Report

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

Air Quality Impact Assessment

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For:
Boral Cement

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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 (PM_{10}), ultra-fine particulate ($PM_{2.5}$), nitrogen oxides (NO_x) comprising nitric oxide (NO) and nitrogen dioxide (NO_2), sulfur dioxide (SO_2), 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

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[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% O_2):

- TSP: 50 mg/Nm^3, calculated over a midday-to-midday 24-hour basis
- NO_x: 1000 mg/Nm^3, 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, PM_{10}, $PM_{2.5}$, NO_2, SO_2, NMHC, dioxins, PAHs, heavy metals, halides, and sulfuric acid mist. Fugitive dust emissions from raw material stockpiling and handling were also modelled for TSP, PM_{10} 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 PM_{10}, 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 PM_{10} modelling, not only stack emissions were included but also all possible fugitive sources of PM_{10} such as stockpiles and exposed areas. The PM_{10} 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 NO_2 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 PM_{10}, for most of the discrete receptors, no additional exceedances of the 24-hour average PM_{10} 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 PM_{10} 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 PM_{10} measured data from the local ambient air quality monitoring station indicates that PM_{10} 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 PM_{10} due to the Project as the model results are insensitive to Kiln 6 stack PM_{10} 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.

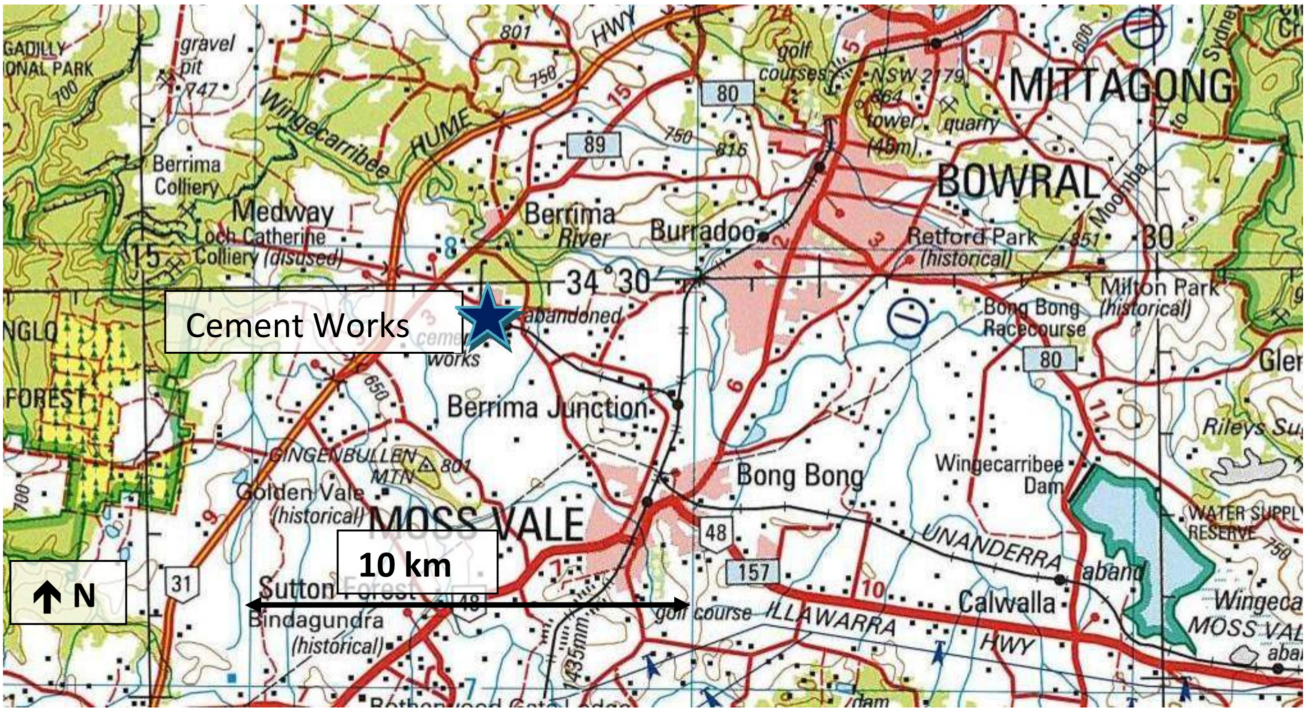

Figure 1: Location of Berrima Cement Works.

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).

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[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.

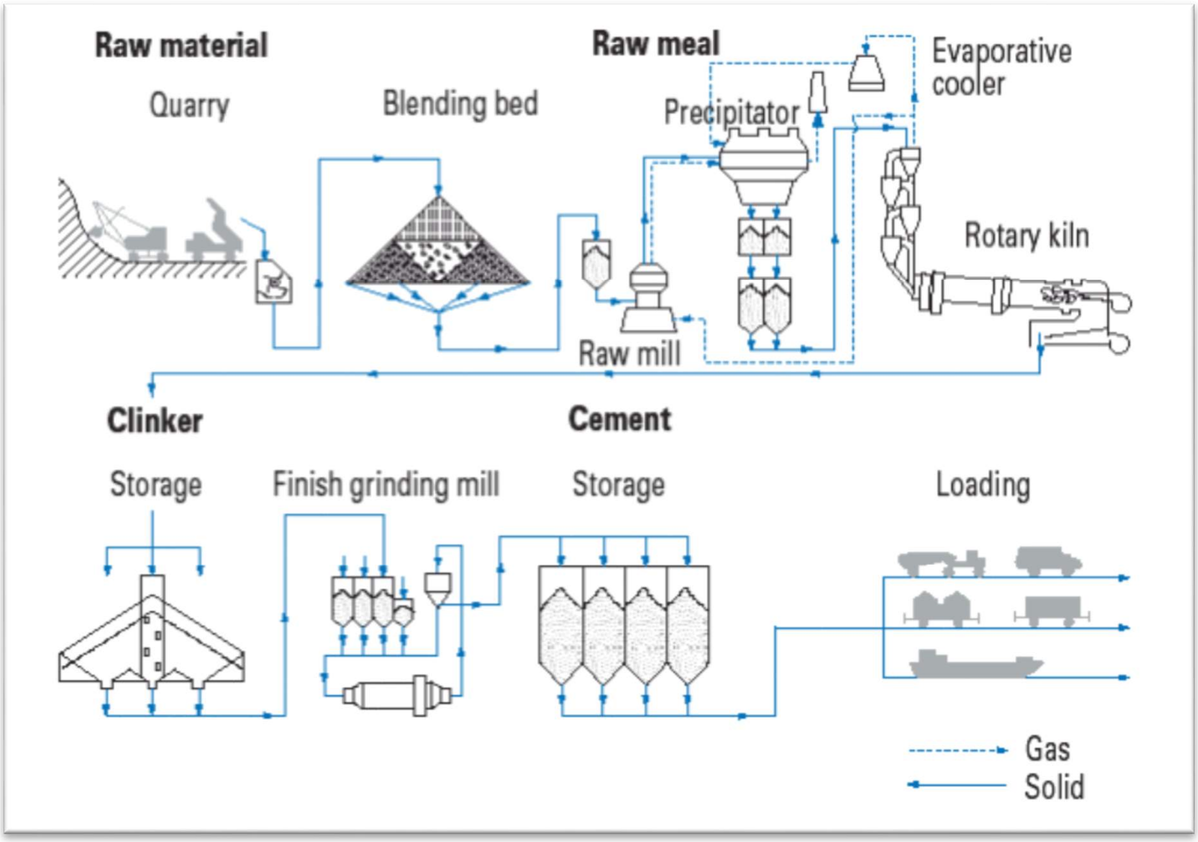

Figure 2: Overview of cement manufacture process at Berrima Works.

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.

