside the Works boundary was $0.0061 \text{ } \mu\text{g/m}^3$ (0.0000061 mg/m^3) (refer Section 8.9.2 of AQIA report). This also represents a dilution factor of about 4100, which confirms that no unit conversion errors have occurred with the dioxin calculations.
- The magnitude of dioxin emission rates used in the dispersion model is further validated by comparison with cement kiln dioxin emission rate data published in the New Zealand Dioxin Emission Inventory¹. In that reference, at Table 17.1, measured dioxin emission factors from a cement kiln are quoted as approximately $0.2 \text{ } \mu\text{g I-TEQ per tonne}$ of clinker produced. At full production, the Berrima kiln produces about 180-205 tonnes of clinker per hour. Assuming an average clinker production rate of 190 T/h, the calculated dioxin emission rate for Berrima using the emission factor of $0.2 \text{ } \mu\text{g I-TEQ per tonne}$ is $38 \text{ } \mu\text{g/h}$, or 0.05 ng/s ($0.0000527 \text{ } \mu\text{g/s}$) at a gas flow rate of $200 \text{ Nm}^3/\text{s}$. This estimated mass emission rate of 0.05 ng/s is the same order of magnitude as the emission rate used in the dispersion modelling for Berrima, which is 0.02 ng/s . Therefore, the dioxin emission rate used in the dispersion modelling is considered to be representative for cement kiln emissions.

4. Conservatism in Emission Rate Assumptions

Comment has been requested of the conservatism built into emission rates used in the dispersion model. These are all detailed in the AQIA report, and summarised as follows:

- In order to allow for potential increases in emissions of PAHs during combustion of solid-waste derived fuels, these emissions were modelled at a conservative emission rate that is ten times higher than current average measured emission rates. This is explained in Section 4.8.2 of the AQIA report.
- To allow for potential increases in emissions of dioxins during combustion of solid-waste derived fuels, these emissions were modelled at the current EPL limit of 0.1 ng/Nm^3 , which is at least 100 times higher than actual measured emission concentrations (see Table 23, AQIA report).
- VOC emission rates were modelled at near-worst case peak 1-hour emission rates and assumed to be constant at this emission rate for a full year, 8760 hours per year.
- Hexavalent chromium emission rates were modelled at a very conservative emission concentration of 0.025 mg/Nm^3 , which is ten times higher than the current maximum measured emission concentration. Actual measured emission rates are quite variable (refer Table 21 of AQIA report), and the modelled emission rate is 25 times higher than the average measured emission rate of 0.0010 mg/Nm^3 .

¹ *New Zealand inventory of dioxin emissions to air, land and water, and reservoir sources*. Ministry for the Environment, March 2000.

Comment on emission concentrations measured during a 2003 burning trial of non-standard fuels at the Berrima Works is provided in Section 4.7 of the AQIA report. Emission concentrations of PAHs cannot be compared with current concentrations as the available data from the 2003 trial does not state whether the PAHs had been converted to BaP-TEQ. However, emission concentrations of VOCs and dioxins measured during those trials did not exceed the current EPL limits specified for combustion of non-standard fuels. This provides reassurance that the emission concentrations adopted for the AQIA are unlikely to have underestimated emission concentrations of these contaminants once solid-waste derived fuel is introduced to the kiln.

Yours faithfully,
Air Quality Professionals Pty Ltd

A handwritten signature in blue ink, reading "Tracy Freeman".

Tracy Freeman
Principal Air Quality Consultant

Attachment 1 – Calculation Spreadsheet for VOC Composition - ESP

	Type of control	Average emission factor per mass of clinker produced, kg/Mg	% of total mass emission factor
species included in AQIA			
acenaphthylene	FF	5.90E-05	1.2%
acetone	ESP	0.00019	3.7%
benzene	ESP	0.0016	31.4%
benzoic acid	ESP	0.0018	35.3%
carbon disulfide	ESP	5.50E-05	1.1%
chloromethane (methyl chloride)	ESP	0.00019	3.7%
formaldehyde	FF	0.00023	4.5%
methylene chloride	ESP	0.00025	4.9%
naphthalene	ESP	0.00011	2.2%
phenanthrene	FF	0.0002	3.9%
toluene	ESP	0.0001	2.0%
xylene	ESP	6.50E-05	1.3%
others:			
1,2,3,4,6,7,8 HpCDD	FF	1.10E-10	0.000002%
C3 benzenes	ESP	1.30E-06	0.0255%
C4 benzenes	ESP	3.00E-06	0.0589%
C6 benzenes	ESP	4.60E-07	0.0090%
benzaldehyde	ESP	1.20E-05	0.2357%
benzo(a)anthracene	FF	2.10E-08	0.0004%
benzo(a)pyrene	FF	6.50E-08	0.0013%
benzo(b)fluoranthene	FF	2.80E-07	0.0055%
benzo(g,h,i)perylene	FF	3.90E-08	0.0008%
benzo(k)fluoranthene	FF	7.70E-08	0.0015%
biphenyl	ESP	3.10E-06	0.0609%
bis(2-ethylhexyl)phthalate	ESP	4.80E-05	0.9426%
bromomethane	ESP	2.20E-05	0.4320%
chlorobenzene	ESP	8.00E-06	0.1571%
chrysene	FF	8.10E-08	0.0016%
di-n-butylphthalate	ESP	2.10E-05	0.4124%
dibenz(a,h)anthracene	FF	3.10E-07	0.0061%
ethylbenzene	ESP	9.50E-06	0.1866%
fluoranthene	FF	4.40E-06	0.0864%
fluorene	FF	9.40E-06	0.1846%
freon 113	ESP	2.50E-05	0.4910%
indeno(1,2,3-cd)pyrene	FF	4.30E-08	0.0008%
methyl ethyl ketone	ESP	1.50E-05	0.2946%
methylnaphthalene	ESP	2.10E-06	0.0412%
phenol	ESP	5.50E-05	1.0801%

pyrene	FF	2.20E-06	0.0432%
styrene	ESP	7.50E-07	0.0147%
HpCDD	FF	2.00E-10	0.000004%
total OCDD	FF	1.00E-09	0.000020%
PCDD	FF	1.40E-09	0.000027%
total PCDF	FF	1.40E-10	0.000003%
total TCDF	FF	1.40E-10	0.000003%
TOTAL kg/Mg CLINKER ALL:		5.09E-03	
TOTAL PERCENTAGE "OTHERS":			4.7%

Attachment 1 – Calculation Spreadsheet for VOC Composition - Bagfilter

	Type of control	Average emission factor per mass of clinker produced, kg/Mg	% of total mass emission factor
species included in AQIA			
acenaphthylene	FF	5.90E-05	0.5%
acetone	ESP	0.00019	1.5%
benzene	ESP	0.0016	65.4%
benzoic acid	ESP	0.0018	14.7%
carbon disulfide	ESP	5.50E-05	0.5%
chloromethane (methyl chloride)	ESP	0.00019	1.6%
formaldehyde	FF	0.00023	1.9%
methylene chloride	ESP	0.00025	2.0%
naphthalene	ESP	0.00011	7.0%
phenanthrene	FF	0.0002	1.6%
toluene	ESP	0.0001	0.8%
xylenes	ESP	6.50E-05	0.5%
others:			
1,2,3,4,6,7,8 HpCDD	FF	1.10E-10	0.000001%
C3 benzenes	ESP	1.30E-06	0.0106%
C4 benzenes	ESP	3.00E-06	0.0245%
C6 benzenes	ESP	4.60E-07	0.0038%
benzaldehyde	ESP	1.20E-05	0.0981%
benzo(a)anthracene	FF	2.10E-08	0.0002%
benzo(a)pyrene	FF	6.50E-08	0.0005%
benzo(b)fluoranthene	FF	2.80E-07	0.0023%
benzo(g,h,i)perylene	FF	3.90E-08	0.0003%
benzo(k)fluoranthene	FF	7.70E-08	0.0006%
biphenyl	ESP	3.10E-06	0.0253%
bis(2-ethylhexyl)phthalate	ESP	4.80E-05	0.3924%
bromomethane	ESP	2.20E-05	0.1799%
chlorobenzene	ESP	8.00E-06	0.0654%
chrysene	FF	8.10E-08	0.0007%
di-n-butylphthalate	ESP	2.10E-05	0.1717%
dibenz(a,h)anthracene	FF	3.10E-07	0.0025%
ethylbenzene	ESP	9.50E-06	0.0777%
fluoranthene	FF	4.40E-06	0.0360%
fluorene	FF	9.40E-06	0.0768%
freon 113	ESP	2.50E-05	0.2044%
indeno(1,2,3-cd)pyrene	FF	4.30E-08	0.0004%
methyl ethyl ketone	ESP	1.50E-05	0.1226%
methylnaphthalene	ESP	2.10E-06	0.0172%
phenol	ESP	5.50E-05	0.4496%

pyrene	FF	2.20E-06	0.0180%
styrene	ESP	7.50E-07	0.0061%
HpCDD	FF	2.00E-10	0.000002%
total OCDD	FF	1.00E-09	0.000008%
PCDD	FF	1.40E-09	0.000011%
total PCDF	FF	1.40E-10	0.000001%
total TCDF	FF	1.40E-10	0.000001%
TOTAL kg/Mg CLINKER ALL:		1.22E-02	
TOTAL PERCENTAGE "OTHERS":			2.0%



global environmental solutions

Boral Cement Works
Use of Solid Fuel in Kiln 6
Human Health Risk Assessment - Response to Peer Review

Report Number 610.15875.00000.0020 HRA

5 May 2016

Boral Cement Limited
Greystaines House
Clunies Ross Street
Prospect NSW 2142

Version: Revision 1

Boral Cement Works

Use of Solid Fuel in Kiln 6

Human Health Risk Assessment - Response to Peer Review

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DOCUMENT CONTROL

Reference	Status	Date	Prepared	Checked	Authorised
610.15875.00000.0020 HRA	Revision 1	5 May 2016	Craig Simpson BAppSc MSc PhD	Nathan Redfern CChem COH	Nathan Redfern CChem COH
610.15875.00000.0020 HRA	Revision 0	25 January 2016	Craig Simpson BAppSc MSc PhD	Nathan Redfern CChem COH	Nathan Redfern CChem COH

Executive Summary

SLR Consulting Australia Pty Ltd (SLR) has been engaged by Boral Cement Limited (Boral) to assess the potential impacts of the proposed application to modify the development consent for Kiln 6 at Berrima Cement Works. The modification seeks to support the sustained and viable use of waste derived fuels.

This report presents the methodology and findings of the Health Risk Assessment completed for the application to modify the development consent for Kiln 6 at Berrima Cement Works, undertaken by SLR Consulting on behalf of Boral Cement.

The objective of the Human Health Risk Assessment is to contribute to the analysis of toxicity of by-products associated with the use of Solid Waste Derived Fuels (SWDF) in Kiln 6 to surrounding communities and provide an assessment of the risk to human health associated with the use of SWDF.

Risk assessments of the nature performed here do not provide definitive assessments of the acceptability of risk for specific individuals. Risk assessments should only be applied on a probabilistic basis to a population of exposed persons.

The communities chosen for the purposes of this assessment were the residents of New Berrima, Berrima, Burradoo and Moss Vale. The local communities in closest proximity to the Boral Cement live in New Berrima (approximately 0.5 km), and the furthest live in Burradoo (approximately 5 km). Outside these population areas the land is rural in nature with scattered houses generally on farmland.

Boral proposed two Solid Waste Derived Fuels (SWDF) for use in the Kiln 6 subject of this modification (modification 9).

- Wood Waste - material left over from industrial processes like milling, furniture making, and building and construction; and
- Refuse Derived Fuel (RDF) - fuel made from the combustible materials recovered and processed from waste streams, such as papers, cardboards, packaging, and construction and demolition materials

The Contaminants of Potential Concern (COPC) associated with the use of SWDF as fuels in Kiln 6 were identified as the following: Fine particulates (TSP, PM₁₀, PM_{2.5}), SO₂, NO_x, CO, VOCs, PAHs, heavy metals, hydrogen chloride, hydrogen fluoride, chlorine, sulphuric acid mist/sulphur trioxide and dioxins.

The Primary exposure pathways relating to the operations of the Berrima Cement works were determined to be via the airborne pathway and inhalation and ingestion of the COPC. This was due to the anticipated mass of airborne COPC emissions being the dominant source for both point sources (such as Kiln 6 and fugitive sources). The Secondary exposure pathway was considered to be the indirect pathway in which COPC emissions are transported off site through environmental forces such as wind and then partition into settled dusts or soils and are remobilised when the soil or dusts are disturbed, at which point human exposure may take place via inhalation, ingestion or dermal absorption.

Executive Summary

The majority of COPCs identified in the Issue Identification stage of the risk assessment were assessed as unlikely to be present at concentrations likely to impact on the health risks to receptors in the surrounding communities. This was based on comparisons of predicted COPC concentrations at or near receptor sites in communities with relevant air quality assessment criteria, such as NSW EPA criteria or health based benchmarks. This group of COPCs included fine particulates (TSP, PM₁₀, PM_{2.5}), SO₂, NO_x, CO, VOCs, PAHs, heavy metals, hydrogen chloride, hydrogen fluoride, and dioxins. The exception to this was chlorine and sulphuric acid mist/sulphur trioxide which required further assessment.

The peak GLC concentrations of chlorine of 48.4µg/m³ which exceed the acute health based criteria of 15µg/m³ and the chronic health based criteria of 0.15µg/m³. The predicted peak Ground Level Concentrations (GLC) of sulphuric acid mist / sulphur trioxide were 24.2µg/m³ which exceed the EPA Criteria of 18µg/m³. Therefore the potential for health risks, if any, to the local communities was assessed further.

The principal benchmark used in this assessment for both chlorine and airborne sulphuric acid was the lowest concentration reported to illicit a physiological response, being transient changes in pulmonary function, in the population group reported as most sensitive to these chemicals. In the case of chlorine the most susceptible sections of the populations to chlorine gas exposure include individuals with respiratory conditions such as asthma, hay fever, and chronic bronchitis, heavy smokers, and children. The lowest concentrations reported to illicit a physiological response has been 0.5ppm (761.5µg/m³) being respiratory tract irritation and transient alterations in parameters of respiratory function in susceptible individuals after 15 minutes exposure. With regards to sulphuric acid inhalation, the most susceptible sections of the populations are adolescent asthmatic children with the concentration being 70µg/m³.

In the current study, the maximum exposure concentration for chlorine was predicted to occur at receptors near the site boundary and was 48.4µg/m³. The exposure is significantly less than the lowest concentration of airborne sulphuric acid reported to illicit a response, that is 761.5µg/m³.

In the current study, the maximum exposure concentration for sulphuric acid was predicted to occur at receptors near the site boundary and was 24.2µg/m³. The exposure is less than half the lowest concentration of airborne sulphuric acid reported to illicit a response, that is 70µg/m³.

Furthermore the actual exposure concentration of the surrounding communities is likely to be less for both chlorine and sulphuric acid. This is based on two considerations, firstly the dilution of emissions as they travel away from the facility boundary to a receptor. Secondly the conservative nature of the air modelling which allowed predicted concentrations for chlorine to be possibly as much as two hundred times higher the probable concentrations and predicted concentrations for sulphuric acid to be possibly as much as ninety times higher the probable concentrations as set out in section 2.3.3.

Based on this, the Primary Exposure pathway was considered unlikely to lead to receptor exposure at concentrations likely to increase the health risk to receptors. Therefore the predicted chlorine and sulphuric acid emissions during the operation of Kiln 6 were not expected to lead to an increase health risk to the surrounding communities.

Therefore, predicted concentrations of identified COPC at or near receptor sites were unlikely to be present at concentrations likely to impact on the health risks to receptors in the surrounding communities. Accordingly, the use of SWDF as fuels in Kiln 6 under the conditions proposed by Boral are considered unlikely to increase the human health risk to surrounding communities.

Table of Contents

1	INTRODUCTION	8
1.1.1	What is Risk Assessment	9
1.1.2	Risk Assessment Approach	10
1.2	Objectives	10
1.3	Details of Local Communities	11
1.3.1	Community Demographic	11
1.3.2	Special Populations	13
1.3.3	Community Health Data	14
1.4	BERRIMA CEMENT WORKS PROCESS INFORMATION SOURCES	15
1.5	EXISTING ENVIRONMENT	15
1.5.1	Topography	15
1.5.2	Surrounding Land Use	16
1.6	EXISTING OPERATIONS	17
1.7	Existing emission control equipment	21
1.8	SCOPE OF MONITORING OF EXISTING EMISSIONS	23
1.9	BERRIMA CEMENT WORKS PROPOSED MODIFICATION	23
1.9.1	Current Approvals and Recent Modifications	23
1.9.2	Non-Standard Fuels	24
1.9.3	Outcome of trials involving non-standard fuels	25
1.9.4	Stack emission testing summary	25
1.9.5	Proposed Activities of the Project	26
1.9.6	Emission changes	29
1.9.7	Fuel storage and feeding system	31
1.10	Traffic and Access	32
1.10.1	Existing Environment	32
2	RISK ASSESSMENT	35
2.1	Issue Identification	35
2.1.1	Community Chosen for Assessment	35
2.1.2	Solid Waste Derived Fuels (SWDF)	36
2.1.3	Potential Contaminant Emission Sources at the Cement Works	37
2.1.4	Emissions from the Co-Processing of SWDF in Cement Kilns	38
2.1.5	Conceptual Site Model	38
2.1.6	Contaminants of Potential Concern (COPC)	41
2.1.7	Exposure Concepts	42
2.1.8	Fine Particulates	42
2.1.9	Sulphur Dioxide (SO ₂)	53
2.1.10	Nitrogen Oxide (NO _x)	54
2.1.11	Carbon Monoxide (CO)	55
2.1.12	Volatile Organic Compounds (VOCs)	56

Table of Contents

2.1.13	Polycyclic Aromatic Hydrocarbons (PAHs)	61
2.1.14	Heavy Metals	62
2.1.15	Hydrogen Halides & Sulphuric Acid Mist / Sulphur Trioxide	68
2.1.16	Dioxins	71
2.1.17	Summary of COPC Emissions Exceeding Regulatory or Health Based Criteria	73
2.2	Issue Identification Summary	75
2.3	Toxicity Assessment	76
2.3.1	Chlorine	76
2.3.2	Sulphuric Acid / Sulphur Trioxide	76
2.4	Exposure Assessment	77
2.4.1	Exposure Pathways and Receptors	77
2.4.2	Assessment of Exposure Concentration	78
3	RISK CHARACTERISATION	79
4	CONCLUSIONS	80
5	REFERENCES	81

TABLES

Table 1	Details of communities in proximity to Berrima Cement Works	11
Table 2	Details of special populations based on age, within communities in proximity to Berrima Cement Works	14
Table 3	NSW Community Health Summary – Indicators Relevant to Airborne Particulates	15
Table 4	Modifications to the original development approvals	24
Table 5	Approved and proposed classes and quantities of standard and waste derived fuel	27
Table 6	Emissions limits for particulate matter for burning of standard fuels	29
Table 7	Emission limits for other contaminants from No. 6 Kiln Stack for burning of standard fuels	29
Table 8	Emission limits for particulates, NO _x and VOCs from No. 6 Kiln Stack for burning of non-standard fuels	29
Table 9	Comparison of current emission limits for Particulates, NO _x and VOCs from No. 6 Kiln Stack for burning of standard fuels and non-standard fuels	30
Table 10	Proposed emission limits for burning non-standard fuel	30
Table 11	Existing and proposed operational truck traffic	34
Table 12	Traffic implications for Taylor Avenue	35
Table 13	Indicative breakdown of Solid Waste Derived Fuels waste streams	37
Table 14	Potential emission sources – point sources and controls	37
Table 15	Contaminants of Potential Concern (COPC), sources and potential exposure pathways	41
Table 16	Particulate Matter Air Quality Goals	43
Table 17	Location of potentially impacted receptors in relation to Berrima Cement Works	45
Table 18	Dust PM ₁₀ Emissions from Berrima Plant that may exceed regulatory criteria	46
Table 19	Summary of incremental risks for exposure at off site receptors from PM ₁₀ & PM _{2.5} from fugitive dusts & combined point sources,	48
Table 20	Highest predicted cumulative SO ₂ concentrations at off site receptors	53
Table 21	Highest predicted cumulative NO ₂ concentrations at offsite receptors (Air Quality Professionals, 2015)	55

Table of Contents

Table 22 Assumed breakdown of organic compounds from Portland cement kilns from USEPA (1995)	56
Table 23 Evaluation of potential acute impacts based on incremental individual NMHC species GLCs, 99.9 th percentile one hour maximum concentrations predicted outside works boundary (Air Quality Professionals, 2015)	59
Table 24 Evaluation of potential chronic impacts based on Incremental individual NMHC species GLCs, annual average concentration predicted outside works boundary (Air Quality Professionals, 2016)	60
Table 25 Summary of results of heavy metal testing at AQMS, 2011-2014. 24 hour average concentrations measured in particulate during 1 day in 6 testing programme (no samples = 243) (source <i>Air Quality Professionals, 2015</i>).	64
Table 26 Evaluation of potential acute impacts based on incremental individual metal species GLCs, 99.9 th percentile one hour maximum concentrations (including both particulate bound and volatile) predicted outside works boundary (Air Quality Professionals, 2015)	66
Table 27 Evaluation of potential chronic impacts based on incremental individual metal species annual average concentrations (including both particulate bound and volatile) predicted outside works boundary (Air Quality Professionals, 2015)	67
Table 28 Halide and other chemical species GLCs and comparison to assessment criteria (source <i>Air Quality Professionals, 2015</i>).	69
Table 29 Highest predicted incremental Cl ₂ concentrations at off site receptors	70
Table 30 Highest predicted incremental sulfuric acid concentrations at off site receptors	71
Table 31 Emissions from Berrima Cement Works that may exceed regulatory or health based criteria	74

FIGURES

Figure 1 New Berrima population by age, 2011	12
Figure 2 Berrima population by age, 2011	12
Figure 3 Moss Vale population by age, 2011	13
Figure 4 Burradoo population by age, 2011	13
Figure 5 Topographical map of region around Berrima works (Air Quality Professionals, 2015)	16
Figure 6 Surrounding land uses around Berrima works (Air Quality Professionals, 2015)	17
Figure 7 Aerial photograph of Berrima Works with locations of various activities indicated. Aerial photography from nearmap, imagery dated 22 May 2014 (source: Air Quality Professionals, 2015).	19
Figure 8 Flow chart describing current process operations	20
Figure 9 Existing emission control equipment	22
Figure 10 Conceptual Site Model - Berrima Cement Works	40

APPENDICES

Appendix A	Quantification of Risk Associated with Airborne Particulates as PM ₁₀ & PM _{2.5}
Appendix B	Uncertainties and Limitations

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1 INTRODUCTION

SLR Consulting Australia Pty Ltd (SLR) has been engaged by Boral Cement Limited (Boral) to assess the potential impacts of the proposed application to modify the development consent for Kiln 6 at Berrima Cement Works. The modification seeks to support the sustained and viable use of waste derived fuels.

The application relates to the Cement Works at New Berrima (the Works) in the Wingecarribee Local Government Area (Lot 1 DP 582277, Lot 2 DP 774598, Lot 22 DP 582276, Lot 100 DP 882139, Taylor Avenue, New Berrima). The cement works operate subject to development approval issued by the Department of Planning and Environment (DA 401-11-2002, May 2003 and DA 85-4-2005, Aug 2005). Eight subsequent modifications have also been issued by DP&E. The location of the site in relation to New Berrima is shown in Photograph 1.

Photograph 1 Aerial photograph showing site proximity to New Berrima



This report presents the methodology and findings of the Health Risk Assessment completed for the proposed application to modify the development consent for Kiln 6 at Berrima Cement Works, undertaken by SLR Consulting on behalf of Boral Cement.

The Health Risk Assessment was conducted as per the recommendations contained in *Environmental Health Risk Assessment. Guidelines for assessing human health risks from environmental hazards*. (enHealth, 2012).

1.1.1 What is Risk Assessment

Risk assessments have been defined in many ways but all share the concept of a process for estimating and characterising the potential risks associated with various agents or activities.

The National Research Council (1983) definition is:

Risk assessment is the systematic scientific characterisation of potential adverse health effects resulting from human exposures to hazardous agents or situations.

The underlying concept to risk assessment is the Conceptual Site Model (CSM) whereby risk is assessed using the concept of the links between source – pathway – receptor. This can include the source of Contaminants of Potential Concern (COPC) which may impact on the communities in question and transport mechanisms whereby COPC can be moved to exposure points (human receptors). If any of these links are missing then an exposure pathway is incomplete and human exposure will not occur. If the exposure pathway is potentially complete then likely impact on the receptor may need to be assessed.

The exposure pathway describes the course a COPC takes from the source to an exposed receptor. This pathway is unique for specific situations involving particular COPC and specific communities or individuals.

Once a COPC has travelled along the exposure pathway to the receptor, it may then be exposed to the COPC through a number of exposure routes. The basis of these routes are:

- Inhalation of contaminants, either as gases, mists, fumes or airborne particulates,
- Ingestion of contaminants, through food, drink or through secondary transfer from skin to mouth through poor hygiene practices, and
- Direct contact leading to absorption through skin (dermal absorption).

The exposure pathway and exposure route through which contaminants exposure can potentially occur will depend on the chemical characteristics of a contaminant and how the contaminant behaves in the environment. If the normal form of a chemical in the environment is a gas then the likely exposure route will be through inhalation. In contrast if the contaminant usually binds to particulate matter such as dust, soils or sediments, then the exposure routes may be inhalation of contaminated dusts, ingestions of soils or possible direct contact with contaminated soils.

The most common approach to risk assessment is a simple comparison of site specific data on COPC concentrations against relevant guidelines such as regulatory limits, investigation levels or screening levels. In most cases if the COPC meets the adopted guidelines, then the risk is considered low and acceptable. If the COPC exceeds the adopted guidelines then further evaluation is usually required.

1.1.2 Risk Assessment Approach

The methodology adopted in the conduct of the Human Health Risk Assessment is consistent with that used to evaluate risks to human health associated with a population's exposure to a hazardous agent. The current study pertains to the application for the Project to use of SWDF in the Kiln 6 at Berrima Cement Works. Therefore this health risk assessment is focused on potential by-products associated with the use of SWDF as fuels in cement kilns.

The approach to the assessment of risk to human health is based on the protocols/guidelines recommended by the enHealth Council. These are detailed in the document "*Guidelines for assessing human health risks from environmental hazards*. June, 2012."

Identification and assessment of the potential risks to human health within the site have been undertaken by implementing four prime tasks. These tasks are:

1. **Issue Identification** – This involves an evaluation of the available information on the key issues amenable to risk characterisation relating to the use of SWDF in Kiln 6.
2. **Hazard Assessment** – This task provides a review of the current understanding of the toxicity issues to humans associated with the use of SWDF as fuels in Kiln 6 and the identifies hazards associated with exposure to by-products from the use of SWDF.
3. **Exposure Assessment** – This task draws on the evaluation undertaken as part of the "Issue Identification" stage identifying the groups of people in surrounding communities who may be exposed to by-products associated with the use of SWDF as fuels in Kiln 6 and quantifying exposure concentrations.
4. **Risk Characterisation** – This task provides the qualitative evaluation of potential risks to human health. The characterisation of risk is based on the review of toxicity of by-products associated with the use of SWDF as fuels in Kiln 6 and assessment of the magnitude of exposure.

1.2 Objectives

The objective of the Human Health Risk Assessment is to contribute to the analysis of toxicity of by-products associated with the Project to use of SWDF as fuels in Kiln 6 to surrounding communities and provide an assessment of the risk to human health associated with the use of SWDF.

The risk assessment aims to:

- Identify the any COPC associated with the use of SWDF as fuels in Kiln 6,
- Identify the groups of people who may be exposed to any COPC associated with the use of SWDF as fuels in Kiln 6,
- Compare exposure concentrations with contemporary health standards (where available),
- Identify the health risks associated with exposure should it occur; and
- Assess and communicate the identified risks.

Risk assessments of the nature performed here do not provide definitive assessments of the acceptability of risk for specific individuals. Risk assessments should only be applied on a probabilistic basis to a population of exposed persons.

It should be noted that the scope of this Human Health Risk Assessment is limited to potential by-products associated with the use of SWDF as fuels in Kiln 6 and does not include any other agents of potential concern (if any).

1.3 Details of Local Communities

The local communities in closest proximity to the Berrima Cements Works live in for state suburb areas of New Berrima (SSC 11711), Berrima (SSC 10196), Moss Vale (SSC 11604) and Burradoo (SSC 10396). From the 2011 Census, the usual population size for these state suburb areas, the areas and the approximate distance of the urban areas from the site has been set out below in **Table 1**.

Table 1 Details of communities in proximity to Berrima Cement Works

Community	Population (Australian Bureau of Statistics (2012))	Area (sq Kms)	Approximate Distance and Direction of Urban Area from Kiln 6
New Berrima (SSC 11711)	542	3	0.3 km north
Berrima (SSC 10196)	600	23.1	2 km north
Moss Vale (SSC 11604)	7,305	92.2	3.5 km south east
Burradoo (SSC 10396)	2,555	12.4	5 km east

1.3.1 Community Demographic

The demographics of the state suburb areas New Berrima (SSC 11711), Berrima (SSC 10196), Moss Vale (SSC 11604) and Burradoo (SSC 10396) have been set out in **Figure 1 to Figure 4**.

Figure 1 New Berrima population by age, 2011

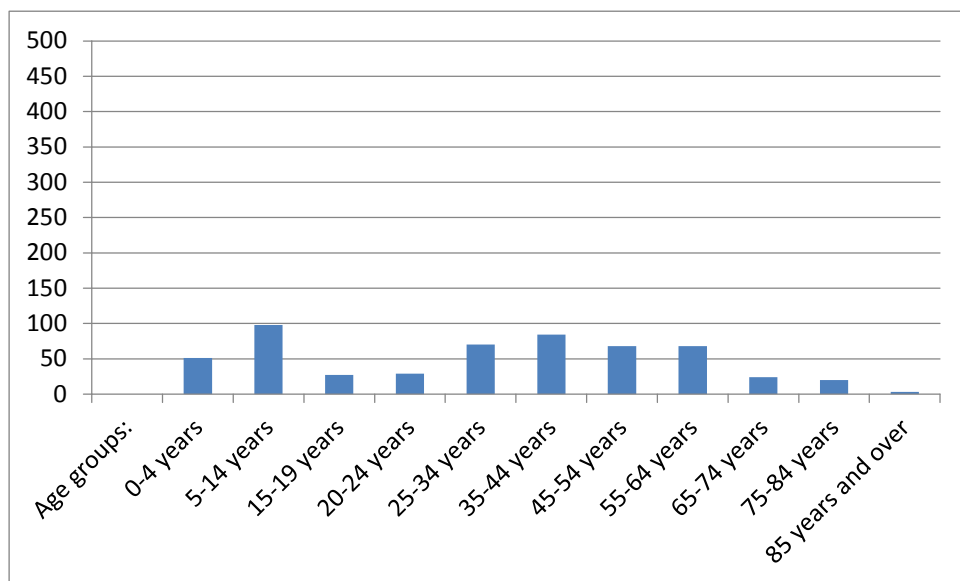


Figure 2 Berrima population by age, 2011

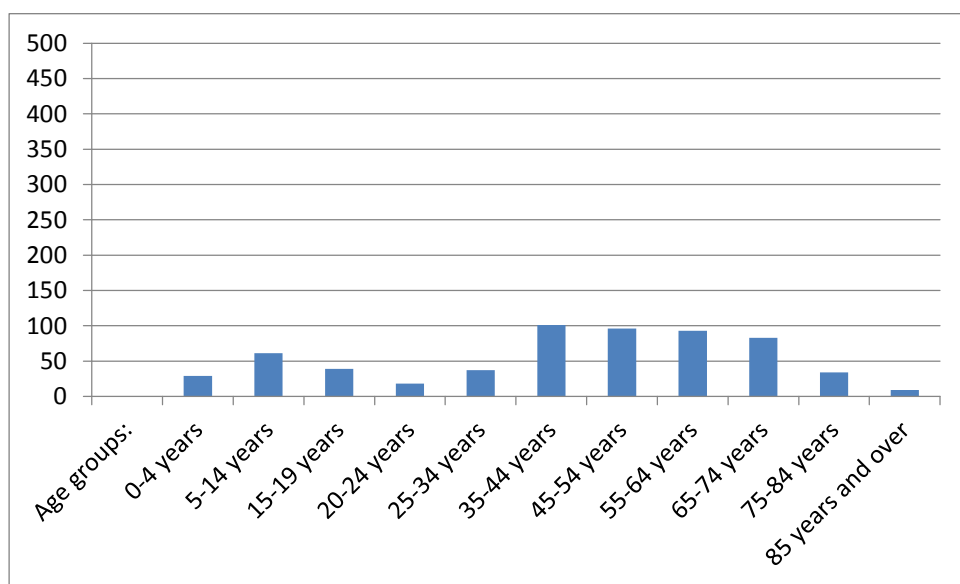


Figure 3 Moss Vale population by age, 2011

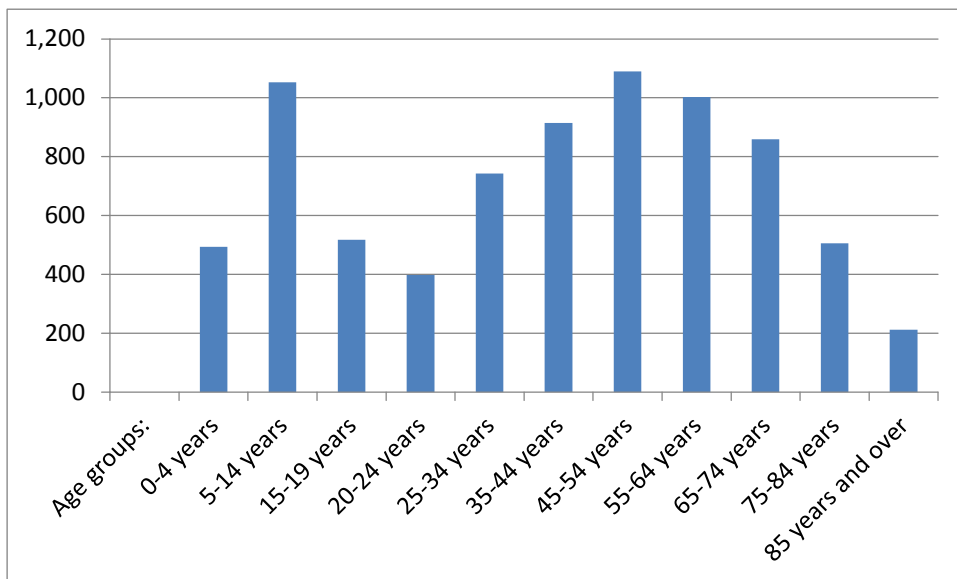
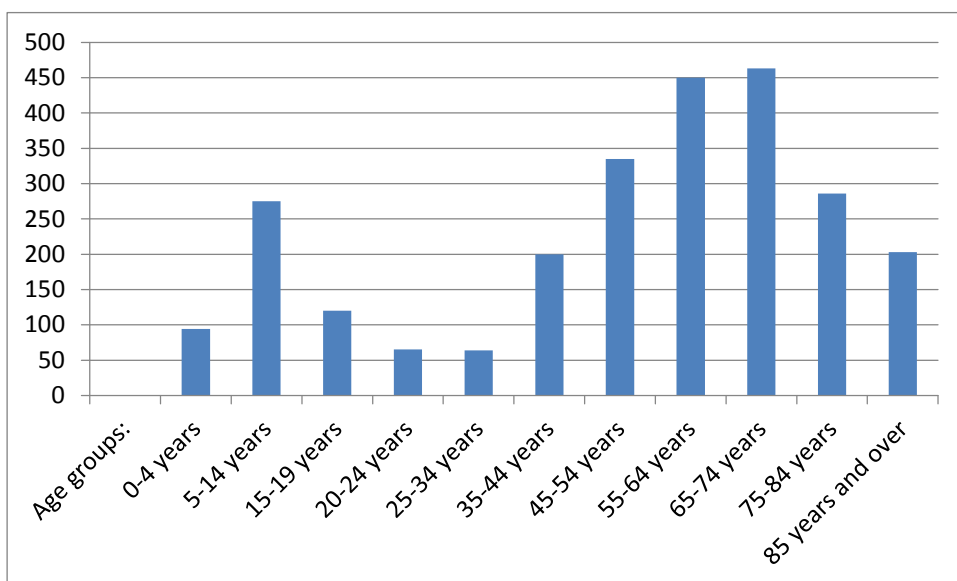


Figure 4 Burradoo population by age, 2011



1.3.2 Special Populations

Special populations are sub groups within the community who may be at greater risk of adverse health effects. The increased risk may be due to factors such as age, ill health or close proximity to an identified hazard, in this case the potential pollutants from the Berrima Cement Works.

Children or teenagers under eighteen years of age are considered at higher risk than older members of the population. In this age group humans are considered to have not reached maturity. Therefore their bodies may respond differently to adults when exposed to a toxic or carcinogenic threat. In many cases they will be at higher risk from the exposure compared to adults. Details of the special populations based on age of the communities chosen for the assessment have been set out in **Table 2**.

Table 2 Details of special populations based on age, within communities in proximity to Berrima Cement Works

Community	Population Under 18 years of Age	Population Over 74 years of Age*
New Berrima (SSC 11711)	176	23
Berrima (SSC 10196)	129	43
Moss Vale (SSC 11604)	2,065	718
Burradoo (SSC 10396)	489	489

* Elderly taken to be over 74 years of age due to limitations of Census data.

1.3.3 Community Health Data

Health data on small populations, such as New Berrima or Berrima, may lack epidemiological power to detect health effects (enHealth, 2001). Accordingly the health statistics for NSW were utilised in this report as a basis for the risk determinations in later sections of the report.

It is anticipated that there may slight differences in the local community health data compared with the overall NSW health data. However, differences are likely to be small and therefore the NSW statistics may be used in the assessment.

The health statistics set below in **Table 3** were chosen for their relevance to the health risk assessment of airborne particulates later in the report.