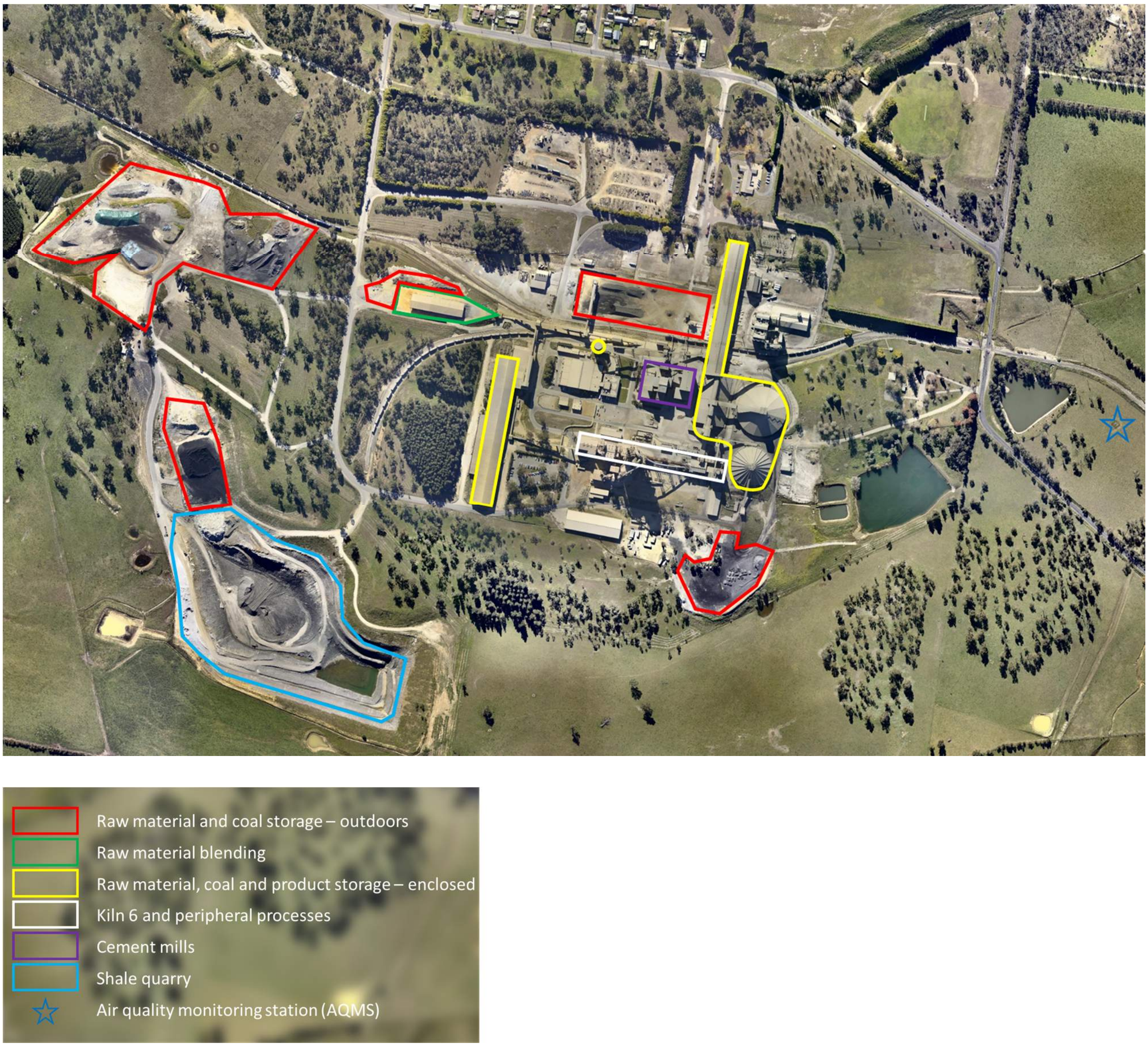

Figure 3: Aerial photograph of Berrima Works with locations of various activities indicated. Aerial photography from nearmap, imagery dated 22 May 2014.

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, SO_2 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.

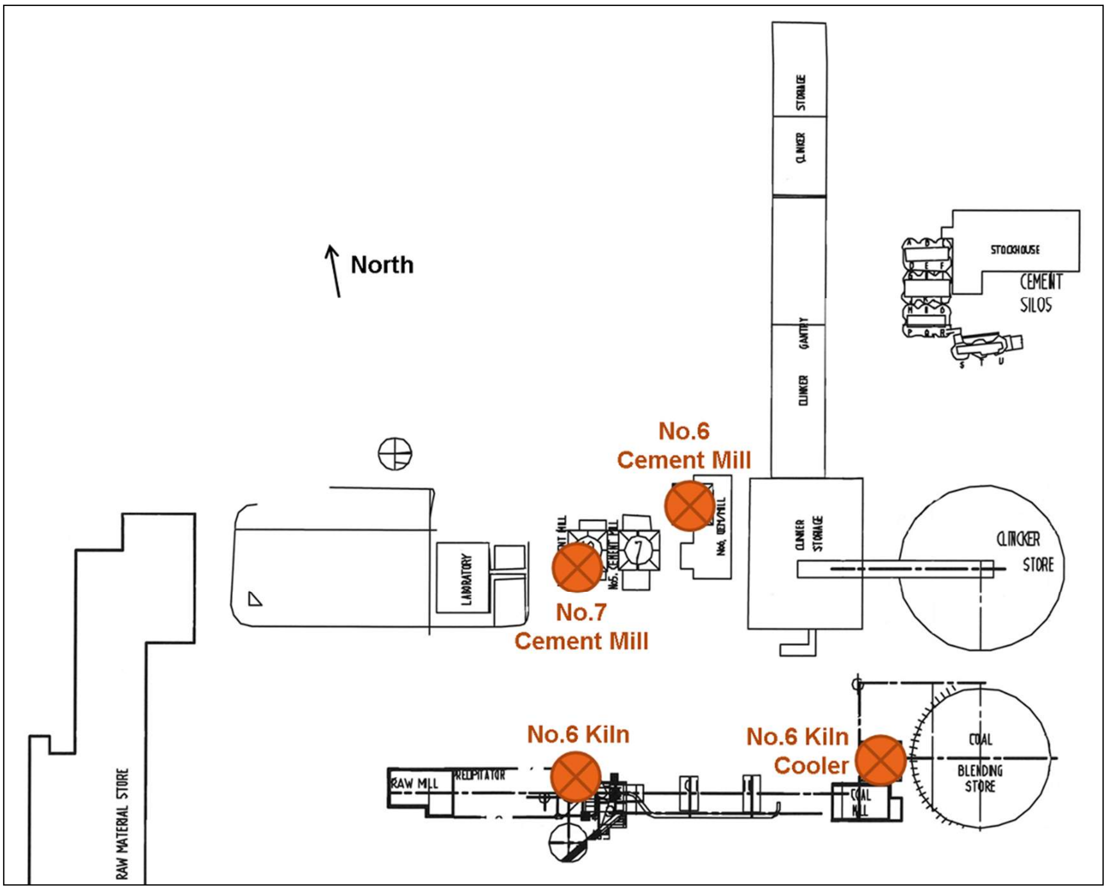

Figure 4: Stack Locations

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 and 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 (SO_2), 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 $PM_{2.5}$). $PM_{2.5}$ is a subset of PM_{10}. $PM_{2.5}$ 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 $PM_{2.5}$ range as well.

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

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:

Source	*Cumulative mass percent equal to or less than 10 microns*	*Cumulative mass percent equal to or less than 2.5 microns*
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 (NO_2) in a gas, with the mass of NO_x calculated by assuming that all of the NO has been oxidised to NO_2.

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 NOx is predominately made up of NO. NO is slowly converted to NO_2 in the environment through complex atmospheric reactions.

The continuous emissions monitoring programme in the No.6 Kiln Stack records both NO and NO_2 concentrations. As shown in Section 4.6.3, NO_2 emissions make up a very small proportion of the total NO_x emissions from the No.6 Kiln Stack.

Only the concentration of the NO_2 fraction of NO_X is regulated in ambient air. To determine the resulting ambient concentrations of NO_2 in the atmosphere, it is necessary to determine how much NO_X will be converted to NO_2.

The “Approved Methods” guidelines provide three alternative methods for estimating NO-NO_2 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 (SO_2) 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 SO_2 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 SO_2 or NO_2. 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.

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[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 [*required temperature as specified in Article 50(2)*] has been reached (b) Whenever the [*required temperature as specified in Article 50(2)*] 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. *[an allowed exceedance duration is also provided in Article 46(6), listed below]*.	(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) means[4]:

> *"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 alterative 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/Nm^3 (@10% O_2) 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;

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[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 (NO_2), NMHCs, methane, oxygen, carbon monoxide (CO), and sulfur dioxide (SO_2).

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, PM_{10} 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.

[&] “Nm^3” = 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/Nm^3.

[≠] New limit specified in EPL update of 30 March 2012 – prior to this update, the applicable limit was 175 mg/Nm^3.

[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 Nm^3 = standard temperature and pressure - 0°C or 273K, dry gas and 101.3kPa, 10% O_2.

[&] "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 = 2.406m^2. Equivalent diameter to give same area of a circle = 1.75m.

b. Rectangular duct 1800mm x 1600mm. Area of opening = 2.88m^2. 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}

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

b. 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).

c. Assuming approximate angle of discharge of 30 degrees above horizontal, vertical component of exhaust velocity is 3.7m/s (calculated from 7.7 x sin(30 degrees), where sin(30°) = 0.5). This was used in the dispersion model.

d. 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 NO_2, expressed as NO_2

[#] 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 * *Data for each year is average of a pair of individual samples*					Mass emission rates *Data for each year is average of a pair of individual samples*				
	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 Nm^3 = dry gas, standard temperature and pressure - 0°C or 273K, and 101.3kPa, 10% O_2.

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 Nm^3 = dry gas, standard temperature and pressure - 0°C or 273K, and 101.3kPa, 10% O_2.

** *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	
			Nm³/min &	Nm³/s &
Mean	103	38.8	11189	186
50th percentile	102	38.7	11367	189
75th percentile	104	39.4	11733	196
90th percentile	109	40.8	11999	200
95th percentile	116	42.5	12165	203
98th percentile	120	43.9	12457	208
99th percentile	122	44.5	12642	211
99.9th 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% O_2.