Table 3 NSW Community Health Summary – Indicators Relevant to Airborne Particulates

Health Indicator	Incidence Rate per 100,000 Population
Mortality	
All causes-all ages	670*
All causes - ≥ 30 years	1087*
Cardiopulmonary - ≥ 30 years	490*
Cardiovascular – All ages	164*
Respiratory – All ages	57*
Hospital Admissions	
Cardiovascular - ≥ 65 years	2335.2 [#]
Respiratory - ≥ 65 years	8807 [#]

Data from *=2005-2007; [#]=2009-2011; *+=2010-2011 (EnRiskS, 2014)

1.4 BERRIMA CEMENT WORKS PROCESS INFORMATION SOURCES

The background information on site processes at Berrima Cement Works and potential contamination sources, used in the current report was based on a desktop review of existing reports including

Air Quality Professionals, 2015. *Boral Cement Berrima Works Use of Solid Waste Derived Fuels in Kiln 6 Air Quality Assessment*. 24 April 2015

SLR, 2015 *Use of Solid Waste Derived Fuels Kiln 6, Berrima Cement Works DA 401-11-2002-Modification 9 Environmental Assessment July 2015*. Report Number 610.14460. SLR Consulting Australia Pty Ltd

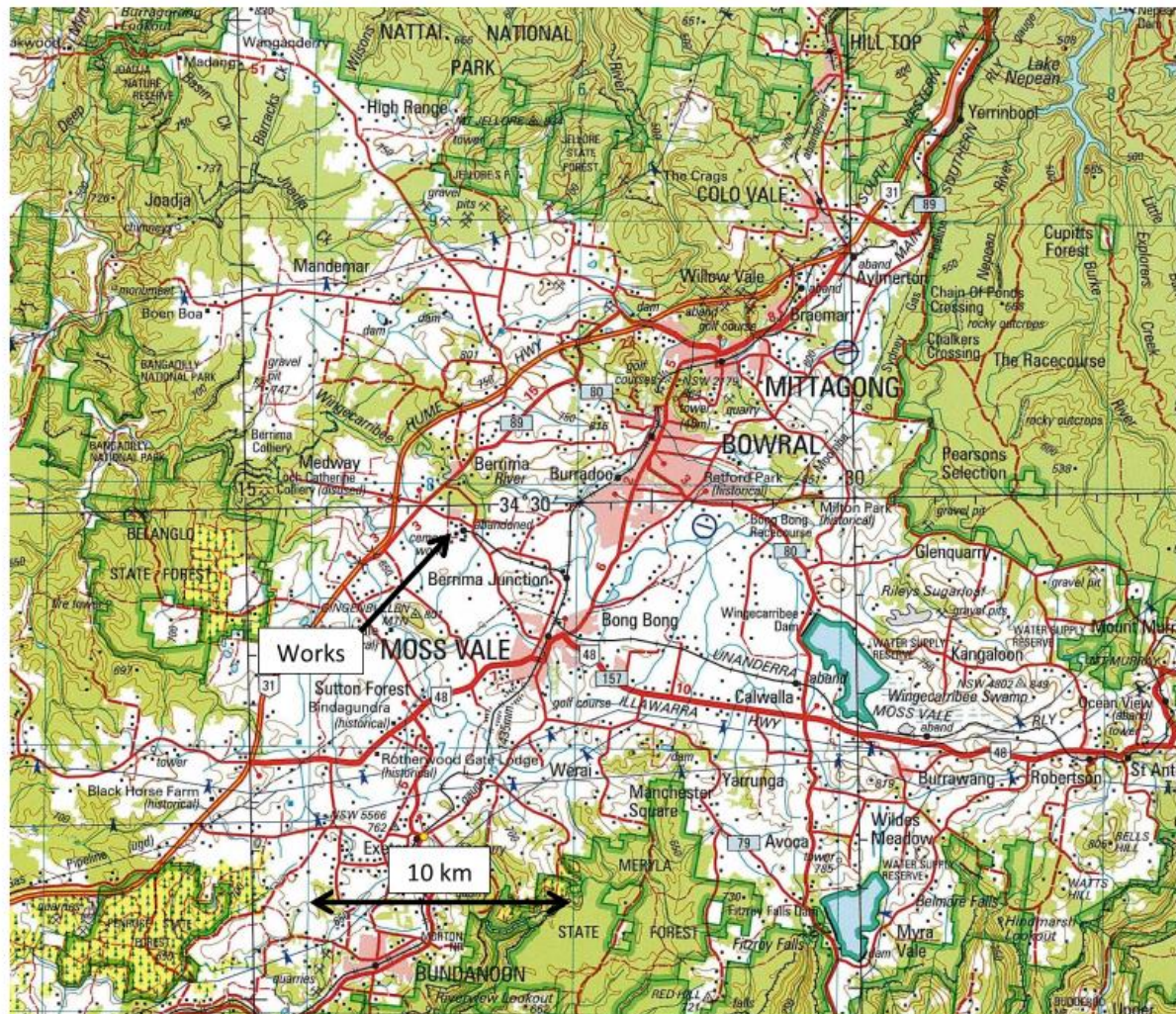
1.5 EXISTING ENVIRONMENT

1.5.1 Topography

The Berrima region is flanked by hills on all sides within about 10-20km of the Works. These hills rise to an elevation of about 60-130m above local ground level at the cement works, which is about 675m above mean sea level. The Australian coastline is 50km to the east of the works. (Air Quality Professionals, 2015)

The cement works site is flat and the immediate surrounding area is characterised by gently rolling shallow hills and valleys with some flat areas. The topographical elevation information is shown **Figure 5**.

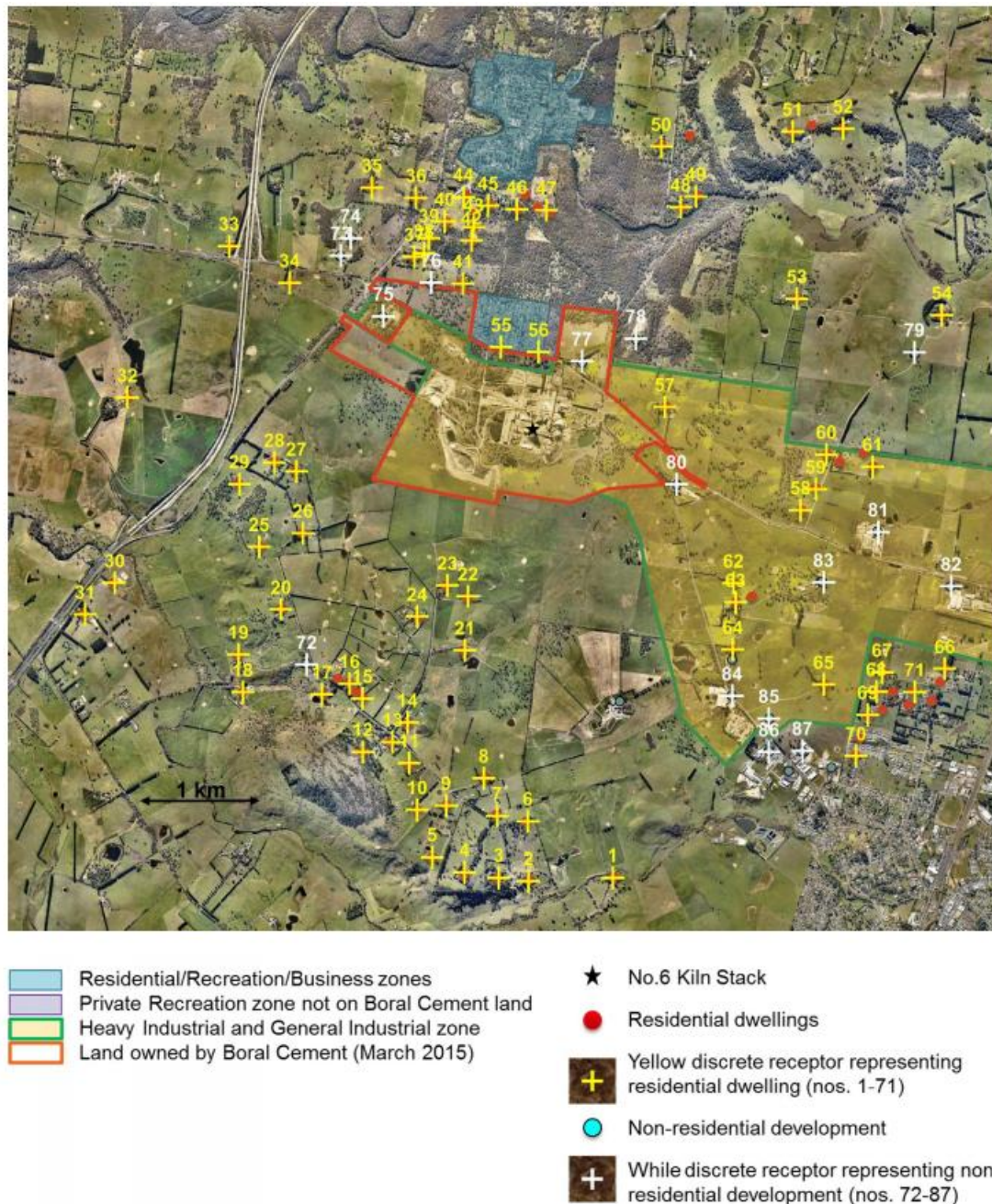
Figure 5 Topographical map of region around Berrima works (Air Quality Professionals, 2015)



1.5.2 Surrounding Land Use

Figure 6 shows the surrounding land uses, residential dwellings and sensitive Receptors used in the air quality modelling study of Air Quality Professionals, (2015). It should be noted that Receptor 88 is not shown on the map but is located at the corner of Howard St and Taylor Ave New Berrima, west of Receptor 55, approximately 300m from the cement works boundary.

Figure 6 Surrounding land uses around Berrima works (Air Quality Professionals, 2015)



1.6 EXISTING OPERATIONS

Berrima Cement Works has been operating since 1929 and produces cement products (cement and clinker) for sale in NSW, the ACT and for export. The Cement Works is approved to produce up to 1.56 million tonnes per annum of cement products which has historically represented 60% of cement sold for building and construction in NSW. Cement products are dispatched to domestic customers by train and truck and international customers through Port Kembla.

The facility operates one kiln and two cement mills, along with storage and stockpile facilities, and a substantial fleet of heavy vehicles for transportation.

The clinker, which looks like small balls of pumice, is stored before being passed to the grinding mill where it is ground into cement. The cement is stored on site before being loaded for transport off-site.

Cement manufacture is an energy intensive process due to the high temperatures required for the production of clinker. Currently 220,000 tonnes per year of coal is used to heat the kiln to a temperature of up to 1500°C. Up until 2013 coal was sourced from the nearby Medway Colliery but since the colliery's closure, coal is currently sourced from the Illawarra area by road. This reliance on coal contributes to the total energy cost at the facility, which represents 40% of Boral's costs in the cement production process.

The facility supports a direct workforce of 130 employees, a further 20 in engineering and procurement, as well as many indirect jobs in the region through logistics, contractors and suppliers.

Some of the pressures on the facility's existing operation include:

- increased energy prices,
- increased costs of raw materials, and
- increased affordability in importing clinker from overseas.

Boral has implemented a number of efficiency measures over the years to address these pressures and reduce its operating costs. The use of SWDF is another such measure which would reduce energy costs and help secure the commercial and environmental sustainability of the Cement Works into the future.

Figure 7 shows the site layout and **Figure 8** provides a flow diagram of the current operating process at the facility. The main raw material inputs are limestone, sourced from the Marulan mine, and shale, sourced on site. Limestone is transported via rail and combined with the shale. The blended material is passed through a raw milling and gas cleaning system and into the rotary kiln where the material elements are combined at very high temperature to form clinker.

Figure 7 Aerial photograph of Berrima Works with locations of various activities indicated. Aerial photography from nearmap, imagery dated 22 May 2014 (source: Air Quality Professionals, 2015).

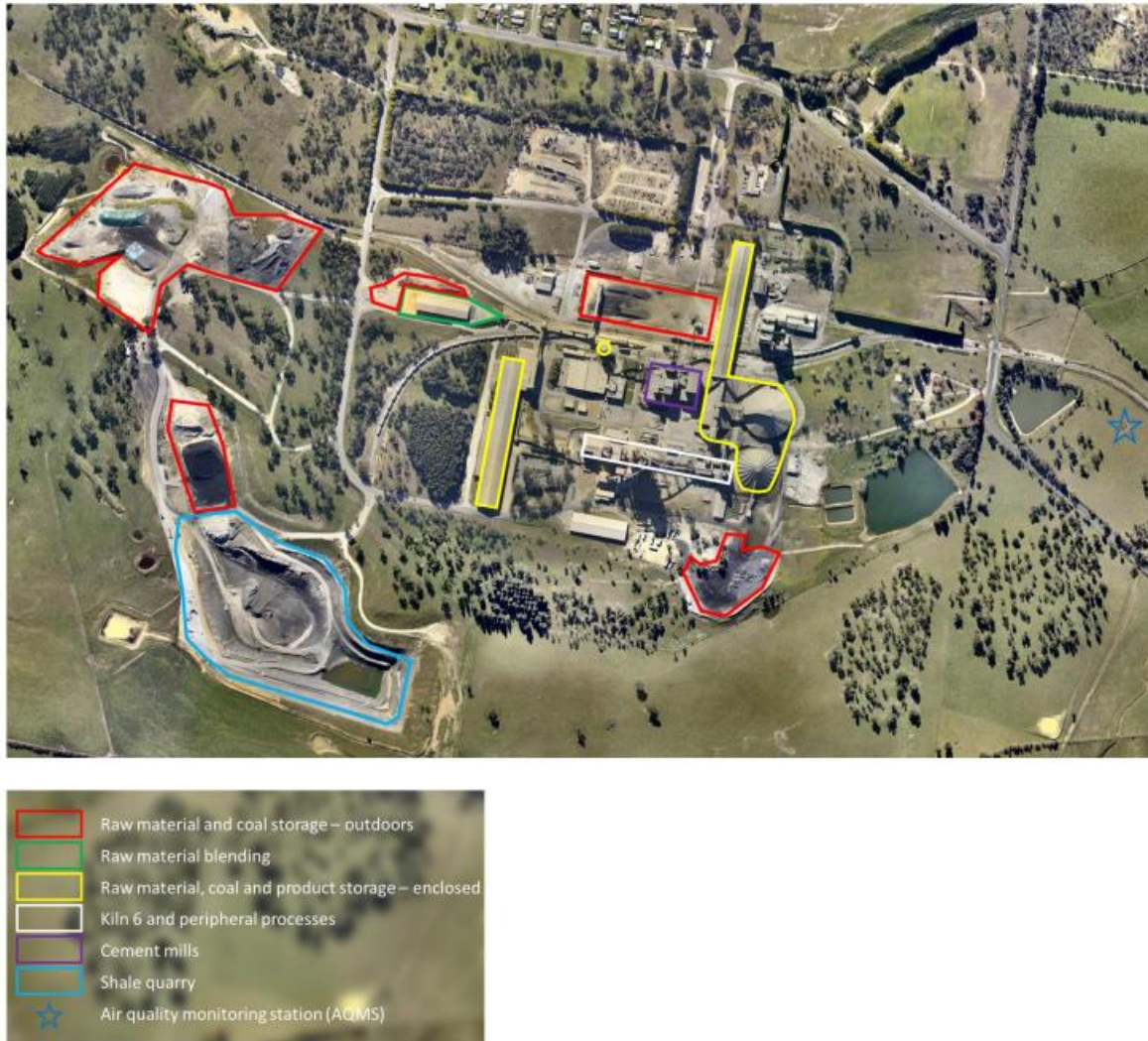
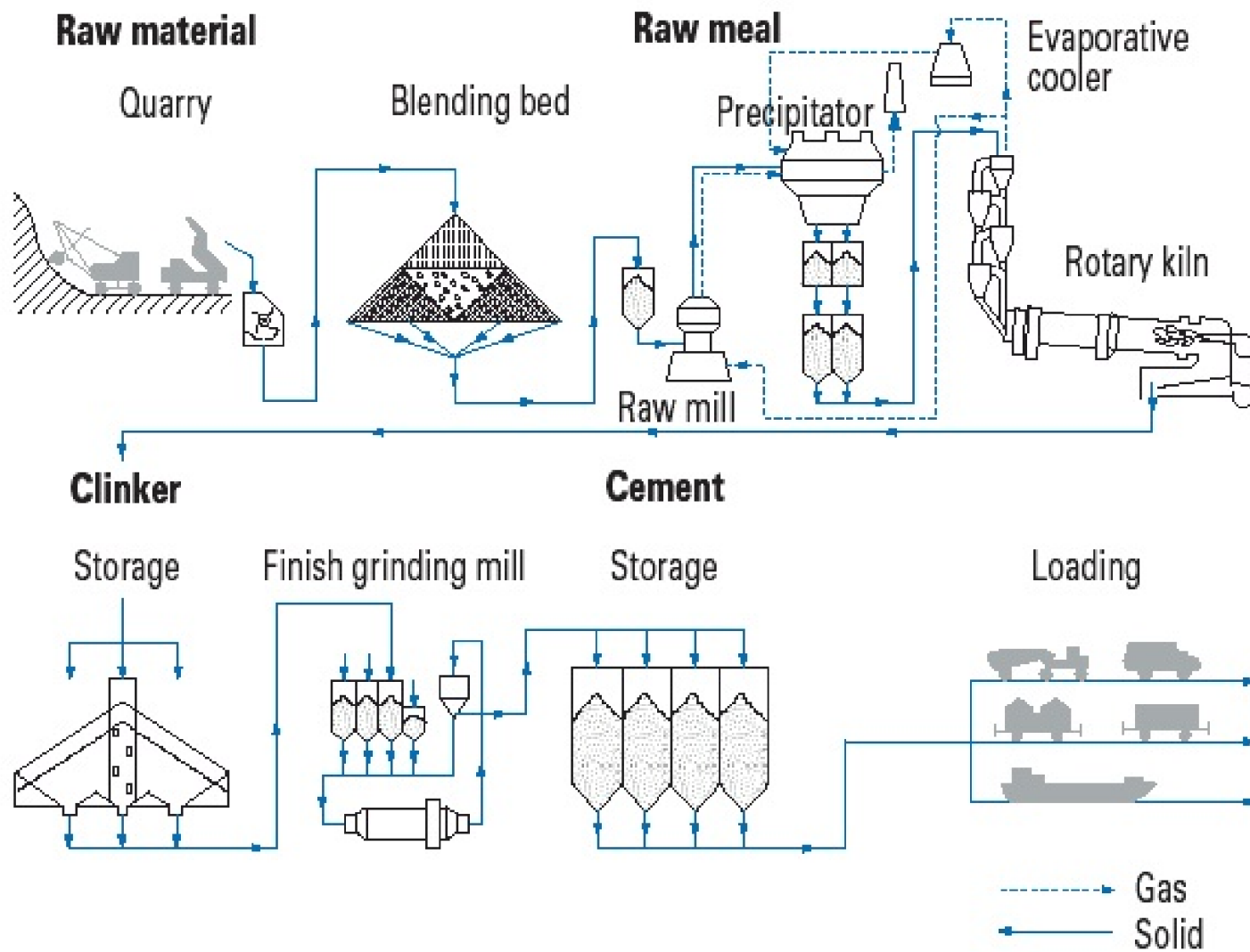


Figure 8 Flow chart describing current process operations



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1.7 Existing emission control equipment

Cement kilns offer a superior solution for handling wastes due to high temperatures and residence times with no solid residues. In 2004, Boral upgraded Kiln 6 and installed additional equipment specifically suited to the burning of SWDF.

The key features of this equipment are:

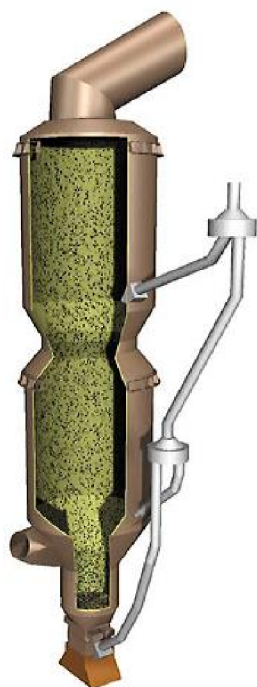
- a large volume pre-calciner combustion vessel, which gives fuels longer time to burn out (>6 seconds) at high temperatures (>800°C). This means that all of the solid fuel is given the chance to burn out and eliminates residues like smoke;
- the raw mill dust collector, which filters kiln exhaust gas particulates and provides additional high efficiency cleaning capacity to minimise stack emissions; and
- the installation of continuous monitoring equipment for key gaseous pollutants, which allows prompt response to any adverse trends in stack emissions.

Figure 9 illustrates some of this equipment and the emissions benefits.

Figure 9 Existing emission control equipment

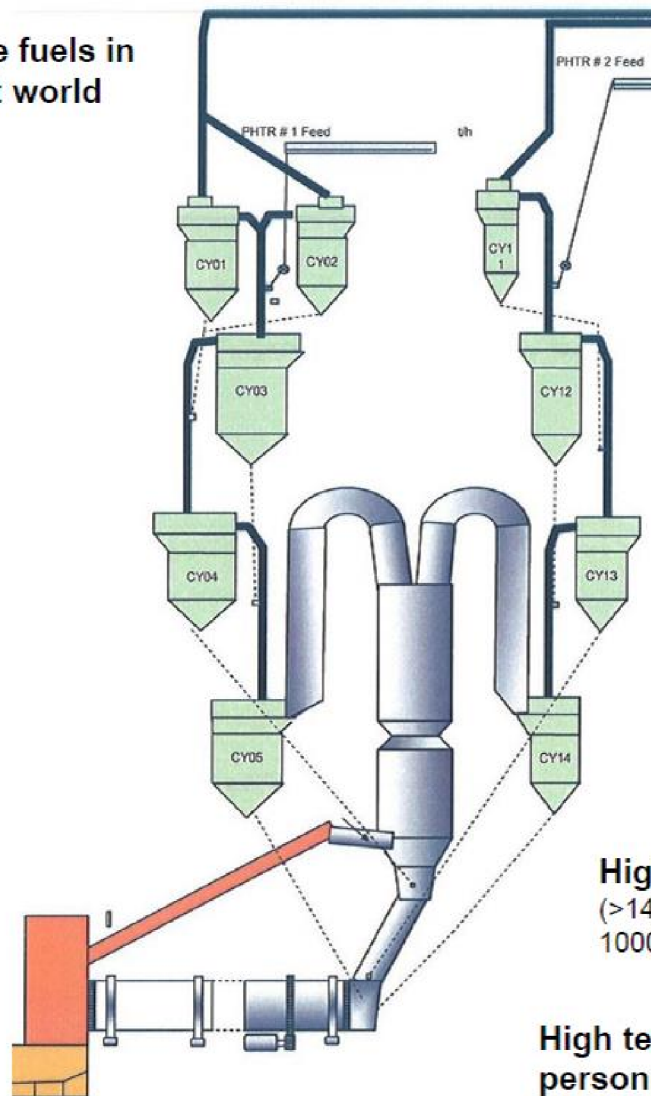
Use of wide range of solid waste fuels in cement kilns proven throughout world

Reduces CO2 emissions with biomass fuels



High combustion residence time in kiln and pre-calciner
(>6 seconds gas residence time @>800 Deg C in calciner)

No solid residues to dispose of (ash combined in clinker)

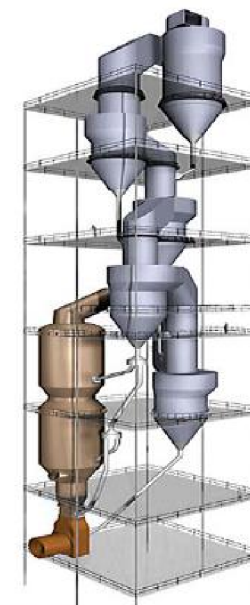


High efficiency filtration of kiln exhaust gas particulates (ash combined in clinker)

High level of automated combustion and chemistry control

High gas temperatures (>1400 deg C in kiln 1000 to 800 deg C in calciner)

High technical competency of personnel



Preheater acts as efficient acid gas scrubber (high limestone/lime environment)

1.8 SCOPE OF MONITORING OF EXISTING EMISSIONS

Details of the historic and current air quality testing regime in place at the cement works was detailed in the report Air Quality Professionals (2015). This report stated:

A range of sampling and analysis programmes are conducted at the Berrima site to monitor air discharges from the four discharge points. These programmes are as follows:

Monitoring required by the EPL during combustion of standard fuels:

- a. Annual stack testing. This applies to all four discharge points.*
- b. Continuous measurement in No.6 Kiln stack of total suspended particulate (TSP) (required in EPL since 30 March 2012, although the measurement has been conducted for several years outside of this EPL requirement as a voluntary process control measure).*

Additional monitoring that is only required by the EPL during combustion of NSF (Non Standard Fuels) (a requirement that has not been initiated yet because the site hasn't been using any NSF) – this testing is currently carried out voluntarily by the site during combustion of standard fuels as well:

- a. Additional annual testing on discharges from No.6 Kiln stack, as would be required if NSF were being used, as well as testing of PAHs.*
- b. Continuous measurement in No.6 Kiln stack of nitric oxide (NO), nitrogen dioxide (NO₂), NMHCs, methane, oxygen, carbon monoxide (CO), and sulfur dioxide (SO₂).*

All monitoring is carried out or equipment is maintained and calibrated by independent, suitably qualified contractors. In accordance with Special Condition E2 of the EPL and condition 4.1B of the DA (required only when NSF are used, currently undertaken on a voluntary basis), Boral Cement also operates an ambient air quality monitoring station (AQMS) beyond the site boundary which records meteorological data continuously and TSP, PM₁₀ and heavy metals on a one-day-in-six basis.

1.9 BERRIMA CEMENT WORKS PROPOSED MODIFICATION

1.9.1 Current Approvals and Recent Modifications

Berrima Cement Works operates under two development consents that were granted by the Minister in 2003 (Kiln 6) and 2005 (Mill 7). Boral Cement is permitted to produce up to 1.56 million tonnes of cement a year at the facility. These consents have since been modified as per **Table 4**.

Table 4 Modifications to the original development approvals

Modification	Reference/Date	Scope
1	MOD 2-1-2004 Sept 2005	Use of non-standard fuels, including used tyres, liquid oil residues and spent aluminium electrode carbon
2	MOD 109-9-2006 Sep 2006	Removal of hazardous waste prohibition
3	MOD 12-2-2007 Feb 2007	Trial use of tyre chips
4	MOD 4 April 2008	Varying usage of coke fines
5	MOD 5 Aug 2009	Coal deliveries by rail
6	MOD 6 June 2012	Stockpiling of coal for sale and transport to Port Kembla
7	MOD 7 April 2012	Trial and use of blast furnace slag
8	MOD 8 July 2012	Administrative changes to align DA and EPL conditions

1.9.2 Non-Standard Fuels

Boral has been investigating the use of non-standard fuels in Kiln 6 since 1999. The types of non-standard fuels considered included: carbon anode dust, used tyres, recycled oils and grease, and waste wood with preliminary trials conducted in 2000 and 2001.

On 12 May 2003 the Minister for Infrastructure and Planning approved a development application for an upgrade to Kiln 6 at the existing Cement Works. The Minister's consent only permitted the use of standard fuels at the upgraded development as no assessment had been undertaken as part of the application for use of any non-standard fuels.

Further trials were conducted in 2003 to inform a modification application seeking approval for the use of non-standard fuels at Berrima (MOD 2-1-2004). The Modification application sought approval for:

- use of three non-standard fuels (being used tyres (AKF5), liquid oily residues (AKF1) and carbon anode dust (Hi Cal 50) which had been trialled and tested in accordance with an EPA licence; and
- a protocol describing the trialling, testing and approval procedures for possible new fuels at the upgraded Kiln 6.

The Department granted approval for the use of the three trialled and tested non-standard fuels, subject to stringent environmental controls, but did not grant approval to the implementation of any protocol. This would result in any future proposal to use additional non-standard fuels requiring further approvals under the Environmental Planning and Assessment Act 1979.

Approval for used tyres (AKF5) was granted subject to the necessary approvals under the Act being obtained for storage facilities and kiln feeding infrastructure. No AKF5 is permitted to be received at the site until the necessary storage facilities and kiln feeding infrastructure have been constructed in accordance with any such approvals.

Approval for Hi Cal 50 and AKF1 was granted subject to the detailed design for any necessary storage facilities and kiln feeding infrastructure being approved by the Director-General.

A subsequent modification application (MOD 12-2-2007) granted approval for Boral to undertake a single operational trial of chipped tyres in the development, ahead of the construction of storage facilities and kiln feeding infrastructure for AKF5, subject to a number of requirements.

1.9.3 Outcome of trials involving non-standard fuels

As part of Modification 2-1-2004-i of the Kiln 6 Development Consent, trials of waste-derived fuels were conducted on two days in August 2003 and two days in October 2003.

Blends of the waste-derived fuels were tested against a baseline of coal and 5% coke as follows:

- Coal/coke + HiCal 1.3 tph (Trial Blend 1);
- Coal/coke + HiCal + Waste Oil (AKF1) 1 tph (Trial Blend 2); and
- Coal/coke + HiCal 1.3 tph+ Waste Oil (AKF1) 1 tph + chipped tyres (AKF5) 4.5 tph (Trial Blend 3).

The stack emissions were monitored during the trial by the external provider, Air Labs (report dated 4 December 2004). The trial was regarded as a success. This success was measured in terms of:

- No adverse impact on emissions, land, noise and traffic;
- No adverse impact on clinker quality; and
- No community complaints or adverse comments.

1.9.4 Stack emission testing summary

Most of the parameters tested were well below the safe emission limits imposed later in the modified consent for the combustion of waste-derived fuels. The only exceptions were Total Particulate and Nitrogen Oxides.

During the trials, Total Particulates were measured at 40, 44 and 51 mg/m³ for the trial blends 1, 2 and 3, respectively against the limit of 30 mg/m³ that was later applied to the Consent. For MOD 9, Boral is proposing to change this limit to 50 mg/m³ in line with the NSW Energy from Waste Policy, 2014. Total Particulate levels measured during the past year have been well below this proposed limit.

Nitrogen Oxides were at the level of 1700 mg/m³ for the baseline (coal and coke), dropping down to approximately 1200 mg/m³ which was still higher than the limit of 800 mg/m³ that was applied in the consent. For MOD 9, Boral is proposing to change this limit to 1000 mg/m³ being the same level currently being complied with for standard fuels.

The potential for Dioxin and Furan emissions was a key concern for the community at the time. The baseline measurement was 0.0034 ng/m³ while blend 1 was 0.0049 and blend 3 was 0.013 ng/m³. There was no adequate sample obtained for blend 2 due to a process upset during the 6-hr timeframe required for dioxin sample collection. The highest level recorded during blend 3 was nearly 8 times below the limit of 0.1 ng/m³ that was later applied to the consent. The trials demonstrated that even with all three waste-derived fuels being fed into the kiln simultaneously, there were no potentially unsafe dioxin emissions.

Heavy metal emissions were at a similar level to the baseline or lower, including the more volatile metals such as cadmium and mercury when compared to emissions from normal fuels (Air Quality Professionals, 2016).

VOC emissions were up to two times higher with the use of waste-derived fuels but still well within the applicable emission limit. Due to the marked variability of VOC emissions observed over the years from the contribution of blue shale, in MOD 9 Boral are proposing to change this limit to 40 ppm when waste-derived fuels are used.

1.9.5 Proposed Activities of the Project

This modification, Modification 9, seeks approval for the following:

- use of Solid Waste Derived Fuel (SWDF) as an energy source;
- changes to the air emission limits of particulate matter (PM), nitrous oxides (NOx) and volatile organic compounds (VOC); and
- construction of a fuel storage and kiln feeding system.

The fuels that are the subject of this modification are the following SWDF:

- Wood Waste - material left over from industrial processes like milling, furniture making, and building and construction; and
- Refuse Derived Fuel (RDF) - fuel made from the combustible materials recovered and processed from waste streams, such as papers, cardboards, packaging, and construction and demolition materials

These fuels are considered to be an ideal fuel source for Kiln 6 and would be sorted, tested and shredded off-site by authorised waste suppliers to maintain compliance with relevant specifications.

Boral proposes to use up to 100,000 tonnes per year of SWDF in Kiln 6 operations. This would replace 20-30% of the coal used in the facility. **Table 5** compares the quantities of fuel that Boral currently has approval to use with the quantities proposed by this modification.

Table 5 Approved and proposed classes and quantities of standard and waste derived fuel

Fuel	Category	Tonnes per annum	% of total fuel (by mass)	Tonnes per annum	% of total fuel (by mass)
		Current		Proposed	
Natural Gas, Fuel Oil, Diesel	Standard Fuel	No Limit		No change	
Coal	Standard Fuel	No Limit	≥ 60.0	No Limit	No Limit
Coke Fines	Standard Fuel	No Limit	≤ 30.0	No Limit	≤ 30.0
Aluminium electrode carbon (Hi Cal 50)	SWDF	10,000	≤ 6.0	10,000	≤ 6.0
Liquid Oil Residues (AKF1)	LWDF	20,000	≤ 4.7	20,000	≤ 4.7
Waste Tyres (AKF5)	SWDF	30,000	≤ 21.0	100,000	≤ 50
Wood Waste	SWDF	Not currently approved			
RDF	SWDF				

Boral would only source feedstock from suppliers that have agreed to meet the requirements of the EPA guidelines, including the resource recovery criteria for energy recovery facilities set out in the NSW EPA Energy from Waste Policy (2014). This would be a prerequisite when establishing supply contracts for kiln feedstock.

The policy specifies what is considered to be an 'eligible waste fuel' which would be reviewed over time.

Boral proposes to adopt a risk based approach to minimise any potential environmental impact of using SWDF. Boral's approach would involve four levels of risk protection as follows:

Detailed fuel specifications

Boral has developed detailed fuel specifications for the proposed SWDF based on established European and USA standards. The levels of contaminants, such as heavy metals, in these standards are low enough to ensure that when used as a fuel in the cement kiln, emissions are unlikely to exceed the limits defined in the Energy from Waste Policy and the sites EPL. The fuel specifications would be the basis of acceptance of deliveries of fuels from suppliers.

Supplier control systems

Suppliers of SWDF to Berrima would be required to establish rigorous Quality Assurance / Quality Control procedures to ensure the SWDF products produced from their operations meet Boral's specifications. The QA/QC of suppliers would be subject to regular audit by Boral or external parties.

Check sampling and testing of waste fuels supplied

Regular statistical check sampling and testing of dispatched waste fuel products would be established based on the European standards. Using this methodology, samples of fuel would be taken at either the supplier's site or at the Cement Works on a regular basis and analysed to determine compliance with the fuel specification. This will provide a regular check of the effectiveness of the supplier's quality assurance processes. Analysis of test results would be undertaken by suitably accredited laboratories using standard test methods.

Inherent capture efficiency of the cement kiln process

Boral and industry data demonstrates that cement kilns have inherently high capture efficiency for contaminants such as heavy metals which are captured as a stable component of the kilns clinker product. Therefore in the unlikely event that the preceding three stages fail to prevent out-of-specification fuels being fed into the kiln, the risk of a significant environmental impact resulting from such an event is low.

Concrete is an artificial stone made of cement, aggregates, sand and water and is known for its high environmental performance. This performance is not impaired when waste derived fuels are used for cement production. Concrete made from cement manufactured using waste derived fuels has the same properties as concrete made from cement manufactured using fossil fuels.

One aspect of the environmental performance of concrete is the behaviour of heavy metals in concrete. These trace elements are found in various concentrations in the raw materials and fuels used in the manufacture of cement and may be found at a slightly higher proportion in the waste-derived fuels. However, high temperatures maintained in the clinker kiln and the kiln's highly alkaline environment cause most of the metals to precipitate becoming irreversibly bound into the newly-formed clinker. The metals will not solubilise again which is a pre-requisite for leaching to occur; with the clinker matrix acting as a permanent immobiliser. As heavy metals are found in raw materials and fuels used in clinker manufacture only at trace concentrations, the added quantities are negligible in comparison with the bulk of the cement material produced.

The heavy metals bound in the cement are further chemically bound in the alkaline reaction between the cement and water which produces concrete. This fixation as well as the high density and low permeability of concrete result in a very low potential for heavy metals to be released from the concrete structures.

The leaching of heavy metals from concrete has been examined in a number of investigations (Alternative Fuels in Cement Manufacture, Cembureau, Brussels 1997; M.T. Webster and R.C. Loehr, Long-Term Leaching of Metals from Concrete Products, Journal of Environmental Engineering, Vol. 122, No. 8, 1996; S.R. Hilliera, C.M. Sangha, B.A. Plunkettb, P.J. Walden, Long-term leaching of toxic trace metals from Portland cement concrete, Cement and Concrete Research, Vol. 29, No.4, 1999). They all show that the release is very low, independently of the kind of fuels used for cement clinker production. The leached quantities have always been found to be either not measurable or significantly below allowable environmental and/or public health limits. The only benchtop leaching tests that can demonstrate any extent of leaching of heavy metals from cement or concrete are those based on acid extraction.

European Union countries have been using waste derived fuels extensively in cement manufacture for around 50 years now. Many concrete structures in Europe have therefore been built using cement that incorporates heavy metals from the waste derived fuels, with no evidence of any environmental impacts that may have originated from heavy metals that have leached out of concrete.

1.9.6 Emission changes

Emission limits

Boral seeks a modification to the emission limits of three air pollutants to align with the requirements of the EPA's NSW Energy from Waste Policy (2014).

Boral Cement holds the Development Consent (DA 401-11-2002) for Kiln 6, last modified in August 2012, and the EPL 1698 for the site, last updated May 2013. The DA and EPL regulate the discharges of contaminants to air from the burning of standard fuels (such as coal, diesel, and heavy oil). From 2005, the DA and EPL also allow for the burning of "non-standard fuels" (NSF) in the kiln with specific air discharge conditions. These conditions associated with the burning of NSF are onerous and difficult to meet. As a result, the NSF programme has never been implemented.

Condition 3.10, Table 3 of the Development Consent and Conditions L3.1 and L44-L3.5 in EPL 1698 define permitted contaminant **emission limits for the four discharge points during the burning of standard fuels, and are shown in Table 6 and Table 7.**

Table 6 Emissions limits for particulate matter for burning of standard fuels

Discharge point (and EPL point reference number)	Particulate matter 100 percentile concentration limit
No. 6 Kiln Stack (2)	95 mg/Nm ³
No. 6 Cement Mill (4)	100 mg/ Nm ³
No. 6 Kiln Cooler (5)	100 mg/ Nm ³
No. 7 Cement Mill (10)	20 mg/ Nm ³

Table 7 Emission limits for other contaminants from No. 6 Kiln Stack for burning of standard fuels

Contaminant	100 percentile concentration limit
Nitrogen oxides	1000 mg/ Nm ³

Condition 3.10 Table 4 of the Development Consent and Conditions L3.6 to L3.8 of EPL 1698 define permitted contaminant emission limits for the No.6 Kiln Stack during the burning of NSF, as shown in **Table 8.**

Table 8 Emission limits for particulates, NOx and VOCs from No. 6 Kiln Stack for burning of non-standard fuels

Contaminant	100 percentile concentration limit
Nitrogen oxides	800 mg/ Nm ³
Particulate matter	30 mg/ Nm ³
Volatile organic compounds	20 ppm

Table 9 provides a comparison of the current emission limits for particulate matter, NO_x and VOCs for burning of Standard Fuels and Non-Standard Fuels.

Table 9 Comparison of current emission limits for Particulates, NO_x and VOCs from No. 6 Kiln Stack for burning of standard fuels and non-standard fuels

Contaminant	Non-Standard Fuels	Standard Fuels
	100 percentile concentration limit	100 percentile concentration limit
Nitrogen oxides	800 mg/ Nm ³	1000 mg/ Nm ³
Particulate matter	30 mg/ Nm ³	95 mg/ Nm ³
Volatile organic compounds	20 ppm	No limit specified

Boral has undertaken monitoring and annual reporting on air emissions from the No. Kiln 6 stack, which demonstrates that the Cement Works complies with the emission limits for standard fuels. However, the more onerous conditions with regard to WDF would be more difficult to comply with, and therefore Boral has never progressed the use of WDF.

Additionally, and of relevance to this proposed modification, is the release of the EPA's NSW Energy from Waste Policy (2014), which defers to the emission limits specified in the Protection of the Environment Operations Regulation (Clean Air) 2010. To align with the regulation and policy, as well as to facilitate the use of SWDF, Boral proposes changes to the emission limits of particulate matter (PM), nitrogen oxides (NO_x) and volatile organic compounds (VOCs). **Table 10** details the current air emission limits and the proposed changes.