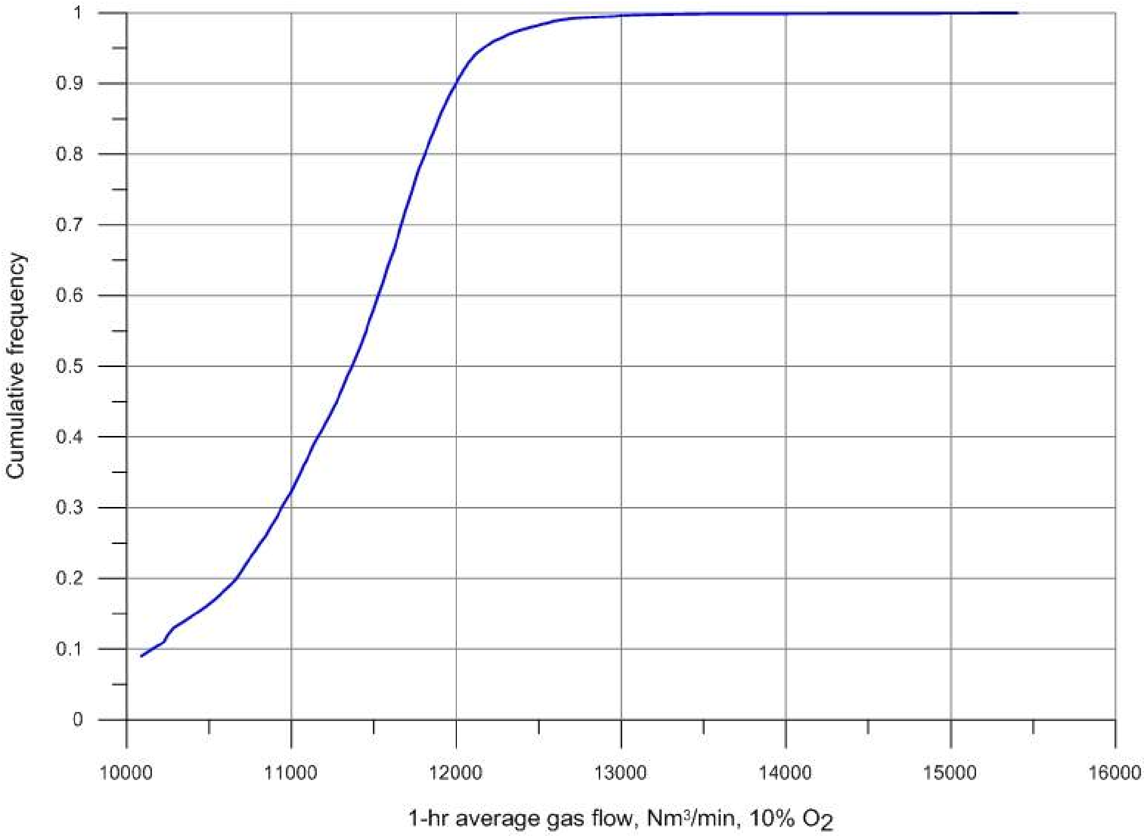

Figure 5: Cumulative frequency of No.6 Kiln stack gas flow rates, 0°C, dry, 10% O_2. Compiled from 1-hour average data with feed rate of at least 250tph, collected continuously over 2012 and 2013.

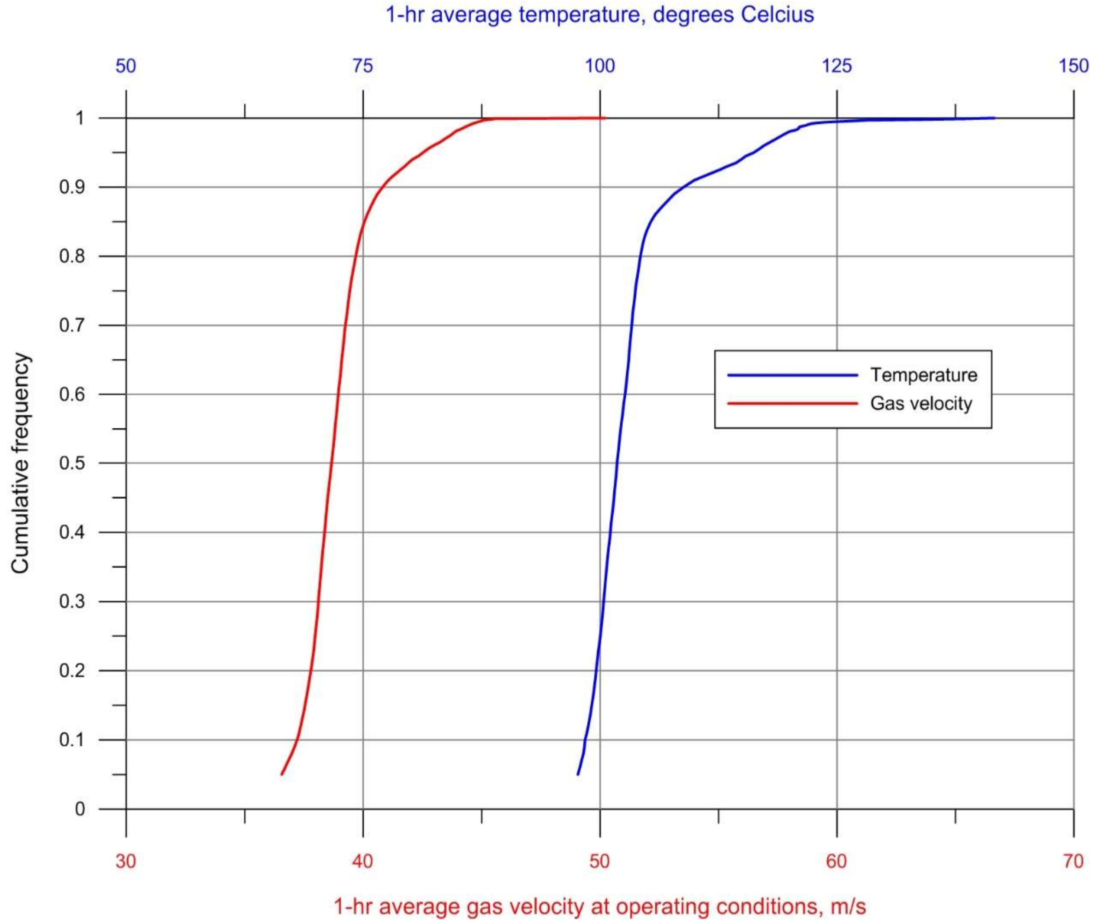

Figure 6: Cumulative frequency of No.6 Kiln stack gas velocities and temperatures at stack conditions. Velocity was calculated from records of gas flow at STP. Compiled from 1-hour average data with feed rate of at least 250tph, collected continuously over 2012 and 2013.

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

Test results from the monitoring of PM_{10} and $PM_{2.5}$ in the No.6 Kiln Stack discharge are summarised in Table 16. In the EPL, PM_{10} 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 PM_{10} 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, PM_{10} 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 PM_{10} data. TSP and PM_{10} data was collected concurrently on each occasion. TSP and PM_{10} data for each year is arithmetic mean of two individual samples.

** Results not reported

Concentrations and mass emission rates for SO_2 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 SO_2 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 C_3 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% O_2 (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 cogeners, 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, NO_2, SO_2, 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 NO_2 data[5].

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[5] By multiplying NO by the molar weight ratio of NO_2:NO (46/30), then adding the NO_2 value.

The 1-hour data is calculated from the original filtered 5-minute data (filtered for high O_2, 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/Nm^3 at 10% O_2), 1-hour averages calculated from 2012 and 2013 continuous emissions monitoring data. Minimum kiln feed throughput 250 tph.

Pollutant$^\alpha$ 1-hr average *	NO	NO_2	NO_X (as NO_2)	SO_2	TSP	NMHC$^\%$
Mean	424	2.9	652	1.2	34	22
50th percentile	421	2.8	649	0.5	32	21
75th percentile	460	3.3	709	0.7	41	24
90th percentile	497	3.8	766	1.4	48	29
99.9th percentile	688	6.9	1063	43	115	121
Maximum	746	17.5	1150	68	181	126

* All units reported as mg/Nm^3 corrected to 10% O_2.

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

$^\%$ Converted from ppm to mg/Nm^3 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/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.

Pollutant$^\alpha$ 24-hr average$^\$$ *	NO	NO_2	NO_X (as NO_2)	SO_2	TSP	NMHC$^\%$
Mean	423	2.9	652	1.2	34	22
50th percentile	422	2.9	649	0.6	32	21
75th percentile	455	3.2	701	1.0	41	24
90th percentile	487	3.7	750	2.5	48	28
99.9th percentile	619	5.4	955	25	75	114
Maximum	623	5.4	960	34	77	114

* All units reported as mg/Nm^3 corrected to 10% O_2.

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

$^\%$ Converted from ppm to mg/Nm^3 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, NO_2, SO_2, 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$^{\alpha}$ 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
50th percentile	78	0.53	121	0.10	5.8	3.8
75th percentile	84	0.60	130	0.13	7.5	4.6
90th percentile	91	0.68	140	0.25	8.9	5.6
95th percentile	95	0.75	147	0.75	9.5	6.7
98th percentile	104	0.89	160	2.16	11	18
99th percentile	114	1.00	175	3.20	13	20
99.5th percentile	120	1.07	185	4.21	14	22
99.9th percentile	125	1.23	192	8.13	22	24
Maximum	147	2.95	227	12.6	33	25

* All units reported as g/s.

$^{\alpha}$ 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$^{\alpha}$ 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
50th percentile	78	0.53	121	0.12	5.7	3.8
75th percentile	84	0.60	129	0.18	7.6	4.6
90th percentile	88	0.67	136	0.46	8.9	5.5
99.9th percentile	121	1.06	187	4.47	14	22
Maximum	122	1.08	187	4.79	15	22

* All units reported as g/s.