Table 10 Proposed emission limits for burning non-standard fuel

Emission types	Limit using standard fuel	Current limit using non standard fuel	Proposed limit using non standard fuel
Particulate matter (PM)	95 mg/m ³	30 mg/ m ³	50 mg/ m ³ *
Nitrogen Oxides (NO _x)	1000 mg/ m ³	800 mg/ m ³	1000 mg/ m ³ **
Volatile Organic Compounds (VOCs)	N/A	20 ppm	40 ppm **

* NSW Group 6 emission criteria as per *Energy from Waste Policy 2014*

** Alternative emission standards applied for as per Clause 36 of *POEO (Clean Air) Regulation 2010*

These proposed emission limits are considered safe with regards to public health and environmental impacts (Air Quality Professionals, 2015) and are also realistic for Boral to achieve at a commercially acceptable cost.

Emissions reporting

Boral also seeks minor changes in the development consent to the way two emissions are reported. The changes sought are:

- the definition of Volatile Organic Compounds to be changed to Non-Methane Volatile Organic Compounds; and
- the averaging period for the reporting of Nitrogen Oxides changed from 1-hour averaging, to 24-hour averaging.

The reasons for these changes are outlined below.

Volatile Organic Compounds

Within Kiln 6, it can be demonstrated that VOC emissions are not associated with the combustion of fuels. Rather, the VOC's are associated with the natural composition of onsite blue shale used as a raw material in Kiln 6.

In Europe, where there is widespread use of WDF in cement kilns, there is recognition in their policy document (Waste Incineration Directive, 2000 (WID)) that VOC emissions are not necessarily linked to the use of waste-derived fuels. Rather, it is recognised that these emissions may be caused by other factors, therefore providing the regulator with discretion to allow exemptions based on other parameters such as Total Organic Carbon (TOC).

The WID states:

"Exemptions may be authorised by the competent authority in cases where TOC (i.e. VOC) and SO₂ do not result from incineration of waste".

Boral seeks recognition of established practices used in WID and submits that Non-Methane Volatile Organic Compounds as Propane (C3) are the appropriate VOC to measure compliance to account for the inherent VOC levels within the blue shale. Accordingly, Boral seeks modification of Condition 3.10A, Table 4 in the consent to acknowledge Non-Methane Volatile Organic Compounds as Propane.

Averaging period for Nitrogen Oxides

Continuous monitoring results for Nitrogen Oxides (NO_x) are currently required to be averaged over a 1 hour period when burning non-standard fuels. However, other pollutants, like particulate matter, are required to be averaged over 24 hours.

Interactions between fuel combustion and chemical processes in a cement kiln can result in significant hourly variations in NO_x which are not reflective of the environmental impact of the kiln emissions. This is important from a regulatory and community point of view, so that reporting is consistent and an accurate reflection of potential environmental impact, rather than short term variations.

Boral seeks consistency of averaging periods across monitoring of all pollutants when using non-standard fuels and requests that the averaging period for NO_x be changed to a 24-hour average, counted from midday to midday.

1.9.7 Fuel storage and feeding system

The following sections discuss the design, construction and operation of the necessary fuel storage and feeding system to enable the use of SWDF at the Cement Works.

The SWDF that are proposed to be used at Berrima would be transported by road from tier one waste management facilities and unloaded directly into an onsite enclosed purpose built steel clad building on the Berrima Cement works site.

Design

The storage and handling facility is designed to store and handle SWDF such as waste tyre chips (AKF5), wood waste and RDF. The SWDF fuel storage, handling and feeding system comprises:

- a receival and storage building located on the southern side of the Kiln 6 pre-heater tower. The building would be 33m long, 50m wide and 13m high;

- a RDF bale feed conveyor to feed bales into the receival shed;
- a de-baler/shredder and feed system at the back end of the storage shed;
- an enclosed conveyor from the storage building to the existing pre-calciner vessel located in the preheater tower;
- a screw conveyor and air sealing device around the pre-calciner within the preheater tower; and
- a designated ground outdoor storage area for SWDF received in the form of covered (plastic wrapped) bales or within covered delivery vehicles.

Potential suppliers of SWDF have nominated bales as the preferred method of transporting in the short term. However, in the future, as the market develops, transportation may move to using shipping containers, which would necessitate an alternate feeding system. This would be subject to future development assessment.

The daily SWDF would require approximately ten (10) truck deliveries per day with the planned trucks to be covered tippers.

The SWDF receiving and storage building has provision to accommodate the necessary buffer tyre (TDF) and (C&I) wood chips stockpile on site at Berrima in order to cater for weekends. The intended onsite stockpile for TDF would be up to 350m³ and for C&I wood chips the onsite stockpile of 1,110m³.

The SWDF bales would be unloaded and stored in the SWDF building until required to be transferred by the SWDF material handling system to the Kiln 6. To cater for weekends, the intended onsite stockpile would include provision for 850 SWDF 1 m³ bales.

1.10 Traffic and Access

1.10.1 Existing Environment

Traffic travelling to and from the Cement Works use the following roads:

- Taylor Avenue – a local road that runs in an east-west direction and which connects Berrima Road in the east to Old Hume Highway in the west. It carries approximately 2,795 vehicles per day and provides a key link for the Cement Works with the majority of heavy vehicles using it to access the Hume Highway (M31 Motorway) to the west;
- Berrima Road – a RMS Main Road (MR372) that runs in a north-south direction and which connects Berrima in the north with Moss Vale in the south. It carries approximately 3,700 vehicles per day; and
- Hume Highway (M31 Motorway) – a national highway that runs in a generally north east-south west direction which connects the Sydney and Melbourne metropolitan area. It carries approximately 9,850 vehicles per day.

Existing site characteristics

The Cement Works operates 24 hours a day and seven days a week, however, a typical transport day occurs mainly for a 12-hour period during weekdays (4.00am to 4.00pm), and on Saturdays for a 6 hour period (7.00am to 1.00pm). Limited heavy traffic volumes are generated outside of these periods.

Access to the site is via :

- Gate 1: On Argyle Street, used for access to administration, reception and stores; and
- Gate 2: On Perth Street, used for all truck deliveries and dispatches.

A private railway line also operates through the site which enters the site at Berrima Road.

Existing traffic generation

An average total of 207 loads are required to be transported to and from the Cement Works daily. Due to the efficiency benefits of backloading trucks, whereby a truck arrives carrying a load of material (i.e. aggregate) and departs carrying a load of another material (i.e. clinker product), these 207 individual loads translates to only approximately 297 truck movements (arrival trips and departure trips) per weekday. It is also worth noting that raw materials, clinker and cement products are also delivered and dispatched via the privately operated railway line.

The 297 truck movements generally occur uniformly throughout an average 12-hour weekday, therefore on average the works site generates 24.8 movements (trips) per hour. There are 90 truck movements on Saturdays translating into an average of 15.0 movements (trips) per hour over the 6-hour operating period.

Deliveries and dispatches of materials by road to and from the Cement Works can be broken down as follows:

- deliveries of raw materials used for production of clinker and cement: 375,000 tonnes/year;
- deliveries of fuels for energy to operate the Kiln: 220,000 tonnes/year;
- dispatch of manufactured clinker: 300,000 tonnes/year; and
- dispatch of manufactured cement: 550,000 tonnes/year.

The majority of Cement Works truck traffic accesses the New Berrima area via the Hume Highway (M31 Motorway) to the west of the site. The remainder travel east along Berrima Road to the Concrete Plant in Moss Vale. To access the Hume Highway, trucks depart via Gate 2 and travel west through New Berrima along Taylor Avenue to the roundabout intersection at its western termination. From this roundabout, trucks travel either west along Medway Road or south west along the Old Hume Highway.

All additional waste fuel delivery truck traffic would use the same local truck routes as existing cement works trucks; that is, accessing the Hume Highway via Taylor Avenue and Medway Road or the Old Hume Highway. Accordingly, the proposal would not increase truck movements on roads that do not already support cement works trucks.

Proposed Operation Traffic

The proposal seeks to use solid waste fuel to supplement and partially replace the existing use of coal to generate energy for the operation of Kiln 6. Provision of up to 100,000 tonnes of solid waste fuel is proposed to be sourced per year, which would reduce the reliance on coal from 220,000 tonnes consumed per year to 170,000 tonnes. Due to the lower caloric value of the solid waste fuel compared to coal, an extra 50,000 tonnes of solid waste fuel would be required to service the existing energy needs of the site. The solid waste-derived fuels intended for Berrima would also have lower bulk density, translating into more trucks for the same tonnage. As a result there would be minor additional truck loads and movements to the site as a result of the proposed modification.

The changes to the existing truck movements as a result of the shift to waste derived fuel would be:

- coal and coke breeze: the reduction in coal required would result in five (5) fewer truck loads to 18 truckloads per day with 36 associated truck movements per day, a reduction from the 46 trips per typical weekday. On Saturdays, there would be approximately 18 trips; and
- waste derived fuel: the waste fuel is to be delivered by either truck and dog trailer vehicles or B-Double trucks with 24 tonne payload capacity. Based on this, 15 truckloads would need to be transported daily, resulting in 30 truck movements per day now needed. On Saturdays, there would be approximately 15 trips.

As staffing levels remain unchanged, no additional parking is required.

All heavy vehicle traffic, include deliveries of solid waste derived fuel, would be weighed upon site entry and exit.

Details of the existing operational traffic for the Berrima Cement Works and future operation traffic anticipated for the Cement Works following the proposed modification are summarised in **Table 11** along with the net increase in traffic volumes.

Table 11 Existing and proposed operational truck traffic

Scenario	12-hour weekday		6-hour Saturday	
	Daily	Hourly	Daily	Hourly
Existing (trucks)	297	24.8	90	15.0
Future (trucks)	317	26.4	100	16.7
Net increase (trucks)	20	1.6	10	1.7
Net increase (%)	6.7%	6.5%	11.1%	11.3%

The assessment indicates that the net increase in traffic generation as a result of the proposed modification would be:

- weekday: 20 additional trips on an average 12-hour working weekday, equivalent to 1.6 additional trucks per hour or an increase in truck trips of approximately 6.5%; and
- Saturday: 10 additional trips on an average 6-hour working Saturday, equivalent to 1.7 additional trucks per hour or an increase in truck trips of approximately 11.3%.

This demonstrates that the forecast increase in traffic generation as a result of the proposed modification would be minor.

As all additional waste fuel delivery truck traffic would use the same local truck routes as existing Cement Works trucks, the proposed modification would not lead to truck movements on roads that do not already support Cement Works trucks.

Details of the existing traffic flow volumes on Taylor Avenue (recorded by tube count survey) and the anticipated net increase in traffic as a result of the proposed modification are summarised in **Table 12**.

Table 12 Traffic implications for Taylor Avenue

Scenario	Weekday		Saturday	
	Daily	12-hour day,	Daily	6-hour day
Existing (vehicles)	2,795	2,025	1,866	698
Net increase (vehicles)	20	20	10	10
Net increase (%)	0.7%	1.0%	0.5%	1.4%

The assessment indicates that the impacts to Taylor Avenue traffic as a result of the proposed modification would be:

- weekday: An increase of just 1% in Taylor Avenue traffic volumes during the typical 12-hour working weekday and just 0.7% across all 24-hours on an average weekday; and
- Saturday: An increase of just 1.4% in Taylor Avenue traffic volumes during the typical 6-hour working Saturday and just 0.5% across all 24-hours of an average Saturday.

The increases in traffic on the local road network as a result of the proposed modification are of such a low order that they would have no material impact on the performance or safety of the local road network and therefore no external infrastructure upgrades are required.

2 RISK ASSESSMENT

2.1 Issue Identification

2.1.1 Community Chosen for Assessment

The communities chosen for the purposes of this assessment were the residents of New Berrima, Berrima, Burradoo and Moss Vale. The local communities in closest proximity to the cement works live in New Berrima (approximately 0.5 km), and the furthest live in Burradoo (approximately 5 km). Outside these population areas the land is rural in nature with scattered houses generally on farmland.

The location of the site in relation to New Berrima is shown in **Photograph 2**.

Photograph 2 Aerial photograph showing site proximity to New Berrima



2.1.2 Solid Waste Derived Fuels (SWDF)

Boral proposes two SWDF for use in the Kiln 6 subject of this modification (modification 9):

- Wood Waste - material left over from industrial processes like milling, furniture making, and building and construction; and
- Refuse Derived Fuel (RDF) - fuel made from the combustible materials recovered and processed from waste streams, such as papers, cardboards, packaging, and construction and demolition materials

Table 13 provides an indicative breakdown of the waste streams that make up Wood Waste and Refuse Derived Fuel based on information provided by potential suppliers. It should be noted that the actual breakdown could vary from the data presented here, depending on the final product specification prepared by each supplier and the ability to tailor the specification to the specific requirements of the Berrima site.

Table 13 Indicative breakdown of Solid Waste Derived Fuels waste streams

Wood Waste				Refuse Derived Fuel			
Supplier 1		Supplier 2		Supplier 1		Supplier 2	
Component	% (range)	Component	% (range)	Component	% (range)	Component	% (range)
Plastics	5-15%	Plastics and textiles	5-10%	Plastics	35%	Plastics	45% (+/- 15%)
Paper and cardboard	5- 20%	Furniture (lacquered / painted MDF and Wood	10-15%	Paper and Cardboard	20%	Paper / cardboard	35% (+/- 15%)
Wood	60-80%	Untreated boards	30-40%	Organic materials	14%	Wood	5-10%
Other (textiles, fines)	5-15%	MDF / chipboard	30-40%	Textiles	11%	Other	0-5%
				Other including fines	20%		

2.1.3 Potential Contaminant Emission Sources at the Cement Works

The source of potential contaminant release into the environment at the Berrima Cement Works can be divided into two broad classes, point sources, such as kiln number 6 stack, and fugitive sources from more diffuse sources such as that caused by truck movements. The list of potential point emission sources and controls has been set out below in **Table 14**.

Table 14 Potential emission sources – point sources and controls

Point Source	Description	Particulate Control Equipment
Kiln No 6 stack	Stack discharging exhaust gases from kiln	Full exhaust gas flow split between electrostatic precipitator (ESP) and bag filter
Cement Mill No 6	Vent discharging from side of Cement Building No 6	Bag filter
Kiln No 6 Cooler	Stack discharging large volume of air used to cool clinker after it comes out of kiln	Bag filter
Cement Mill No 7	Vent at end of a large duct coming out of the side of Cement Building No 7	Bag filter

Fugitive sources are more diffuse in nature and generally relate to activities. The reported fugitive sources were reported by Air Quality Professionals (2015) to be the following:

- Stockpiles of bulk dry materials such as coal, blue shale, yellow shale, steel or blast furnace slag, cement fibreboard, and gypsum.
- Trucks and loaders generating dust from vehicle tracks and movement of materials.

- Unpaved roads and dusty surfaces in stockpile areas.
- Quarry area.
- Crushing and mixing of materials prior to kiln processing.

The report went on to note the predicted new emission sources but concluded fugitive emissions of odour from within the storage building are the only potential new air emission identified within the Project. This conclusion was based on the design of the new storage and handling facilities. A key control feature of this was that the SWDF was wrapped in plastic for transport to the works and only unwrapped once inside the storage building. Details of the proposed design features have been set out previously in the current report section 1.9.7.

2.1.4 Emissions from the Co-Processing of SWDF in Cement Kilns

The European Commission (2013) Industrial Emissions Directive 2010/75/EU sets out a general indicative list of the main air-polluting substances to be taken into account, if they are relevant for fixing emission limit values, for the co-processing of waste derived fuels such as SWDF in cement kilns.

Emissions relevant to cement manufacture including the use of waste are:

- Oxides of nitrogen (NO_x) and other nitrogen compounds
- Sulphur dioxide (SO₂) and other sulphur compounds
- Dust
- Total organic compounds (TOC) including volatile organic compounds (VOC)
- Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD and PCDF) (dioxins and furans)
- Metals and their compounds
- Hydrogen fluoride (HF)
- Hydrogen chloride (HCl)
- Carbon monoxide (CO)

2.1.5 Conceptual Site Model

Conceptual Site Model (CSM) uses the concept of the links between source – pathway – receptor to assess risk. This can include the source of Contaminants of Potential Concern (COPC) which may impact on the communities in question and transport mechanisms whereby COPC can be moved to exposure points (human receptors). If any of these links are missing then an exposure pathway is incomplete and human exposure will not occur. If the exposure pathway is potentially complete then likely impact on the receptor may need to be assessed.

The CSM development indicated that following factors:

- Potential COPCs

- The release mechanism whereby the COPCs may be released into the environment
- The transport pathways moving the COPCs through the environment
- Exposure pathways
- Exposure Routes whereby the a person takes in the COPC
- Location of potential receptors
- Significant pathways by which exposure may occur
- Minimal exposure pathways, considered as less likely to led to human exposure
- Primary exposure pathways considered to be the pathway by which the largest quantities of emissions of a identified COPC move
- Secondary exposure pathways considered to be the pathway by which lessor quantities (compared to the Primary exposure pathway) of the emissions of a identified COPC move

The Primary exposure pathway relating to the operations of the Berrima Cement works were determined to be via the airborne pathway. This was due to the anticipated mass of airborne COPC emissions being the dominate source for both point sources (such as the kiln and fugitive sources. The Secondary exposure pathway was considered to be the indirect pathway in which COPC emissions are transported off site through environmental forces such as wind, the COPC then settle into dusts or soils and are subsequently remobilised when the soil or dusts are disturbed, at which point human exposure may take place.

The Primary exposure pathway can be relatively easily quantified through the combination of site specific data such as both background and process specific measurements, coupled with COPC concentration estimates derived from the air quality modelling. Thus any increase in risk associated with the proposed modifications may be quantified.

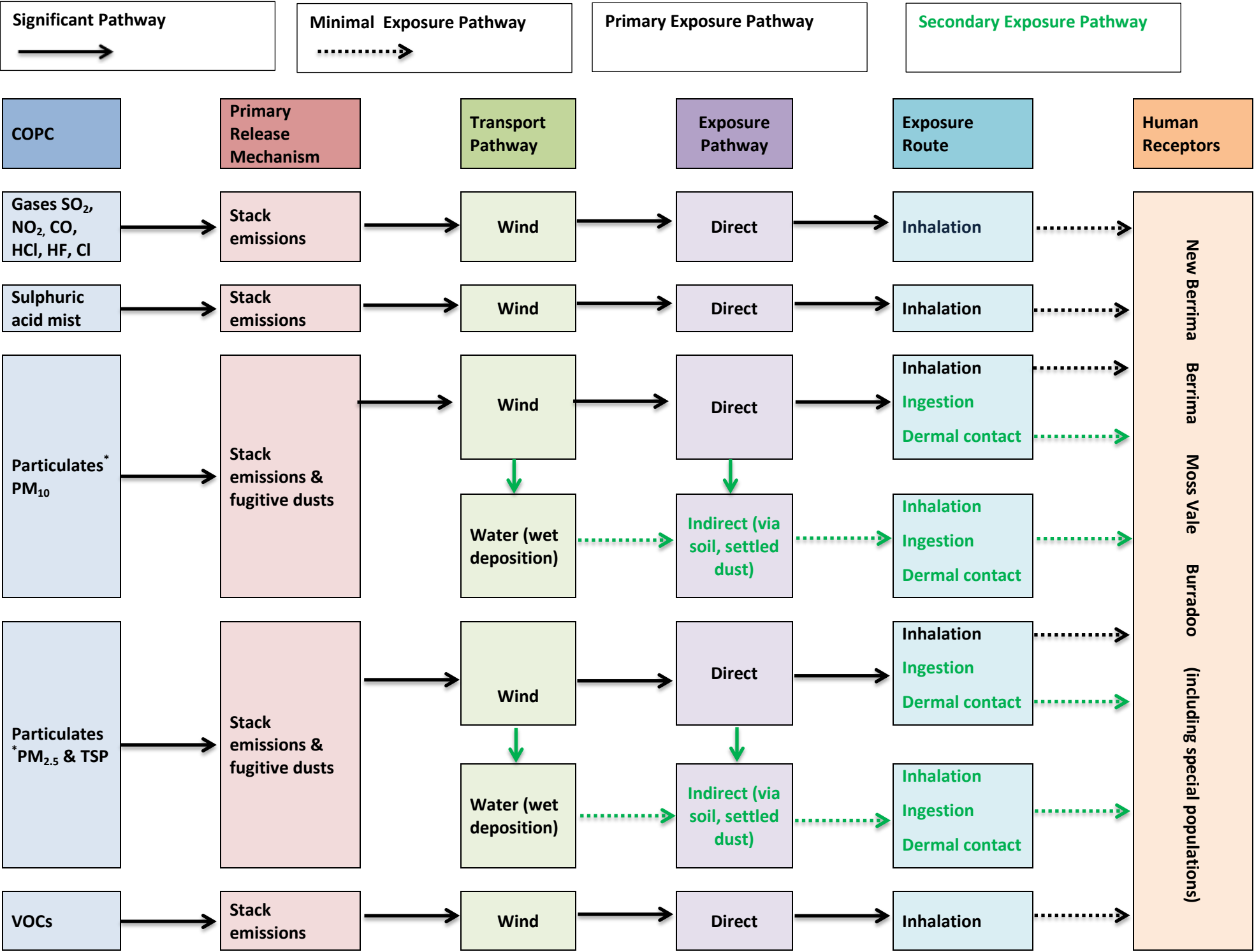
In contrast, there is a lack of data relevant to the Secondary exposure pathways. For example regarding particulate associated COPCs, such as heavy metals where the ultimate environmental sink is soil, sediments or settled dusts there appears to be no available data relating to existing soil concentrations of COPCs in the local communities, or in settled dusts within residences or on food crops such as home grown vegetables. Nor is there data related to particle size and particle deposition in the air quality monitoring and air quality modelling. Accordingly accurately quantifying Secondary exposure pathways is not possible.

What can be said about Secondary exposure pathways is that if the proposed modifications do not lead to significant changes in the emission of particulate associated COPCs compared to emissions from the existing processes then there should be no increase in risk from Secondary exposure pathways to the local communities associated with the proposed modifications.

The CSM diagram has been set out in **Figure 10**.

Figure 10 Conceptual Site Model - Berrima Cement Works

Figure 10 Conceptual Site Model - Berrima Cement Works



Note * Includes particle associated COPCs such as dioxins, PAHs & heavy metals

2.1.6 Contaminants of Potential Concern (COPC)

The groups of substances relevant to the Co-Processing of SWDF in Boral Kiln 6 were detailed in *Boral Cement Berrima Works Use of Solid Waste Derived Fuels in Kiln 6 Air Quality Assessment* (Air Quality Professionals, 2015). These groups of substances form the COPC for the health risk assessment and have been set out below in **Table 15**.

Table 15 Contaminants of Potential Concern (COPC), sources and potential exposure pathways

COPC	Source	Exposure Transport Pathways or Environmental Sink	Exposure Routes [#]
Fine Particulates PM ₁₀ and PM _{2.5}	Combustion processes and dry goods handling / milling processes	airborne	Inhalation Ingestion
Sulphur dioxide	Combustion processes	airborne	Inhalation
Nitrogen oxides	Combustion processes	airborne	Inhalation
Carbon monoxide	Combustion processes	airborne	Inhalation
Volatile organic compounds VOCs	Combustion processes and dry goods handling / milling processes	airborne	Inhalation
Polycyclic aromatic hydrocarbons PAHs	Combustion processes and dry goods handling / milling processes	airborne & soils	Inhalation Ingestion Dermal absorption
Heavy metals	Combustion processes and dry goods handling / milling processes	airborne & soils	Inhalation Ingestion Dermal absorption
Hydrogen halides – hydrogen chloride, hydrogen fluoride, chlorine	Combustion processes	airborne	Inhalation
Sulphuric acid mist / sulphur trioxide	Combustion processes	airborne	Inhalation
Dioxins	Combustion processes and dry goods handling / milling processes	airborne & soils	Inhalation Ingestion Dermal absorption

Note [#] Examples of these exposure Pathways and Routes are listed below:

Inhalation – Inhalation of airborne gases and particulates from point sources like Kiln 6 or fugitive sources. This is a primary route of potential exposure highlighted in **Table 15**.

Ingestion – Ingestion of particulate matter, from point sources like Kiln 6 or fugitive sources, either travelling directly from the source to the receptor or indirectly where the particulates have settled into settled dust or soils then are ingested through contamination of food, drink or through poor hygiene practices. This is the secondary route of potential exposure highlighted in **Table 15**.

Dermal Absorption – Absorption into the body through skin after contact with contaminated particulates either travelling directly from the source to the receptor or indirectly where the particulates have settled into dust or soils then are ingested through contamination of food, drink or through poor hygiene practices. This is a secondary route of potential exposure highlighted in **Table 15**.

2.1.7 Exposure Concepts

To assess the potential health impact of a COPC on a population the exposure can be assessed in two broad concepts, acute exposure and chronic exposure.

Acute exposure refers to short term exposures of up to 14 days, often with immediate effects on the exposed individuals. This may be due to the inherent toxicity of a contaminant or the physiological response the contaminate elicits such as irritation to an individual's airways.

Examples of parameters used to assess acute exposure can include peak concentrations of a contaminate, predicted 24 hour average concentrations and the like.

Chronic exposure refers to long term exposures based on exposure all day every day for a lifetime. An example of a parameter used to assess chronic exposure is the annual average concentrations of air pollutants.

2.1.8 Fine Particulates

Fine particulates refer to any particles likely to be potentially airborne. In terms of human health risk, the issues may arise from physical damage to the respiratory system from inhaled particles. Total Suspended Particulates (TSP) includes particles with an approximate aerodynamic diameter of 50µm and less. Particles at the larger end of this size range may be inhaled but do not as a rule penetrate far into the respiratory system. Accordingly the larger particulates may have little role in health impacts associated with inhaled particulates. The smaller particles such as PM₁₀ and PM_{2.5} are more of a health hazard as their size allows the particle to penetrate deeply into the respiratory system. Aside from physical damage, the particulates may also act as carriers of chemical contaminants, bound to the particulates, transporting the chemical into the lungs where absorption of the chemical into the body is more likely or into the gut if contaminated particulates are ingested. The current study will focus on the potential health impacts associated with the smaller particles (PM₁₀ and PM_{2.5}) that can potentially penetrate deep in to the lungs and therefore have the greatest potential for adverse health impacts.

Air Quality Professionals (2015) state that the particulate matter discharged from various sources at the site, including Kiln 6 and Cement Mill stacks as well as stockpiles and open sources, will be comprised of a variety of size fractions that will vary for each source. These size fractions are listed as:

- Larger depositable dust generally greater than 50µm in diameter.
- Total Suspended Particulates (TSP), which is finer than the depositional dust.
- PM₁₀, that is the fraction of TSP less than 10µm in diameter
- PM_{2.5}, that is the fraction of TSP less than 2.5µm in diameter

The report goes on to comment that Kiln 6 and Cement Mill stacks are fitted with particulate control equipment that traps the majority of depositable dusts. Thus the majority of the particulates discharged from these stacks are likely to be in the PM₁₀ and PM_{2.5} size range. Annual stack testing of the existing facility between 2011, 2013 & 2014 has confirmed this showing the particulate emissions to consist of approximately 61-74% PM₁₀ and 30-33% PM_{2.5}.

2.1.8.1 National Airborne Particulates Air Quality Goals and Health Based Criteria.

The current national air quality goals for particulates were set with a view to be protective of health and achievable for industry, based on the scientific evidence available at the time of setting the goals. With the advancement of scientific knowledge, there has been some debate as to whether the national goals need to be revised and on the adequacy of current national air quality goals for particulate matter for health risk assessments. The review by NEPC (2011) reported current national air standards were not meeting the requirements for adequate protection of human health. The review further commented that there was substantial new evidence on both short-term and long-term effects for particles (PM₁₀ and PM_{2.5}) associated with increases in mortality and morbidity, with much stronger evidence now for cardiovascular outcomes. Therefore it is likely that future revision of the goals may lead to a lowering of the acceptable concentrations for PM₁₀ and PM_{2.5}.

It is widely considered there is no lower threshold concentrations for the health effects of air pollution. That is to say there is no known lower limit threshold concentrations below which health impacts will definitely not occur in sensitive individuals. This does not mean that health impacts will definitely occur rather it indicates there may be a risk to health and that the risk of an incidence of adverse health impact will decrease as the concentrations of PM₁₀ and PM_{2.5} decrease. Therefore there may be some residual health risk associated with national air quality standards (NEPC, 2010). The question then becomes what is an acceptable level of health risk? This will be discussed below.

The current national air quality goals for airborne particulates have been set out below in **Table 16**.

Table 16 Particulate Matter Air Quality Goals

Particulate Class	Averaging Period	Goal (µg/m ³)
TSP	Annual	90 [#]
PM ₁₀	24 hours	50* (maximum of 5 days exceedances per year)
	Annual	30*
PM _{2.5}	24 hours	25*
	Annual	8*

* NEPC (2003), [#] DEC (2005)

The current national air quality goals are set as total airborne particulates concentrations. Referred to as cumulative airborne particulate concentrations in air quality modelling predictions. Comparison of total airborne particulate concentrations, over the relevant averaging periods such as 24 hours or annual averages, to standards or goals can demonstrate potential for health risks. However, the natural fluctuations in background concentrations can make it difficult to determine the extent of potential risks associated with particulate emissions from a proposed development. That is, the additional contribution locally to the already existing health risks from airborne particulates in a particular geographical area.

The accepted method to investigate additional contribution to health risk from airborne particulates, as PM₁₀ and PM_{2.5}, is to determine the increase in risk associated with the increase in airborne particulates (PM₁₀ and PM_{2.5}) predicted from a proposed development. In this, the predicted incremental airborne particulates concentrations from modelling, that is the likely change in local concentrations caused by the proposed development are utilised rather than the predicted total concentrations. Established risk calculations are used to determine the potential increase in health risk to a community. The basis of these risk calculations have been set out in **Appendix A**.

The quantification of risk is an imprecise practise, based on available evidence, estimating level of risk within generally accepted ranges rather than absolute risk. The level of negligible / acceptable risk is generally considered to be less than 1 in 1,000,000 (i.e 1×10^{-6}) for contaminants with health effects considered to non-threshold in nature or carcinogenic chemicals (enHealth, 2012). At this level of risk, it is considered essentially non-existent. The level of risk is considered unacceptable at greater than 1 in 10,000 (1×10^{-4}). Tolerable risk occurs in the range between 1×10^{-6} and 1×10^{-4} (DEC, 2005). Tolerable risks are considered acceptable when best practise for minimising air toxics has been utilised.

2.1.8.2 TSP

As previously stated, it is the finer particles in TSP (PM₁₀ and PM_{2.5}) that are associated with health impacts. Accordingly the current health risk assessment will focus on the PM₁₀ and PM_{2.5} size particles in the next sections.

However with regards to the TSP it was noted that the predicted cumulative annual average concentrations were reported to be all below the Approved Methods assessment criteria of 90 $\mu\text{g}/\text{m}^3$ at each of the discrete receptors with the highest concentration being 15.2 $\mu\text{g}/\text{m}^3$ at Receptor 75 (Air Quality Professionals, 2015).

Furthermore the authors considered the predictions to be highly conservative in nature, stating that:

In addition, TSP concentrations occurring beyond the site boundary due to emissions from the Works are very insensitive to changes in TSP emission rates from the Kiln 6 stack.

The model results and calculated cumulative GLCs (Ground Level Concentrations) are very conservative as the model was run using a constant (365 days per year, 24 hours per day) 1-hour average emission concentration that represents the peak 1-hour average concentration that might occur within the maximum 24-hour average concentration proposed in the EPL modification for the burning of NSF.

Therefore it is concluded that adverse air quality impacts will not arise due to TSP emissions due to the Project.

2.1.8.3 PM₁₀

Cumulative Concentrations PM₁₀

The modelling of Air Quality Professionals (2015) concluded that there will be no adverse changes in annual average PM₁₀ concentrations, due to the Project, stating that:

Cumulative annual average concentrations of PM₁₀ from both fugitive and point sources at the Works, including background concentrations, are below the Approved Methods assessment criteria of 30 $\mu\text{g}/\text{m}^3$ at each of the discrete receptors even with the conservative assumption that the Works operates continuously for 365 days per year.

However, with regards to PM₁₀ 24 hour average concentrations the report found some exceedances, stating that:

For most of the discrete receptors, no additional exceedances of the 24-hour average PM₁₀ air quality criteria are generated due to PM₁₀ emissions from the Works. However a small number of discrete receptors near the site boundary do show some possible additional exceedances. For receptors 23 and 57, GLC exceedances are highly dependent on background data. For receptors 75 and 88, and to an extent receptor 57 as well, the number of cumulative GLCs exceeding 50 µg/m³ is highly dependent on the modelled incremental concentrations, and therefore highly dependent on the magnitude of the fugitive dust concentrations. Those fugitive dust concentrations are considered to be over-estimates of actual maximum incremental GLCs at receptors close to the site boundary because of the assumptions required for the fugitive dust dispersion analysis. In most cases, the cumulative GLCs that exceed 50 µg/m³ are only 10-20% greater than that threshold concentration, so overestimates of fugitive dust concentrations will play a large role in the number of predicted exceedances.

The receptors potentially affected by the exceedances have been set below in **Table 17** and are also displayed on **Figure 6**. Receptor 88, which is not noted on Figure 6, is located on the corner of corner of Howard St and Taylor Ave New Berrima.

Table 17 Location of potentially impacted receptors in relation to Berrima Cement Works

Receptor	Approximate Distance from Site Boundary	Direction from Site
23	790m	south west
57	1000m	north east
75	700m	north west
88	300m	north

To put the exceedances attributed to the facility in perspective, it should be noted these exceedances are similar in number but at lower concentrations (maximum 69.7µg/m³) than exceedances due to general environmental conditions excluding the influence of the facility (maximum 177.5µg/m³).

Fugitive dust from the works has been determined as the main source of airborne dust as PM₁₀ exceedances attributed to the facility. However, background environmental conditions (excluding dust emissions from the facility) are predicted to give rise to PM₁₀ 24 hour averages approximately eight times greater than those attributed to the facility alone.

The predicted exceedances of PM₁₀ 24 hour average concentrations and frequency have been set out below in **Table 18**.

Table 18 Dust PM₁₀ Emissions from Berrima Plant that may exceed regulatory criteria

Airborne Pollutant	Regulatory Criteria	Predicted Concentrations at Ground Level	Comments
Dust PM ₁₀ 24 hour average – Additional exceedances beyond background	50µg/m ³ GLC* Maximum of 5 exceedances per year	50 – 69.7µg/m ³ When background environmental dust levels are less than 47µg/m ³	Ground level receptors, limited number affected near boundary (R23, R57, R75, R88). Source expected to be fugitive dust not kiln emissions. Frequency 2 to 5 times per year.
Dust PM ₁₀ 24 hour average Background exceedances due to environmental conditions	50µg/m ³ GLC*	52 – 177.5µg/m ³ Background environmental dust levels only	Ground level receptors, near boundary (R23, R57, R75, R88). Source background dust unrelated to Berrima Plant. Frequency 2 to 7 times per year.

2.1.8.4 PM_{2.5}

Cumulative Concentrations PM_{2.5}

The modelling of Air Quality Professionals (2015) concluded that with regards to PM_{2.5} concentrations there will be no effective change to off-site local air quality impacts of PM_{2.5} due to the Project, stating that:

Cumulative annual average concentrations of PM_{2.5} from both fugitive and point sources at the Works, including background concentrations, are below the Approved Methods assessment criteria of 8 µg/m³ at each of the discrete receptors even with the conservative assumption that the Works operates continuously for 365 days per year.

24-Hour average - No additional exceedances of the NSW EPA criteria arise from the cumulative assessment of PM_{2.5} emissions from the site combined with contemporaneous background data. Therefore it is concluded that adverse air quality impacts will not arise from 24-hour average PM_{2.5} concentrations due to the Project.

2.1.8.5 Health Risk Assessment of Changes in PM₁₀ & PM_{2.5} Concentrations

As discussed above in 2.1.8.1 while the current NEPC (2003) air quality goals for PM₁₀ and PM_{2.5} were established to be protective of health it is widely recognised concentrations below these levels may impact on health. Moreover the natural background fluctuations unrelated to a Project also may impact on health outcomes in the community. Therefore to determine if the Project will generate changes in PM₁₀ and PM_{2.5} community exposure that may impact on community health, risk assessments were undertaken based on the incremental changes predicted at the Receptors identified in the air quality report.

The quantified risk assessment of predicted incremental increases in total PM₁₀ and PM_{2.5} concentrations combining all point sources and fugitive sources, based on annual average concentrations, (maximums: PM₁₀ = 5.2 µg/m³; PM_{2.5} = 1 µg/m³) found that the risks were in the negligible (risk = ≤ 1 x 10⁻⁶) to tolerable risks (risk = ≤ 1 x 10⁻⁴ to ≥ 1 x 10⁻⁶) range at most Receptor locations. That is, risks may be considered acceptable when best practise for minimising air toxics have been utilised. However seven Receptor locations were found to have potentially unacceptable risks (risk = ≥ 1 x 10⁻⁴) with regards to PM_{2.5} particulates (six Receptors risk = 1 x 10⁻⁴ & one Receptors risk = 2 x 10⁻⁴). This equates to 1 – 2 extra incidents of the chosen health endpoints per population of 10,000 people.

The reported maximum incremental increases in total PM₁₀ and PM_{2.5} at locations other than Receptors, based on annual average concentrations, (maximums: PM₁₀ = 18 µg/m³; PM_{2.5} = 3 µg/m³, source: personal communications Air Quality Professionals to SLR 19/1/16), found at these concentrations there were potentially unacceptable risks (risk = $\geq 1 \times 10^{-4}$) with regards to PM_{2.5} particulates (risk = 1×10^{-4} & 2×10^{-4}). This equates to 1 – 2 extra incidents of the chosen health endpoints per population of 10,000 people. However, it should be noted that the location of these maximum concentrations was just outside a small section of the western boundary of the site and not in an area of habitation. As such, it is unlikely to be a realistic exposure scenario for the community.

It appears that much of the incremental increases in total PM₁₀ and PM_{2.5} may be due to fugitive dusts not linked to the proposed modification, rather than point sources associated with the proposed operation of the kiln. The incremental increases in total PM₁₀ and PM_{2.5} are considered to be conservative. Boral is proposing to undertake additional PM₁₀ monitoring between the possible sources of fugitive dust and the New Berrima village in order to validate the model predictions and the potential health risks and inform any further plans to reduce potential fugitive dust emissions. It is proposed to include this in the modified consent.

The potential risk caused by changes in PM₁₀ & PM_{2.5} associated with the Project was assessed as set out above in **2.1.8.1**. The results of the assessments have been set out in **Table 19**.