$^{\alpha}$ 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).
- SO_2 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 SO_2, 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$^{\alpha}$	NO	NO_2	NO_X	SO_2	TSP	NMHC
50th percentile	1.00	1.00	1.00	0.94	0.99	1.00
75th percentile	1.04	1.06	1.04	1.05	1.03	1.05
90th percentile	1.08	1.15	1.08	1.36	1.09	1.12
95th percentile	1.12	1.22	1.12	1.98	1.16	1.18
99.0th percentile	1.20	1.39	1.20	5.24	1.37	1.37
99.5th percentile	1.24	1.49	1.24	6.95	1.54	1.53
99.9th percentile	1.41	1.92	1.41	10.7	2.37	3.75
99.95th percentile	1.50	2.15	1.50	11.9	2.60	6.39
99.99th 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$^{\alpha}$	NO	NO_2	NO_X	SO_2	TSP	NMHC
50th percentile	1.00	1.00	1.00	0.94	1.00	1.00
75th percentile	1.04	1.07	1.04	1.05	1.03	1.06
90th percentile	1.08	1.14	1.08	1.35	1.08	1.14
95th percentile	1.11	1.20	1.11	1.97	1.14	1.20
99.0th percentile	1.19	1.35	1.19	5.03	1.33	1.41
99.5th percentile	1.22	1.41	1.22	6.77	1.49	1.51
99.9th percentile	1.33	1.87	1.34	10.4	2.40	3.69
99.95th percentile	1.37	2.02	1.37	10.9	2.62	6.26
99.99th 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, NOx 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_2SO_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% O_2):

- TSP: 50 mg/Nm^3, calculated over a midday-to-midday 24-hour basis
- NO_x: 1000 mg/Nm^3, 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 NO_2 that represent a 24-hour average NO_x emission concentration of 1000 mg/Nm^3. Using the NO:NO_2 molar ratio of 30:46, a NO_x emission concentration of 1000 mg/Nm^3 is equivalent to a NO emission concentration of 652 mg/Nm^3. As shown in Table 24, NO_2 emission concentrations are typically less than 1% of NO emission concentrations, and therefore an NO_2 emission concentration of 6.5 mg/m^3 was assumed. This assumed emission concentration was greater than the 99.8th percentile of the measured NO_2 emission concentrations and is therefore considered to be conservative. The NO emission concentration was then reduced to 648 mg/Nm^3 so that the total NO (as NO_2) + NO_2 concentration did not exceed 1000 mg/Nm^3.

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 Nm^3/s (10% O_2). 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 Nm^3/s (10% O_2) 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/Nm^3 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 NO_2, 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 NOx, 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 Nm^3/s (10% O_2). 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/Nm^3, each metal was assumed to have an emission concentration of 0.025 mg/Nm^3. For all other metals defined in the “hazardous substances” list, for which the cumulative emission limit in the EPL is 0.5 mg/Nm^3, 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 SO_2 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)	1.36×10^{-5}
Dioxins and Furans as I-TEQ	0.0000001 (0.1 ng/Nm^3)	2×10^{-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/Nm^3 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 PM$_{10}$ and PM$_{2.5}$ Emissions

Emission rates of PM$_{10}$ 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 PM$_{10}$ and PM$_{2.5}$ were based on the measured data reported in Table 16; PM$_{10}$ 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, PM$_{10}$ 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, PM$_{10}$ 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 PM$_{10}$ emissions.

PM$_{10}$ 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 PM$_{10}$ 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 PM$_{10}$ 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 m^2 (4m x 4m) giving an air flow of 3.2 m^3/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 m^3/s, the odour emission rate from the storage building would be 3200 $OU.m^3/s$. This is equivalent to the odour emission from a pond of $320m^2$ containing municipal wastewater that is in anoxic or anaerobic condition (i.e. at an odour emission rate of about 10 $OU.m^3/m^2/s$). 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 $OU.m^3/s$ 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 PM_{10}, 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 PM_{10} for material handling and wind erosion and 10% of PM_{10} for vehicle tracked emissions (USEPA 2006a, 2006b, 2006c, 2006d). $PM_{2.5}$ emission rates for fugitive sources were determined based on the $PM_{2.5}$:PM_{10} ratios described above.

For each activity category, preliminary TSP and PM_{10} 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 PM_{10} 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 PM_{10} 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 PM_{10} 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 PM_{10}, it was concluded that PM_{10} 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.

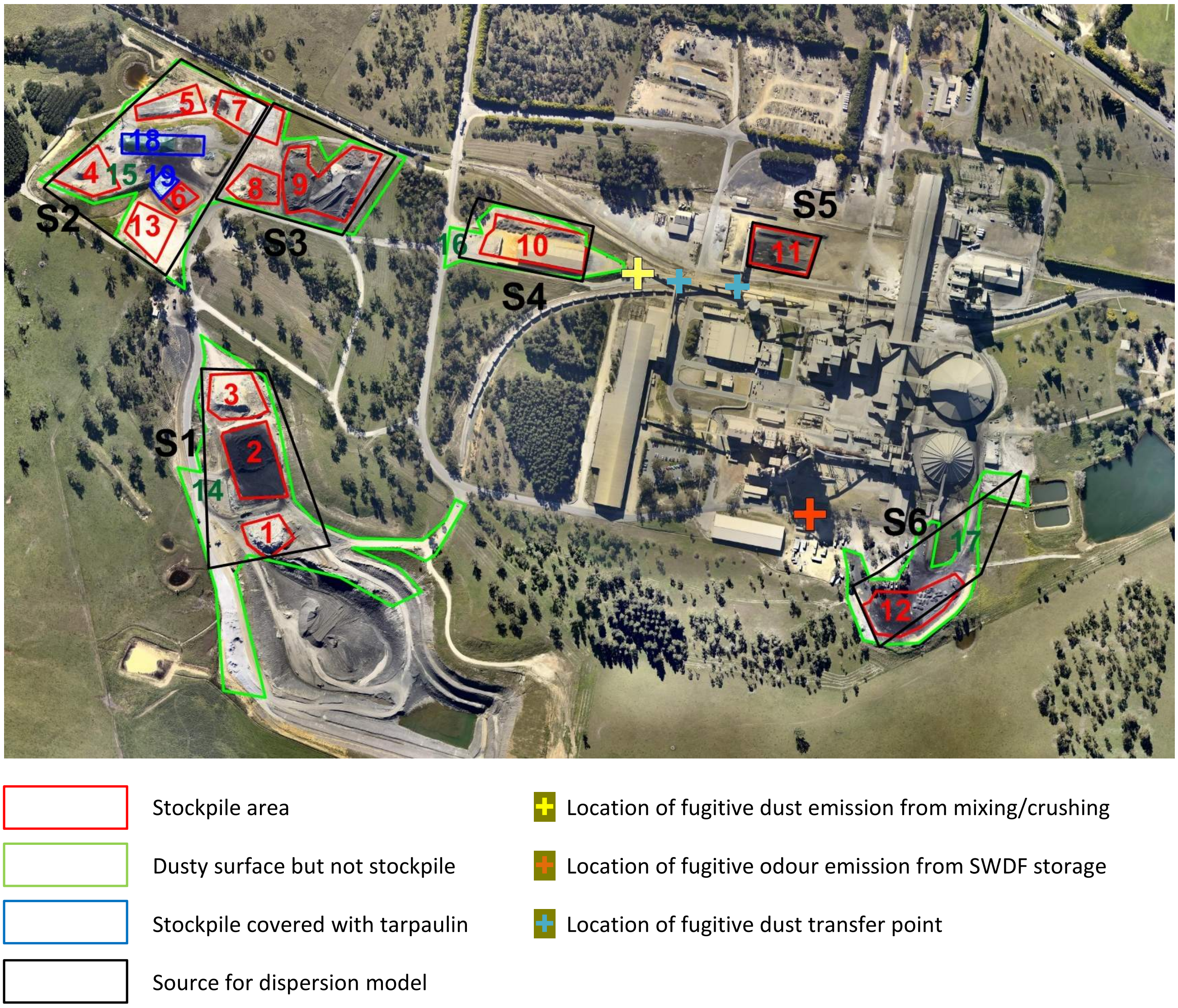

Figure 7: Location of fugitive dust and odour sources used in dispersion model

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 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 PM_{10} 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 PM_{10}. 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 PM_{10}. 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 PM_{10}. 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 PM_{10}. 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 PM_{10}. 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 PM_{10}. 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 sources 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 site[6] 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.

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[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).

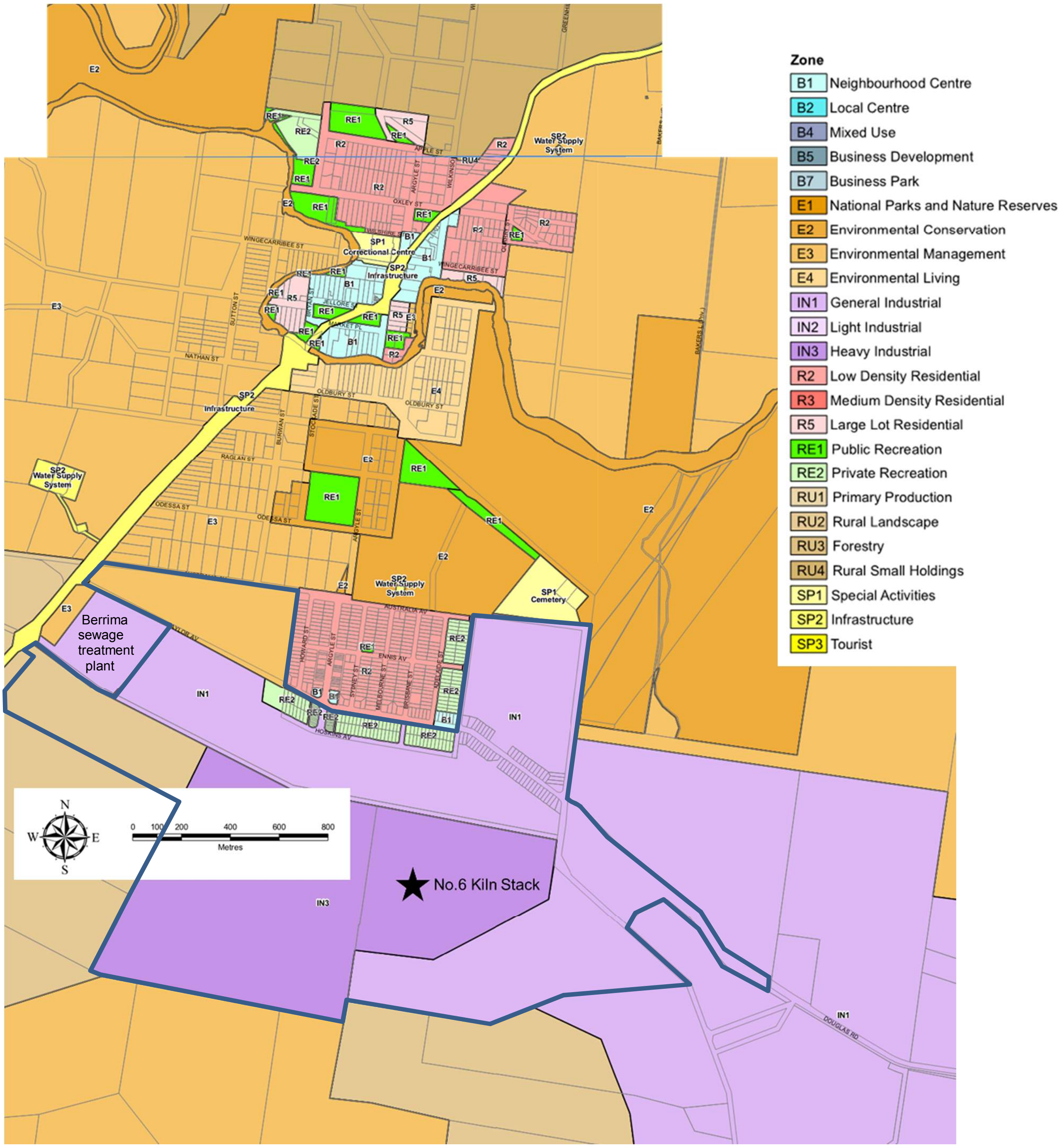

Figure 11: Land Use Zones around Berrima Works. Heavy blue line shows boundary of land owned by Boral Cement (as of March 2015).

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.

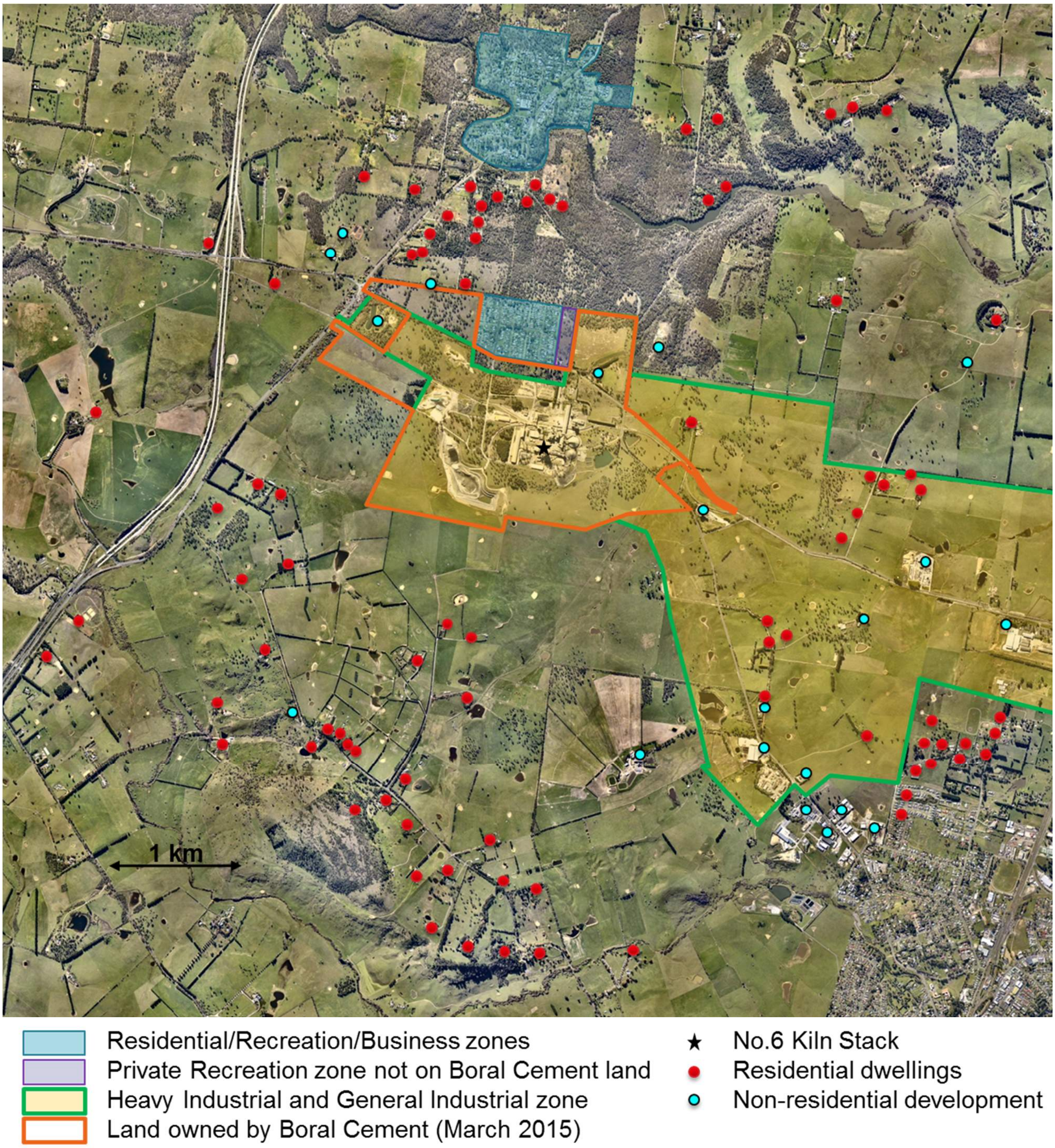

Figure 12: Berrima Works location and surrounding dwelling locations (red circle = dwelling or building where use and occupancy is unclear; yellow circle = non-residential development). Image from nearmap, aerial flown 22 May 2014.

6.3 Meteorology

Boral Cement operates an ambient air quality monitoring station (AQMS) beyond the site boundary. Meteorological data is recorded continuously, and TSP, PM_{10} 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.