Table 19 Summary of incremental risks for exposure at off site receptors from PM₁₀ & PM_{2.5} from fugitive dusts & combined point sources,

Particulate Fraction	PM2.5	PM2.5	PM2.5	PM10	PM2.5	PM2.5	PM2.5	PM2.5
Health Endpoint	Mortality - All causes Long Term ≥ 30 years	Hospitalisations - Cardiovascular Short Term ≥ 65 years	Hospitalisations - Respiratory Short Term ≥ 65 years	Mortality - All causes Short Term all ages	Mortality - All causes Short Term all ages	Mortality - Cardiopulmonary Long Term ≥ 30 years	Mortality - Cardiovascular Short Term all ages	Mortality - Respiratory Short Term all ages
Receptor	Risk	Risk	Risk	Risk	Risk	Risk	Risk	Risk
Maximum	6 x 10⁻⁵	2 x 10⁻⁴	4 x 10⁻⁵	2 x 10⁻⁵	6 x 10⁻⁶	6 x 10⁻⁵	2 x 10⁻⁶	1 x 10⁻⁶
1	7 x 10 ⁻⁶	2 x 10 ⁻⁵	4 x 10 ⁻⁶	2 x 10 ⁻⁶	7 x 10 ⁻⁷	7 x 10 ⁻⁶	2 x 10 ⁻⁷	1 x 10 ⁻⁷
2	9 x 10 ⁻⁶	3 x 10 ⁻⁵	5 x 10 ⁻⁶	2 x 10 ⁻⁶	9 x 10 ⁻⁷	9 x 10 ⁻⁶	2 x 10 ⁻⁷	2 x 10 ⁻⁷
3	1 x 10 ⁻⁵	3 x 10 ⁻⁵	6 x 10 ⁻⁶	2 x 10 ⁻⁶	1 x 10 ⁻⁶	1 x 10 ⁻⁵	3 x 10 ⁻⁷	2 x 10 ⁻⁷
4	1 x 10 ⁻⁵	4 x 10 ⁻⁵	7 x 10 ⁻⁶	3 x 10 ⁻⁶	1 x 10 ⁻⁶	1 x 10 ⁻⁵	3 x 10 ⁻⁷	2 x 10 ⁻⁷
5	1 x 10 ⁻⁵	3 x 10 ⁻⁵	6 x 10 ⁻⁶	3 x 10 ⁻⁶	1 x 10 ⁻⁶	1 x 10 ⁻⁵	3 x 10 ⁻⁷	2 x 10 ⁻⁷
6	1 x 10 ⁻⁵	3 x 10 ⁻⁵	6 x 10 ⁻⁶	3 x 10 ⁻⁶	1 x 10 ⁻⁶	1 x 10 ⁻⁵	3 x 10 ⁻⁷	2 x 10 ⁻⁷
7	1 x 10 ⁻⁵	4 x 10 ⁻⁵	7 x 10 ⁻⁶	3 x 10 ⁻⁶	1 x 10 ⁻⁶	1 x 10 ⁻⁵	3 x 10 ⁻⁷	2 x 10 ⁻⁷
8	1 x 10 ⁻⁵	4 x 10 ⁻⁵	8 x 10 ⁻⁶	4 x 10 ⁻⁶	1 x 10 ⁻⁶	1 x 10 ⁻⁵	4 x 10 ⁻⁷	2 x 10 ⁻⁷
9	1 x 10 ⁻⁵	4 x 10 ⁻⁵	8 x 10 ⁻⁶	3 x 10 ⁻⁶	1 x 10 ⁻⁶	1 x 10 ⁻⁵	3 x 10 ⁻⁷	2 x 10 ⁻⁷
10	1 x 10 ⁻⁵	4 x 10 ⁻⁵	8 x 10 ⁻⁶	3 x 10 ⁻⁶	1 x 10 ⁻⁶	1 x 10 ⁻⁵	3 x 10 ⁻⁷	2 x 10 ⁻⁷
11	2 x 10 ⁻⁵	5 x 10 ⁻⁵	9 x 10 ⁻⁶	4 x 10 ⁻⁶	2 x 10 ⁻⁶	2 x 10 ⁻⁵	4 x 10 ⁻⁷	3 x 10 ⁻⁷
12	2 x 10 ⁻⁵	6 x 10 ⁻⁵	1 x 10 ⁻⁵	5 x 10 ⁻⁶	2 x 10 ⁻⁶	2 x 10 ⁻⁵	5 x 10 ⁻⁷	4 x 10 ⁻⁷
13	2 x 10 ⁻⁵	5 x 10 ⁻⁵	1 x 10 ⁻⁵	5 x 10 ⁻⁶	2 x 10 ⁻⁶	2 x 10 ⁻⁵	5 x 10 ⁻⁷	3 x 10 ⁻⁷
14	2 x 10 ⁻⁵	6 x 10 ⁻⁵	1 x 10 ⁻⁵	5 x 10 ⁻⁶	2 x 10 ⁻⁶	2 x 10 ⁻⁵	5 x 10 ⁻⁷	3 x 10 ⁻⁷
15	2 x 10 ⁻⁵	7 x 10 ⁻⁵	1 x 10 ⁻⁵	7 x 10 ⁻⁶	2 x 10 ⁻⁶	2 x 10 ⁻⁵	6 x 10 ⁻⁷	4 x 10 ⁻⁷
16	2 x 10 ⁻⁵	7 x 10 ⁻⁵	1 x 10 ⁻⁵	7 x 10 ⁻⁶	2 x 10 ⁻⁶	2 x 10 ⁻⁵	6 x 10 ⁻⁷	4 x 10 ⁻⁷
17	2 x 10 ⁻⁵	6 x 10 ⁻⁵	1 x 10 ⁻⁵	6 x 10 ⁻⁶	2 x 10 ⁻⁶	2 x 10 ⁻⁵	5 x 10 ⁻⁷	3 x 10 ⁻⁷

Particulate Fraction	PM2.5	PM2.5	PM2.5	PM10	PM2.5	PM2.5	PM2.5	PM2.5
Health Endpoint	Mortality - All causes Long Term ≥ 30 years	Hospitalisations - Cardiovascular Short Term ≥ 65 years	Hospitalisations - Respiratory Short Term ≥ 65 years	Mortality - All causes Short Term all ages	Mortality - All causes Short Term all ages	Mortality - Cardiopulmonary Long Term ≥ 30 years	Mortality - Cardiovascular Short Term all ages	Mortality - Respiratory Short Term all ages
Receptor	Risk	Risk	Risk	Risk	Risk	Risk	Risk	Risk
18	1×10^{-5}	3×10^{-5}	6×10^{-6}	4×10^{-6}	1×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-7}
19	1×10^{-5}	3×10^{-5}	6×10^{-6}	4×10^{-6}	1×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-7}
20	2×10^{-5}	6×10^{-5}	1×10^{-5}	7×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	3×10^{-7}
21	2×10^{-5}	7×10^{-5}	1×10^{-5}	7×10^{-6}	2×10^{-6}	2×10^{-5}	6×10^{-7}	4×10^{-7}
22	4×10^{-5}	1×10^{-4}	2×10^{-5}	1×10^{-5}	4×10^{-6}	4×10^{-5}	1×10^{-6}	6×10^{-7}
23	4×10^{-5}	1×10^{-4}	2×10^{-5}	1×10^{-5}	4×10^{-6}	4×10^{-5}	1×10^{-6}	7×10^{-7}
24	3×10^{-5}	9×10^{-5}	2×10^{-5}	1×10^{-5}	3×10^{-6}	3×10^{-5}	8×10^{-7}	5×10^{-7}
25	2×10^{-5}	6×10^{-5}	1×10^{-5}	7×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	3×10^{-7}
26	3×10^{-5}	8×10^{-5}	2×10^{-5}	1×10^{-5}	3×10^{-6}	3×10^{-5}	7×10^{-7}	5×10^{-7}
27	3×10^{-5}	9×10^{-5}	2×10^{-5}	1×10^{-5}	3×10^{-6}	3×10^{-5}	7×10^{-7}	5×10^{-7}
28	2×10^{-5}	7×10^{-5}	1×10^{-5}	9×10^{-6}	2×10^{-6}	2×10^{-5}	6×10^{-7}	4×10^{-7}
29	2×10^{-5}	6×10^{-5}	1×10^{-5}	7×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	3×10^{-7}
30	6×10^{-6}	2×10^{-5}	4×10^{-6}	2×10^{-6}	6×10^{-7}	6×10^{-6}	2×10^{-7}	1×10^{-7}
31	6×10^{-6}	2×10^{-5}	4×10^{-6}	2×10^{-6}	6×10^{-7}	6×10^{-6}	2×10^{-7}	1×10^{-7}
32	8×10^{-6}	2×10^{-5}	5×10^{-6}	3×10^{-6}	8×10^{-7}	8×10^{-6}	2×10^{-7}	1×10^{-7}
33	1×10^{-5}	4×10^{-5}	7×10^{-6}	4×10^{-6}	1×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-7}
34	2×10^{-5}	6×10^{-5}	1×10^{-5}	7×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	3×10^{-7}
35	2×10^{-5}	5×10^{-5}	1×10^{-5}	7×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	3×10^{-7}
36	2×10^{-5}	5×10^{-5}	1×10^{-5}	7×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	3×10^{-7}
37	3×10^{-5}	8×10^{-5}	1×10^{-5}	1×10^{-5}	3×10^{-6}	3×10^{-5}	7×10^{-7}	4×10^{-7}

Particulate Fraction	PM2.5	PM2.5	PM2.5	PM10	PM2.5	PM2.5	PM2.5	PM2.5
Health Endpoint	Mortality - All causes Long Term ≥ 30 years	Hospitalisations - Cardiovascular Short Term ≥ 65 years	Hospitalisations - Respiratory Short Term ≥ 65 years	Mortality - All causes Short Term all ages	Mortality - All causes Short Term all ages	Mortality - Cardiopulmonary Long Term ≥ 30 years	Mortality - Cardiovascular Short Term all ages	Mortality - Respiratory Short Term all ages
Receptor	Risk	Risk	Risk	Risk	Risk	Risk	Risk	Risk
38	2×10^{-5}	7×10^{-5}	1×10^{-5}	9×10^{-6}	2×10^{-6}	2×10^{-5}	6×10^{-7}	4×10^{-7}
39	2×10^{-5}	6×10^{-5}	1×10^{-5}	8×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	4×10^{-7}
40	2×10^{-5}	5×10^{-5}	1×10^{-5}	6×10^{-6}	2×10^{-6}	2×10^{-5}	4×10^{-7}	3×10^{-7}
41	3×10^{-5}	8×10^{-5}	1×10^{-5}	9×10^{-6}	3×10^{-6}	3×10^{-5}	7×10^{-7}	4×10^{-7}
42	2×10^{-5}	5×10^{-5}	9×10^{-6}	5×10^{-6}	2×10^{-6}	2×10^{-5}	4×10^{-7}	3×10^{-7}
43	1×10^{-5}	4×10^{-5}	8×10^{-6}	5×10^{-6}	1×10^{-6}	1×10^{-5}	4×10^{-7}	2×10^{-7}
44	1×10^{-5}	4×10^{-5}	7×10^{-6}	4×10^{-6}	1×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-7}
45	1×10^{-5}	3×10^{-5}	6×10^{-6}	3×10^{-6}	1×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-7}
46	9×10^{-6}	3×10^{-5}	5×10^{-6}	3×10^{-6}	9×10^{-7}	9×10^{-6}	2×10^{-7}	2×10^{-7}
47	8×10^{-6}	2×10^{-5}	4×10^{-6}	2×10^{-6}	8×10^{-7}	8×10^{-6}	2×10^{-7}	1×10^{-7}
48	7×10^{-6}	2×10^{-5}	4×10^{-6}	2×10^{-6}	7×10^{-7}	7×10^{-6}	2×10^{-7}	1×10^{-7}
49	7×10^{-6}	2×10^{-5}	4×10^{-6}	2×10^{-6}	7×10^{-7}	7×10^{-6}	2×10^{-7}	1×10^{-7}
50	6×10^{-6}	2×10^{-5}	3×10^{-6}	1×10^{-6}	6×10^{-7}	6×10^{-6}	1×10^{-7}	1×10^{-7}
51	7×10^{-6}	2×10^{-5}	4×10^{-6}	1×10^{-6}	7×10^{-7}	7×10^{-6}	2×10^{-7}	1×10^{-7}
52	6×10^{-6}	2×10^{-5}	4×10^{-6}	1×10^{-6}	6×10^{-7}	6×10^{-6}	2×10^{-7}	1×10^{-7}
53	2×10^{-5}	5×10^{-5}	9×10^{-6}	4×10^{-6}	2×10^{-6}	2×10^{-5}	4×10^{-7}	3×10^{-7}
54	2×10^{-5}	4×10^{-5}	9×10^{-6}	4×10^{-6}	2×10^{-6}	2×10^{-5}	4×10^{-7}	3×10^{-7}
55	4×10^{-5}	1×10^{-4}	2×10^{-5}	1×10^{-5}	4×10^{-6}	4×10^{-5}	1×10^{-6}	7×10^{-7}
56	4×10^{-5}	1×10^{-4}	2×10^{-5}	1×10^{-5}	4×10^{-6}	4×10^{-5}	9×10^{-7}	6×10^{-7}
57	6×10^{-5}	2×10^{-4}	4×10^{-5}	2×10^{-5}	6×10^{-6}	6×10^{-5}	2×10^{-6}	1×10^{-6}

Particulate Fraction	PM2.5	PM2.5	PM2.5	PM10	PM2.5	PM2.5	PM2.5	PM2.5
Health Endpoint	Mortality - All causes Long Term ≥ 30 years	Hospitalisations - Cardiovascular Short Term ≥ 65 years	Hospitalisations - Respiratory Short Term ≥ 65 years	Mortality - All causes Short Term all ages	Mortality - All causes Short Term all ages	Mortality - Cardiopulmonary Long Term ≥ 30 years	Mortality - Cardiovascular Short Term all ages	Mortality - Respiratory Short Term all ages
Receptor	Risk	Risk	Risk	Risk	Risk	Risk	Risk	Risk
58	2×10^{-5}	6×10^{-5}	1×10^{-5}	6×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	4×10^{-7}
59	2×10^{-5}	7×10^{-5}	1×10^{-5}	6×10^{-6}	2×10^{-6}	2×10^{-5}	6×10^{-7}	4×10^{-7}
60	3×10^{-5}	8×10^{-5}	1×10^{-5}	7×10^{-6}	3×10^{-6}	3×10^{-5}	7×10^{-7}	4×10^{-7}
61	2×10^{-5}	6×10^{-5}	1×10^{-5}	5×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	4×10^{-7}
62	2×10^{-5}	5×10^{-5}	9×10^{-6}	5×10^{-6}	2×10^{-6}	2×10^{-5}	4×10^{-7}	3×10^{-7}
63	2×10^{-5}	4×10^{-5}	9×10^{-6}	4×10^{-6}	2×10^{-6}	2×10^{-5}	4×10^{-7}	3×10^{-7}
64	1×10^{-5}	4×10^{-5}	7×10^{-6}	4×10^{-6}	2×10^{-6}	2×10^{-5}	4×10^{-7}	3×10^{-7}
65	9×10^{-6}	3×10^{-5}	5×10^{-6}	2×10^{-6}	9×10^{-7}	9×10^{-6}	2×10^{-7}	2×10^{-7}
66	8×10^{-6}	2×10^{-5}	4×10^{-6}	2×10^{-6}	8×10^{-7}	8×10^{-6}	2×10^{-7}	1×10^{-7}
67	8×10^{-6}	2×10^{-5}	5×10^{-6}	2×10^{-6}	8×10^{-7}	8×10^{-6}	2×10^{-7}	1×10^{-7}
68	8×10^{-6}	2×10^{-5}	4×10^{-6}	2×10^{-6}	8×10^{-7}	8×10^{-6}	2×10^{-7}	1×10^{-7}
69	7×10^{-6}	2×10^{-5}	4×10^{-6}	2×10^{-6}	7×10^{-7}	7×10^{-6}	2×10^{-7}	1×10^{-7}
70	6×10^{-6}	2×10^{-5}	4×10^{-6}	2×10^{-6}	6×10^{-7}	6×10^{-6}	2×10^{-7}	1×10^{-7}
71	8×10^{-6}	2×10^{-5}	4×10^{-6}	2×10^{-6}	8×10^{-7}	8×10^{-6}	2×10^{-7}	1×10^{-7}
72	2×10^{-5}	6×10^{-5}	1×10^{-5}	7×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	4×10^{-7}
73	2×10^{-5}	7×10^{-5}	1×10^{-5}	9×10^{-6}	2×10^{-6}	2×10^{-5}	6×10^{-7}	4×10^{-7}
74	2×10^{-5}	6×10^{-5}	1×10^{-5}	9×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	4×10^{-7}
75	5×10^{-5}	1×10^{-4}	3×10^{-5}	2×10^{-5}	5×10^{-6}	5×10^{-5}	1×10^{-6}	9×10^{-7}
76	3×10^{-5}	9×10^{-5}	2×10^{-5}	1×10^{-5}	3×10^{-6}	3×10^{-5}	8×10^{-7}	5×10^{-7}
77	4×10^{-5}	1×10^{-4}	2×10^{-5}	1×10^{-5}	4×10^{-6}	4×10^{-5}	1×10^{-6}	7×10^{-7}

Particulate Fraction	PM2.5	PM2.5	PM2.5	PM10	PM2.5	PM2.5	PM2.5	PM2.5
Health Endpoint	Mortality - All causes Long Term ≥ 30 years	Hospitalisations - Cardiovascular Short Term ≥ 65 years	Hospitalisations - Respiratory Short Term ≥ 65 years	Mortality - All causes Short Term all ages	Mortality - All causes Short Term all ages	Mortality - Cardiopulmonary Long Term ≥ 30 years	Mortality - Cardiovascular Short Term all ages	Mortality - Respiratory Short Term all ages
Receptor	Risk	Risk	Risk	Risk	Risk	Risk	Risk	Risk
78	3×10^{-5}	8×10^{-5}	2×10^{-5}	9×10^{-6}	3×10^{-6}	3×10^{-5}	7×10^{-7}	5×10^{-7}
79	2×10^{-5}	6×10^{-5}	1×10^{-5}	5×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	3×10^{-7}
80	4×10^{-5}	1×10^{-4}	2×10^{-5}	1×10^{-5}	4×10^{-6}	4×10^{-5}	1×10^{-6}	7×10^{-7}
81	1×10^{-5}	4×10^{-5}	8×10^{-6}	4×10^{-6}	1×10^{-6}	1×10^{-5}	4×10^{-7}	2×10^{-7}
82	9×10^{-6}	3×10^{-5}	5×10^{-6}	2×10^{-6}	9×10^{-7}	1×10^{-5}	2×10^{-7}	2×10^{-7}
83	1×10^{-5}	4×10^{-5}	8×10^{-6}	3×10^{-6}	1×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-7}
84	1×10^{-5}	3×10^{-5}	8×10^{-6}	3×10^{-6}	1×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-7}
85	9×10^{-6}	3×10^{-5}	5×10^{-6}	2×10^{-6}	9×10^{-7}	1×10^{-5}	2×10^{-7}	2×10^{-7}
86	8×10^{-6}	2×10^{-5}	5×10^{-6}	2×10^{-6}	8×10^{-7}	8×10^{-6}	2×10^{-7}	1×10^{-7}
87	8×10^{-6}	2×10^{-5}	4×10^{-6}	2×10^{-6}	8×10^{-7}	8×10^{-6}	2×10^{-7}	8×10^{-7}
88	4×10^{-5}	1×10^{-4}	3×10^{-6}	2×10^{-6}	4×10^{-6}	5×10^{-5}	1×10^{-6}	8×10^{-7}

2.1.9 Sulphur Dioxide (SO₂)

Sulphur dioxide is a colourless gas with a pungent odour. Sulphur dioxide in the air results primarily from activities associated with the burning of fossil fuels (coal, oil) such as at power plants or from copper smelting. In nature, sulphur dioxide can be released to the air, for example, from volcanic eruptions (ASTDR, 1998a). In the environment sulphur dioxide will normally be found in the gaseous phase.

Air Quality Professionals (2015) comment that sulphur dioxide emissions from dry process kilns are mostly linked to sulphur in raw material feed rather than fuel sulphur. The report goes on to state that up to 95% of potential sulphur dioxide emissions are not released into the environment but rather become physically bound up in clinker product. This is due to the highly alkaline nature of the cement kiln systems.

Sulphur dioxide can easily and rapidly enter the bloodstream through lungs. At elevated concentrations, SO₂ can cause irritation to the airways. Once in the body, it breaks down to sulphate and leaves through the urine (ASTDR, 1998a).

The acute LOAEL for sulphur dioxide has been reported as low as 0.1ppm (286µg/m³) in sensitive asthmatics, however healthy non asthmatics respond to higher concentrations equal to or greater than 1.0ppm (2,860µg/m³) (ASTDR, 1998a).

NEPC (2003) set air quality guidelines for sulphur dioxide considered to be protective of adverse health impacts for acute exposure and chronic exposure. The acute guidelines have been set at 0.2ppm (572 µg/m³) for one hour exposure, 0.08ppm (246 µg/m³) for a 24 hour exposure. The chronic exposure guidelines have been set at 0.02ppm (57 µg/m³). These guidelines are in line with the NSW EPA Criteria of 570 µg/m³, 288 µg/m³ and 60 µg/m³, respectively.

The air quality modelling of the proposed use of SWDF at the cement works predicted the cumulative SO₂ concentrations, as 1 hour, 24 hour and annual averages, to be significantly less than the health based criteria. These concentrations have been set out below in **Table 20**.

Table 20 Highest predicted cumulative SO₂ concentrations at off site receptors

Averaging Period	Cumulative SO ₂ Concentration (µg/m ³)	NSW EPA Criteria (µg/m ³)	Acute Health Based Guideline (NEPC) (µg/m ³)	Chronic Health Based Guideline (NEPC) (µg/m ³)
1 hour	37.4	570	572	N/A
24 hour	10.6	288	286	N/A
Annual	0.84	60	N/A*	60

* N/A = not applicable

Therefore it is concluded the SO₂ from the operations are unlikely to increase the health risks to the local communities. Accordingly SO₂ can be excluded from further risk assessment.

Based on this the Primary Exposure pathways were considered unlikely to lead to receptor exposure at concentrations likely to increase the receptors health risk. Therefore SO₂ will not require further risk assessment.

2.1.10 Nitrogen Oxide (NO_x)

Oxides of nitrogen are a group of chemical compounds produced during the combustion process. The gaseous compounds produced by combustion include a range of oxides of nitrogen. Making up the majority of nitrogen oxides is the compound nitrogen oxide (NO) which accounts for roughly 90-95% of nitrogen oxides released with combustion of fossil fuels. The second most prolific combustion compound is nitrogen dioxide (NO₂) accounting for 5 -10% of nitrogen oxides. However, nitrogen dioxide concentrations rise over time as atmospheric reactions convert NO in to NO₂ in the time frame of several hours after emission into the environment.

Amongst this group, the main compounds of concern for human health are NO and NO₂. Only the concentration of NO₂ is regulated in ambient air (Air Quality Professionals, 2015).

The primary route of exposure to nitrogen oxides is by inhalation; however exposure by any route can cause systemic effects. Low levels of nitrogen oxides in the air are irritating to the eyes, skin, mucous membranes and respiratory tract (ATSDR 2002).

Populations that may be particularly sensitive to nitrogen oxides include asthmatics and those with chronic obstructive pulmonary disease or airway disease (ATSDR 2002).

NEPC (2003) set air quality guidelines for nitrogen dioxide considered to be protective of adverse health impacts for acute exposure and chronic exposure. The acute guideline has been set at 246 µg/m³. Based on the lowest observed adverse effect level (LOAEL) of 409 to 613 µg/m³ derived from statistical reviews of epidemiological data suggesting an increased incidence of lower respiratory tract symptoms in children and aggravation of asthma with an uncertainty factor of two added to protect susceptible individuals (EnRiskS, 2014).

The chronic guideline has been set at 62 µg/m³. Based on the lowest observed adverse effect level (LOAEL) of 75 to 150 µg/m³ during early and middle childhood which may lead to recurrent upper respiratory tract symptoms, with an uncertainty factor of two added to protect susceptible individuals (EnRiskS, 2014).

The air quality modelling of the proposed use of SWDF at the cement works predicted the offsite maximum NO₂ concentrations, as 1 hour maximums and mean annual concentrations, at discrete receptors. These concentrations were calculated using two methods for conversion of NO to NO₂ and two sources of background data, from Bargo and Camden. The results have been set out below in **Table 21**.

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Table 21 Highest predicted cumulative NO₂ concentrations at offsite receptors (Air Quality Professionals, 2015)

NO to NO ₂ Calculation	Source of Background Data	Maximum Predicted 1 Hour Concentration (µg/m ³)	Maximum Predicted Annual Concentration (µg/m ³)
Method 2 (Ozone Limiting Method)	Bargo (excluding peaks 17-21 October 2013)	180	13.2
	Camden	188	11.3
Method 3 (Janssen Method)	Bargo (excluding peaks 17-21 October 2013)	128	10.7
	Camden	135	8.9
Acute Health Based Guideline		246	N/A
Chronic Health Based Guideline		N/A*	62

* N/A = not applicable

The predicted concentrations of NO₂ are below both acute and chronic health based criteria. Therefore it is concluded the NO₂ from the operations are unlikely to increase the health risks to the local communities. Accordingly NO₂ can be excluded from further risk assessment.

Based on this, the Primary Exposure pathway was considered unlikely to lead to receptor exposure at concentrations likely to increase the receptors health risk. Therefore NO₂ will not require further risk assessment.

Receptors 65-70 have some of the highest incremental impacts in the NO₂ assessment. This may be due to the modelling methods utilised. The NO₂ assessment is a special case because the incremental concentration is a function of background ozone concentration (for the “ozone-limiting method”) and also is a function of distance from the discharge source (for the “Janssen method”). It may be that ozone concentrations are higher under northwesterly winds, meaning higher NO₂ conversion rates. Another reason that receptors 65-70 show higher concentrations of NO₂ under the “Janssen method” is they are further from the stack than most of the other receptors (Air Quality Professional, personal communications 19/1/16.).

2.1.11 Carbon Monoxide (CO)

Carbon monoxide is an odourless colourless gas produced to varying extents during the fuel burning processes. Carbon monoxide quickly enters the blood when inhaled into the lungs. Levels normally present in the atmosphere are unlikely to cause ill effects. Carbon monoxide concentrations may reach harmful levels in poorly ventilated rooms during operation of unflued gas heaters or in the passenger compartment of vehicles with defective exhaust systems.

In the current situation, Air Quality Professionals (2015) considered that the only source of CO was the kiln stack. The report further went on to comment that industrial burning of fuels in the presence of sufficient oxygen has very minor potential to cause adverse effects because of the high combustion efficiency and the relatively high air quality impact criteria for CO. The NEPC ambient air quality guideline of 10,000 µg/m³ over an 8 hour period, have been considered to provide protection from both acute and chronic exposure (EnRiskS, 2014). Furthermore the NEPC guidelines are in line with the WHO (2005) recommendations for derived guidelines in ambient air (WHO, 1999).

Therefore CO was not considered as part of the air quality assessment. For similar reasons CO is not considered further in the current risk assessment.

Based on this, the Primary Exposure pathways were considered unlikely to lead to receptor exposure at concentrations likely to increase the receptors health risk. Therefore CO will not require further risk assessment.

2.1.12 Volatile Organic Compounds (VOCs)

Volatile organic compounds or VOCs are organic chemical compounds, that is, compounds (that contain carbon) whose composition makes it possible for them to evaporate under normal indoor atmospheric conditions of temperature and pressure. VOCs thus comprise a broad grouping of compounds with varying reactivity with other atmospheric components and varying impacts on human health.

Air Quality Professionals (2015) reported that VOCs were emitted as trace amounts in gaseous combustion products and therefore may be discharged from Kiln 6.

As set out in the Environmental Assessment (SLR, 2015), Boral is seeking for current VOC criteria of 20ppm to be changed to NMHC of 40ppm. The reason being the major source of VOCs in the emission has been demonstrated to be the blue shale mined on site. NMHC are considered appropriate VOCs to measure compliance to account for the inherent VOC levels within the blue shale.

Air Quality Professionals (2015) reported that:

As NMHC represents a wide collection of organic compounds there is no single generic representative assessment threshold. An indicative breakdown of organic compounds in emissions from Portland cement kilns is provided in USEPA (1995). In this breakdown, a large proportion of the organic emission is comprised of benzene and benzoic acid, with smaller amounts of other constituents. Further breakdown of NMHC constituents is not considered to be useful unless chemical composition data is collected at the Berrima site.

The assumed breakdown of organic compounds from Portland cement kilns from USEPA (1995) has been set out below in **Table 22**.

Table 22 Assumed breakdown of organic compounds from Portland cement kilns from USEPA (1995)

Individual organic compounds	Mass percentage of organic compounds as per USEPA (1995)
acetone	3.7%
benzene	31.4%
benzoic acid	35.3%
carbon disulfide	1.1%
chloromethane	3.7%
formaldehyde	4.5%
methylene chloride	4.9%
naphthalene*	2.2%
phenanthrene*	3.9%
toluene	2.0%
xylenes	1.3%
others	4.7%

* Included in PAH assessment as BaP-TEQ rather than NMHC assessment for this report.

Modelling using the proposed 40ppm criteria indicated that the highest one hour maximum NMHC concentration occurring beyond the site boundary GLC was $21\mu\text{g}/\text{m}^3$. The report goes on to use the VOC species assumed to be present in the total NMHC mix for comparisons against available regulatory criteria for specific VOCs.

This comparison indicated that NMHCs likely to be present in the emissions were all below applicable criteria and mostly at concentrations at least two orders of magnitude below the regulatory criteria (Air Quality Professionals, 2015).

For the purpose of this health risk assessment the predicted maximum concentrations of individual NMHCs were compared against health based criteria. These criteria include in order of priority Australian air quality guidelines, USEPA Regional Screening Levels (RSLs), Texas Commission on Environmental Quality (TCEQ) Effects Screening Levels (ESLs), Office of Environmental Health Hazard Assessment (OEHHA) California Reference Exposure Level (REL), ATSDR Minimum Risk Levels (MRLs).

Regional Screening Levels (RELs), ESLs, MRLs, etc are chemical concentrations in the air that are considered safe. ESLs protect human health in the general public, including children, the elderly, pregnant women, and people with pre-existing health conditions (TCEQ, 2010). These screening levels are considered reputable by many organisations, both local and international. Accordingly screening levels are often used as part of health risk assessments.

To assess the potential for health risks for individual NMHCs the concept of Hazard Quotients (HQ) for each was utilised. To assess the potential for health risks from the mixture of NMHCs predicted to be present, a cumulative Hazard Index (HI) made up of the summed Hazard Quotients (HQ) for individual NMHCs was utilised. The definitions of HQ and HI have been set out below.

Hazard Quotient (HQ)

The ratio of the potential exposure to the substance and the level at which no adverse effects are expected. A hazard quotient less than or equal to 1 indicates that adverse noncancer effects are not likely to occur, and thus can be considered to have negligible hazard. HQs greater than 1 are not statistical probabilities of harm occurring. Instead, they are a simple statement of whether (and by how much) an exposure concentration exceeds the reference concentration (RfC) (USEPA, 2016). The reference concentration used in the current assessment is the chosen health based criteria.

Hazard Index (HI)

The sum of hazard quotients (HQ) for substances that affect the same target organ or organ system. The hazard index (HI) is only an approximation of the aggregate effect on the target organ (e.g., the lungs) because some of the substances might cause irritation by different (i.e., non-additive) mechanisms. As with the HQ, aggregate exposures below an HI of 1 will not result in adverse non-cancer health effects over a lifetime of exposure and would ordinarily be considered acceptable. An HI equal to or greater than 1, however, does not necessarily suggest a likelihood of adverse effects. Because of the inherent conservatism of the reference concentration (RfC) methodology, the acceptability of exceedances must be evaluated on a case-by-case basis (USEPA, 2016).

Regarding the current report, the predicted one hour peak concentrations and annual average concentrations for VOC species (Air Quality Professionals, 2016) assumed to be present in the NMHC emissions mix were compared with the relevant acute and chronic health based criteria. The determination of HQ and HI values for both acute and chronic exposures indicated that there was unlikely to be a health risk to the community. The detailed information has been set out in **Table 23 and Table 24**.

It should be noted that Air Quality Professionals (2016) did not include some of the volatile chemicals listed in the USEPA AP42 guidance document, if the chemicals contributed less than one percent of the total VOCs. The excluded VOCs were listed in Table 43 of the Air Quality Professionals Report (Air Quality Professionals, 2016).

Table 23 Evaluation of potential acute impacts based on incremental individual NMHC species GLCs, 99.9th percentile one hour maximum concentrations predicted outside works boundary (Air Quality Professionals, 2015)

Individual NMHC species	Mass percentage assumed in total NMHC	Incremental 1 hour max GLC calculated pro-rata from total GLC of 21µg/m ³	Health Based Acute criteria adopted* (µg/m ³)	Acute Hazard Quotient (HQ)
acetone	3.7%	0.78	6000 ^C	<0.01
acenaphthylene	1.2%	0.252	100 ^T	<0.01
benzene	31.4%	6.6	29-170 ^C	0.23
benzoic acid	35.3%	7.4	No guideline for air exists in USEPA RSLs as this chemical is not volatile enough and thus would be a particulate bound chemical in the emissions.	-
carbon disulfide	1.1%	0.23		<0.01
chloromethane	3.7%	0.78		<0.01
formaldehyde	4.5%	0.95		0.02
methylene chloride	4.9%	1.0	2000 ^A	<0.01
naphthalene	2.2%	0.46	440 ^T	<0.01
phenanthrene	3.9%	0.82	8 ^T	0.1
toluene	2.0%	0.42	7600 ^A	<0.01
xylenes	1.3%	0.27	8800 ^C	<0.01
TOTAL				0.35

Note:

- C CRC CARE (2013)
- A ASTDR Acute Minimal Risk Levels as reported in Toxicological Profiles for each chemical available at www.atsdr.cdc.gov/toxprofiles/index.asp#L
- U USEPA Regional Screening Levels (Residential Air) (USEPA 2015a)
- # ASTDR lists acute guideline value for oral intake only; when this is converted (using standard assumptions) to a concentration in air it is lower (more stringent) than this value from the USEPA RSLs for chronic exposures. The chronic value has been left in the table.
- T TCEQ Short term ESL

Table 24 Evaluation of potential chronic impacts based on Incremental individual NMHC species GLCs, annual average concentration predicted outside works boundary (Air Quality Professionals, 2016)

Individual NMHC species	Mass percentage assumed in total NMHC	Annual average GLC ($\mu\text{g}/\text{m}^3$) [#]	Health Based Chronic criteria ($\mu\text{g}/\text{m}^3$)	Chronic Hazard Quotient (HQ)
acetone	3.7%	0.018	3200 ^U	<0.01
acenaphthylene	1.2%	0.0005 [^]	10 ^T	<0.01
benzene	31.4%	0.15	1.7 ^C	0.088
benzoic acid	35.3%	0.17	No guideline for air exists in USEPA RSLs as this chemical is not volatile enough and thus would be a particulate bound chemical in the emissions.	-
carbon disulfide	1.1%	0.01		<0.01
chloromethane	3.7%	0.02		<0.01
formaldehyde	4.5%	0.02		0.01
methylene chloride	4.9%	0.02	100/630 ^{U*}	<0.01
naphthalene	2.2%	0.013 [^]	50 ^T	<0.01
phenanthrene	3.9%	0.0004 [^]	0.8 ^T	<0.01
toluene	2.0%	0.01	5000 ^C	<0.01
xylenes	1.3%	0.01	870 ^C	<0.01
TOTAL				0.09

Note:

- C CRC CARE (2013)
U USEPA Regional Screening Levels (Residential Air) (USEPA 2015a)
T TCEQ Long Term ESL
* Carcinogenic Hazard Risk / Non Cancer Hazard Index
Air Quality Professionals, 2016, section 8.6.2; ^ Air Quality Professionals, 2016 Personal communications

The predicted concentrations of NHMCs were significantly below both the acute and chronic health based criteria. Therefore it is concluded the NHMCs from the operations are unlikely to increase the health risks to the local communities.

Based on this, the Primary Exposure and Secondary Exposure pathways were considered unlikely to lead to receptor exposure at concentrations likely to increase the receptors health risk. Therefore NMHCs will not require further risk assessment.

2.1.13 Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are a group of over 100 different chemicals that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances like tobacco or charbroiled meat. PAHs are ubiquitous environmental pollutants formed from both natural and anthropogenic sources. The latter are by far the major contributors. Natural sources include forest fires, volcanic eruptions, and degradation of biological materials, which has led to the formation of these compounds in various sediments and fossil fuels. Major anthropogenic sources include the burning of coal refuse banks, coke production, automobiles, commercial incinerators, and wood gasifiers. PAHs are usually found as complex mixtures containing two or more of these compounds, such as soot (ASTDR,1995, U.S. Geological Survey, 2015).

In the environment, PAHs are often attached to particulates such as dusts, soils and sediments. Some PAHs are volatile and become gases in the air. PAHs cover a broad class of chemicals and accordingly the differing nature of the chemicals is reflected in the toxicity, carcinogenicity and breakdown of PAHs. Some PAHs breakdown relatively quickly in the environment whereas others can persist for weeks or months. The toxicity and carcinogenicity varies greatly across the class of chemicals. Most of the carcinogenic potential of PAHs resides with four to seven ringed compounds (WHO, 2013).

Benzo (a) pyrene (BaP) is the most studied PAH. However, many other PAHs present with BaP in complex mixtures, such as tobacco smoke and diesel exhaust, are also potential carcinogens. In order to address the carcinogenicity of PAHs in ambient air as a class, potency equivalency factors (PEFs) for some PAHs relative to BaP have been developed using carcinogenesis studies in experimental animals. (OEHHA, 1994) These PEFs are used to calculate a BaP-Toxicity Equivalency (BaP-TEQ) for the mixture of PAHs. Once the BaP-TEQ has been calculated then this value can be multiplied by the WHO unit risk for BaP-TEQ (0.087 risk per $1\mu\text{g}/\text{m}^3$) to estimate the risk of lung cancer from life time exposure (WHO, 2000).

The air quality modelling of the proposed use of SWDF at the cement works predicted the highest ground level concentrations of PAHs beyond the site boundary to be $0.000017\mu\text{g}/\text{m}^3$ as BaP-TEQ 1 hour incremental GLC. To put this concentration in a health based context, WHO (2013) noted that with regards to risk of lung cancer from lifetime exposure to inhaled PAHs associated with airborne particles, a concentration of $0.000012\mu\text{g}/\text{m}^3$ gave a lifetime risk of 1×10^{-6} . This level of risk is classed as a negligible risk of cancer. The document went on to state a concentration of $0.0012\mu\text{g}/\text{m}^3$ as BaP-TEQ equated to a lifetime risk of 1×10^{-4} . (However it should be noted there was some discussion as to whether the EC guideline of $0.001\mu\text{g}/\text{m}^3$ as BaP-TEQ was more appropriate.) This is the level of risk (1×10^{-4}) is generally considered to lower limit of an unacceptable risk of cancer. Accordingly with regards to current project, the maximum predictions of $0.000017\mu\text{g}/\text{m}^3$ as BaP-TEQ 1 hour incremental GLC give a lifetime risk of :

$$0.000017\mu\text{g}/\text{m}^3 \times 0.087 \text{ (WHO unit risk)} = \text{a lifetime risk of } 1.5 \times 10^{-6}.$$

This indicated proposed use of SWDF at the cement works is expected to produce emissions of PAHs that lead to a negligible risk in most cases and a tolerable risk in the worst case scenarios.

Moreover the highest ground level concentrations of PAHs beyond the site boundary to be $0.000017\mu\text{g}/\text{m}^3$ as BaP-TEQ 1 hour incremental GLC are only 0.004% of the NSW EPA air quality criteria of $0.4\mu\text{g}/\text{m}^3$ (Air Quality Professionals, 2015).