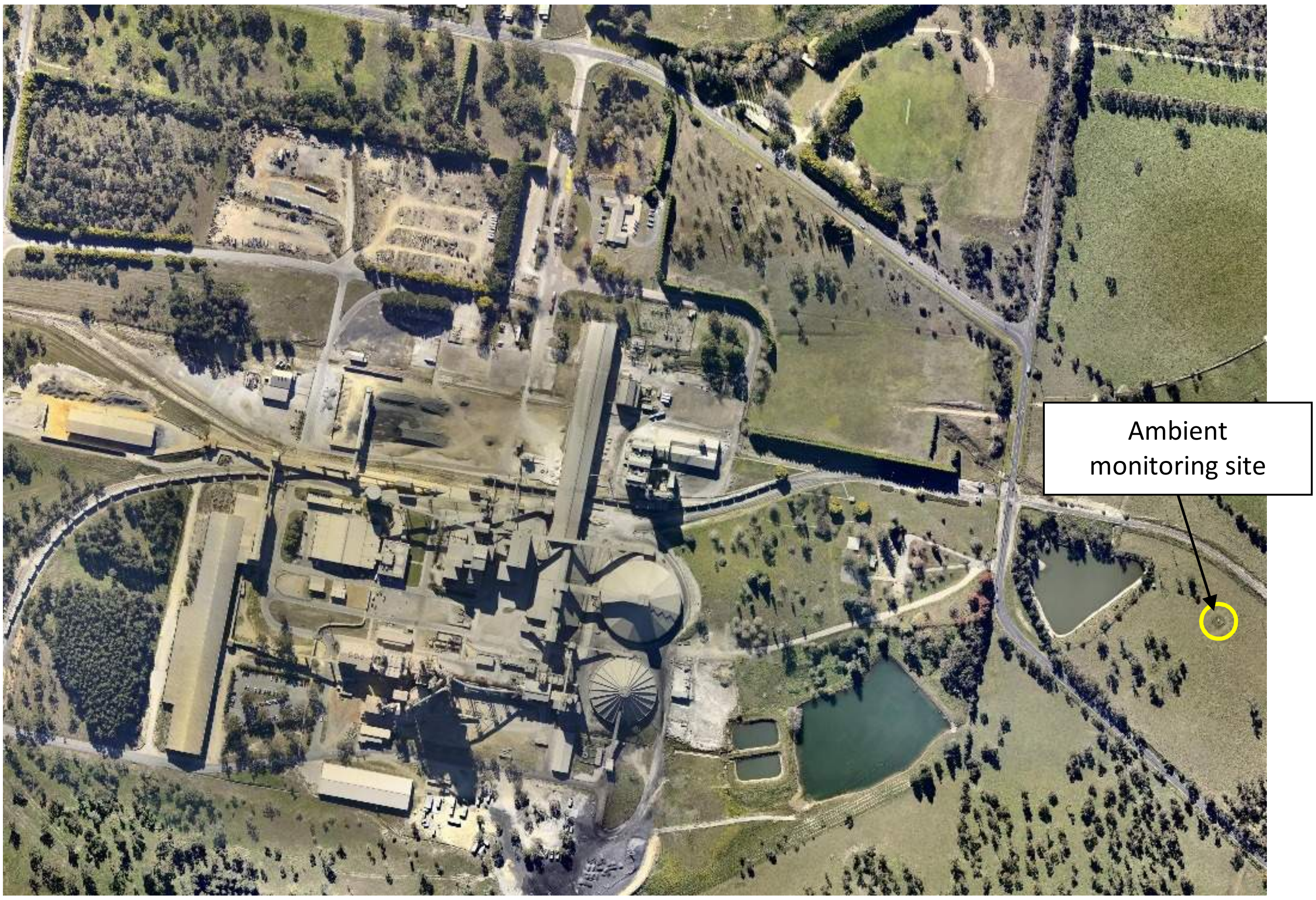

Figure 13: Location of ambient monitoring site. Image from nearmap.

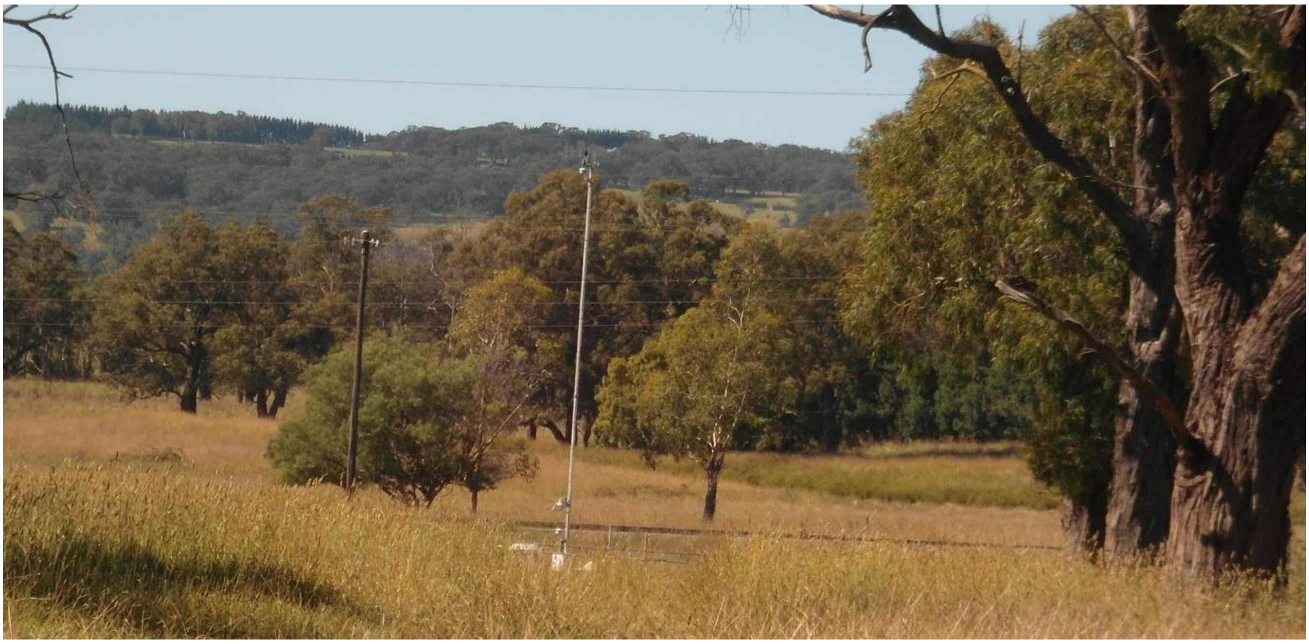

Figure 14: Ambient air quality monitoring station (AQMS). Photo taken 19 March 2015.

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.

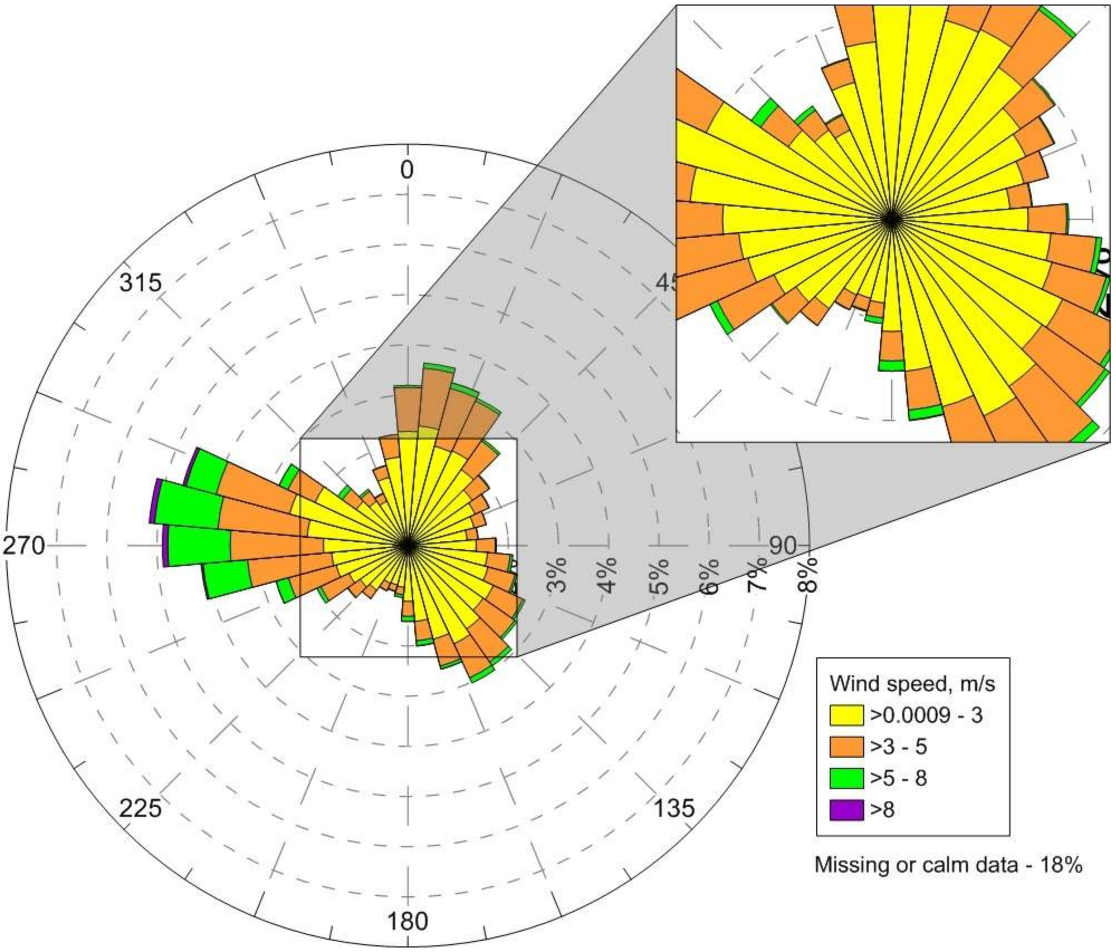

Figure 15: Windrose of meteorological monitoring data for Berrima site; January 2010 – December 2014, data recorded at 1-hour frequency.

6.4 Ambient Monitoring Data from AQMS

TSP, PM_{10} 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 PM_{10} and TSP

Annual average concentrations of PM_{10} 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/m^3 set by NSW EPA (refer Section 7.6.2). The annual average concentrations of PM_{10} are also less than (or equal to) half of the NSW EPA goal level of 30 µg/m^3 (refer Section 7.6.1).

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.

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 PM_{10} and TSP

Figure 16 shows the monitoring results for 24-hour TSP and PM_{10} measured over the four year period from January 2011 to December 2014.

For most of the time, the measured 24-hour PM_{10} concentrations (fraction of potential health significance) were below the national air quality standard for PM_{10} which is 50 µg/m^3 averaged over 24 hours. Figure 17 shows the cumulative distribution of measured concentrations. The graph shows that, for example, 80% of measured PM_{10} concentrations were less than 20 µg/m^3, and 96% of measured PM_{10} concentrations were less than 36 µg/m^3.

However there were a few occasions when the 24-hour average PM_{10} concentration approached or exceeded the national standard – 18/10/13 (56 µg/m^3), 24/9/13 (52 µg/m^3), 30/8/12 (52 µg/m^3), 10/12/11 (48 µg/m^3), and 30/12/14 (46 µg/m^3). The relative contribution of PM_{10} 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.

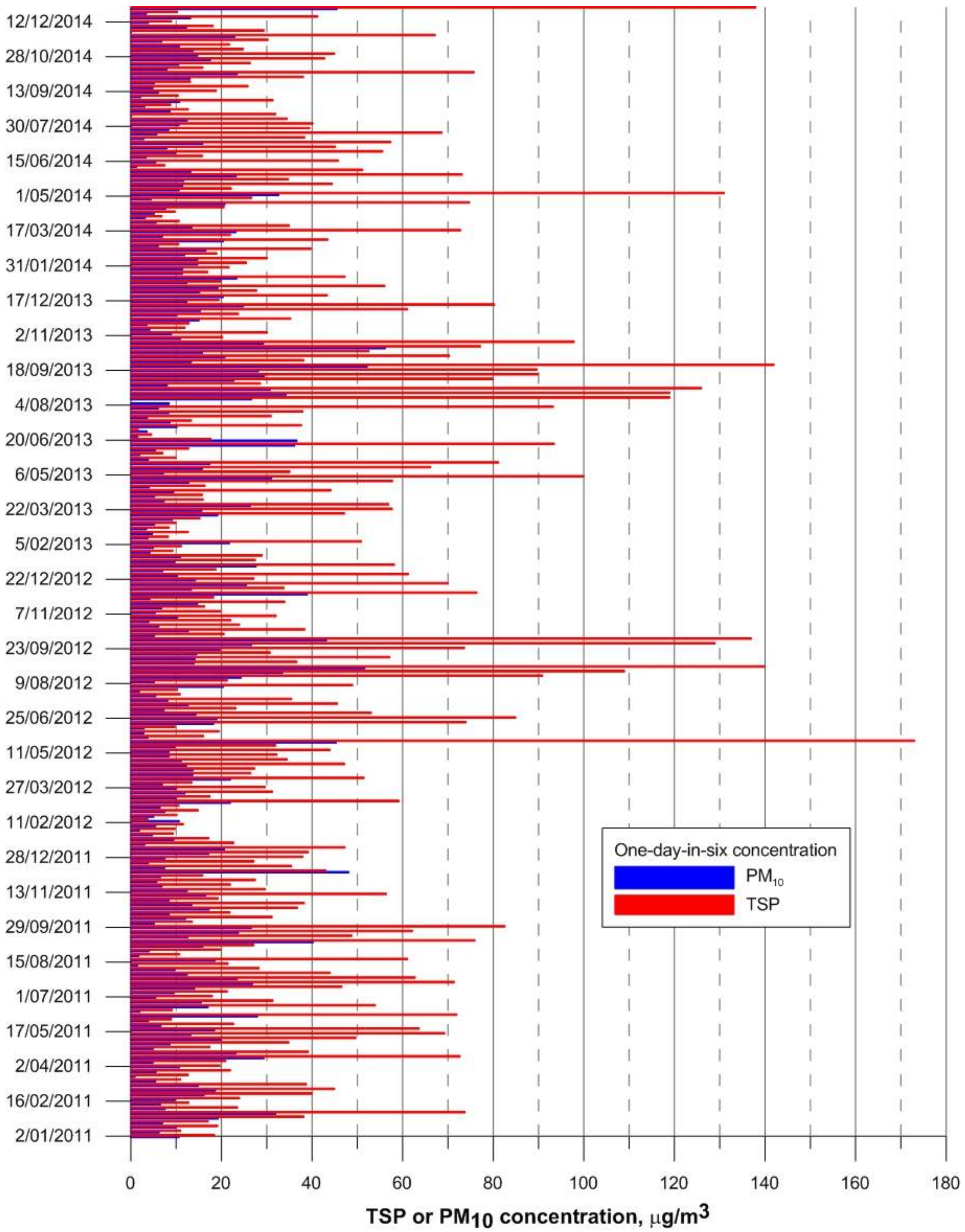

Figure 16: TSP and PM_{10} ambient monitoring data (24-hour average, 1-day-in-6 sampling), from Berrima ambient monitoring station; 2 January 2011 to 30 December 2014.

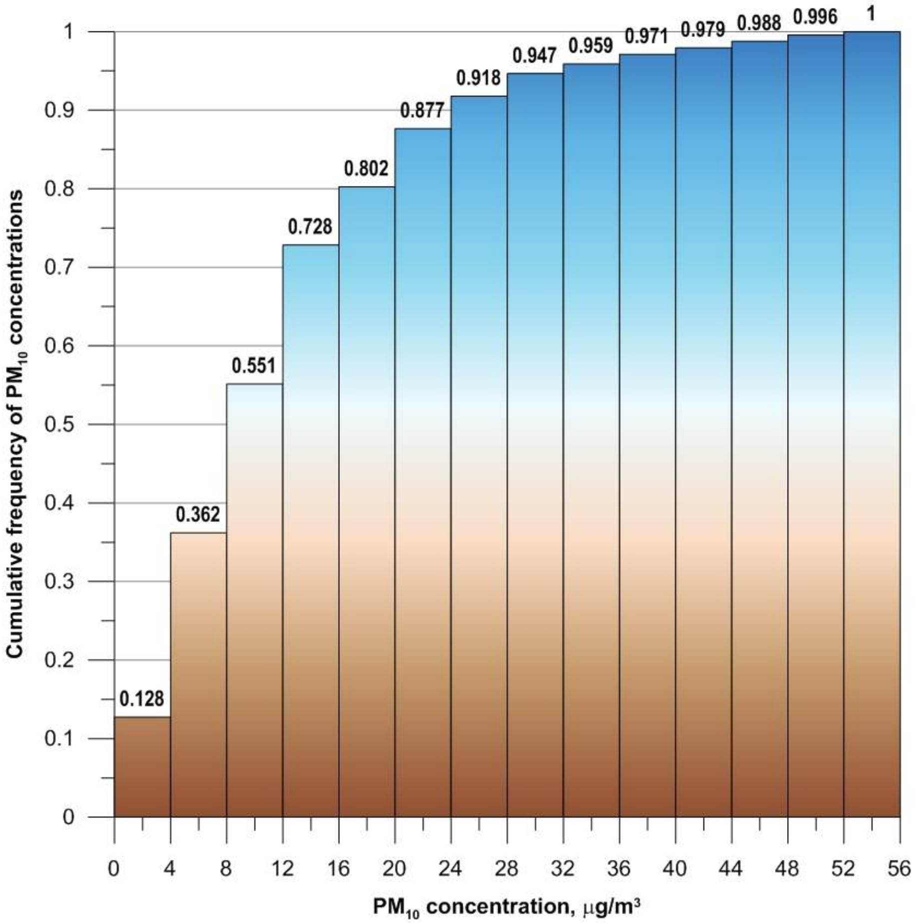

Figure 17: Cumulative frequency of PM_{10} ambient monitoring data (24-hour average, 1-day-in-6 sampling), from Berrima ambient monitoring station; 2 January 2011 to 30 December 2014.

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 PM_{10} concentrations measured on those two days. Alternative sources of PM_{10} 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 Berrima[7]. This is considered very likely to be the cause of the PM_{10} concentration of 56 $\mu g/m^3$ 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 $\mu g/m^3$ on each occasion. It is considered likely that fugitive dust emissions from the Works would have contributed to the PM_{10} 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.

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[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 PM_{10} 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 PM_{10} 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 PM_{10}) 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 PM_{10} 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 PM_{10} 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 PM_{10} 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 PM_{10} 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 PM_{10}:TSP ratio is highly variable ranging typically from 10% to 70%.

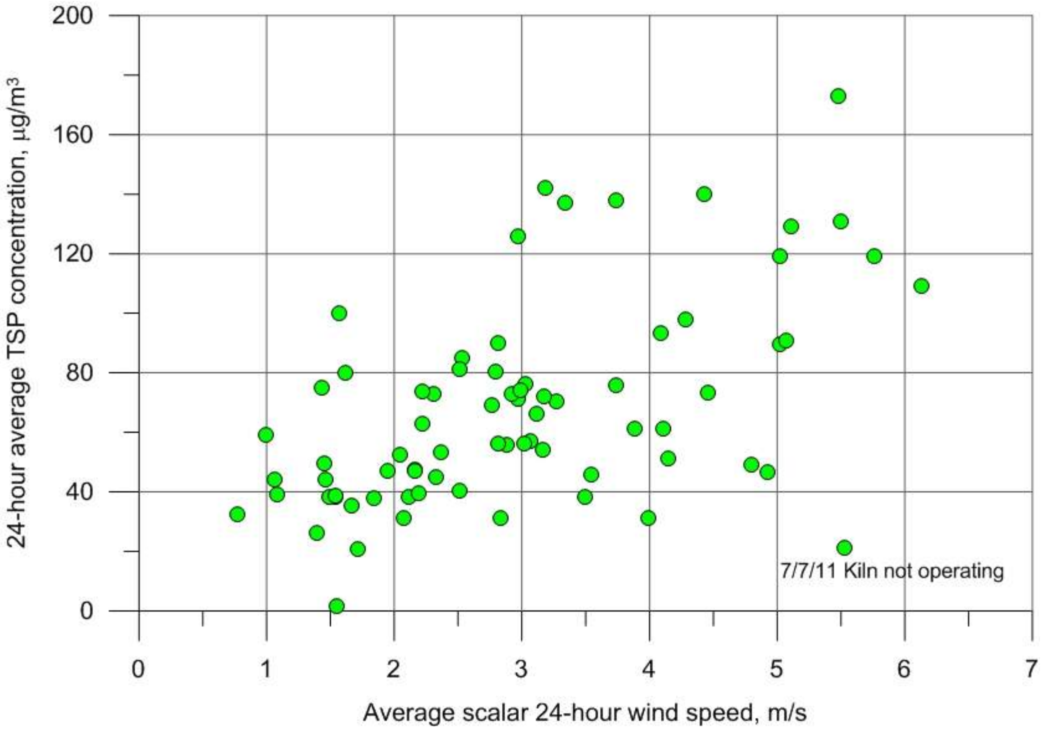

Figure 18: 24-hour average TSP concentration measured at AQMS (1-day-in-6 basis) as a function of daily average wind speed. Showing only days where the wind was blowing from the direction of the Works for at least 11 out of the 24 hours – i.e. Works upwind of AQMS for some or most of the day.