The predicted airborne concentrations of PAHs are significantly below both NSW EPA criteria and health based criteria. Therefore it is concluded the PAHs from the operations are unlikely to increase the health risks to the local communities. Accordingly airborne PAHs can be excluded from further risk assessment.

PAH exposure through ingestion of contaminated particulate matter, such as dusts or soils is possible in the surrounding communities. However, given the general background levels of PAHs from multiple sources, for example fires, vehicle exhausts, industrial sources, unrelated to the cement works the very low concentrations of PAHs predicted to be emitted from the kiln, it is more likely that in most cases the sources of PAHs in soils are unrelated to the kiln.

Based on this, the Primary Exposure and Secondary Exposure pathways were considered unlikely to lead to receptor exposure at concentrations likely to increase the receptors health risk. Therefore PAHs will not require further risk assessment.

2.1.14 Heavy Metals

The term, heavy metals, is used to describe a number of metallic elements with high atomic weights such as mercury, chromium, cadmium, arsenic, and lead. However the term heavy metals is considered by some to be too ill defined and not necessarily reflecting all toxic metals. Accordingly metals and metallic compounds are the focus of the current report.

Regarding the metals associated with the cement kilns, Air Quality Professionals (2015) state:

Emissions of metal compounds from cement kilns can be grouped into three general classes:

- *Volatile metals, including mercury (Hg) and thallium (Tl);*
- *Semivolatile metals, including antimony (Sb), cadmium (Cd), lead (Pb), selenium (Se), zinc (Zn), potassium (K), and sodium (Na); and*
- *Refractory or non-volatile metals, including barium (Ba), chromium (Cr), arsenic (As), nickel (Ni), vanadium (V), manganese (Mn), copper (Cu), and silver (Ag).*

Although the partitioning of these metal groups is affected by kiln operating conditions, the refractory metals tend to concentrate in the clinker, while the volatile and semivolatile metals tend to be discharged to air (USEPA, 1995).

Metals in feed and fuel are volatile at high temperatures experienced in the kiln burning zone but then condense as temperatures decrease. In general, the more volatile metals condense on small dust particles, and the high boiling point metals tend to remain in the clinker. This, to a large degree, depends on the quantities of metals present in the feed and fuel, the manufacturing process, and the chloride content. Volatile metals such as thallium and mercury tend to remain unbonded and are emitted to atmosphere primarily in elemental form.

Chromium can be present as either the hexavalent (+6) oxidation state or the less toxic trivalent (+3) oxidation state. In the Berrima kiln, the hexavalent chromium emission has been measured in each of the annual stack testing programmes in addition to total chromium.

It should be noted that when Boral conducted trials of non-standard waste derived fuels, results of emissions testing found that heavy metal emissions were at a similar level to the baseline or lower, including the more volatile metals such as cadmium and mercury when compared to emissions from normal fuels (Air Quality Professionals, 2016).

2.1.14.1 Heavy Metal Measured Emissions – Current Operations

The scope of historic and current emissions testing, as set out in Section 1.8, included analysis of particulate matter for a range of heavy metals. Furthermore in the case of arsenic, beryllium, cadmium, cobalt, nickel, selenium and mercury, all results were less than the detection limit of the analysis (Air Quality Professionals, 2015).

The summary of heavy metal testing from 2011 to 2014 has been set out below in **Table 25**.

Table 25 Summary of results of heavy metal testing at AQMS, 2011-2014. 24 hour average concentrations measured in particulate during 1 day in 6 testing programme (no samples = 243) (source *Air Quality Professionals, 2015*).

Metal	Number of times the test result was higher than the MDL [#]	Concentrations when test results were higher than MDL (µg/m ³)		
		Minimum measured concentrations	Maximum measured concentrations	Average concentration
Antimony	16	0.007	0.104	0.025
Arsenic	0	<0.007	<0.01	n/a*
Beryllium	0	<0.004	<0.01	n/a*
Cadmium	0	<0.004	<0.005	n/a*
Chromium (total)	98	0.004	0.021	0.0055
Chromium VI	1	0.008	0.008	0.008
Cobalt	0	<0.004	<0.01	n/a*
Copper	103	0.004	0.026	0.0053
Lead	5	0.008	0.019	0.013
Manganese	240	0.004	0.147	0.029
Mercury	0	<0.00015	<0.0005	n/a*
Nickel	0	<0.004	<0.01	n/a*
Selenium	0	<0.007	<0.01	n/a*
Thallium	3	0.004	0.005	0.0047
Tin	7	0.009	0.027	0.015
Vanadium	39	0.004	0.012	0.0063
Zinc	243	0.005	0.779	0.034

Notes: [#] MDL = method detection limit of analysis; * n/a = not calculated as all results < MDL; [%] n/d= no data- no standards or guidelines;

2.1.14.2 Heavy Metal Predicted Emissions – Proposed Modification

The air quality modelling of the proposed use of SWDF at the cement works predicted the ground level concentrations of a range of metals beyond the site boundary. The emission rates used for modelling metals was equal to ten times the maximum measured concentrations from 2011 to 2014. The study reported all metals investigated, both by modelling and from historic monitoring data, were significantly below NSW EPA assessment criteria.

The Air Quality Professionals (2015) states:

Lead emissions are assessed separately from other heavy metals due to the requirement for lead to be assessed as an annual averaging period. NSW EPA requires 100th percentile lead GLCs to be assessed at the nearest existing or likely future off-site sensitive receptor, and background concentrations must be included.

A mean 24-hour background concentration for lead of 29.9 ng/m (0.0299 µg/m³) was identified in the NSW. The equivalent annual average background concentration is expected to be lower than this value, however for the purpose of this assessment this concentration of 0.0299 µg/m³ has been adopted as representing the background annual average as well.

The highest incremental annual average GLCs occurring anywhere beyond the site boundary is 0.00033 µg/m³. This occurs in the industrial-zoned area to the east of the Works, and does not occur near one of the discrete receptors 1-87.

The maximum cumulative lead concentration of 0.030 µg/m³ (sum of maximum background plus maximum GLC).

The NSW EPA criteria for annual average airborne lead is currently 0.5 µg/m³. This criteria was established at a time when it was considered that lead had a threshold of effect, below which adverse health impacts were unlikely. Current knowledge from epidemiological studies indicate that it maybe there is no lower threshold concentrations for the health effects of lead. In light of this new evidence, compliance with the standards alone may not achieve the desired environmental outcome of 'adequate protection' (NEPC, 2011).

In contrast the USEPA RSL for lead and lead compounds has been set at 0.15 µg/m³, much lower than the NSW EPA criteria. Accordingly the USEPA RSL was used to screen for potential health impacts. Comparing the current projects predicted maximum cumulative lead concentration of 0.030 µg/m³ with the more stringent USEPA RSL health based chronic criteria indicated the predicted maximum cumulative lead concentration was less than the RSL. Therefore with regards to airborne lead concentrations adverse impacts from discharges of lead from the Works are anticipated to be negligible.

For metals other than lead comparison of predicted metal concentrations against health based criteria, both acute and chronic, found that for the majority of metals concentrations were significantly below adopted criteria. Acute exposure Hazard Index for the mixture of metals present was 1.09 with the main contributors being beryllium and cadmium, predicted at 38% and 34% respectively of the acute assessment criteria. Chronic exposure Hazard Index for the mixture of metals present was less than 1.0, which indicated the health risks were unlikely from the mixture of metals present.

The exception to this was the hexavalent chromium. This chemical was significantly below health based criteria relating to toxicity (Non Cancer Hazard Index) for both acute and chronic exposure. However the predicted worst case chronic exposure concentration of hexavalent chromium (0.0001375 µg/m³ annual average GLC beyond site boundary) was above the USEPA RSL for Carcinogenic Hazard Risk (0.000012 µg/m³). Accordingly with regards to current project, the maximum predictions of 0.0001375 µg/m³ annual incremental GLC give a lifetime cancer risk of :

$0.0001375 \mu\text{g}/\text{m}^3 \times 0.04 \text{ (WHO inhalation unit risk, (WHO,2000))} = \text{a lifetime risk of } 5.5 \times 10^{-6}.$

This indicated proposed use of SWDF at the cement works is expected to produce emissions of hexavalent chromium that lead to a negligible risk in most cases and a tolerable risk in the worst case scenarios.

These results have been set out below in **Tables 26 and 27**. It should be noted that the concentrations listed in the air quality modelling included both volatile and particulate phases (Air Quality Professionals, 2015). Accordingly volatile metals such as mercury and thallium are considered as well as the metals more likely to be found in the particulate phase of emissions.

Table 26 Evaluation of potential acute impacts based on incremental individual metal species GLCs, 99.9th percentile one hour maximum concentrations (including both particulate bound and volatile) predicted outside works boundary (Air Quality Professionals, 2015)

* The lowest of the two health based criteria was utilized in the assessment. # Hazard Quotient rounded off to 2 decimal places.

Individual NMHC species	Highest 99.9th Percentile incremental 1 hour GLC beyond site boundary ($\mu\text{g}/\text{m}^3$)	NSW EPA (2005) ambient air quality ($\mu\text{g}/\text{m}^3$)	TCEQ Acute ESL ($\mu\text{g}/\text{m}^3$ 1 hour average)	Health Based Acute criteria adopted* ($\mu\text{g}/\text{m}^3$)	Acute Hazard Quotient (HQ) [#]
Antimony	0.036	9	5	5	<0.01
Arsenic	0.0015	0.09	3	0.09	0.02
Beryllium	0.0015	0.004	0.02	0.004	0.38
Cadmium	0.0061	0.018	0.1	0.018	0.34
Chromium (total)	0.01	9	-	9	<0.01
Chromium VI	0.0061	0.09	0.39	0.09	0.07
Cobalt	0.0036	0.2	0.2	0.2	0.02
Copper	0.031	18	10	10	<0.01
Manganese	0.17	18	2	2	0.09
Mercury	0.012	1.8	0.25	0.25	0.05
Nickel	0.019	0.18	0.33	0.18	0.11
Selenium	0.007	2	2	2	<0.01
Thallium	0.0061	1	1	1	0.01
Tin (inorganic)	0.015	20	20	20	<0.01
Vanadium	0.0058	0.5	20	0.5	<0.01
TOTAL					Acute Hazard Index (HI) 1.09

Table 27 Evaluation of potential chronic impacts based on incremental individual metal species annual average concentrations (including both particulate bound and volatile) predicted outside works boundary (Air Quality Professionals, 2015)

Individual NMHC species	Annual Average GLC beyond site boundary (µg/m ³)	Health Based Chronic criteria adopted* (µg/m ³)	Chronic Hazard Quotient (HQ)	Carcinogenic Hazard Quotient
Antimony	0.000825	1 ^U	<0.01	
Arsenic	0.000033	0.016 ^U	<0.01	
Beryllium	0.000033	0.021 ^U	<0.01	
Cadmium	0.0001375	0.01 ^T	0.01	
Chromium (total)	0.00022	0.1 ^U	<0.01	
Chromium VI	0.0001375	0.000012 / 0.1 ^{U*}	<0.01	11.46
Cobalt	0.0000825	0.02 ^T	<0.01	
Copper	0.000715	0.0063 ^U	0.11	
Manganese	0.003905	0.2 ^T	0.02	
Mercury	0.000275	0.0031 ^U	0.09	
Nickel	0.000429	0.0015 ^U	0.29	
Selenium	0.0001595	0.21 ^U	<0.01	
Thallium	0.0001375	0.1 ^T	<0.01	
Tin (inorganic)	0.00033	0.1 ^U	<0.01	
Vanadium	0.000132	0.2 ^T	<0.01	
TOTAL			0.54	

Note:

U USEPA Regional Screening Levels (Residential Air) (USEPA 2015a)

T TCEQ Long Term ESL

* Carcinogenic Hazard Risk / Non Cancer Hazard Index

The majority of metals released from the operations will be associated with particulate matter. Therefore the ultimate environmental fate of these metals will be to be deposited in soils or sediments. As metals are elements, the metals will not breakdown but rather will be buried over time, unless disturbed. Therefore there may be potential for localised build-up of metals in soils, the extent of which is unclear. The likelihood of this will be dependent on how far particulate matter that becomes airborne travels and disperses before settling out. The data associated with this is currently lacking.

Based on the historic emissions monitoring by Boral, the lack of difference in measured heavy metal emissions between trials of waste derived fuels compared to standard fuels and the predicated metal emissions from Kiln 6 it is concluded that heavy metals emissions associated with the proposed modifications are unlikely to increase the existing potential health risks to the local communities. Accordingly, heavy metals can be excluded from further risk assessment.

2.1.15 Hydrogen Halides & Sulphuric Acid Mist / Sulphur Trioxide

The COPC in this category listed in the Air Quality Professionals(2015) report were hydrogen chloride, chloride, hydrogen fluoride, sulphuric acid mist and sulphur trioxide. All of these are potentially emitted from Kiln 6 during operations. It should be noted that the report does not specify at which receptor GLC of sulphuric acid mist / sulphur trioxide exceeded the regulatory criteria.

The predicted emissions of sulphuric acid / sulphur trioxide as well as chlorine and hydrogen chloride were considered to be highly conservative overestimations. Calculations based on data from four years of annual testing at the site indicated the overestimations are possibly as much as ninety times, one hundred and eighty times or thirty times, respectively, higher than actual emissions (Air Quality Professionals, 2015).

It is worth quoting the Air Quality Professionals (2015) in detail to demonstrate the basis of these overestimations.

Chlorine, hydrogen chloride and sulfuric acid mist/sulfur trioxide GLCs were assessed as incremental 99.9th percentile 1-hour average concentrations at or beyond the site boundary in accordance with the "Approved Methods" guidelines For each of these species, the emission concentration used in the model was the maximum specified in the current EPL for burning of NSF – i.e. 200, 10, and 100 mg/Nm³ for chlorine, hydrogen chloride and sulfuric acid mist/sulfur trioxide respectively.

The maximum GLC for each of these species was calculated by adjusting the GLCs in proportion with emission rate relative to the maximum GLC for a unitary emission rate of 1 g/s.

The GLC for emissions of sulfuric acid mist/sulfur trioxide exceeds the NSW EPA assessment criteria for sulfuric acid. This GLC was derived from an assumed discharge at the emission concentration limit specified in the EPL, which is 100 mg/Nm³ (at 10% O₂) yielding a mass emission rate of 20 g/s. In reality, emissions of sulfuric acid mist/sulfur trioxide are much lower than this..... From the four years of annual testing, sulfuric acid mist/sulfur trioxide has only been detected on one occasion, with an emission concentration of 1.5 mg/Nm³ (at 10% O₂) and a mass emission rate of 0.23 g/s. If that emission rate was applied to the dispersion model, the maximum GLC beyond the site boundary would be 0.28 mg/m³ which is 1.5% of the NSW EPA assessment criteria. The reason for the low acidic emissions is the nature of the cement kiln which acts as a large alkaline scrubber neutralising acid gases.

The GLC for emissions of chlorine at the EPL limit of 200 mg/Nm³ (at 10% O₂) is close to exceeding the NSW EPA assessment criteria. In reality, emissions of chlorine are much lower than this. From the four years of annual testing, chlorine has only been detected on two occasions, with a maximum emission concentration of 0.32 mg/Nm³ (at 10% O₂) and a mass emission rate of 0.18 g/s (compared to 40 g/s used in the model). If that emission rate was applied to the dispersion model, the maximum GLC beyond the site boundary would be 0.22 µg/m³ which is 0.4% of the NSW EPA assessment criteria. Chlorine is a carefully controlled operational parameter in the feed as it impacts clinker quality and marked increases in emission concentrations for this element are unlikely.

The GLC for hydrogen chloride is small compared to the NSW EPA assessment criteria. However the emission rate that this GLC is derived from is also large compared with measured results. From the four years of annual testing, hydrogen chloride was detected on all but one occasion, with a maximum emission concentration of 0.25 mg/Nm³ (at 10% O₂) and a mass emission rate of 0.12 g/s. If that emission rate was applied to the dispersion model, the maximum GLC beyond the site boundary would be 0.15 µg/m³ which is 0.1% of the NSW EPA assessment criteria.

The predicted maximum emissions have been set out in **Table 28**.

Table 28 Halide and other chemical species GLCs and comparison to assessment criteria (source Air Quality Professionals, 2015).

Chemical	Highest 99.9 th Percentile incremental GLC beyond site boundary ($\mu\text{g}/\text{m}^3$)	NSW EPA Air quality assessment criteria ($\mu\text{g}/\text{m}^3$) (DEC, 2005)	GLC as a percentage of air quality assessment criteria ($\mu\text{g}/\text{m}^3$)
Sulphuric acid mist and/or sulphur trioxide	24.2	18	134
Hydrogen chloride	2.4	140	17
Chlorine	48.4	50	97
Hydrogen Fluoride	Highest 100 th Percentile incremental GLC beyond site boundary ($\mu\text{g}/\text{m}^3$)	Air quality assessment criteria – 24 hour average ($\mu\text{g}/\text{m}^3$)	
Hydrogen fluoride	0.11	1.5	7.3

Health effects and health based criteria for hydrogen chloride, chloride, hydrogen fluoride, sulphuric acid mist and sulphur trioxide are set out below.

Hydrogen Chloride (HCl)

Hydrogen chloride is a by-product from combustion of many materials, especially materials with high chlorine content (OEHHA, 2015a). In the atmosphere, HCl aggregates into aerosols and is removed from the atmosphere by rainfall.

The acidic nature of HCl means that at elevated concentrations HCl can irritate human tissue for example respiratory tract, skin, eyes, etc. Regarding acute exposure, the lowest concentration at which inhalation of HCl is likely to impact on humans has been reported as 1.4ppm (2,100 $\mu\text{g}/\text{m}^3$) over a 1 hour period based on an acute NOAEL (no observed adverse effect level, based on experimental data) of 1.8ppm (2,100 $\mu\text{g}/\text{m}^3$) over a 45 minute period (OEHHA, 2015b).

The data relating to chronic exposure of humans to HCl via the respiratory route is more limited than that available for acute exposures. OEHHA (2015b) calculated the concentration unlikely to impact on humans 0.06ppm (9 $\mu\text{g}/\text{m}^3$) as a Chronic Reference Exposure Level (REL) which is an airborne level of a chemical that is not anticipated to present a significant risk of an adverse non-cancer health effect.

The TCEQ (2015) listed for HCl a Short term ESL, (equivalent to an acute exposure) of 190 $\mu\text{g}/\text{m}^3$. The USEPA RSL (equivalent to a chronic exposure) was listed as 21 $\mu\text{g}/\text{m}^3$.

In the current project, the modelled HCl concentrations were reported as 2.4 $\mu\text{g}/\text{m}^3$ (see **table 28** above). This concentration is below both chronic and acute health based criteria listed above. Therefore HCl was not considered further in the current risk assessment.

Chlorine (Cl₂)

Chlorine is a heavier-than-air, greenish-yellow reactive gas with a pungent, irritating odour (ATSDR, 2010). Chlorine is a very reactive gas and as such after release into the environment does not persist but quickly reacts with other chemicals in the environment. The main human exposure route is via inhalation with eyes also affected, however the dermal exposure only a minor route. The affect of chlorine on the respiratory tract and other tissue, is to act as an irritant at low concentrations, such as 1ppm to 3ppm (1,583 to 4,748 µg/m³) (ASTDR, 2010).

The TCEQ (2015) listed Short term ESLs for Cl₂ (equivalent to an acute exposure) of 15 µg/m³. The USEPA RSL (equivalent to an chronic exposure) is set at of 0.15 µg/m³.

The air quality modelling of the proposed use of SWDF at the cement works predicted the maximum Cl₂ concentration as 48.4 µg/m³. This concentration exceeds both the acute health based criteria and the chronic health based criteria. The predicted Cl₂ concentration is also close to the NSW EPA Criteria of 50 µg/m³ (DEC, 2005). These concentrations have been set out below in **Table 29**.

Table 29 Highest predicted incremental Cl₂ concentrations at off site receptors

Highest 99.9th Percentile incremental GLC beyond site boundary (µg/m ³)	NSW EPA Criteria (µg/m ³)	Acute Health Based Guideline (µg/m ³)	Chronic Health Based Guideline (µg/m ³)
48.4	50	15 ^T	0.15 ^U

Note:

U USEPA Regional Screening Levels (Residential Air) (USEPA 2015a)

T TCEQ Short Term ESL

Therefore it is concluded further risk assessment of predicted chlorine concentrations is required in Sections 2.3 and 2.4.

Hydrogen Fluoride

Hydrogen fluoride is a colourless, corrosive gas or liquid (it boils at 19.5 °C) that is made up of a hydrogen atom and a fluorine atom. It fumes strongly, readily dissolves in water, and both the liquid and vapour will cause severe burns upon contact (ASTDR, 2003).

Health based criteria for acute and chronic hydrogen fluoride exposure via inhalation have been determined, based on the LOAEL of 0.5 ppm (446 µg/m³) fluoride for upper respiratory tract irritation. ASTDR (2003) determined the acute Minimal Risk Levels (MRL) to be 0.02ppm (17.8 µg/m³). This was in line with the TCEQ listed for hydrogen fluoride a Short term ESL, (equivalent to an acute exposure) of 18 µg/m³ and USEPA RSL (equivalent to a chronic exposure) has been set at 15 µg/m³.

The air quality modelling of the proposed use of SWDF at the cement works predicted the maximum hydrogen fluoride concentration as 0.11µg/m³. This concentration is within both the acute health based criteria, and chronic health based criteria. Therefore hydrogen fluoride will not require further risk assessment.

Sulphuric acid mist / Sulphur trioxide

Sulphur trioxide in the pure form is a colourless liquid but can also exist as crystals or a gas. When exposed to air sulphur trioxide quickly reacts with water to form sulphuric acid. It is unlikely to exist in the atmosphere except as a transitory compound prior to conversion to sulphuric acid. Furthermore any sulphur trioxide inhaled by a person reacts with water and converts to sulphuric acid in the upper respiratory tract (ASTR, 1998b). Accordingly, the focus of this toxicity assessment will be on sulphuric acid.

Sulphuric acid in pure form is a clear colourless liquid and a strong acid. Much of the atmospheric sulphuric acid forms when sulphur dioxide degrades to sulphur trioxide which reacts with water in the air to form sulphuric acid. Sulphuric acid vapours can condense and form airborne particles, nuclei, which can grow in size overtime with the inclusion of water in the particles (ATSDR, 1998; WHO, 2006).

ATSDR (1998) did not set either acute or chronic MRLs for sulphuric acid. It was felt the methodology for derivation did not incorporate all the variables in addition to concentration that determine the response to sulfuric acid.

However the California Government Office of Environmental Health Hazard Assessment (OEHHA) set health based Reference Exposure Levels (REL) for both acute and chronic exposures of $120 \mu\text{g}/\text{m}^3$ and $1 \mu\text{g}/\text{m}^3$ respectively. REL are defined as *"The concentration level at or below which no adverse health effects are anticipated for a specified exposure duration is termed the reference exposure level (REL). RELs are based on the most sensitive, relevant, adverse health effect reported in the medical and toxicological literature. RELs are designed to protect the most sensitive individuals in the population by the inclusion of margins of safety."* (OEHHA, 1999).

The USEPA RSL for chronic exposures has also been set at $1 \mu\text{g}/\text{m}^3$.

Regarding the chronic REL it should be noted that the derivation of this was based on one small study. Therefore chronic REL may be overly conservative to take into account the limited data on which it is based. As the USEPA RSL is the same as the REL it can be assumed the RSL includes an inbuilt conservatism.

The air quality modelling of the proposed use of SWDF at the cement works predicted the maximum sulphuric acid concentration as $24.2 \mu\text{g}/\text{m}^3$. This concentration is within the acute health based criteria, but significantly higher than chronic health based criteria. The predicted sulfuric acid concentration was also above to the NSW EPA Criteria of $18 \mu\text{g}/\text{m}^3$ (DEC, 2005). These concentrations have been set out below in **Table 30**.

Table 30 Highest predicted incremental sulfuric acid concentrations at off site receptors

Highest 99.9th Percentile incremental GLC beyond site boundary ($\mu\text{g}/\text{m}^3$)	NSW EPA Criteria ($\mu\text{g}/\text{m}^3$)	Acute Health Based Guideline ($\mu\text{g}/\text{m}^3$)	Chronic Health Based Guideline ($\mu\text{g}/\text{m}^3$)
24.2	18	120^{C}	1^{U}

Note:

U USEPA Regional Screening Levels (Residential Air) (USEPA 2015a)

C California Government Office of Environmental Health Hazard Assessment (OEHHA) Reference Exposure Levels (REL)

Therefore it is concluded the sulphuric acid mist / sulphur trioxide from the operations is within the acute health based criteria. However the predicted concentrations exceed the NSW EPA criteria and the chronic health criteria. Therefore further risk assessment of predicted sulphuric acid mist / sulphur trioxide concentrations is required in Sections 2.3 and 2.4 of the current report.

2.1.16 Dioxins

The term Dioxins is generally used to refer to both dioxins and furans. Dioxins are a family of toxic chemicals that all share a similar chemical structure and a common mechanism of toxic action. This family includes seven of the polychlorinated dibenzo dioxins (PCDDs), ten of the polychlorinated dibenzo furans (PCDFs) and twelve of the polychlorinated biphenyls (PCBs) (USEPA, 2015b).

The toxicity of different dioxins in a mixture can be considered to be additive. To help represent the overall toxicity of complex mixtures of dioxins, the concept of Toxicity Equivalent (TEQ) is used. The TEQ is based on concentrations of various dioxin species in the mixture each multiplied by a relative toxicity factor and added together to give a single TEQ, expressed in grams.

Dioxins are not commercial chemical products but are trace level unintentional by-products of most forms of combustion and several industrial chemical processes. Dioxins are generally formed as a result of poorly controlled or uncontrolled combustion (Bawden *et al*, 2004). The formation of dioxins is complex and many factors are important, including the material being burned, the conditions of combustion, the composition of the particulate matter generated, and the design and operation of the burners all exert influence over dioxin formation (Air Quality Professionals, 2015). However dioxin formation tends to occur in a zone where combustion gases cool from approximately 450°C to 250°C (UNEP,1999).

Controlling and limiting the formation of dioxins in an industrial process, such as cement kilns, depends significantly on temperature control. In cement kilns the nature of the combustion and necessary pollution control processes limit the production of dioxins. Furthermore, the presence of chlorine is required for dioxin formation. In the operations of Kiln 6, chlorine is a carefully controlled operational parameter in the feed as it impacts clinker quality (Air Quality Professional, 2015).

Air Quality Professional (2015) state that:

A review report released by the United National Environment Programme (UNEP, 2005) notes that provided combustion is good and excess oxygen is present in the exhaust gases, the main factor controlling dioxin emissions in the air discharge from a cement kiln is the temperature of the dust collection device in the gas cleaning system. The UNEP report highlights the importance of stack gas temperature of less than 200°C into the particulate control equipment (electrostatic precipitator or bag filter). The UNEP report also states that in a dry process kiln with preheater (such as that at the Berrima Works), this prerequisite is inherent in the process.

The emissions of dioxins from Australian cement kilns has been noted to be well controlled by current practises over a range of processes and fuels. The Australian Inventory of Dioxin Emissions 2004 (Bawden *et al*, 2004) state that:

Australian dioxin emission testing data were provided by the CIF for all Australian cement kilns. The emissions testing data provided were the results of repeated measurements over the period 1991 – 2003 and were obtained from all cement kilns in Australia using a range of process conditions, primary fuels and raw materials. Both wet and dry processes are represented as were plants using gas, coal and alternative fuels.

All measured dioxin concentrations for the period 1991-2003 were well below 0.1 ng TEQ/Nm³ (@ 11% O₂) indicating a high level of dioxin control at Australian cement production facilities. (note * ng = nanogram that is 0.000000001g)*

The air quality modelling of the proposed use of SWDF at the cement works predicted the highest ground level concentrations of dioxins beyond the site boundary to be 0.000024ng/m³. That is 83,000 times less than the NSW EPA air quality criteria of 2 ng/m³ (Air Quality Professionals, 2015).

The predicted airborne concentrations of airborne dioxins are significantly below criteria. Therefore it is concluded the airborne dioxins from the operations are unlikely to increase the health risks to the local communities. Accordingly airborne dioxins can be excluded from further risk assessment.

In the environment, dioxins are often attached to particulates such as dusts, soils and sediments. Breakdown of dioxins occurs slowly if at all in the environment and dioxins can persist for years in soils. Therefore it is possible for soil to be enriched with dioxins over time in areas with a history of dioxin production such as might have occurred in areas of many industries.

In the case of Berrima Cement Works, with the predicted airborne concentrations beyond the site boundary being 83,000 times less than the NSW EPA air quality criteria, it is unlikely that these emissions will lead to a significant impact on soil dioxin levels in the communities surrounding the works.

Based on this, the Primary Exposure and Secondary Exposure pathways were considered unlikely to lead to receptor exposure at concentrations likely to increase the health risk to receptors. Therefore Dioxins will not require further risk assessment.

2.1.17 Summary of COPC Emissions Exceeding Regulatory or Health Based Criteria

The emissions predicted to periodically exceed the criteria include dust as PM₁₀ 24 hour average, sulphuric acid mist / sulphur trioxide, and VOCs. The predicted concentrations of these emissions and number of predicted exceedances per year have been set out below in **Table 31**.

Table 31 Emissions from Berrima Cement Works that may exceed regulatory or health based criteria

Airborne Pollutant	Regulatory /Health Based Criteria	Predicted Concentrations at Ground Level (GLC)	Comments
Dust PM ₁₀ 24 hour average – Additional exceedances beyond background	50µg/m ³ GLC	50 – 69.7µg/m ³ When background environmental dust levels are less than 47µg/m ³	Ground level receptors, limited number affected near boundary (R23, R57, R75, R88). Source expected to be fugitive dust not kiln emissions. Frequency 2 to 5 times per year.
Dust PM ₁₀ 24 hour average Background exceedances due to environmental conditions	50µg/m ³ GLC	52 – 177.5µg/m ³ Background environmental dust levels only	Ground level receptors, near boundary (R23, R57, R75, R88). Source background dust unrelated to Berrima Plant. Frequency 2 to 7 times per year.
Chlorine	15µg/m ³ Acute Health Criteria ^T 0.15µg/m ³ ^U Chronic Health Criteria	48.4µg/m ³	Maximum predicted concentration at any receptor.
Sulphuric acid mist / Sulphur trioxide	18µg/m ³ * GLC (99 th Percentile) 1µg/m ³ ^U Chronic Health Guideline	24.2µg/m ³	Maximum predicted concentration at any receptor.
Volatile Organic Compounds (VOC) 24 hour average	20 ppm [#] Emission criteria	Not applicable	EPA Current Criteria is VOC 20ppm. Boral is requesting a change to NMHC 40ppm

Note:

U USEPA Regional Screening Levels (Residential Air) (USEPA 2015a)

VOC criteria of 40 ppm as NMHC proposed by Boral

* NSW EPA (DEC, 2005)

T TCEQ Short Term ESL

Fugitive dust has been determined as the main source of airborne dust as PM₁₀ exceedances attributed to the facility. To put the exceedances attributed to the facility in perspective, it should be noted these exceedances are similar in number but at lower concentrations (maximum 69.7µg/m³) than exceedances due to general environmental conditions excluding the influence of the facility (maximum 177.5µg/m³).

Accordingly, environmental conditions (excluding dust emissions from the facility) are predicted to give rise to PM₁₀ 24 hour averages approximately eight times greater than those attributed to the facility alone.

The quantification of potential health risk associated with PM₁₀ and PM_{2.5} determined the increased risk to the surrounding community to be negligible to tolerable in most cases. The exception being seven Receptor locations were found to have potentially unacceptable risks (risk = $\geq 1 \times 10^{-4}$) with regards to PM_{2.5} particulates (six Receptors risk = 1×10^{-4} & one Receptors risk = 2×10^{-4}). This equates to 1 – 2 extra incidents of the chosen health endpoints per population of 10,000 people. (as set out in **Section 2.1.8.5**).

It appeared that much of the incremental increases in total PM₁₀ and PM_{2.5} may be due to fugitive dusts not linked to the proposed modification, rather than point sources associated with the proposed operation of the kiln. Accordingly the contribution of fugitive dusts should be further explored in the air quality assessment with a view to determining engineering controls which may be able to reduce fugitive dust emissions and hence lower the potential health risks to acceptable levels. SLR understands that this aspect will be investigated further by Boral in a future document.

As previously stated Boral is requesting the VOC criteria of 20ppm be changed to NMHC of 40ppm. The reason being the major source of VOCs in the emission has been demonstrated to be the blue shale mined on site. NMHC are considered appropriate VOCs to measure compliance to account for the inherent VOC levels within the blue shale.

Modelling using the proposed 40ppm criteria indicated that the highest NMHC concentration occurring beyond the site boundary GLC was 21 $\mu\text{g}/\text{m}^3$. The VOC species assumed to be present in the total NHMC mix were compared against available regulatory and health based criteria for individual VOCs. This comparison indicated that NHMCs likely to be present in the emissions were all below applicable criteria. Therefore, it is considered that the NHMC emissions beyond the site boundary will be unlikely to pose an unacceptable health risk to the surrounding communities. As such further risk assessment is not required.

2.2 Issue Identification Summary

The main issues identified relating to the use of SWDF in Kiln 6 and the local populations are the following:

- The air quality modelling in this document indicated that the majority of emissions from the proposed use of SWDF would be within the relevant regulatory and health based criteria.
- Fugitive dusts from the facility are likely to lead to two to five incidents of airborne dust as PM₁₀ 24 hour average, exceeding the EPA criteria of 50 $\mu\text{g}/\text{m}^3$, with predicted concentrations of 50 – 69.7 $\mu\text{g}/\text{m}^3$ at four receptors close to the facility. However concentrations of these exceedances are less than that caused by exceedances due to general environmental conditions excluding the influence of the facility.
- Moreover quantification of potential increased risk to the surrounding community demonstrated negligible to tolerable risk in most cases. The exception being potential health risk associated with seven Receptor locations found to have potentially unacceptable risks with regards to PM_{2.5}. It appeared that this potential health risk may be due to fugitive dusts not linked to the proposed modification, rather than point sources associated with the proposed operation of the kiln.
- Emissions of NHMC in the range of 40ppm or less from Kiln 6 are predicted to lead to GLC concentrations of individual VOC species below applicable regulatory and health based criteria and therefore unlikely to pose an unacceptable health risk to the surrounding communities.
- Emissions from Kiln 6 are predicted to lead to peak GLC concentrations of chlorine of 48.4 $\mu\text{g}/\text{m}^3$ which exceed the acute health based criteria of 15 $\mu\text{g}/\text{m}^3$ and the chronic health based criteria of 0.15 $\mu\text{g}/\text{m}^3$. Therefore the potential for health risks, if any, to the local communities will be detailed in the following sections.

- Emissions from Kiln 6 are predicted to lead to peak GLC concentrations of sulphuric acid mist / sulphur trioxide of $24.2\mu\text{g}/\text{m}^3$ which exceed the EPA Criteria of $18\mu\text{g}/\text{m}^3$ and the chronic health based criteria of $1\mu\text{g}/\text{m}^3$. Therefore the potential for health risks, if any, to the local communities will be detailed in the following sections.

2.3 Toxicity Assessment

The COPC carried through into the risk assessment were chlorine and sulphuric acid / sulphur trioxide. All other COPCs were eliminated in the preceding Hazard Identification stage.

2.3.1 Chlorine

Chlorine is a heavier-than-air, greenish-yellow reactive gas with a pungent, irritating odour. Chlorine is a very reactive gas and as such after release into the environment does not persist but quickly reacts with other chemicals in the environment. The primary mechanism for breakdown of Cl_2 in the atmosphere is direct photolysis through sunlight. The chlorine molecule is split to form chlorine radicals that then react with organic molecules to form hydrochloric acid. When released into the atmosphere chlorine has been reported to breakdown in the minutes (ATSDR, 2010).

The main human exposure route is via inhalation with eyes also affected, with the dermal exposure only a minor route. Its effects depend on its concentration, as well as the duration of exposure and the water content of the tissue involved. The affect of chlorine on the respiratory tract and other tissue, is to act as an irritant at low concentrations, such as 1ppm to 3ppm ($1,583$ to $4,748\mu\text{g}/\text{m}^3$) (ASTDR, 2010).

The most susceptible sections of the populations to chlorine gas exposure include individuals with respiratory conditions such as asthma, hay fever, and chronic bronchitis, heavy smokers, and children. The lowest concentrations reported to illicit a physiological response has been 0.5ppm ($761.5\mu\text{g}/\text{m}^3$) being respiratory tract irritation and transient alterations in parameters of respiratory function in susceptible individuals after 15 minutes exposure. In contrast, in healthy adults few lung function responses have been documented below 1ppm ($1,583\mu\text{g}/\text{m}^3$) (ATSDR, 2010).

2.3.2 Sulphuric Acid / Sulphur Trioxide

Sulphur trioxide in the pure form is a colourless liquid but can also exist as crystals or a gas. When exposed to air sulphur trioxide quickly reacts with water to form sulphuric acid. It is unlikely to exist in the atmosphere except as a transitory compound prior to conversion to sulphuric acid. Furthermore any sulphur trioxide inhaled by a person reacts with water and converts to sulphuric acid in the upper respiratory tract (ASTR, 1998b). Accordingly, the focus of this toxicity assessment will be on sulphuric acid.

Sulphuric acid in pure form is a clear colourless liquid and a strong acid. Much of the atmospheric sulphuric acid forms when sulphur dioxide degrades to sulphur trioxide which reacts with water in the air to form sulphuric acid. Sulphuric acid vapours can condense and form airborne particles, nuclei, which can grow in size overtime with the inclusion of water in the particles. (ATSDR, 1998; WHO, 2006)

Sulphuric acid has a direct action on the tissues it contacts. Once absorbed sulphuric acid converts to salts of the sulphate ion which are excreted from the body in urine as organic sulphates, neutral sulphur or neutral sulphur compounds such as amino acids. The low toxicity of these metabolites means the main health impact from inhaled sulphuric acid will be the direct irritation of the respiratory tract (OEHHA, 2001).

Asthmatics and particularly adolescent asthmatics are the most sensitive group to the impacts of inhaled sulphuric acid. The lowest concentrations reported to illicit a physiological response in asthmatics has been $70\mu\text{g}/\text{m}^3$, being transient changes in pulmonary function in adolescent children after 40 to 45 minutes exercise, with other studies reporting $100\mu\text{g}/\text{m}^3$ as the lowest observable effect limit (ATSDR, 1998). In contrast, in healthy adults few lung function responses have been documented below $500\mu\text{g}/\text{m}^3$ (Folinsbee, 1992).

The action of inhaled sulphuric acid on a person's respiratory system is dependent on the acid buffering capacity of the respiratory mucous layer. It has been estimated that a person with normal mucous buffering capacity and protein content can accommodate an exposure of approximately $300\mu\text{g}/\text{m}^3$ for 30 minutes. In contrast asthmatics' mucous has been reported to be of lower pH and buffering capacity when compared with a healthy individual. This may explain asthmatics greater sensitivity to inhaled sulphuric acid (ATSDR, 1998).

Children's Susceptibility

The impact of a chemical exposure on children may vary from that experienced by adults. Children, from conception to 18 years old, are actively growing and some of their biological systems may still be developing. Children are not small adults and moreover children's behaviour may lead to different exposures to that of adults.

A number of studies have concluded that adolescent asthmatics may be more susceptible to transient sulphuric acid induced changes in respiratory function than adult asthmatics (ATSDR, 1998).

2.4 Exposure Assessment

In general, an exposure assessment aims to provide the magnitude, frequency, extent, character and duration of exposures to a chemical or material of concern. An exposure assessment also aims to identify human populations or groups who may be exposed and potential exposure pathways, which in this case is inhalation.

2.4.1 Exposure Pathways and Receptors

An exposure pathway describes the mechanism by which persons may be exposed to airborne sulphuric acid emissions originating from Kiln 6. Each exposure pathway must include a source, in this case Kiln 6, and a transport mechanism for sulphuric acid to enter the breathing zone, in this case environmental air movement. The exposure pathway is incomplete if any of these factors are not present, and therefore no additional risks are associated with that activity as the COPC does not reach the receptor.

Receptors

Receptors are similar groups of people from the defined communities. In this assessment, receptors are considered to be individuals who usually reside in the communities within close proximity to the facility. For the purposes of this study a nominal 5km cut off distance has been used to delineate these communities. These communities were set out above in **Table 1** and included the following:

- New Berrima
- Berrima
- Moss Vale
- Burradoo

2.4.2 Assessment of Exposure Concentration

The exposure concentration used for the current study was based on results of air quality modelling as previously mentioned.

2.4.2.1 Chlorine

The maximum exposure concentration for chlorine ($48.4\mu\text{g}/\text{m}^3$) was predicted to occur near the site boundary. It would be expected that exposure concentration for chlorine for communities away from the facility boundary would be less due to the effective dilution of emissions from Kiln 6 with distance from the source to receiver. Air Quality Professional (2015) considers their modelling to be overly conservative for Cl_2 emissions, based on a Cl_2 emission rate roughly two hundred times higher than the measured Cl_2 emissions. Air Quality Professional (2015) reported Cl_2 has only been detected in kiln 6 emissions twice from four years of annual monitoring data. Moreover the concentrations detected were significantly less than the concentration used in the air quality modelling. If the measured emission concentrations were used in the modelling then the maximum concentrations beyond the boundary was predicted to be $0.22\mu\text{g}/\text{m}^3$. This concentration is within both the acute and chronic health based guideline of $1.5\mu\text{g}/\text{m}^3$.

It should also be noted that the results of test burns of non standard fuels in 2003 reported no significant differences in measured Cl_2 emission from kiln 6 when non standard fuel was tested compared with routinely used fuels (Air Quality Professional, 2015). This would indicate use of SWDF in operations was unlikely to change the concentrations of Cl_2 local communities are exposed to from current operations of the kiln 6.

2.4.2.2 Sulphuric Acid

The maximum exposure concentration for sulphuric acid was predicted to occur near the site boundary and was $24.2\mu\text{g}/\text{m}^3$. It would be expected that exposure concentration for sulphuric acid for communities away from the facility boundary would be less than $24.2\mu\text{g}/\text{m}^3$ due to the effective dilution of emissions from Kiln 6 with distance from the source to receiver. Moreover the conservative nature of the air quality modelling leads to predicted concentrations that are probably much higher than actual concentrations. This aspect will be discussed in detail below.

To put the predicted concentration of airborne sulphuric acid in context, the maximum exposure concentration for sulphuric acid of $24.2\mu\text{g}/\text{m}^3$ is less than half the lowest concentration of airborne sulphuric acid reported to illicit a physiological response, being transient changes in pulmonary function, in the population group reported as most sensitive to sulphuric acid inhalation. The most sensitive group to this exposure being adolescent asthmatic children and the lowest concentration reported to affect this group being $70\mu\text{g}/\text{m}^3$.

Regarding the current project, it should be noted that modelling may be overly conservative for sulphuric acid mist / sulphur trioxide emissions, based on an emission rate roughly one hundred times higher than the measured emissions. Air Quality Professional (2015) reported sulphuric acid mist / sulphur trioxide emissions have only been detected in kiln 6 emissions once in four years of annual monitoring data. Moreover the concentrations detected were significantly less than the concentration used in the air quality modelling. If the measured emission concentrations were used in the modelling then the maximum concentrations beyond the boundary was predicted to be $0.28\mu\text{g}/\text{m}^3$. This concentration is within chronic health based guideline of $1\mu\text{g}/\text{m}^3$.

It should also be noted that the results of test burns of non standard fuels in 2003 reported no significant differences in measured sulphuric acid mist / sulphur trioxide emissions from kiln 6 when no standard fuels was tested compared with routinely used fuels (Air Quality Professional, 2015). This would indicate use of SWDF in operations was unlikely to change the concentrations of sulphuric acid local communities are exposed to from current operations of the kiln 6.

3 RISK CHARACTERISATION

Risk characterisation involves the incorporation of the exposure assessment and the hazard assessment to provide an overall evaluation and assessment of risk. Risk assessment is used extensively in Australia and overseas to assist decision making on project acceptability and chemical use. Risk is the probability of an unwanted event happening and is often expressed as a multiple of its consequences and frequency. Risks can be defined to be acceptable or tolerable if the population will bear them without undue concern. The quantification of risk is an imprecise practise, based on available evidence, estimating level of risk within generally accepted ranges rather than absolute risk. The level of negligible / acceptable risk is generally considered to be less than 1 in 1,000,000 (i.e. 1×10^{-6}) for contaminants with health effects considered to be non-threshold in nature or carcinogenic chemicals (enHealth, 2012). At this level of risk it is considered essentially non-existent. The level of risk is considered unacceptable at greater than 1 in 10,000 (1×10^{-4}). Tolerable risk occurs in the range between 1×10^{-6} and 1×10^{-4} (DEC, 2005). Tolerable risks are considered acceptable when best practise for minimising air toxics has been utilised.

Regulatory limits are set at points deemed 'acceptable' by the regulator, taking into account objective evidence of harm and the general views of society. However in some cases, health based guidelines from reputable sources may be more appropriate in determining risk.

As with any risk assessment there is always a degree of uncertainty associated with the assessment. The factors involved in this uncertainty and the implications are discussed in **Appendix B**

Negligible risks are those so small that there is no cause for concern, or so unlikely that there is no valid reason to take action to reduce them. Humans continually expose themselves to, or have imposed upon them, the risk of injury or fatality. Self-imposed risk is known as voluntary risk and includes everyday events such as smoking, swimming and driving. Each has an associated risk that people voluntarily accept when weighed against the perceived benefits.

A simple comparison of an air measurement and a health benchmark can be thought of as a "screening" exercise, that is, the risk assessor is screening for possible problems. If the majority of samples are much less than the benchmark, then in a majority of cases it would be appropriate to conclude that a health impact is unlikely.

The majority of COPCs identified in the Issue Identification stage of the risk assessment were assessed as unlikely to be present at concentrations likely to impact on the health risks to receptors in the surrounding communities. This was based on comparisons of predicted COPC concentrations at or near receptor sites with relevant air quality assessment criteria, such as NSW EPA criteria or health based benchmarks. This group of COPCs included fine particulates (TSP, PM₁₀, PM_{2.5}), SO₂, NO_x, CO, VOCs, PAHs, heavy metals, hydrogen chloride, hydrogen fluoride, chlorine, and dioxins. The exception to this was chlorine and sulphuric acid mist/sulphur trioxide which required further assessment.

The principal benchmark used in this assessment for both chlorine and airborne sulphuric acid was the lowest concentration reported to illicit a physiological response, being transient changes in pulmonary function, in the population group reported as most sensitive to these chemicals. In the case of chlorine the most susceptible sections of the populations to chlorine gas exposure include individuals with respiratory conditions such as asthma, hay fever, and chronic bronchitis, heavy smokers, and children. The lowest concentrations reported to illicit a physiological response has been 0.5ppm (761.5µg/m³) being respiratory tract irritation and transient alterations in parameters of respiratory function in susceptible individuals after 15 minutes exposure. With regards to sulphuric acid inhalation, the most susceptible sections of the populations are adolescent asthmatic children with the concentration being 70µg/m³.

In the current study, the maximum exposure concentration for chlorine was predicted to occur at receptors near the site boundary and was 48.4µg/m³. The exposure is significantly less than the lowest concentration of airborne sulphuric acid reported to illicit a response, that is 761.5µg/m³.

In the current study, the maximum exposure concentration for sulphuric acid was predicted to occur at receptors near the site boundary and was $24.2\mu\text{g}/\text{m}^3$. The exposure is less than half the lowest concentration of airborne sulphuric acid reported to illicit a response, that is $70\mu\text{g}/\text{m}^3$.

Furthermore the actual exposure concentration of the surrounding communities is likely to be less for both chlorine and sulphuric acid. This is based on two considerations, firstly the dilution of emissions as they travel away from the facility boundary to a receptor. Secondly the conservative nature of the air modelling which allowed predicted concentrations for chlorine to be possibly as much as two hundred times higher the probable concentrations and predicted concentrations for sulphuric acid to be possibly as much as ninety times higher the probable concentrations as set out in section 2.3.3.

If the measured emission concentrations were used in the modelling then the maximum chlorine concentrations beyond the boundary was predicted to be $0.22\mu\text{g}/\text{m}^3$. This concentration is within both the acute and chronic health based guideline of $1.5\mu\text{g}/\text{m}^3$.

If the measured emission concentrations were used in the modelling then the maximum sulphuric acid concentrations beyond the boundary was predicted to be $0.28\mu\text{g}/\text{m}^3$. This concentration is within chronic health based guideline of $1\mu\text{g}/\text{m}^3$.

Therefore the predicted chlorine and sulphuric acid emissions during the operation of Kiln 6 are not expected to lead to an increased health risk to the surrounding populations.

Based on this the Primary Exposure pathway of inhalation was considered unlikely to lead to receptor exposure at concentrations likely to increase the health risk to receptors. Therefore chlorine and sulphuric acid mist/sulphur trioxide is not considered to require further risk assessment.

4 CONCLUSIONS

SLR assessed the potential exposure pathways for human health from contamination during the operations of Kiln 6 at the Berrima Cement Works while using SWDF. The assessment was based on a desktop review of available documents including environmental assessment and air quality report as set out in section 1.4.

A desktop evaluation it is considered appropriate given the limited scope of the proposed works.

As this project involves only minor physical changes in process, the potential impact on the surrounding communities is limited.

Taking available information sources into account and considering the nature and scope of the proposed works, it is considered that the proposed works are sufficiently characterised to enable an assessment of risks.

From the information available, it was concluded that:

- The communities who may be exposed to any COPCs associated with the use of SWDF as fuels in Kiln 6 were identified as New Berrima, Berrima, Moss Vale and Burradoo.
- The COPC associated with the use of SWDF as fuels in Kiln 6 were identified as fine particulates (TSP, PM_{10} , $\text{PM}_{2.5}$), SO_2 , NO_x , CO, VOCs, PAHs, heavy metals, hydrogen chloride, hydrogen fluoride, chlorine, sulphuric acid mist/sulphur trioxide and dioxins

- Comparisons of predicted COPC concentrations at or near receptor sites with relevant air quality assessment criteria or health based benchmarks determined that none of the identified COPCs were likely to be present at concentrations likely to impact on the health risks to receptors in the surrounding communities.

Emission control measures to minimise any potential impacts have been noted in section 1.7.

Therefore it is concluded the proposed modification for the use of SWDF in kiln 6 is unlikely to lead to an increase in any existing potential health risks to the identified communities.

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Appendix A

Report Number 610.15875.00000.0020 HRA

Page 1 of 2

Appendix A

QUANTIFICATION OF RISK ASSOCIATED WITH AIRBORNE PARTICULATES AS PM₁₀ & PM_{2.5}

The methodology regarding quantification of risk followed that outlined by the WHO (Ostro, 2004). This method has been utilised to quantify health risks associated with airborne particulates (PM₁₀ & PM_{2.5}) in recent major developments in NSW where airborne particulate pollution has been as a significant concern for the community, such as the WestConnex M4 East and NorthConnex motorway tunnels proposed for the Sydney roads system (EnRiskS, 2014 & EnRiskS, 2014).

In the WestConnex M4 East and NorthConnex reports EnRiskS (2014 & 2015) provided extensive and detailed background to the use and development of the risk quantification methodology as well as the chosen health endpoints associated with the risk. Furthermore those projects required agreement with the NSW Department of Health with regards to the appropriateness of methodology. An example of this can be seen in NorthConnex reports (EnRiskS, 2014) which states *"The health impact functions presented in this table (referring to Table 5-1) have been discussed and agreed with NSW Health as the most current and appropriate for the quantification of potential health effects for the health endpoints considered in this assessment."* This indicates a level of robustness in the methodology and functions chosen.

Based on this acceptance health impact functions in those previous reports, it was decided the current report would use the same health impact functions. This would then follow previous practise on major developments and if required allow comparison with risks levels from previous major developments

The NorthConnex report (EnRiskS, 2014) succinctly summarised the adopted health impact functions and exposure response relationships used in the risk assessment. As such the table has been quoted in full below as Table B-1.

The risk equation utilised in the WestConnex M4 East and NorthConnex reports to calculate annual risk for individuals exposed to increased PM emission from the project at specific locations (such as maximum, or at specific sensitive receiver locations) has been set out below (EnRiskS, 2014).

The baseline health incidence data utilised in the current report was for NSW from NSW Health data sets from either 2005-2007 or 2009-2011 (see annotations Table B-2) as used in the NorthConnex report (EnRiskS, 2014).

Risk = $\beta \times \Delta X \times B$

Where

β = slope coefficient relevant to the per cent change in response to a 1 $\mu\text{g}/\text{m}^3$ change in particulate matter exposure (as per Table B-1)

ΔX = change (increment) in PM₁₀ or PM_{2.5} exposure concentration in $\mu\text{g}/\text{m}^3$ relevant to the project at the point of exposure

B = baseline incidence of a given health effect per person (eg annual mortality rate)

Table A-1 Adopted health impact functions and exposure response relationships (source: EnRiskS, 2014)

Health endpoint	Exposure period	Age Group	Published relative risk (95% confidence interval) per 10 $\mu\text{g}/\text{m}^3$	Adopted β coefficient (as %) for 1 $\mu\text{g}/\text{m}^3$ increase in PM	Reference
Primary assessment health endpoints					
PM _{2.5} : Mortality, all causes	Long Term	≥30yrs	1.06 [1.04-1.08]	0.0058 (0.58%)	Relationship derived for all follow-up time periods to the year 2000 (for approx. 500 000 participants in the US) with adjustment for seven ecologic (neighbourhood level) covariates (Krewski et al. 2009). This study is an extension (additional follow-up and exposure data) of the work undertaken by Pope (2002), is consistent with the findings from California (19992002) (Ostro et al. 2006) and is more conservative than the relationships identified in a more recent Australian and New Zealand study (EPHC 2010).
PM _{2.5} : Cardiovascular hospital admissions	Short term	≥65yrs	1.008 [1.0059-1.011]	0.0008 (0.08%)	Relationship established for all data and all seasons from US data for 1999 to 2005 for lag 0 (exposure on same-day)(strongest effect identified) (Bell, M. L. 2012; Bell, Michelle L. et al. 2008)
PM _{2.5} : Respiratory hospital admissions	Short Term	≥65yrs	1.0041 [1.0009-1.0074]	0.00041 (0.041%)	Relationship established for all data and all seasons from US data for 1999 to 2005 for lag 2 (exposure 2 days previous)(strongest effect identified) (Bell, M. L. 2012; Bell, Michelle L. et al. 2008)

Table A-1 Adopted health impact functions and exposure response relationships (source: EnRiskS, 2014) (con't)

Health endpoint	Exposure period	Age Group	Published relative risk (95% confidence interval) per 10 $\mu\text{g}/\text{m}^3$	Adopted β coefficient (as %) for 1 $\mu\text{g}/\text{m}^3$ increase in PM	Reference
Secondary assessment health endpoints					
PM ₁₀ : Mortality, all causes	Short Term	All ages*	1.006 [1.004-1.008]	0.0006 (0.06%)	Based on analysis of data from European studies from 33 cities and includes panel studies of symptomatic children (asthmatics, chronic respiratory conditions) (Anderson et al. 2004)
PM _{2.5} : Mortality, all causes	Short Term	All ages*	1.0094 [1.0065-1.0122]	0.00094 (0.094%)	Relationship established from study of data from 47 US cities for the years 1999 to 2005 (Zanobetti & Schwartz 2009)
PM _{2.5} : Cardiopulmonary Mortality	Long Term	≥30yrs	1.14 [1.11-1.17]	0.013 (1.3%)	Relationship derived for all followup time periods to the year 2000 (for approx. 500 000 participants in the US) with adjustment for seven ecologic (neighbourhood level) covariates (Krewski et al. 2009).
PM _{2.5} : Cardiovascular mortality	Short Term	All ages*	1.0097 [1.0051-1.0143]	0.00097 (0.097%)	Relationship established from study of data from 47 US cities for the years 1999 to 2005 (Zanobetti & Schwartz 2009)
PM _{2.5} : Respiratory mortality (including lung cancer)	Short Term	All ages*	1.0192 [1.0108-1.0278]	0.0019 (0.19%)	Relationship established from study of data from 47 US cities for the years 1999 to 2005 (Zanobetti & Schwartz 2009)

* Relationships established for all ages, including young children and the elderly

Regarding the current project, the calculated changes in health risk from incremental changes in both PM₁₀ and PM_{2.5} at each Receptor identified by Air Quality Professional (2015) have been set out below in Table B-2. At the majority of the Receptor locations the increased risk were calculated to be within the range considered to be negligible to tolerable risk as set out in DEC (2005). However seven Receptor locations were found to have potentially unacceptable risks (risk = $\geq 1 \times 10^{-4}$) with regards to PM_{2.5} particulates (six Receptors risk = 1×10^{-4} & one Receptors risk = 2×10^{-4}). This equates to 1 – 2 extra incidents of the chosen health endpoints per population of 10,000 people.

Table A-2 Calculated changes in health risk from changes in PM₁₀ & PM_{2.5} concentrations at each receptor location

(Baseline Health Data: NSW 2005-2007 Mortality - All causes, Mortality - All causes ≥ 30 years, Mortality – Cardiopulmonary ≥ 30 years, Mortality – Cardiopulmonary All ages, Mortality – Respiratory – All ages. NSW 2009-2011 Hospitalisations – Cardiovascular ≥ 65 years, Hospitalisations – Respiratory ≥ 65 years)

Fugitive Dusts & Combined Point Sources	Primary Assessment Health End Points			Secondary Assessment Health End Points				
Particulate Fraction Endpoint	PM2.5 Mortality - All causes	PM2.5 Hospitalisations - Cardiovascular	PM2.5 Hospitalisations - Respiratory	PM10 Mortality - All causes	PM2.5 Mortality - All causes	PM2.5 Mortality - Cardiopulmonary	PM2.5 Mortality - Cardiovascular	PM2.5 Mortality - Respiratory
Effect Exposure Duration	Long Term	Short Term	Short Term	Short Term	Short Term	Long Term	Short Term	Short Term
Age Group	≥ 30 years	≥ 65 years	≥ 65 years	all ages	all ages	≥ 30 years	all ages	all ages
β	0.0058	0.0008	0.00041	0.0006	0.00094	0.013	0.00097	0.0019
Baseline Incidence per 100,000	1087	23352	8807	670	670	490	164	57
Baseline Incidence per person	0.01087	0.23352	0.08807	0.0067	0.0067	0.0049	0.00164	0.00057

Sensitive Receiver	Change in annual average PM10 concentration (µ/m3)	Change in annual average PM2.5 concentration (µ/m3)	Risk	Risk	Risk	Risk	Risk	Risk	Risk	Risk
Maximum Receptor	5.2	1	6E-05	2E-04	4E-05	2E-05	6E-06	6E-05	2E-06	1E-06
Maximum Offsite (Non Receptor)	18	3	2E-04	6E-04	1E-04	7E-05	2E-05	2E-04	5E-06	3E-06
Individual Receptors										
1	0.4	0.11	7E-06	2E-05	4E-06	2E-06	7E-07	7E-06	2E-07	1E-07
2	0.51	0.14	9E-06	3E-05	5E-06	2E-06	9E-07	9E-06	2E-07	2E-07
3	0.6	0.17	1E-05	3E-05	6E-06	2E-06	1E-06	1E-05	3E-07	2E-07
4	0.68	0.2	1E-05	4E-05	7E-06	3E-06	1E-06	1E-05	3E-07	2E-07
5	0.69	0.18	1E-05	3E-05	6E-06	3E-06	1E-06	1E-05	3E-07	2E-07
6	0.67	0.18	1E-05	3E-05	6E-06	3E-06	1E-06	1E-05	3E-07	2E-07
7	0.75	0.2	1E-05	4E-05	7E-06	3E-06	1E-06	1E-05	3E-07	2E-07
8	0.9	0.23	1E-05	4E-05	8E-06	4E-06	1E-06	1E-05	4E-07	2E-07
9	0.82	0.21	1E-05	4E-05	8E-06	3E-06	1E-06	1E-05	3E-07	2E-07
10	0.84	0.21	1E-05	4E-05	8E-06	3E-06	1E-06	1E-05	3E-07	2E-07
11	1.06	0.25	2E-05	5E-05	9E-06	4E-06	2E-06	2E-05	4E-07	3E-07
12	1.33	0.33	2E-05	6E-05	1E-05	5E-06	2E-06	2E-05	5E-07	4E-07
13	1.25	0.29	2E-05	5E-05	1E-05	5E-06	2E-06	2E-05	5E-07	3E-07
14	1.32	0.31	2E-05	6E-05	1E-05	5E-06	2E-06	2E-05	5E-07	3E-07
15	1.68	0.36	2E-05	7E-05	1E-05	7E-06	2E-06	2E-05	6E-07	4E-07
16	1.8	0.37	2E-05	7E-05	1E-05	7E-06	2E-06	2E-05	6E-07	4E-07
17	1.61	0.32	2E-05	6E-05	1E-05	6E-06	2E-06	2E-05	5E-07	3E-07
18	0.94	0.18	1E-05	3E-05	6E-06	4E-06	1E-06	1E-05	3E-07	2E-07
19	0.93	0.18	1E-05	3E-05	6E-06	4E-06	1E-06	1E-05	3E-07	2E-07
20	1.64	0.3	2E-05	6E-05	1E-05	7E-06	2E-06	2E-05	5E-07	3E-07
21	1.72	0.39	2E-05	7E-05	1E-05	7E-06	2E-06	2E-05	6E-07	4E-07
22	2.83	0.6	4E-05	1E-04	2E-05	1E-05	4E-06	4E-05	1E-06	6E-07
23	3.13	0.64	4E-05	1E-04	2E-05	1E-05	4E-06	4E-05	1E-06	7E-07
24	2.38	0.49	3E-05	9E-05	2E-05	1E-05	3E-06	3E-05	8E-07	5E-07
25	1.77	0.3	2E-05	6E-05	1E-05	7E-06	2E-06	2E-05	5E-07	3E-07
26	2.68	0.44	3E-05	8E-05	2E-05	1E-05	3E-06	3E-05	7E-07	5E-07
27	2.88	0.46	3E-05	9E-05	2E-05	1E-05	3E-06	3E-05	7E-07	5E-07
28	2.22	0.36	2E-05	7E-05	1E-05	9E-06	2E-06	2E-05	6E-07	4E-07

Fugitive Dusts & Combined Point Sources	Primary Assessment Health End Points			Secondary Assessment Health End Points				

Particulate Fraction Endpoint	PM2.5 Mortality - All causes	PM2.5 Hospitalisations - Cardiovascular	PM2.5 Hospitalisations - Respiratory	PM10 Mortality - All causes	PM2.5 Mortality - All causes	PM2.5 Mortality - Cardiopulmonary	PM2.5 Mortality - Cardiovascular	PM2.5 Mortality - Respiratory
Effect Exposure Duration	Long Term	Short Term	Short Term	Short Term	Short Term	Long Term	Short Term	Short Term
Age Group	≥ 30 years	≥ 65 years	≥ 65 years	all ages	all ages	≥ 30 years	all ages	all ages
β	0.0058	0.0008	0.00041	0.0006	0.00094	0.013	0.00097	0.0019
Baseline Incidence per 100,000	1087	23352	8807	670	670	490	164	57
Baseline Incidence per person	0.01087	0.23352	0.08807	0.0067	0.0067	0.0049	0.00164	0.00057

Sensitive Receiver	Change in annual average PM10 concentration (μ/m3)	Change in annual average PM2.5 concentration (μ/m3)	Risk	Risk	Risk	Risk	Risk	Risk	Risk	Risk
Individual Receptors (con't)										
29	1.81	0.31	2E-05	6E-05	1E-05	7E-06	2E-06	2E-05	5E-07	3E-07
30	0.51	0.1	6E-06	2E-05	4E-06	2E-06	6E-07	6E-06	2E-07	1E-07
31	0.49	0.1	6E-06	2E-05	4E-06	2E-06	6E-07	6E-06	2E-07	1E-07
32	0.78	0.13	8E-06	2E-05	5E-06	3E-06	8E-07	8E-06	2E-07	1E-07
33	1.04	0.19	1E-05	4E-05	7E-06	4E-06	1E-06	1E-05	3E-07	2E-07
34	1.77	0.3	2E-05	6E-05	1E-05	7E-06	2E-06	2E-05	5E-07	3E-07
35	1.63	0.29	2E-05	5E-05	1E-05	7E-06	2E-06	2E-05	5E-07	3E-07
36	1.63	0.29	2E-05	5E-05	1E-05	7E-06	2E-06	2E-05	5E-07	3E-07
37	2.5	0.41	3E-05	8E-05	1E-05	1E-05	3E-06	3E-05	7E-07	4E-07
38	2.33	0.39	2E-05	7E-05	1E-05	9E-06	2E-06	2E-05	6E-07	4E-07
39	1.91	0.34	2E-05	6E-05	1E-05	8E-06	2E-06	2E-05	5E-07	4E-07
40	1.45	0.27	2E-05	5E-05	1E-05	6E-06	2E-06	2E-05	4E-07	3E-07
41	2.28	0.41	3E-05	8E-05	1E-05	9E-06	3E-06	3E-05	7E-07	4E-07
42	1.36	0.26	2E-05	5E-05	9E-06	5E-06	2E-06	2E-05	4E-07	3E-07
43	1.17	0.23	1E-05	4E-05	8E-06	5E-06	1E-06	1E-05	4E-07	2E-07
44	0.96	0.19	1E-05	4E-05	7E-06	4E-06	1E-06	1E-05	3E-07	2E-07
45	0.87	0.18	1E-05	3E-05	6E-06	3E-06	1E-06	1E-05	3E-07	2E-07
46	0.63	0.14	9E-06	3E-05	5E-06	3E-06	9E-07	9E-06	2E-07	2E-07
47	0.48	0.12	8E-06	2E-05	4E-06	2E-06	8E-07	8E-06	2E-07	1E-07
48	0.46	0.11	7E-06	2E-05	4E-06	2E-06	7E-07	7E-06	2E-07	1E-07
49	0.44	0.11	7E-06	2E-05	4E-06	2E-06	7E-07	7E-06	2E-07	1E-07
50	0.32	0.09	6E-06	2E-05	3E-06	1E-06	6E-07	6E-06	1E-07	1E-07
51	0.36	0.11	7E-06	2E-05	4E-06	1E-06	7E-07	7E-06	2E-07	1E-07
52	0.35	0.1	6E-06	2E-05	4E-06	1E-06	6E-07	6E-06	2E-07	1E-07
53	1.09	0.25	2E-05	5E-05	9E-06	4E-06	2E-06	2E-05	4E-07	3E-07
54	1	0.24	2E-05	4E-05	9E-06	4E-06	2E-06	2E-05	4E-07	3E-07
55	3.59	0.67	4E-05	1E-04	2E-05	1E-05	4E-06	4E-05	1E-06	7E-07
56	3.11	0.58	4E-05	1E-04	2E-05	1E-05	4E-06	4E-05	9E-07	6E-07
57	4.54	1.01	6E-05	2E-04	4E-05	2E-05	6E-06	6E-05	2E-06	1E-06
58	1.42	0.34	2E-05	6E-05	1E-05	6E-06	2E-06	2E-05	5E-07	4E-07

Fugitive Dusts & Combined Point Sources	Primary Assessment Health End Points			Secondary Assessment Health End Points				
Particulate Fraction	PM2.5	PM2.5	PM2.5	PM10	PM2.5	PM2.5	PM2.5	PM2.5

Endpoint	Mortality - All causes	Hospitalisations - Cardiovascular	Hospitalisations - Respiratory	Mortality - All causes	Mortality - All causes	Mortality - Cardiopulmonary	Mortality - Cardiovascular	Mortality - Respiratory
Effect Exposure Duration	Long Term	Short Term	Short Term	Short Term	Short Term	Long Term	Short Term	Short Term
Age Group	≥ 30 years	≥ 65 years	≥ 65 years	all ages	all ages	≥ 30 years	all ages	all ages
β	0.0058	0.0008	0.00041	0.0006	0.00094	0.013	0.00097	0.0019
Baseline Incidence per 100,000	1087	23352	8807	670	670	490	164	57
Baseline Incidence per person	0.01087	0.23352	0.08807	0.0067	0.0067	0.0049	0.00164	0.00057

Sensitive Receiver	Change in annual average PM10 concentration (μ/m3)	Change in annual average PM2.5 concentration (μ/m3)	Risk	Risk	Risk	Risk	Risk	Risk	Risk
Individual Receptors (con't)									
59	1.51	0.35	2E-05	7E-05	1E-05	6E-06	2E-06	2E-05	6E-07
60	1.68	0.41	3E-05	8E-05	1E-05	7E-06	3E-06	3E-05	7E-07
61	1.34	0.33	2E-05	6E-05	1E-05	5E-06	2E-06	2E-05	5E-07
62	1.14	0.25	2E-05	5E-05	9E-06	5E-06	2E-06	2E-05	4E-07
63	1.05	0.24	2E-05	4E-05	9E-06	4E-06	2E-06	2E-05	4E-07
64	0.89	0.2	1E-05	4E-05	7E-06	4E-06	1E-06	1E-05	3E-07
65	0.57	0.14	9E-06	3E-05	5E-06	2E-06	9E-07	9E-06	2E-07
66	0.44	0.12	8E-06	2E-05	4E-06	2E-06	8E-07	8E-06	2E-07
67	0.48	0.13	8E-06	2E-05	5E-06	2E-06	8E-07	8E-06	2E-07
68	0.46	0.12	8E-06	2E-05	4E-06	2E-06	8E-07	8E-06	2E-07
69	0.45	0.11	7E-06	2E-05	4E-06	2E-06	7E-07	7E-06	2E-07
70	0.4	0.1	6E-06	2E-05	4E-06	2E-06	6E-07	6E-06	2E-07
71	0.43	0.12	8E-06	2E-05	4E-06	2E-06	8E-07	8E-06	2E-07
72	1.73	0.33	2E-05	6E-05	1E-05	7E-06	2E-06	2E-05	5E-07
73	2.29	0.37	2E-05	7E-05	1E-05	9E-06	2E-06	2E-05	6E-07
74	2.16	0.34	2E-05	6E-05	1E-05	9E-06	2E-06	2E-05	5E-07
75	5.25	0.8	5E-05	1E-04	3E-05	2E-05	5E-06	5E-05	1E-06
76	3.01	0.49	3E-05	9E-05	2E-05	1E-05	3E-06	3E-05	8E-07
77	3.46	0.64	4E-05	1E-04	2E-05	1E-05	4E-06	4E-05	1E-06
78	2.17	0.42	3E-05	8E-05	2E-05	9E-06	3E-06	3E-05	7E-07
79	1.29	0.32	2E-05	6E-05	1E-05	5E-06	2E-06	2E-05	5E-07
80	3.22	0.64	4E-05	1E-04	2E-05	1E-05	4E-06	4E-05	1E-06
81	0.94	0.23	1E-05	4E-05	8E-06	4E-06	1E-06	1E-05	4E-07
82	0.6	0.15	9E-06	3E-05	5E-06	2E-06	9E-07	1E-05	2E-07
83	0.85	0.22	1E-05	4E-05	8E-06	3E-06	1E-06	1E-05	3E-07
84	0.72	0.17	1E-05	3E-05	6E-06	3E-06	1E-06	1E-05	3E-07
85	0.62	0.15	9E-06	3E-05	5E-06	2E-06	9E-07	1E-05	2E-07
86	0.53	0.13	8E-06	2E-05	5E-06	2E-06	8E-07	8E-06	2E-07
87	0.49	0.12	8E-06	2E-05	4E-06	2E-06	8E-07	8E-06	2E-07
88	4.27	0.71	4E-05	1E-04	3E-05	2E-05	4E-06	5E-05	1E-06

Appendix B

Report Number 610.15875.00000.0020 HRA

Page 1 of 3

Appendix B

UNCERTAINTIES AND LIMITATIONS

Uncertainties are present in all risk assessments and this reinforces the need for a systematic and rigorous approach. The enHealth human health risk assessment process attempts to estimate risk as accurately as possible, however there are various sources of uncertainty in the process that should be examined. Understanding these uncertainties places the risk estimates in a proper perspective allowing them to be applied in practice with an appropriate level of confidence.

In general, the uncertainties and limitations of human health risk assessment can be classified into the following categories:

- Personnel exposure assessment.
- Toxicological assessment.
- Risk characterisation.

Various sources of uncertainty are briefly discussed below.

Uncertainty related to Exposure Assessment

The uncertainties that may exist in exposure assessment include the estimation of concentrations in the air:

- Uncertainties relating to air modelling.
- Models are generally conservative and overestimate concentrations

Uncertainty related to Toxicity Assessment

In general, the available scientific literature is insufficient to provide a thorough understanding of all of the potential toxic properties of chemicals or materials to which humans may be exposed. It is necessary therefore, to extrapolate these properties from data obtained under other conditions of exposure and involving experimental laboratory animals. This may introduce two types of uncertainties into the risk assessment, as follows:

- Those related to extrapolation from one species to another
- Those related to extrapolating from high exposure doses, usually in experimental animal studies, to the lower doses usually estimated for human exposure situations

Safety factors are introduced to compensate for these uncertainties. The use of safety factors and extrapolating from high exposure concentrations typically leads to a conservative over-estimation of dose response relationships.

Uncertainties in Site Specific Data and Modelling.

Much of the data relied upon in this report was based on Boral's historic air quality and stack testing data from existing operations and also predicted COPC concentrations from the air quality modelling outlined by Air Quality Professionals (2015). The uncertainty associated with Boral's air quality testing data is expected to be distributed around the actual concentration and no different from measured data any air monitoring programme. The uncertainty associated with the air quality modelling predictions is more directed as the modelling deliberately chooses conservative parameters which are more likely to overestimate COPC concentrations. Therefore the predicted data used for exposure assessments in the risk assessment were likely to be much higher than what the actual concentrations will be when the Cement Works is in operation.

Uncertainties Conclusion

While a number of parameters used within the risk assessment have a moderate degree of uncertainty associated with them, values used to define these parameters have been selected to be conservative. This has resulted in estimates of risk which tend towards a conservative overestimation.

Data Gaps

The contribution of fugitive dusts (not linked to the proposed modification) to the incremental increases in total PM₁₀ and PM_{2.5} should be further explored in the air quality assessment with a view to determining engineering controls which may be able to reduce fugitive dust emissions and hence lower the potential health risks to acceptable levels. SLR understands that this aspect will be further explored by Boral in a future document.

As previously stated, there is a paucity of data relevant to the Secondary exposure pathways. For example regarding particulate associated COPCs, such as heavy metals, dioxins, PAHs, etc where the ultimate environmental sink is soil or settled dusts there appears to be little or no available data relating to existing soil concentrations of COPCs in the local communities, or in settled dusts within local residences or on local food crops such as home grown vegetables. Nor is there data related to particle size and particle deposition in the available air quality monitoring and modelling. Accordingly accurately quantifying Secondary exposure pathways is not possible. Therefore ingestion and dermal pathways could not be fully accessed.

What can be said about Secondary exposure pathways is that if the proposed modifications do not lead to significant changes in the emission of particulate associated COPCs compared to emissions from the existing processes then there should be no increase in any existing risk from Secondary exposure pathways to the local communities associated with the proposed modifications.

Regarding VOCs, the actual composition of the VOC mixture present in the Kiln 6 emissions is unknown at this time.



Our reference: EF13/2676:DOC15/286517-64:MF
Contact: Matt Fuller (02) 4224 4100

Department of Planning and Environment
(Attention: Sally Munk)
GPO Box 39
SYDNEY NSW 2001

Dear Ms Munk

DA 401-11-2002 MOD 9
BORAL CEMENT – BERRIMA – USE OF WASTE DERIVED FUELS

I am writing in response to additional information submitted to Department of Planning and Environment (DPE) and the Environment Protection Authority (EPA) by Boral Cement Berrima (Boral) to address issues previously raised in EPA correspondence.

On the basis of a review of the information received to date, the EPA provides the following advice to assist DPE in the assessment of the above development application:

- The QA/QC documentation submitted by Boral adequately addresses the matters raised in previous EPA correspondence.
- DPE and the EPA consider appropriate conditions of consent in relation to POP trials for the proposal could be developed if approval is granted.
- The HHRA has not adequately addressed all of the issues previously raised by the EPA. This includes:
 - The assessment of impacts associated with non-direct inhalation exposure pathways.
 - The risk associated with airborne particulates.
 - The assessment of heavy metals (including mercury, thallium and lead) and VOC's.

The EPA provides detailed comment on the above matters in **Attachment A**. In providing the HHRA comments in **Attachment A**, Boral should consider the additional information provided by the Air Quality Professionals (AQP) in their report dated April 2016, when addressing the outstanding HHRA matters.

In providing this response, the EPA has considered the following information:

- The revised HHRA submitted by Boral.
- Further updated data from the Air Quality Impact Assessment (AQIA) to support the proposal submitted on 30 June.
- An updated quality assurance/quality control framework (QA/QC) in accordance with the requirements of the *NSW Energy from Waste Policy Statement (The Policy)*.
- Information from recent discussions/meetings between Boral, DPE and the EPA on the above matters.

The assessment of the HHRA (and additional AQP data) was also undertaken by an independent consultant (EnRisks) appointed by the EPA. The independent consultants comments have previously been provided to DPE in separate correspondence.

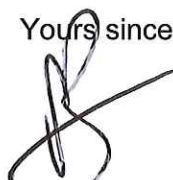
Given the importance of the assessment of health risks associated with the proposal, the EPA considers that issues concerning the HHRA need to be resolved prior to Project determination.

The EPA is yet to finalise comments relating to the assessment of supplemental air quality and emissions information submitted by Boral. This includes demonstrating that Kiln 6 will achieve the proposed emission limits, Kiln 6 VOC emissions are associated with blue shale and justification that a 24 hour averaging period for NOx is appropriate. This also includes confirmation that the Clean Air Regulation and Environment Protection Licence limits apply at all times (that is, there is no 'allowable' number of hours for upset conditions where emission limits can be exceeded). These comments will be the subject of an additional response from the EPA to DPE. The EPA will endeavour to provide a response on these remaining matters as soon as possible.

The EPA will continue to liaise with DPE during its assessment of this proposal. The EPA may have additional comments upon receipt and review of the information requested.

If you have questions regarding the above, please phone the contact Mr Matt Fuller on (02) 4224 4100.

Yours sincerely



02/08/16

PETER BLOEM
Manager Illawarra
Environment Protection Authority

Att: Attachment A

ATTACHMENT A

Comments on the Human Health Risk Assessment

1. The HHRA lacks an assessment of impacts associated with non-direct inhalation exposure pathways. In addition the HHRA does not robustly justify why an assessment of non-direct inhalation exposure pathways is not required.

The EPA notes this issue remains to be adequately addressed.

The HHRA assesses exposure from the direct inhalation of potential pollutants. However, the HHRA does not assess exposure from indirect pathways such as exposure via inhalation, ingestion or dermal absorption, to contaminants that have been partitioned from the air into settled dusts or soils.

To justify why these other exposure routes were not assessed, the HHRA states there is a lack of data relevant to secondary exposure pathways to enable accurate quantification of any associated exposure. However, the HHRA does not clarify why, for example, deposition estimates cannot be obtained from air quality modelling, or other methods can't be used to estimate exposure.

In addition, the HHRA states that there should be no increase in risk from secondary exposure pathways if the project modifications do not lead to significant changes in emissions of chemicals of potential concern (COPC) associated with particulate matter, compared to emissions from the existing process.

Despite the above, the EPA notes the HHRA does not clarify if the modification will, or is likely to result in significant changes to the emissions profile with respect to COPC.

EPA recommends Boral revise the HHRA so that it clearly justifies the lack of further consideration or quantification of exposure to COPC, and associated risk, via non-direct inhalation pathways.

2. The HHRA has been amended to provide details of the baseline incidence data used to quantify the risk associated with airborne particulates. However the revised calculated risk associated with exposure to PM_{2.5} at some receptor locations is greater than 1×10^{-4} which is considered to be unacceptable.

The EPA notes the issue of baseline incidence data has been resolved, however another issue has arisen associated with the revised risk calculations.

The HHRA has been amended to include details of the baseline incidence data used in the quantification of risk associated with airborne particulates (PM₁₀ and PM_{2.5}). The baseline incidence data used was NSW data from 2005- 2007 or 2009-2011. The data was "as used in the NorthConnex report (EnRiskS, 2014)".

The EPA notes the calculated risk associated with cardiovascular hospitalisation for people older than 65, based on short term exposure to PM_{2.5}, exceeds 1×10^{-4} at seven receptor locations, which is considered unacceptable (Table 19). The predicted incremental increases in PM₁₀ and PM_{2.5} annual average concentrations at the modelled receptors are 5.2ug/m³ and 1ug/m³ respectively. The maximum predicted incremental increases in PM₁₀ and PM_{2.5} concentrations at non-receptor locations were 18ug/m³ and 3ug/m³ respectively. However, the location of the maximum concentrations is stated to be just outside a small section of the western boundary of the site, not in an area of habitation, and therefore is "unlikely to be a realistic exposure scenario for the community".

In addition, the HHRA states the incremental increases in total PM₁₀ and PM_{2.5} are considered to be conservative and may be due to fugitive dusts not linked to the proposed modification, rather than emissions from the kiln. However, the EPA notes the HHRA does not provide information to substantiate these statements, or demonstrate potential risks associated with exposure to particulate matter is acceptable.

The EPA advises that the baseline incidence issue has been satisfactorily addressed. However the calculated risk at some receptor locations is greater than 1×10^{-4} which is considered unacceptable. Consequently the EPA recommends Boral revise the HHRA to clearly demonstrate the calculated risk from exposure to particulate matter, in particular PM_{2.5}, is acceptable.

3. The use of mercury and thallium data from ambient particulate sampling to demonstrate low ambient air levels of these metals should be justified.

The EPA notes that this issue remains to be adequately addressed.

The HHRA notes (Section 2.1.14) cement kiln emissions of volatile metals such as thallium and mercury tend to remain un-bonded and are emitted to atmosphere primarily in elemental form (that is, as a vapour not a particulate). Consequently, it is not valid to use air particulate monitoring to assist to demonstrate kiln thallium and metal emissions are not significant.

The HHRA has been amended to state that during trials of non-standard waste derived fuels, results of emission testing found heavy metal emissions, including “cadmium” (*EPA notes this should presumably be thallium, as cadmium is not a volatile metal*) and mercury at a similar level to baseline. However, details of this emission testing is not provided in the HHRA.

The EPA notes the predicted metal GLCs from the air quality modelling include both volatile and particulate phases. This provides a line of evidence that can be used in the assessment of these COPC.

The EPA recommends Boral revise the HHRA to clarify the reference to particulate based mercury and thallium concentrations, to assist in demonstrating kiln mercury and thallium impacts are minimal.

4. The HHRA lacks clarity with respect to the assessment of heavy metals.

The EPA notes the criteria issues appear to have been resolved, however other related issues remain to be adequately addressed.

a) Acute impacts - assessment of metal species

The HHRA has been amended to more appropriately compare the 99th percentile 1-hour average GLC predictions beyond the boundary of the facility, with the lowest of either NSW EPA 1-hour average criteria, or TECQ acute (1-hour average) effect screening level (ESL). An acute hazard index of 1.09 was calculated based on the sum of individual hazard quotients for each metal species. In addition, the HHRA states the potential extent for build-up of metals in soils is unclear due to the lack of relevant data to determine or estimate the dispersion and settling of particulate matter emitted.

However, the EPA note that despite the hazard index being slightly above the acceptable level of 1, and the stated potential for exposure to heavy metals through other routes, the HHRA excludes heavy metals from further assessment based on “the lack of difference in measured heavy metal emissions between trials of waste derived fuels compared to standard fuels and the predicted emissions from Kiln 6”.

The EPA recommends Boral revise the HHRA to provide additional justification that exposure to heavy metals via direct inhalation, and exposure across all exposure routes, is unlikely to result in adverse acute health impacts.

b) Chronic non-cancer impacts - assessment of metal species

The HHRA compares annual average GLC predictions beyond the boundary of the facility with TCEQ chronic health based criteria. The hazard index calculated for chronic exposure (annual average in this case) was 0.54 which is considered acceptable. However, the EPA notes that as for the assessment of acute impacts from heavy metals, the HHRA does not include exposure due to non-direct inhalation in the hazard index calculation.

The EPA recommends Boral revise the HHRA to provide additional justification that exposure to heavy metals via inhalation, and exposure across all exposure routes, is unlikely to result in adverse chronic health impacts.

c) Chronic cancer impacts - assessment of metal species

The HHRA evaluates the potential human carcinogenic risks associated with exposure to metal species namely chromium VI, by dividing the annual average GLC prediction beyond the boundary of the facility (0.0001375ug/m³) with the USEPA slope factor for inhalation carcinogenic risk (1.21E-05ug/m³) based on a carcinogenic target risk of 1E-06. The resulting value is stated as a "Carcinogenic hazard quotient" and has a value of 11.46. The method used to calculate carcinogenic risk, is not discussed in the report, despite an apparently high and potentially unacceptable value with respect to inhalation carcinogenic risk. The HHRA then calculates an acceptable lifetime inhalation risk from exposure to chromium VI of 5.5x10⁻⁶ based on a WHO inhalation unit risk value, however the HHRA does not include any discussion on this method, and why the WHO value was chosen over the value derived using the USEPA slope factor.

The EPA recommends Boral revise the HHRA to clarify the method and findings of carcinogenic risk associated with exposure to heavy metals.

d) Acute and chronic metal air criteria

The NSW EPA acute criteria for metal species have been corrected. Other errors in Tables 25, 26 and 27 identified in the last review also appear to have been corrected (*note the EPA has not checked every value in each of the revised tables*).

5. The HHRA does not discuss the appropriateness of the criteria or methodology used to assess health risks associated with lead emissions.

The EPA notes that this issue remains to be adequately addressed.

The HHRA has been revised to include the use of the more recent US EPA regional screening level (RSL) annual average value for lead of 0.15ug/m³, compared to the EPA value of 0.5ug/m³. The predicted annual average GLC for lead is 20% of the RSL and consequently the HHRA states lead impacts are anticipated to be negligible.

However, the EPA notes the methodology used for lead assessment does not further consider other potential exposure pathways, nor is the inclusion of lead considered with respect to hazard index calculations for acute or chronic impacts.

The EPA recommends Boral provide information to justify the methodology used to assess impacts associated with lead emissions.

6. The HHRA does not justify the contaminants of concern assessed, in particular VOCs, are representative of Kiln 6 emissions when solid waste derived fuels are used.

The EPA recommends Boral revise the HHRA to include more information and discussion to justify the contaminants of concern assessed, and their modelled emission concentrations, in particular with regard to VOCs, are representative of emissions when solid waste derived fuel will be used in Kiln 6.

Compliance with the NSW Energy from Waste Policy Statement

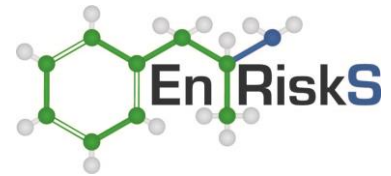
7. Quality Control/Quality Assurance framework (QA/QC), Ambiguity over Fuel composition

This issue has been adequately addressed. The EPA has assessed the additional QA/QC documentation submitted by Boral on 11 July 2016 and considers that the document now adequately addresses the matters raised in previous correspondence. The QA/QC document now includes provisions for addressing the identification and isolation of wastes containing more than 1% of halogenated organic substances expressed as chlorine as required in the *NSW Energy from Waste Policy Statement*.

Additionally, the updated QA/QC addresses ambiguity over the fuel composition and its sources and a revised fuel specification has been provided.

8. Proof of Performance (POP) Trials

The EPA accept that Proof of Performance Trials for the proposal could be developed and adequately addressed as a condition of consent if approval is granted.



18 July 2016

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Attention: Deanne Pitts

www.enrisks.com.au

Re: Review – Boral Cement Berrima Works, Use of Solid Waste Derived Fuels in Kiln 6, Human Health Risk Assessment

1.0 Introduction

Environmental Risk Sciences Pty Ltd (enRiskS) has been commissioned by the NSW EPA to review the revised Human Health Risk Assessment (HHRA) for the proposed use of solid waste derived fuels in Kiln 6 at the Boral Cement Works, Berrima dated May 2016. The HHRA was revised by SLR Consulting Australia Pty Ltd in response to previous comments by enRiskS provided in October 2015 and in February 2016 and during a meeting in April 2016.

2.0 Comments

Minor amendments have been made to the HHRA to address comments provided by enRiskS in a letter in February and at a meeting in April 2016. The comments provided in this letter relate just to these changes.

A revised HHRA dated May 2016 was provided for review. Further requests in late June provided a revised version of the AQIA from January 2016 which had not been previously provided to the NSW EPA and an additional letter from April 2016 addressing matters raised in the meeting related to the air quality modelling.

■ Particulate Matter

The additional information provided end June/early July does not adequately address this matter. The following suggestion for resolving this matter is provided for consideration.

The mathematical error present in the January 2016 version of the HHRA has been corrected. As was discussed at the meeting in April, fixing the mathematical error results in the risk estimates becoming unacceptable which does need to be addressed.

The human health risk assessment calculates that the risks due to PM₁₀ are estimated to be in excess of 1×10^{-4} . It is quite clearly stated in the NSW EPA Approved Methods Manual for Modelling and Assessment that risks in excess of 1×10^{-4} make a facility unacceptable (see table 7.3 in the manual). NSW Health would also be likely to be concerned with such a high risk estimate.

Also, other developments that I am aware of (road infrastructure/tunnels) have been required to ensure the risks from PM are within acceptable levels. This was one of the issues that led to remodelling/design adjustment. NSW Health were insistent that this be addressed. Allowing such a risk to be considered acceptable without some detailed explanations appears inconsistent with the approach adopted by NSW Health and planning decisions over the last few years.

The HHRA only comments that some additional monitoring around the site will be undertaken around the site and that air quality modelling is conservative. This is not sufficient nor in compliance with the Approved Methods Manual requirements. **Further action is required.**

It is suggested the further action take the following approach:

- The estimates for PM should be separated into those from the emissions from the stack and those from the emissions from fugitive sources. I believe this data exists within the AQIA so no additional modelling should be needed.
- The risks should then be calculated separately for the two types of emissions.
- The DA is about changes to the fuel so only affects the stack emissions. If the separated risk estimate for the emissions from the stack shows risks below 1×10^{-4} this should be sufficient for this development application.
- The contribution from fugitive emissions from the stockpiles can then be discussed in a more qualitative sense. This discussion can include information about why the modelling estimates are likely to have overestimated fugitive emissions, the actions already taken to reduce fugitive emissions, the actions proposed in the future to better understand fugitive emissions and the way this can/will be addressed in the licence and consent.

This should allow the finalisation of the HHRA in regard to this matter.

■ Air Toxics

The additional information provided end June/early July allows the following comments on outstanding matters.

The matters that were flagged in May 2016 as requiring further work were:

- Annual average VOCs value – the January version of the AQIA has now been provided to the relevant reviewers. While the information provided was not totally transparent, it does appear that the approach has provided a conservative estimate of the annual average VOCs. **No further action is required.**
- Speciation of total VOCs – the January version of the AQIA still does not provide a totally transparent explanation as to how the VOCs were speciated, however, given that the modelling was determined to be conservative **no further action is required.**
- Errors in criteria used to assess air toxics
 - Acetone – the chronic criteria has been entered incorrectly into the table from the previous advice. The correct value would result in a lower risk quotient so **no further action is required.**
 - Naphthalene – the correct chronic value for naphthalene is $3 \mu\text{g}/\text{m}^3$ as specified in both the CRC CARE Technical Report 23 and USEPA RSL references already referenced. This would result in a higher chronic risk quotient than is currently listed in Table 24, however, it would still be very low so **no further action is required.**

■ BaP TEQs

The additional information provided end June/early July briefly addressed this matter in the discussion of the conservatism in the emission rate estimates in the letter advice which also refers to the January version of the AQIA.

The HHRA does not provide a short discussion of the basis for the modelling for this chemical group to indicate whether or not it was likely to be conservative for the proposed change in fuel. This is normally expected in such an assessment to support the robustness of the risk estimates.

The letter advice notes that the emissions were modelled at 10 times the current measured average concentrations and notes that Section 4.8.2 in the AQIA provided additional information.

Section 4.8.2 of the AQIA notes the following:

- Table 32 lists the assumed emission concentration for PAHs as BaP TEQs as 0.000068 mg/Nm³ at 10% O₂.
- Table 23 lists the measured concentrations of PAHs as BaP TEQs between 2011 and 2014 as ranging between 0.00000022 and 0.0000068 mg/Nm³ at 10% O₂
- So the value listed in Table 32 is 10 times the maximum measured concentration during the single monitoring campaign each year which is appropriate
- Table 23 also lists the mass emission rates from these same measurements. These rates ranged from 108 to 3240 mg/hr
- These rates can be converted to the units of g/s as required in the modelling – 3240 mg/hr converts to 0.0009 g/s and ten times this value would be 0.009 g/s
- Table 32 lists the calculated emission rate used in the modelling as 0.0000136 g/s which is 600 times lower than the values from the monitoring data, it is even lower than the lowest measured emission rate of 108 mg/hr (0.00003 g/s) which occurred when the stack concentration was 0.00000022 mg/Nm³ at 10% O₂.
- It is not clear how the emission rate was calculated. The table does note that the listed values were calculated at a gas flow rate of 200 Nm³/s which may explain the difference but this is not clear from the information supplied
- If an emission rate that is too low has been used in the modelling, then the predicted ground level concentrations will be too low and the risk will be underestimated.

The emission rate for PAHs used in the modelling needs to be checked against the measured emission rates and corrected if too low. **Further action is required.**

■ Dioxins

The additional information provided end June/early July addressed this matter. **No further action is required.**

■ Metals

The additional information provided end June/early July did not address this matter.

The comments provided in May 2016 identified a number of matters.

A number of matters remain outstanding:

- For the proposed development to be acceptable both the assessment of acute and chronic risks must result in values in the acceptable range.
 - In this case the acute risk estimate has tripped into the unacceptable range.
 - Cadmium and beryllium are the metals that contribute most to this estimate of acute risk.
 - These metals have been monitored extensively between 2011 and 2014 at the existing plant and neither have ever been detected.
 - If the modelling for these two metals has been based on an emission rate of 10 times the limit of reporting from the monitoring (ranging between 0.004 and 0.01 µg/m³ for beryllium and 0.004 and 0.005 µg/m³ for cadmium then the estimated ground level concentrations will be conservative.
 - If the limits of reporting were used directly to estimate emissions given that these two metals were never detected this would result in an acceptable risk estimate for acute risk (risk quotients would be approximately 0.038 and 0.034 for these two metals resulting in a total acute risk quotient of 0.4 instead of 1.1).

- **No further action is required** although it would be useful to include some discussion of the conservative approach taken in the modelling specifically in relation to these two metals in the HHRA if possible.
- Some of the chronic criteria listed in Table 27 appear to be incorrectly reported or cited. The correct values are listed in the following table. Using these values is likely to lower the hazard index and **so no further action is required**.

Metal	Criteria	Reference	Correct as listed in Table 27 (Y/N?)
Antimony	0.21	USEPA RSLs	N (value)
Arsenic	0.016	USEPA RSLs	Y
Beryllium	0.021	USEPA RSLs	Y
Cadmium	0.01	USEPA RSLs	N (citation)
Chromium (total)	0.041 Cr III/ 0.0043 Cr VI	TCEQ ESL (LT)	N (value)
Chromium VI	0.1/0.000012	USEPA RSLs	Y
Cobalt	0.0063	USEPA RSLs	N (value)
Copper	1	TCEQ ESL (LT)	N (value)
Manganese	0.052	USEPA RSLs	N (value)
Mercury	0.31	USEPA RSLs	N (value)
Nickel	0.015	USEPA RSLs	N (value)
Selenium	21	USEPA RSLs	N (value)
Thallium	0.1	TCEQ ESL (LT)	Y
Tin (inorganic)	2	TCEQ ESL (LT)	N (value) (no value was listed in USEPA RSL)
Vanadium	0.1	USEPA RSLs	N (value)

■ Secondary Exposure Assessment

As discussed previously by both enRiskS and NSW EPA, it is a normal expectation that a risk assessment for such a facility would include an assessment of secondary exposure to the longer lived chemicals that are part of the emissions from the kiln.

The additional information provided end June/early July did not directly address this matter.

While the comments provided in the revised HHRA on page 39 are not sufficient to cover off on this aspect of potential human health risks posed by the project, the additional information provided did confirm the likely conservative estimates of emissions for long-lived chemicals like the dioxins and the metals.

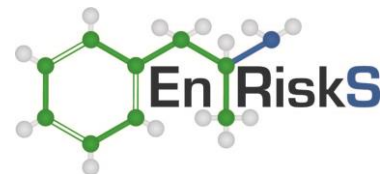
With the low estimates for emissions of dioxins, metals and PAHs, it is unlikely that sufficient levels of these chemicals could accumulate in soil around the plant to make a significant contribution to the risks posed by this facility. **No further action is required**.

3.0 Conclusion

The revised HHRA (May 2016) and the additional information in regard to the air quality modelling (June/July 2016) has provided sufficient information to allow some outstanding matters from the advice provided in May 2016 to be finalised including:

- Dioxins
- Secondary exposure assessment
- Metals
- Air toxics

Outstanding matters now relate only to:



- risk assessment for particulates for which an approach has been suggested that would provide a satisfactory resolution without additional modelling
- estimated ground level concentrations for PAHs – further information about the calculated emission rate versus the measured emission rates may suffice.

4.0 Limitations

Environmental Risk Sciences has prepared this report for the use of NSW EPA in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report.

The methodology adopted and sources of information used are outlined in this letter report. Environmental Risk Sciences has made no independent verification of this information beyond the agreed scope of works and assumes no responsibility for any inaccuracies or omissions.

This report was prepared in July 2016 and is based on the information provided and reviewed at that time. Environmental Risk Sciences disclaims responsibility for any changes that may have occurred after this time.

This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

If you require any additional information or if you wish to discuss any aspect of this letter, please do not hesitate to contact Therese on (02) 9614 0297 or 0487 622 551.

Yours sincerely,

Therese Manning (Fellow ACTRA)
Principal
Environmental Risk Sciences Pty Ltd

Jackie Wright (Fellow ACTRA)
Principal/Director
Environmental Risk Sciences Pty Ltd



APPENDIX B

Particulate Matter Risk Assessment



APPENDIX B

Boral Cement Berrima Works, Use of Solid Waste Derived Fuels in Kiln 6, Human Health Risk Assessment

Golder Associates (Golder) has been engaged by Boral Cement Limited (Boral) to address comments to the HHRA provided by enRiskS on behalf of EPA. The letter sent to NSW EPA on 18th July 2016, EnRisks states that the estimates for PM should be separated into those from the emissions from the stack and those from the emissions from fugitive sources.

Golder extracted the data from the existing AQIA and did not carry out additional modelling. Golder assumes the accuracy of the data in AQIA and calculates the risks separately for the two types of emissions using the same method in HHRA report Appendix A. The two types of emissions include:

- emissions from Kiln 6 stack
- emissions from fugitive sources

The change in fuel source will predominantly impact on Kiln 6 stack emissions and this is the focus of the HHRA.

The emissions of Kiln 6 stack and all 4 point sources were extracted from Table 65 (p143) and Table 73 (p157) of AQIA report, for PM₁₀ and PM_{2.5}, respectively.

The emissions from fugitive sources were calculated by subtracting emissions of all 4 point sources from emissions of fugitive and point sources combined.

Emissions of fugitive and point sources combined were extracted from Table 67 (p146) and Table 75 (p160) of AQIA report, for PM₁₀ and PM_{2.5}, respectively.

The AQIA was conducted in order to assess air quality compliance at discrete receptors. However the quantitative assessment of PM health risk requires a population average exposure. According to the WHO this HHRA method should be applied to the average daily exposure attributed to the emission source and not a maximum 24 hour value at a discrete receptor (Frangos & Di Marco 2013, WHO 2006). The HHRA has applied the quantitative HHRA method to discrete receptors in the modelling domain some of which are not within the community of Berrima. This is not a valid according to the WHO (WHO 2006).

To err on the side of caution an average (95th upper confidence limit around the arithmetic mean) and the 95th percentile daily PM_{2.5} and PM₁₀ have been used to calculate risks in accordance with the method suggested by enRisk.

The risk equation utilised in the calculation has been set out below. The baseline health incidence data is from NSW Health data sets as used in the HHRA report Appendix A.

$$Risk = \beta \times \Delta X \times B$$

Where:

β = slope coefficient relevant to the per cent change in response to a 1 $\mu\text{g}/\text{m}^3$ change in particulate matter exposure,

ΔX = change (increment) in PM₁₀ or PM_{2.5} exposure concentration in $\mu\text{g}/\text{m}^3$ relevant to the project at the point of exposure,

B = baseline incidence of a given health effect per person (e.g. annual mortality rate).

The calculated changes in health risk from incremental changes in both PM₁₀ and PM_{2.5} at each Receptor identified by the AQIA have been set out below in Table 1.

As shown in Table 1, all the 95% percentile and 95% upper confidence limit for the mean are within the target risk of 1 in 10,000 (i.e. 1E-04).



APPENDIX B

Boral Cement Berrima Works, Use of Solid Waste Derived Fuels in Kiln 6, Human Health Risk Assessment

Table 1 Calculated 95% percentile and 95% upper confidence limit for the mean for annual average change in health risk from changes in PM₁₀ & PM_{2.5} concentrations of emissions from kiln 6 stack and fugitive sources

		Change in annual average PM ₁₀ (µg/m ³) ΔX	Change in annual average PM _{2.5} (µg/m ³) ΔX	Primary Assessment Health End Points			Secondary Assessment Health End Points				
				PM _{2.5}	PM _{2.5}	PM _{2.5}	PM ₁₀	PM _{2.5}	PM _{2.5}	PM _{2.5}	PM _{2.5}
				Mortality - All causes	Hospitalisations - Cardiovascular	Hospitalisations - Respiratory	Mortality - All causes	Mortality - All causes	Mortality - Cardiopulmonary	Mortality - Cardiovascular	Mortality - Respiratory
				Long Term	Short Term	Short Term	Short Term	Short Term	Long Term	Short Term	Short Term
				≥ 30 years	≥ 65 years	≥ 65 years	all ages	all ages	≥ 30 years	all ages	all ages
95% percentile	Kiln 6 stack only	0.15	0.07	4.43E-06	1.31E-05	2.54E-06	6.04E-07	4.43E-07	4.48E-06	1.12E-07	7.61E-08
	Fugitive sources	2.89	0.40	2.54E-05	7.54E-05	1.46E-05	1.16E-05	2.54E-06	2.57E-05	6.42E-07	4.37E-07
95% Upper Confidence Limit for the mean*	Kiln 6 stack only	0.10	0.05	2.96E-06	8.78E-06	1.70E-06	4.03E-07	2.96E-07	2.99E-06	7.47E-08	5.09E-08
	Fugitive sources	1.35	0.19	1.19E-05	3.54E-05	6.84E-06	5.43E-06	1.19E-06	1.21E-05	3.01E-07	2.05E-07

*Confidence limits for the mean are an interval estimate for the arithmetic mean. Interval estimates are often desirable because the estimate of the mean varies from sample to sample. Instead of a single estimate for the mean, a confidence interval generates a lower and upper limit for the mean. The interval estimate gives an indication of how much uncertainty there is in our estimate of the true mean. Confidence limits are defined as:

$$\bar{Y} \pm t \times \frac{s}{\sqrt{N}}$$

where $\bar{Y}$ is the sample mean or 90% percentile, s is the sample standard deviation, N is the sample size, and t is the targeted percentile of the t distribution with $N - 1$ degrees of freedom.



APPENDIX B

Boral Cement Berrima Works, Use of Solid Waste Derived Fuels in Kiln 6, Human Health Risk Assessment

References

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APPENDIX C

Secondary Pathways



1.0 SECONDARY EXPOSURE PATHWAYS

Direct inhalation is the most important exposure pathway in majority of circumstances for most pollutants found in industrial emissions. However substances with the appropriate physiochemical (e.g. solubility in fat), environmental (e.g. persistence) and biological (e.g. poor rates of metabolism and excretion) properties, can accumulate through the human food chain.

In the SLR (2016) HHRA exposure via inhalation of emission components is referred to as the direct exposure pathway and has been examined in detail. All other exposure pathways are called secondary exposure pathways, these are summarised in Figure 1.

Evaluation of the secondary exposure pathways requires many assumptions which inherently contain unquantifiable uncertainties. The process of evaluating health risks from exposure via secondary pathways is resource intensive; the assumptions are made because empirical relations for the movement of most substances from air to other media to which humans may be exposed have not been established. Consequently in most risk assessments the secondary exposure pathways are not considered (because in the opinion of the assessor they are not considered important) or unrealistic conjectures are made to establish gross worst case exposure scenarios. In lieu of these approaches a pragmatic alternative is to perform screening assessments to evaluate the need for, and hence benefit from a detailed multi-pathway risk assessment. Usually the pre-evaluation is qualitative and based on the assessor's experience. In this risk assessment the pre-screens for metals and polycyclic aromatic hydrocarbons have been structured to provide a more objective and transparent process.

A pivotal aspect of the screening risk assessment for secondary exposure pathways for dioxin exposure is the estimation used for background intake of dioxin like substances. The Australian Government has published estimates for background intake of dioxin like substances for Australians (OCS 2004). The estimated total background intakes from all sources of exposure for dioxins and furans, polychlorinated biphenyls (PCBs) and total dioxin like substances for Australian adults are presented in Table 1. Intake from food accounts for between 95-99% of the total intakes and intakes from air are generally less than 1-5% (OCS 2004). For the purposes of this risk assessment the upper bound total intake estimates are used from this review.

Table 1: Estimated total intakes of Australian adults to dioxin like substances ^a

Total Intake (pg WHO TEQ/kg bw/month)					
Dioxins & Furans		PCBs		Total Dioxin TEQ	
Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound ^b
1.06	10.37	2.83	5.42	3.89	15.79

^a Data taken from OCS 2004 (Table 3-32).

^b This upper bound intake estimate is used in the risk calculations below.



The HHRA (SLR 2016 pg 71) states that the maximum ground level concentration for dioxin like substances is 0.024 pg TEQ/m³. Hence the monthly average intake for an adult via inhalation¹ (MI_{INHAL}) is:

$$\begin{aligned} \text{MI}_{\text{INHAL}} &= [(0.024 \text{ pg TEQ/m}^3) \times (20\text{m}^3/\text{d} \times 30\text{d})] \div 70\text{kg} \\ &= 0.2057 \text{ pg TEQ/kg /m.} \end{aligned}$$

the incremental increase² due to the cement works emissions is estimated to be 1.3% (OCS (2004).

PAHs are products of incomplete combustion of organic material; the predominant sources of PAH pollution are motor vehicle traffic (both petrol- and diesel-fuelled), residential heating, especially with wood or coal, burning-off and bushfires. Reviews of the scientific literature indicate little uptake and translocation of PAHs by plants from soil (ATSDR 1995, WHO 1998a). In addition organisms that metabolise PAH, such as fish and higher invertebrates and mammals that are human food sources accumulate little or no PAHs (ATSDR 1995, WHO 1998a). It follows therefore that if there is little or no bioaccumulation of PAHs by plants or animals likely to be consumed by humans evaluation of secondary exposure pathways for the PAHs is not warranted.

For metals, the screening procedure³ is pragmatically grounded in a comparison of predicted receptor ground level concentrations with rural background concentrations that are not associated⁴ with significant exposures via secondary pathways. This is augmented firstly by a requirement for a significant inhalation margin of exposure⁵ for individual metals such that if exposure was to occur via secondary pathways there is ample conservatism in the screening process to ensure the additional non-inhalation intakes will not result in adverse health effects in humans, and secondly with a brief review of the literature which indicated lack of potential for most metals to bio-magnify through the food chain⁶.

2.0 SCREENING FOR SECONDARY EXPOSURE PATHWAYS

2.1 Introduction

As depicted in Figure 1 exposure to emissions from the cement works can occur through secondary exposure pathways. The process of evaluating health risks from exposure via secondary pathways is difficult and uncertain because empirical relations for the movement of most substances from air to other media to which humans may be exposed have not been established. Thus the evaluation of secondary exposure pathways inherently requires many assumptions which impart unquantifiable uncertainties to the assessment. Consequently in most risk assessments the secondary exposure pathways are either not considered or unrealistic conjectures are made to establish gross worse case scenarios. In lieu of these approaches a pragmatic alternative is to perform screening assessments to evaluate the need for, and hence benefit from a detailed multi-pathway risk assessment. Usually the pre-evaluation is qualitative and based on the assessor's experience. In this risk assessment the pre-screens have been structured to provide a more objective and transparent process for deciding whether secondary exposure pathways are required to be evaluated.

¹ enHealth 2014 recommend a default inhalation rate for adults of 20 m³/d and 70 kg for adult bodyweight.

² The incremental increase = 0.2057 pg TEQ/kg /m ÷ 15.79pg TEQ/kg /m = 1.3%.

³ This screening process is not one where an approximation of risk is made under assumptions of worst case exposure conditions, rather it a screening process for whether or not a detailed multi-compartmental risk assessment needs to be undertaken. However an inherent outcome in the process is that if such analysis is not required then it follows that the substance in question does not pose a health risk via secondary exposure pathways.

⁴ This assumption is based on the background concentrations used for comparison being from rural or remote i.e. areas regarded as being unpolluted, where deposition to soil/pasture is not expected or shown to be a problem leading to significant exposure by secondary pathways.

⁵ The margin of exposure (MoE) is traditionally established from comparison of estimated exposure concentrations with the Low Observed Adverse Effect Level (LOAEL) for the compound. However in this risk assessment the MoE is established by comparison with the guideline value (i.e. the hazard quotient). With this latter comparison the safety factors are embedded in the guideline (which usually is based on the NOAEL) provide greater safety.

⁶ The exception is cadmium; although the relative biomagnification of cadmium may not be significant sufficient concentrations in certain portions of animals used to prepare food for humans can be high and be a potential health risk.

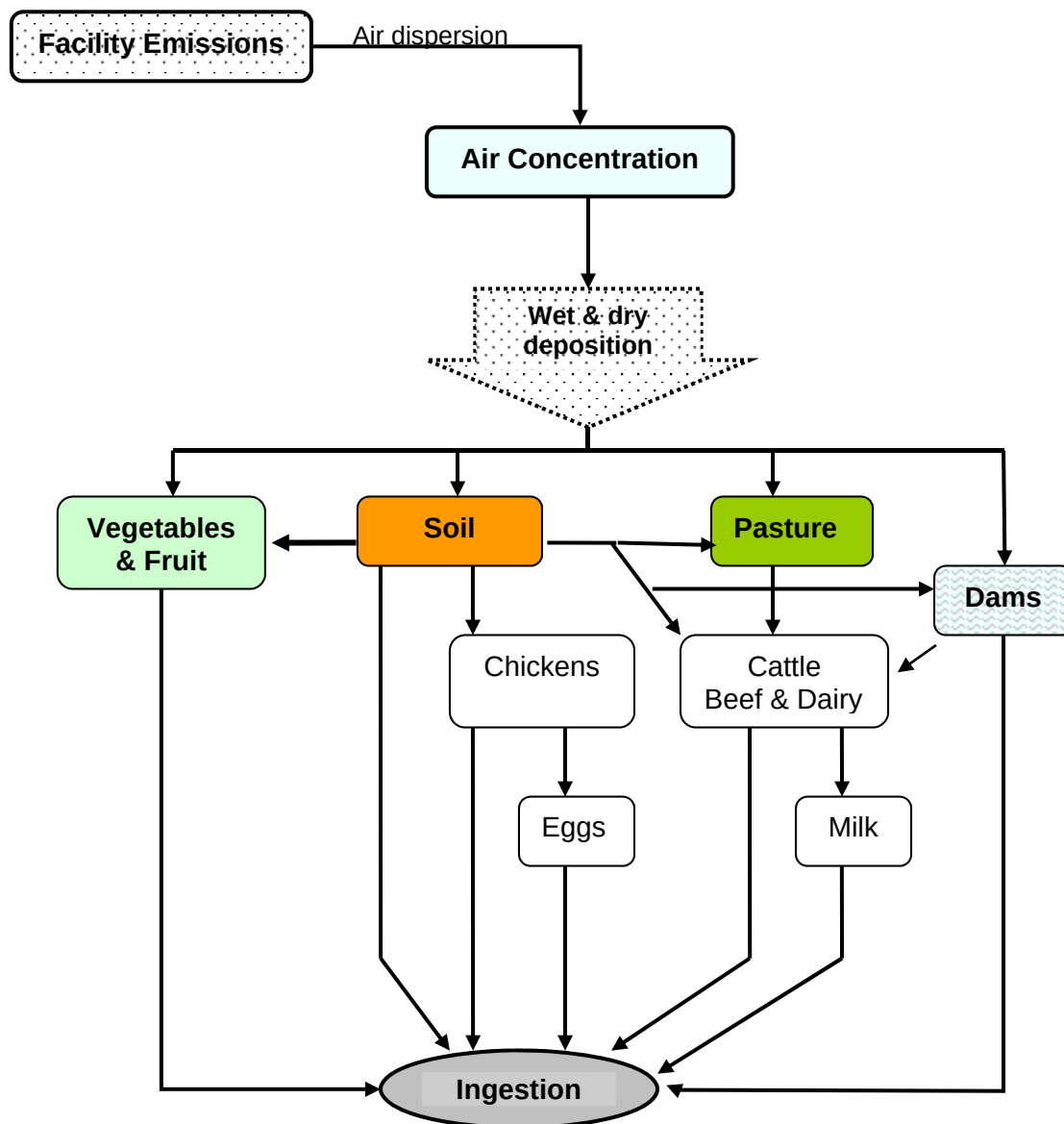


Figure 1: Secondary exposure pathways.

Chemicals of interest for potential evaluation of secondary pathways:

Inspection of the emissions from the Berrima Cement Works indicate the substances likely to be of interest with regard to secondary exposure pathways are metals

It is recognised that many of the above chemicals are bound to particulates and may be deposited directly onto vegetation; the extent to which humans may be exposed by this direct deposition pathway will be influenced by how much particulate is deposited, the extent to which rain washes particulates off vegetation, the extent of washing fruit and vegetables before consumption, and how much of the fruit and vegetables consumed are sourced from the local area. Assuming the vast majority of vegetables and fruit will originate from areas outside of the Berrima Cement Works emission dispersion zone and most of the time the food will be washed prior to consumption then exposure via direct deposition will be very small. This premise is supported by comparison of predicted annual ground level air concentrations with background concentrations from remote and rural areas around the world (Table 1).



Metals:

For metals, the screening procedure is pragmatically grounded in a comparison of predicted receptor ground level concentrations with rural background concentrations that are not associated ⁷ with significant exposures via secondary pathways. This is augmented firstly with a requirement for a significant margin of exposure ⁸ via inhalation exposure for individual metals such that if exposure was to occur via secondary pathways then there is ample conservatism in the screen to ensure the additional non-inhalation intakes will not result in adverse health effects, this is essentially saying the metal has to be toxic/hazardous to a certain degree before there is concern. Secondly with a brief review of the literature which indicated lack of potential for most metals to bio-magnify through the food chain⁹ (ATSDR 1992b, 1992d; ATSDR 1999a, 1999b, 1999c; ATSDR 2000a, 2000b, 2000c; ATSDR 2001b; ATSDR 2003c, 2003d; ATSDR 2004).

⁷ This assumption is based on the background concentrations used for comparison being from rural or remote i.e. areas regarded as being unpolluted, where deposition to soil/pasture is not expected or shown to be a problem leading to significant exposure by secondary pathways.

⁸ The margin of exposure (MoE) is traditionally established from comparison of estimated exposure concentrations with the No Observed Adverse Effect Level (NOAEL) for the compound. However in this risk assessment the MoE is established by comparison with the guideline value (i.e. the hazard quotient). With this latter comparison the safety factors embedded in the guideline are augmented to provide greater safety.

⁹ The exception is cadmium; although the relative biomagnification of cadmium may not be significant sufficient concentrations in certain portions of animals used to prepare food for humans can be high and be a potential health risk.



2.2 *Trigger criteria for metals*

The majority of metals in ambient air are in association with small particulates, generally less than 5µm. Gravitational settling (i.e. dry deposition) governs the removal of large particles (>~5 µm) from air, whereas smaller particles are removed primarily by wet deposition. The partitioning between dry and wet deposition depends on the frequency, intensity and duration of precipitation, the metal in question, its form in the particulate matter, and particle size. The importance of wet deposition relative to dry deposition generally increases with decreasing particle size. Removal of coarse particles may occur in a matter of hours. Small particles with a size range of <2.5 µm may have an atmospheric half-life as long as 30 days and therefore have the potential to be transported over long distances.

Once deposited on soil or plant surfaces it is not always possible to separate the environmental fate processes relating to transport and partitioning of metals between media from those relating to transformation of metals between redox states and/or various compounds/complexes. Part of the problem is that chemical analyses of metals in air, soil or biological matrixes rarely identify the form of the metal. A change of mobility may result from a transformation of a metal to a more or less soluble form which may have a marked effect on its uptake by plants and bioavailability to higher organisms. Specific local information such as soil pH, redox potential, organic and metallo-complex adsorption content is critical in determining a metal's lability and availability to organisms. Consequently it is very difficult to predict environmental behaviour of the metals on a general geographical basis. In addition for each metal, the resources expended gathering the necessary information for a full multi-pathway environmental fate and health risk assessment are not inconsequential. It is usual therefore to conduct a screening evaluation to justify resource expenditure. The basis for the screening process applied in this risk assessment for deciding the requirement for a multi-pathway evaluation is presented below.

Specific information on the metal content of particulate size fractions of the emissions from the Berrima Cement Works is not available. Indeed application of the screening process herein suggests such information, required for estimating deposition rates of metals onto soil and pasture surfaces is not required because the screen criteria are not met for consideration of secondary exposure pathways.

The following general assumptions are made in relation to the possibility of significant incremental exposure/intake of metals over background via secondary exposure pathways. The assumptions are used as the screening criteria to decide whether secondary exposure pathways should be evaluated.

Assumptions and screening criteria:

- a) The metal should exhibit significant bioaccumulation by plants, especially common vegetables and grasses, and animals. If biomagnification occurs then concern for human exposure via food increases as does the need for secondary exposure pathway evaluation. Obviously if the metal in question does not accumulate in the human food sources then concern regarding potential health effects via the secondary exposure pathways is not warranted.

Screening criteria A: The available weight of literature evidence must indicate the metal is able to bioaccumulate, or biomagnify, into human food sources.

- b) It is assumed the increase in exposure to metals via secondary pathways is proportional, in some manner, to any change in long term concentration of metals in air due to emissions from the Berrima Cement Works. For components of industrial emissions to be of concern relative to human exposure through secondary exposure pathways there is a requirement for them to be deposited onto soil or pasture in sufficient quantity that they will increase environmental concentrations at a faster rate than the normal processes of removal. It follows therefore that even for those metals capable of bioaccumulation, that if the predicted chronic air concentrations of emission components are less than those usually found in rural or remote environments then the emission components will not accumulate to an extent where food chain contamination is likely. Hence for there to be an increase in secondary pathway exposures there must be a significant



increase, relative to background, in chronic air concentration of the metals at the receptor locations.

Screening criteria B: To trigger detailed evaluation of secondary exposure pathways the predicted incremental increase in annual ground level concentration of the metal must be about the same, or above those measured in rural and remote areas¹⁰.

- c) The intake of metals into the body via inhalation is a relatively small proportion of total intake; most metals enter the body via the diet. For bioaccumulative metals a small increase in intake via inhalation could result in a larger overall intake since inhalation is only a small part of total intake. The requirement therefore is to ensure the incremental increase in inhalation intake is sufficiently small to keep total intakes low. This will ensure an adequate safety margin is maintained in the screening process such that total intake in the future is kept below any intake level that may be deleterious to health.

The proposed criteria to trigger evaluation of indirect exposure pathways for metals is for the direct inhalation hazard quotient for any given metal to be greater than 0.05. This is saying the incremental increase in exposure to any given metal from the cement works should be greater than 5% of its respective health guideline value before secondary exposure pathways need be evaluated.

Within this criteria is an assumption that 5% of the total intake is via inhalation and that the remaining 95%, which is ingested either in diet or by consuming soil, has the same toxicological potency and health effects as inhalation exposure, this is often not the case. Ingested metals are often less toxic¹¹ because homeostatic mechanisms limit their absorption and spectrum of effects different. Therefore the tacit assumption embedded in using a low inhalation hazard quotient as triggering criteria errs on the side of safety.

The rationale underpinning the inhalation exposure 'cut-off' is similar to that used in the dioxin risk assessment. Inhalation exposure of metals generally constitutes only approximately <1 – 20% of background intake (e.g. Langley 1991a,b; Maynard 1991). Arsenic and cadmium are two metals for which concern is often expressed regarding accumulation in the environment, according to the European Commission (EC 2000) the percentage for arsenic and cadmium uptake via ambient air is less than 1 and 3 % respectively.

Screening criteria C: To trigger detailed evaluation of secondary exposure pathways the hazard quotient for direct inhalational exposure of a metal must be more than 0.05.

¹⁰ Background airborne concentrations of metals are rarely known at the locations of interest. An increase equal to or greater than background levels cited in the literature for remote or rural areas implies at least a two fold increase of those background concentrations. Such an increase may or may not lead in the long term to an increase in metal content human foods; intuitively it is suspected that it would not lead to an increase in food chain concentrations. This criteria is therefore conservative and is unlikely to lead to a 'false negative' situation for the metals.

¹¹ The notable exceptions to this are mercury, cadmium and thallium. With these metals route of intake has relatively little impact on final health outcome and health effects are generally elicited at a lower exposure/intake via inhalation than by ingestion or dermal exposure.



Summary of screening trigger criteria for need for assessing secondary exposure pathways:

The criteria for triggering a detailed multimedia/multipathway health risk assessment for metals in the cement works emissions are:

- 1. The metal must be capable of being bioaccumulated by plants and animals relevant for the human food chain, and*
- 2. The predicted annual ground level concentration increment must be above those measured in rural and remote areas, or*
- 3. The direct inhalation hazard quotient for incremental annual average concentration any given metal is greater than 0.05.*

Discussion of the trigger screening criteria:

Similar criteria have been previously applied by risk assessors of air emissions. Greim (1990) evaluated the health risks posed by 69 modern municipal waste incineration plants (49 in operation and 20 in the planning and construction phase) in Germany. The assessment was conducted by comparing conservatively estimated ground level concentrations to background air concentrations in rural areas, threshold levels, air guideline values. The predicted ground level air concentrations of metals were similar or lower than those found in rural areas and because of this it was concluded that overall exposure to metals emitted by municipal waste incinerators did not present a risk to human health.

Boudet et al (1999) evaluated a modern municipal waste incinerator in France. The authors only evaluated direct inhalation health effects. While acknowledging secondary pathways are potentially relevant to such assessments, they cited previous studies¹² had shown the burden of metals in the food chain in the vicinity of modern facilities was not increased. It can therefore be rationalised that inclusion of those pathways would not influence the results from assessment of direct inhalation.

The general approach and conservativeness of the criteria applied herein for assessing the need for evaluating secondary exposure pathways for metals is supported by the results of a multimedia, multipathway risk assessment for waste combustors¹³ conducted for the US EPA (HWC) in support of establishing technical emission standards for these facilities (RTI 1999a). This very comprehensive health risk assessment addressed direct and indirect (i.e. secondary food chain) exposures for 79 HWCs, it focussed on the population within a radius of 20 km and evaluated 14 metals¹⁴ for each facility. The assessment included likely maximum exposed individuals who, due to their activities, could be at increased risk (e.g. recreational fishermen, and subsistence farmers and home gardeners).

Lead, arsenic and mercury were considered to be the metals of concern and the following findings were made (RTI 1999b,c):

- For lead the highest exposed individual was a child (0 to 5 years old) of a home gardener; nevertheless the incremental increase in blood lead levels due to the point combustion source were predicted to not significantly increase blood concentrations over background exposures.

¹² At the time of writing these studies were not available to Toxikos.

¹³ The hazardous waste combustors were comprised of cement kilns, light-weight kilns and incinerators.

¹⁴ Antimony, chromium VI, chromium III, arsenic, lead, barium, nickel, beryllium, selenium, cadmium, silver, thallium, cobalt, copper, and manganese.



APPENDIX C

- Children of dairy farmers were found to have the greatest exposure to arsenic due to their relatively high consumption of milk. High-end lifetime excess cancer risk (for the child of the dairy farmer) was nonetheless below one in a million.
- Recreational fishermen were identified as the individuals with the highest exposure to mercury due to high consumption fish and the type caught containing high concentrations of methylmercury. Children also had high exposures due to high fish consumption relative to body weight compared to adults. However all hazard quotients for all scenarios and exposure percentiles were less than 1.
- For the remaining metals assessed (i.e. antimony, chromium VI, chromium III, barium, nickel, beryllium, selenium, cadmium, silver, and thallium) hazard quotients for indirect pathways were all less than one and generally less than 0.01.

The results from the US EPA waste combustor assessment showed that for the metals evaluated there was no health risks associated with the indirect, secondary exposure pathways of metals.

The US Department of Energy (US DOE 2003) conducted a quantitative risk assessment to assess mercury health risks associated with two coal fired power plants. Specifically the study quantified the impact of local mercury deposition from coal-fired power plants on risks from foetal exposure through maternal consumption of fish. The risk assessments performed included three different test cases for each plant and two population groups. The population near one plant consumed 17% locally caught fish, similar to the average value in the northeast USA and the population near the other plant consumed 22% locally caught fish, similar to the average value for the Southeast of the United States. Subsistence fishers were assumed to consume 100% locally caught fish. The authors concluded that the risk to the general population from local deposition of mercury from coal-fired power plants is small. The authors identified that the risk assessment is dependent on the size and distance to the water body where fish are caught and the consumption rate of fish. In contrast to these risk assessments is a recent suggestion that environmentally released mercury may be associated with higher local incidences of autism in children (Palmer et al. 2005). While this report calls for further research on the possible link it is noted that the health point measured has not been included as part of previous risk assessments for environmental exposure to mercury.

Predicted air concentrations relative to background.

Because background air concentrations of metals in the Berrima region are not known at this time, background concentrations for other parts of the world have been sought from authority reviews. These are presented in Table 1 together with the predicted ground level concentration for the metals. This table includes data from NSW EPA regional air quality information. All the metals analysed fall below or within guidelines for the predicted ground level concentrations. Metal exposure via either direct inhalation or secondary pathways has not been flagged as an issue at these background locations. If it is reasonably assumed that the background air concentrations of metals zone of influence of Berrima Cement Works emissions is the same as, or lower than those cited in Table 1 it follows that the predicted small increase in air concentration over these backgrounds due to air emissions from the cement works also will not give rise to marked increases in exposure via the secondary pathways.

Thus criteria B for not initiating the multimedia risk assessment is satisfied.



APPENDIX C

Table 1: Comparison of background ambient air concentrations for metals with the predicted increment in annual ground level concentrations due to emissions beyond the site boundary of the Cement Works.

Metal	Predicted annual ground level concentration (ng/m ³)	Ambient background (ng/m ³)	Comment on location	Reference
Antimony	0.825	2 0.6 – 7 0.5-171 0.04-4.6	Ave background. US rural areas. US urban areas NSW Urban	ATSDR (1992b) NSW(2003)
Arsenic	0.033	1 – 3 1 – 28 4.2 – 9.6 20 – 100 0.09-2.5	US remote locations. US rural areas. Long term mean, Great Lakes. US urban areas. NSW Urban	ATSDR (2000a) NSW (2003)
Beryllium	0.033	0.03 0.2 0.03-0.2 0.04-6.7	Average in air. Median in cities. US rural areas. US urban areas.	ATSDR (2002b) WHO (1990)
Cadmium	0.1375	< 5 1-5 5-50 0.03-1	US general ambient. Rural Locations. Urban/ Industrialised Areas NSW Urban	ATSDR (1999b) WHO (1992) NSW (2003)
Chromium	0.1375	5-525 <100 <20	All US Non industrialized areas Australia Urban	ATSDR (2000) WHO (1988a) EA (2002)
Cobalt	0.0825	<1 – 2 <48 0.10-0.39	Unpolluted sites. Urban/ Industrial Area. NSW Urban	ATSDR (2004) NSW (2003)
Copper	0.715	5-50 2.4-28 <650	Rural NSW Urban WA Urban	WHO (1998d) NSW (2003) EA (2002)
Lead	0.33	0.1-8 200-400 100 1000-3000 5000-1000 2.4-99 140-1570 20	Remote areas. US urban areas. Australia Rural. Australia Urban Australia- Near heavy traffic NSW Urban WA Urban WA CBD	WHO (1977) ATSDR (1999c) Maynard (1991) NSW (2003) EA (2002) NEPC (2002b)
Manganese	3.905	10 – 70 1 3 3.7-119 <10	Europe US rural sites US urban sites. NSW Urban WA Urban	WHO (2000) ATSDR (2000c) NSW (2003) EA (2002)
Mercury	0.275	10 – 20	Industrialised areas.	ATSDR (1999d)



APPENDIX C

Metal	Predicted annual ground level concentration (ng/m ³)	Ambient background (ng/m ³)	Comment on location	Reference
		1 2-4 10	Remote Southern Hemisphere Rural areas. Urban areas	WHO (1989) WHO (2000)
Nickel	0.429	2.22 0.6-78 1-328 <0.1-1 0.86-20 <10	General ambient 1996. US rural US urban Marine NSW urban WA Urban	ATSDR (2003c) WHO (1991) NSW (2003) EA (2002)
Selenium	0.1595	1-17 < 10 0.1-0.65	Rural UK. US average. NSW urban	ATSDR (2001b) NSW (2003)
Thallium	0.1375	< 1 0.02 – 0.1	Europe. Six US cities	ATSDR (1992d)
Tin	0.33	NA	NA	NA
Vanadium	0.132	0.001-0.8 0.21-64 50-200 0.16-49	Remote Rural Urban NSW Urban	WHO (1988b) WHO (2000) NSW (2003)

^a Predictions for annual ground level concentrations from Table 27 in SLR HHRA May 2016 (Report No. 610.15875.00000.0020 HRA).

Concentration in air relative to health guideline.

Based on the above comparisons of predicted annual ground level concentrations compared to the health based guidelines for inhalation exposure, no metal annual average GLCs exceed the guidelines. Given the above information, for metals in emissions from the cement works, it was considered an incremental increase in inhalation exposure of 5% relative to the inhalation health guidelines, i.e. a hazard quotient of 0.05, would leave sufficient conservatism for screening purposes to ensure health effects arising from long term exposure from all exposure pathways was unlikely to result in adverse health effects (Donoghue 2014; 2008 Kampa; Smith 1990).

From Table 2, it can be seen that the highest hazard quotients for any of the metals for which there is a health guideline is 0.2 for lead and 0.075 for manganese. Thus the need for examination of secondary exposure pathways is triggered (Donoghue 2014).

Bioaccumulation of metals:

Of the metals considered herein, no metals have potential for accumulation and bioconcentration (Fergusson 1990). Lead and manganese are the only heavy metal to return hazard quotients greater than 0.05. However for manganese its bioconcentration factor in organisms is much greater than the estimated annual average GLC beyond the site boundary as well as the background concentrations recorded. It is, therefore, unlikely to pose a risk. In higher trophic levels such as humans, manganese homeostasis is maintained and therefore absorption is limited (ATSDR 2000c).

The highest incremental annual average GLC recorded for lead was 0.0003 ug/m³. This falls within the remote areas (WHO 1977) health based guideline for inhalation exposure, thus posing no significant risk to



APPENDIX C

human health. The hazard quotient is less than 0.05. Therefore it does not require an assessment of secondary pathways.

Table 2: Margin of Exposure between predicted annual ground level concentrations and chronic guidelines for metals due to emissions at Berrima Cement Works ^a.

Metal	Predicted annual ground level concentration (ug/m ³)	Chronic Guideline Value ^b (ug/m ³)	Hazard Quotient ^c
Antimony	0.000825	0.21 ^U	<0.01
Arsenic	0.000033	0.016 ^U	<0.01
Beryllium	0.000033	0.021 ^U	<0.01
Cadmium	0.0001375	0.01 ^T	0.013
Chromium (total)	0.00022	0.1 ^U	
Chromium VI	0.0001375	0.1 ^U	<0.01
Cobalt	0.0000825	0.0063 ^U	0.013
Copper	0.000715	1 ^T	<0.01
Lead	0.00033	0.15	0.002
Manganese	0.003905	0.052 ^U	0.075
Mercury	0.000275	0.31 ^U	<0.01
Nickel	0.000429	0.15 ^U	0.029
Selenium	0.0001595	21 ^U	<0.01
Thallium	0.0001375	0.1 ^T	<0.01
Tin (inorganic)	0.00033	2 ^T	<0.01
Vanadium	0.000132	0.1 ^U	<0.01

^a Predictions for annual ground level concentrations from Table 27 in SLR HHRA May 2016 (Report No. 610.15875.00000.0020 HRA).

^b Guideline values as per SLA (2016) HHRA and peer review recommendations.

^c Values for the HQ in this column do not mathematically match the division of the annual GLC by the guideline value because the annual average GLC has been rounded to one significant figure. The HQ values are calculated using the 'actual' predicted GLC before rounding.

^U USEPA Regional Screening Levels (Residential Air) USEPA 2015a)

^T TCEQ Long Term ESL



2.3 Notes on the bioaccumulation of metals.

Antimony

Antimony does not appear to bioconcentrate appreciably in fish and aquatic organisms. Only low levels of antimony have been reported in fish and aquatic organisms collected off the coast of Africa, Australia, and the Danube River in Austria. Bioconcentration factors for antimony ranged from 0.15 to 390

A study of the distribution of antimony around a smelter site indicated that antimony occurring in plants results from surface deposition. Uptake from soil is minor and appears to be correlated with the amount of available antimony that is soluble or easily exchangeable.

Antimony bioconcentration was measured in voles, shrews, rabbits, and invertebrates around a smelter. Analysis of antimony in organs of the small mammals, compared with estimates of their antimony intake from food, showed that, although the amount of antimony in the organs was elevated, it was low compared to the amount ingested. The results suggest that antimony does not biomagnify from lower to higher trophic levels in the food chain (ATSDR 1992b).

Therefore, antimony is not a concern for secondary pathways as it falls within the NSW Urban guidelines and has a hazard quotient <0.01.

Arsenic

Arsenic is released into the atmosphere primarily as arsenic trioxide or, less frequently, in one of several volatile organic compounds, mainly arsines. Trivalent arsenic and methyl arsines in the atmosphere undergo oxidation to the pentavalent state, and arsenic in the atmosphere is usually a mixture of the trivalent and pentavalent forms.

The predominant dietary source of arsenic is seafood, followed by rice/rice cereal, mushrooms, and poultry. However, most of the arsenic in seafood is of the non-toxic arsenobetaine form.

Arsenic is largely immobile in agricultural soils; therefore, it tends to concentrate and remain in upper soil layers indefinitely. According to ATSDR (2000) studies indicate uptake of arsenic from soil by vegetables is generally not very high. Even when grown on highly polluted soil or soil naturally high in arsenic, the amount of arsenic taken up by the plants is comparatively low.

Because arsenic concentrations in organisms tended to decrease with increasing trophic level, an extensive study of the factors affecting bioaccumulation of arsenic in two streams in western Maryland in 1997–1998 concluded there was no evidence of biomagnification. Arsenic is mainly accumulated in the exoskeleton of invertebrates and in the livers of fish. No differences were found in the arsenic levels in different species of fish which included herbivorous, insectivorous, and carnivorous species. The major bioaccumulation transfer is between water and algae, at the base of the food chain and this has a strong impact on the concentration in fish.

Arsenic is not biomagnified through the food chain (ATSDR 2000a).

Arsenic is not an issue for secondary pathways as it falls below NSW Urban guidelines and has a hazard quotient <0.01.

Beryllium

Beryllium released to the atmosphere from combustion processes and ore processing will probably be present as beryllium oxide. A study of stack emissions from coal combustion reported that most beryllium is found on particles with diameters of <2.5 µm. Particles of this size can remain airborne for approximately 10 days.

Bioconcentration of beryllium in plants and animals is very low. Soluble forms of beryllium must be present for uptake to occur in plants. In plants uptake of beryllium appears to be restricted to the root system; no



significant translocation of beryllium to the above ground parts of the plant has been observed. Beryllium is not expected to bioconcentrate in aquatic animals.

Beryllium does not bioconcentrate in aquatic organisms. BCFs up to 100 for freshwater and marine plants, vertebrates, and fish have been reported. There is no evidence of the bioaccumulation of beryllium in the food chain of humans (ATSDR 2002).

Therefore, beryllium is not an issue at secondary pathways as it falls within or below guidelines and has a hazard quotient <0.01.

Cadmium

Atmospheric cadmium is in the form of particulate matter. Cadmium emitted to the atmosphere from combustion processes is usually associated with very small particulates that are in the respirable range (<10 µm) and are subject to long-range transport. These cadmium pollutants may be transported from a hundred to a few thousand kilometers and have a typical atmospheric residence time of about 1-10 days before deposition occurs.

The principal chemical species in air is cadmium oxide, although some cadmium salts, such as cadmium chloride, can enter the air, especially during incineration. These are stable compounds that do not undergo significant chemical transformation. The chief fate of airborne cadmium is to be dispersed by the wind and, subsequently, deposited by wet or dry processes.

Wet and dry deposition of cadmium from the atmosphere may also contribute sizable amounts of cadmium to soil in the areas surrounding sources of atmospheric emissions, such as coal power stations, incinerators and vehicular traffic, which may release cadmium from burned fuel and tyre wear.

Contamination of soil by cadmium is of concern because the cadmium is taken up efficiently by some plants and, therefore, enters the food chain for humans and other animals. A low soil pH increases the uptake of cadmium by plants. Cadmium is taken up and retained by aquatic and terrestrial plants and is concentrated in the liver and kidney of animals that eat the plants. Grain and cereal products usually contribute the greatest percentage of dietary cadmium; potatoes, leafy vegetables, and root vegetables also contain relatively high levels. Organ meats (liver and kidney) and shellfish can also contribute to cadmium intake for individuals who consume large amounts of these items.

The data indicate that cadmium bioaccumulates in all levels of the food chain. Cadmium accumulation has been reported in grasses and food crops, and in earthworms, poultry, cattle, horses, and wildlife. The metal burden of a crop depends on uptake by the root system, direct foliar uptake and translocation within the plant, and surface deposition of particulate matter. In general, cadmium accumulates in the leaves of plants and, therefore, is more of a risk in leafy vegetables grown in contaminated soil than in seed or root crops.

Since cadmium accumulates largely in the liver and kidneys of vertebrates and not in the muscle tissue and intestinal absorption of cadmium is low, biomagnification through the food chain may not be significant. Nevertheless, uptake of cadmium from soil by feed crops may result in high levels of cadmium in beef and poultry (especially in the liver and kidneys). This accumulation of cadmium in the food chain has important implications for human exposure to cadmium, whether or not significant biomagnification occurs because these animal parts are often used to manufacture salami and other processed meat products (ATSDR1999b).

Cadmium falls within the NSW Urban guideline and has a hazard quotient 0.013. Therefore secondary pathways do not need further assessment..

Cobalt

Atmospheric cobalt is associated with particulate matter.



APPENDIX C

While cobalt may be taken up from soil by plants, the translocation of cobalt from roots to above-ground parts of plants is not significant in most soils; the transfer coefficient (concentration in plant/concentration in soil) for cobalt is generally 0.01–0.3.

The bioaccumulation factors (dry weight basis) for cobalt in marine fish and freshwater fish are ~100–4,000 and <10–1,000, respectively; accumulation is largely in the viscera and on the skin, as opposed to the edible parts of the fish. Cobalt does not biomagnify up the food chain (ATSDR 2004). Cobalt falls below air quality guidelines and has a hazard quotient of 0.013 therefore secondary pathways .

Copper

Copper is found naturally in a wide range of mineral salts, organic compounds, and in metallic form. It is mildly soluble in water. Natural sources of copper include windblown dust, volcanoes, decaying vegetation, forest fires and sea spray. Anthropogenic emissions of copper include smelters, iron foundries, power stations and combustion sources such as municipal incinerators.

Copper is released to the atmosphere with particulate matter and removed by gravitational settling, dry deposition, washout by rain and rainout. The rate at which Copper is removed, and the distance it travels from the source is a result of particle size and wind velocity. Weathering of soil and discharges from industries and sewage treatment plants are the largest release of Copper to land. Other major sources of Copper are release from mining operations, agriculture, solid waste and sludge treatment works. Most copper deposited in soil is strongly adsorbed and remains in the upper few centimetres of soil. Copper adsorbs to organic matter, carbonate minerals, clay minerals, hydrous iron and manganese oxides. The greatest leaching being from sandy acidic soils. The nature of soil, pH, presence of oxides, redox potential, charged surfaces, organic matter and cation exchange influence the fate of copper in soil. Accumulation factors vary between different organisms, but tend to be higher at lower exposure concentrations. Accumulation can lead to exceptionally high body burdens in certain animals (such as bivalves) and terrestrial plants (such as those growing on contaminated soils). However, many organisms are capable of regulating their body copper concentration. Copper falls below guidelines and with a hazard quotient <0.01. Therefore secondary pathways do not need further assessment..

Lead

Plants and animals may bioconcentrate lead but biomagnification has not been detected. In general, the highest lead concentrations are found in aquatic and terrestrial organisms that live near lead mining, smelting, and refining facilities; storage battery recycling plants; areas affected by high automobile and truck traffic; sewage sludge and spoil disposal areas; sites where dredging has occurred; areas of heavy hunting (lead source from spent shot); and in urban and industrialized areas. Lead may be present on plant surfaces as a result of atmospheric deposition; its presence in internal plant tissues indicates biological uptake from the soil and leaf surfaces. Although the bioavailability of lead in soil to plants is limited because of the strong absorption of lead to soil organic matter, the bioavailability increases as the pH and the organic matter content of the soil are reduced. Lead is not biomagnified in aquatic or terrestrial food chains. It may contaminate terrestrial plants as a result of atmospheric deposition and uptake from soil, and animals as a result of inhalation of contaminated ambient air or ingestion of contaminated plants. Older organisms tend to contain the greatest body burdens of lead. In aquatic organisms, lead concentrations are usually highest in benthic organisms and algae, and lowest in upper trophic level predators (e.g., carnivorous fish) (ATSDR 1999c).

Lead has a hazard quotient of less than 0.05 and is within the NSW Urban guidelines and does not bioconcentrate in plants and animals at elevated concentrations in soil. Therefore secondary pathways do not need further assessment..

Manganese

Elemental manganese and inorganic manganese compounds have negligible vapour pressures but may exist in air as suspended particulate matter derived from industrial emissions or the erosion of soils. Manganese-containing particles are mainly removed from the atmosphere by gravitational settling, with large



particles tending to fall out faster than small particles. The half-life of airborne particles is usually on the order of days, depending on the size of the particle and atmospheric conditions. Some removal by washout mechanisms such as rain may also occur, although it is of minor significance in comparison to dry deposition. About 80% of the manganese in suspended particulate matter is associated with particles having a mass median equivalent of $<5\ \mu\text{m}$.

Data indicate lower organisms such as algae have larger BCFs than higher organisms; the BCF of manganese was 10,000–20,000 for marine and freshwater plants, 10,000–40,000 for invertebrates, and 100–600 for fish. Higher organisms (including humans) tend to maintain manganese homeostasis and therefore limit absorption from high dietary intakes (ATSDR 2000c). As manganese has a bioconcentration factor in organisms much greater than the estimated annual average GLC beyond the site boundary it is unlikely to pose a risk despite a hazard quotient of 0.075.

Mercury

Anthropogenic emissions, mainly from combustion of fossil fuels (coal), account for about 25% of mercury emissions to the atmosphere. These mercury emissions eventually may be deposited on the surrounding soil. From power generators and non-utility power and heat generation the percentage mercury emissions were Hg_0 , Hg^+ , particulates = 50%, 30 % & 20% respectively. The overall residence time of elemental mercury in the atmosphere has been estimated to be 6 days to 2 years.

Over 95% of the mercury found in the atmosphere is gaseous mercury (Hg_0), the form involved in long-range (global) transport of the element. Residence time in the atmosphere has been estimated to range from 6 days to 2 years. Approximately 5% of atmospheric mercury is associated with particulates, which have a shorter atmospheric residence time, are removed by dry or wet deposition, and may show a regional or local distribution pattern.

Dry deposition may account for approximately 70% of the total atmospheric deposition of mercury during the summer, although on an annual basis, wet and dry deposition may be of equal importance. Wet deposition is the primary method of removal of mercury from the atmosphere (approximately 66%) and may account for virtually all of the mercury content in remote lakes that do not receive inputs from other sources (e.g., industrial effluents). Most inert mercury (Hg^{+2}) in precipitation is bound to aerosol particulates, which are relatively immobile when deposited on soil or water.

Fish appear to accumulate methyl mercury from both food sources and the water column with food being the predominant source. The biological concentration factor (BCF) of methyl mercury in fish can be as high as three million. Bioconcentration of mercuric forms is less.

The potential for bioaccumulation in terrestrial food chains is demonstrated by the uptake of mercury by edible mushroom, grown on compost containing mercury at concentrations of up to 0.2 mg/kg (ppm). The bioaccumulation factors reported ranged from 65 to 140, indicating that there are potential risks to human health if these mushrooms are eaten in large quantities.

Data from higher plants indicate that virtually no mercury is taken up from the soil into the shoots of plants such as peas, although mercury concentrations in the roots may be significantly elevated and reflect the mercury concentrations of the surrounding soil (ATSDR 1999d).

As mercury is at concentrations lower than guidelines and bioaccumulation values, with a hazard quotient of <0.01 , secondary pathways do not need further assessment.

Nickel

Nickel is released to the atmosphere in the form of particulate matter or adsorbed to particulate matter. It is dispersed by wind and removed by gravitational settling (sedimentation), dry deposition (inertial impaction characterized by a deposition velocity), washout by rain (attachment to droplets within clouds), and rainout (scrubbing action below clouds). The removal rate and distance travelled from the source depends on source characteristics (e.g., stack height), particle size and density, and meteorological conditions.



Particulates from power plants tend to be smaller than those from smelters. Submicron particles may have atmospheric half-lives as long as 30 days. Monitoring data confirm that nickel can be transported far from its source. In one coal plant, 53 and 32% of nickel in emissions were associated with particles <3 and <1.5 μm in diameter, respectively. Other studies found that only 17–22% of nickel emissions from coal-fired power plants were associated with particles of >2 μm , and that the mass medium diameter (MMD) of nickel-containing particles from a plant with pollution control devices was 5.4 μm . Surface-adsorbed nickel would be more available than embedded nickel. Wood combustion is potentially an important source of nickel emissions.

The form of nickel emitted to the atmosphere varies according to the type of source. Nickel species associated with combustion, incineration, and metals smelting and refining are often complex nickel oxides, nickel sulphate, and metallic nickel, and in more specialized industries, the species commonly found are nickel silicate, nickel sub-sulphide, and nickel chloride.

The speciation and physicochemical state of nickel is important in considering its behaviour in the environment and availability to biota. Nickel is strongly adsorbed at mineral surfaces such as oxides and hydrous oxides of iron, manganese, and aluminium. Such adsorption plays an important role in controlling the concentration of nickel in natural waters.

Bioconcentration factors for nickel in various aquatic organisms (e.g., algae, arthropods, molluscs, and fish) are about of 100. There is no evidence that nickel biomagnifies in aquatic food webs and, in fact, there is evidence to indicate that the nickel concentrations in organisms decrease with increasing trophic level.

Uptake and accumulation of nickel into various plant species is known to occur. For example alfalfa grown from soils contaminated with a Ni(II) at a loading of 50 mg/kg. Concentration ratios of nickel in plant versus soil ranged between 22 and 26 over a pH range of 4.5–7.1.

Two studies concerning levels in voles and rabbits living on sludge-amended land did not indicate any accumulation of nickel in these herbivores or in the plants they fed upon. The lack of significant bioaccumulation of nickel in aquatic organisms, voles, and rabbits indicates that nickel is not biomagnified in the food chain (ATSDR 2003c). Nickel at the site falls within guideline values and is below recorded bioconcentration and bioaccumulation values. In addition the derived hazard quotient is less than 0.05. Therefore secondary pathways do not need further assessment.

Selenium

The primary factor determining the fate of selenium in the environment is its oxidation state. Selenium is stable in four valence states (-2, 0, +4, and +6) and forms chemical compounds similar to those of sulphur. The heavy metal selenides (-2) are insoluble in water, as is elemental selenium. The inorganic alkali selenites (+4) and selenates (+6) are soluble in water and are therefore more bioavailable. Oxidation state is dependent on ambient conditions, particularly on pH, pE, and biological activity.

Selenium in an aquatic environment is bio-accumulated by aquatic organisms, bioconcentration factors of 150–1,850 and bioaccumulation factors of 1,746–3,975 have been reported for selenium in freshwater organisms. Some evidence indicates that under natural conditions selenium might biomagnify in aquatic organisms.

Uptake of selenium by plants is species dependent. When environments favour the soluble forms of selenium (alkaline and oxidizing conditions) it can be accumulated by plants. In addition, although both selenite (Se^{4+}) and selenate (Se^{6+}) are soluble forms of selenium, selenate was found to be the preferred form of selenium taken up by plants. Preferential uptake of selenate may be caused by its tendency to be less strongly adsorbed to soil particles and organic matter than selenite. Selenium uptake by plants is influenced by many factors including soil type, pH, colloidal content, concentration of organic material, oxidation-reduction potentials in the root-soil environment, and total level of selenium in the soil. In acidic soils (pH 4.5–6.5) and under high moisture conditions, selenium is in the form of selenite and is bound to colloids as iron hydroxide selenium complexes. These complexes are insoluble and generally not bioavailable to plants. In basic soils (pH 7.5–8.5), selenium is present as soluble selenate. Soluble selenates



(principally sodium selenate) appear to be responsible for most of the naturally occurring accumulation of high levels of selenium by plants, although much of the total selenium in soil may be present in other forms. The use of lime and plant ash as fertilizers, which would raise the pH of the soil and favour the formation of selenate, has been implicated as a contributing factor in the accumulation of selenium in crops grown in high selenium soil found in certain regions of China.

Aquatic animals accumulate selenium from lakes and rivers high in selenium content (ATSDR 2001b).

Selenium falls within NSW Urban guidelines and has a hazard quotient <0.01 . Secondary pathways do not need further assessment.

Thallium

Thallium is released to the atmosphere mainly from coal-burning power plants, cement factories, and ferrous and nonferrous smelting operations. The airborne particulate emissions from these plants may have high thallium levels, especially on the small-diameter, respirable particles.

Thallium is a non-volatile heavy metal, and if released to the atmosphere by anthropogenic sources, may exist as an oxide (thallium oxide), hydroxide (TIOH), sulphate (thallium sulphate), or as the sulphide Tl_2S . These thallium compounds are not volatile. Compounds of thallium are generally soluble in water. It has been speculated that thallium sulphate and TIOH will partition into water vapour. Thallium oxides are less soluble in water, and may be subject to only atmospheric dispersion, and gravitational settling. The atmospheric half-life of suspended thallium particles is unknown.

Bioconcentration factors for the muscle tissue of juvenile Atlantic salmon have ranged from 27 to 1,430. Thallium is absorbed by plants from soil and can thereby enter the terrestrial food chain. Trace amounts of thallium are found in most foods, but few foods, except vegetables grown in thallium-polluted soil, are likely to have significant thallium concentrations (ATSDR 1992d). The recorded thallium annual GLC at the site is below the bioconcentration values previously derived in literature, and has a hazard quotient of <0.01 . Therefore secondary pathways do not need further assessment.

Tin

Tin's most important inorganic compounds include the tin(II) and tin (IV) chlorides, tin(II) oxide, tin(II) fluoride, and the potassium and sodium stannates. The oxidation states of tin(II) and tin(IV) are both relatively stable. Tin production has increased over recent times with the greatest tin-producing countries being China, Indonesia, Peru, Bolivia, Brazil and Australia. The main uses of tin are for solder alloys in electrical and general industrial applications and protective coating for other metals. Tin(II) chloride is commercially the most important inorganic compound and is used mainly as a reducing agent in organic and inorganic syntheses and in the manufacture of metallized glazing, glass, and pigments.

Tin is released into the atmosphere both naturally as well as a result of anthropogenic activities. Tin is present in many soils and can be released in dusts from wind storms, roads and agricultural activities. Less significant natural sources include forest fires and volcanic emissions. Anthropogenic sources of smelting and refining processes, waste incineration, burning of fossil fuels and industrial uses of tin result in gases, dusts and fumes containing tin to be released into the environment. Tin is non-volatile under environmental conditions. The solubility of tin differs with respect to its chemical form; tin(II) chloride is soluble in water whereas other tin compounds are less soluble. Tin compounds are likely to partition into soils and sediments.

Tin is mainly ingested by humans through foods such as canned fruits, vegetables and juices from unlacquered cans. Drinking-water does not contribute a significant source of tin to humans, and tin is present at very low levels in air, therefore inhalation is low. Absorption of tin by humans and other animals is low in the gastrointestinal tract but is influenced by dose, compound solubility, and presence of other substances. Unabsorbed tin is generally excreted as faeces. Inorganic tin compounds have capacity to bioconcentrate in organisms. Factors estimated for bioconcentration were 100, 1000 and 3000 for marine, freshwater plants, invertebrates, and fish, respectively. No information on the potential transfer of inorganic tin from lower to higher trophic levels exists. The predicted annual GLC value recorded at the site is below the bioconcentration values predicted for tin and with a hazard quotient of <0.01 , secondary pathways do not need further assessment.



Vanadium

Vanadium occurs as two natural isotopes ^{50}V and ^{51}V , forming oxidation states of V^{1-} , V^0 , V^{2+} , V^{3+} , V^{4+} , V^{5+} . Oxidation states; V^{3+} , V^{4+} , V^{5+} are most common. The most common commercial form of Vanadium is Vanadium pentoxide (V_2O_5) which can dissolve in water as well as acids, forming vanadates with bases. V^{3+} is basic and dissolves in acid. V^{3+} salts are strong reducing agents. In general, organic forms of vanadium are generally unstable.

Elemental vanadium does not occur naturally but is present in over 70 minerals, and thus its mining is linked to other metals such as iron, uranium, titanium and aluminium. The largest anthropogenic source of vanadium emissions are power- and heat-producing plants using fossil fuels. In the vicinity of large plants producing steel alloys, vanadium emissions can be high. Vanadium is also released into the air during re-smelting of scrap steel. In seawater, vanadium adsorbs to colloids and does not chemically react, thus its distribution on the seabed is in silt. Vanadium concentrations in sea water are very low, thus suggesting it is continuously removed from sea water.

The main source of vanadium intake for the general population is food. Vanadium interferes with several biochemical processes, penetrating the blood-brain barrier and is present in breast milk. Some marine organisms such as ascidians, bioconcentrate vanadium at much higher concentrations (approximately 10,000 times greater), than in ambient seawater, which upon death, add to the accumulation of vanadium in silt. Bioconcentration is more commonly observed in marine plants and invertebrates than in terrestrial plants. Vanadium levels in terrestrial plants is dependent on the amount of water-soluble vanadium available in soil, pH and the growing conditions.

Vanadium annual GLC concentrations at the site fall below the NSW Urban air quality guidelines and with a hazard quotient of <0.01 , secondary pathways do not need further assessment.

Zinc

In the atmosphere, zinc exists primarily in an oxidized form bound to aerosols, with the size of zinc particulates determined by the source of zinc emission. A major proportion of zinc released from industrial processes is adsorbed on particulates that are small enough to be in the respirable range. Zinc particles with low dry deposition velocities (i.e., particles with small diameters and low densities) can be transported from their emission source to distant regions.

Zinc is an essential nutrient and occurs in the tissues of organisms, even at normal ambient water and soil concentrations. Zinc can accumulate in freshwater animals at 51–1,130 times the concentration present in the water. Microcosm studies indicate, in general, that zinc does not biomagnify through food chains. Steady-state zinc bioconcentration factors (BCFs) for 12 aquatic species range from 4 to 24,000.

With respect to bioconcentration from soil by terrestrial plants, invertebrates, and mammals, BCFs of 0.4, 8, and 0.6, respectively, have been reported. The concentration of zinc in plants depends on the plant species, soil pH, and the composition of the soil. Plant species do not concentrate zinc above the levels present in soil (ATSDR 2003d).

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APPENDIX C

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Important Information



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