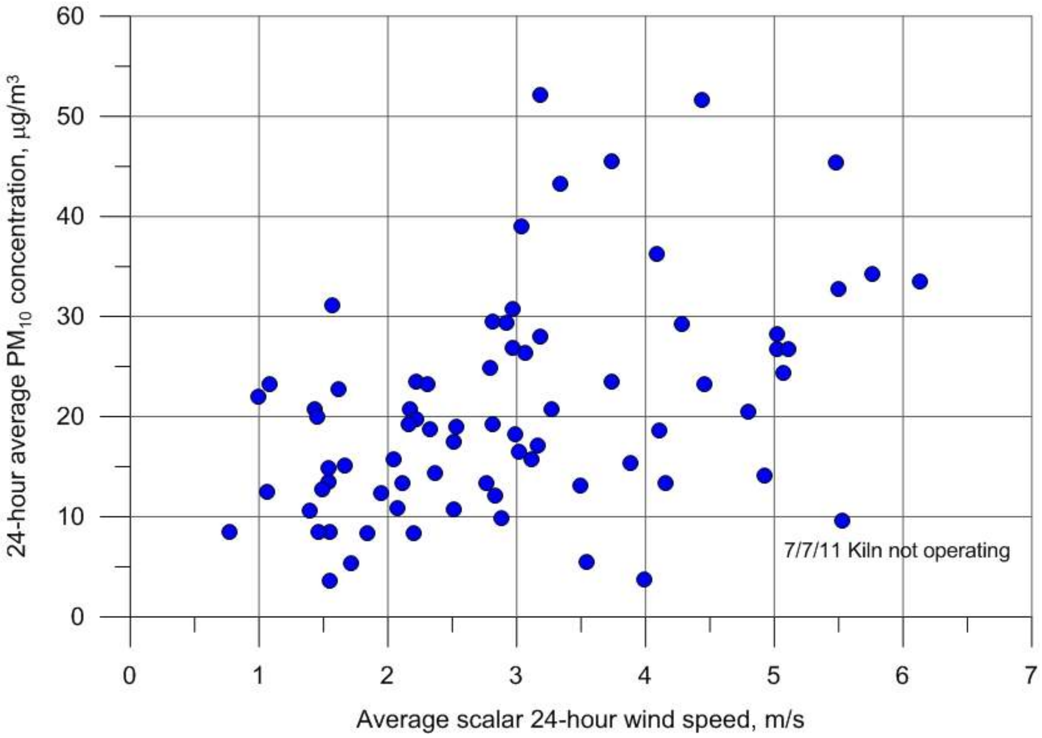

Figure 19: 24-hour average PM$_{10}$ concentration measured at AQMS (1-day-in-6 basis) as a function of daily average wind speed. Showing only days where the wind was blowing from the direction of the Works for at least 11 out of the 24 hours – i.e. Works upwind of AQMS for some or most of the day.

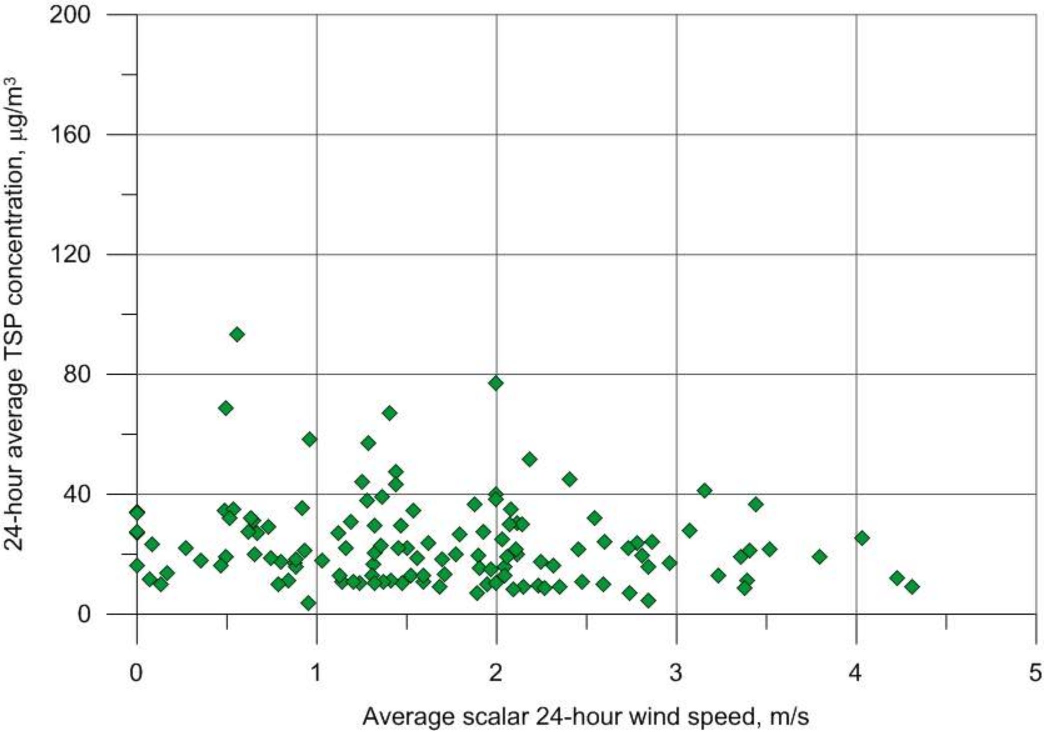

Figure 20: 24-hour average TSP concentration measured at AQMS (1-day-in-6 basis) as a function of daily average wind speed. Showing only days where the wind was blowing from the direction of the Works for no more than 4 out of the 24 hours – i.e. Works *not* upwind of AQMS for most of the day.

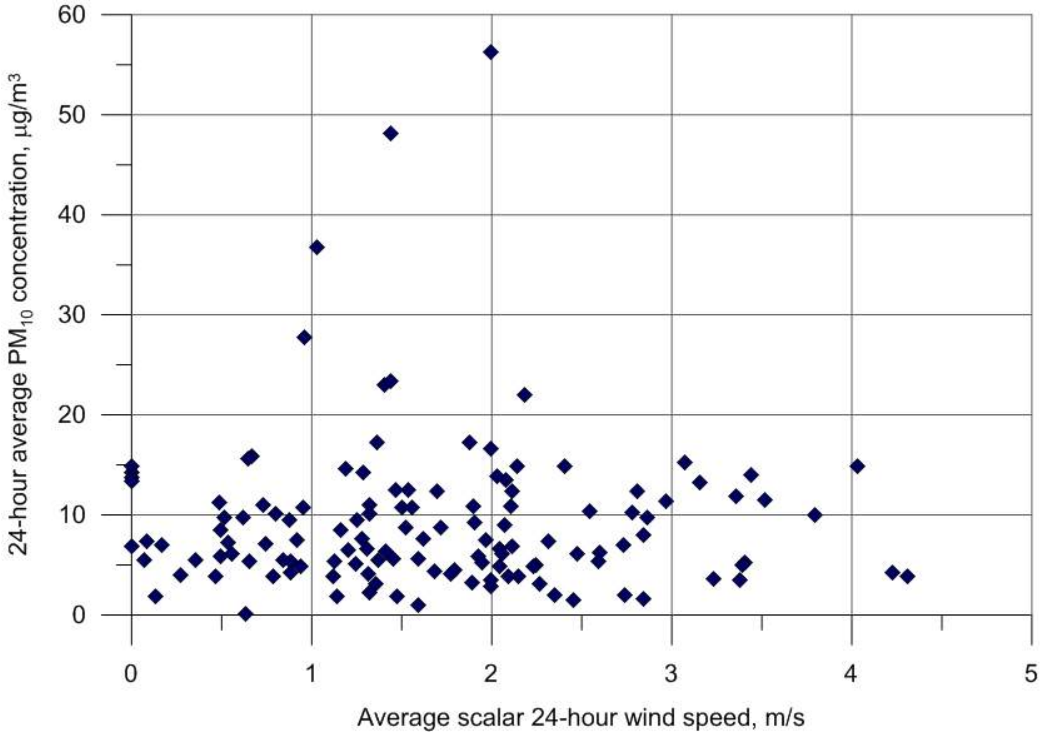

Figure 21: 24-hour average PM_{10} concentration measured at AQMS (1-day-in-6 basis) as a function of daily average wind speed. Showing only days where the wind was blowing from the direction of the Works for no more than 4 out of the 24 hours – i.e. Works *not* upwind of AQMS for most of the day.

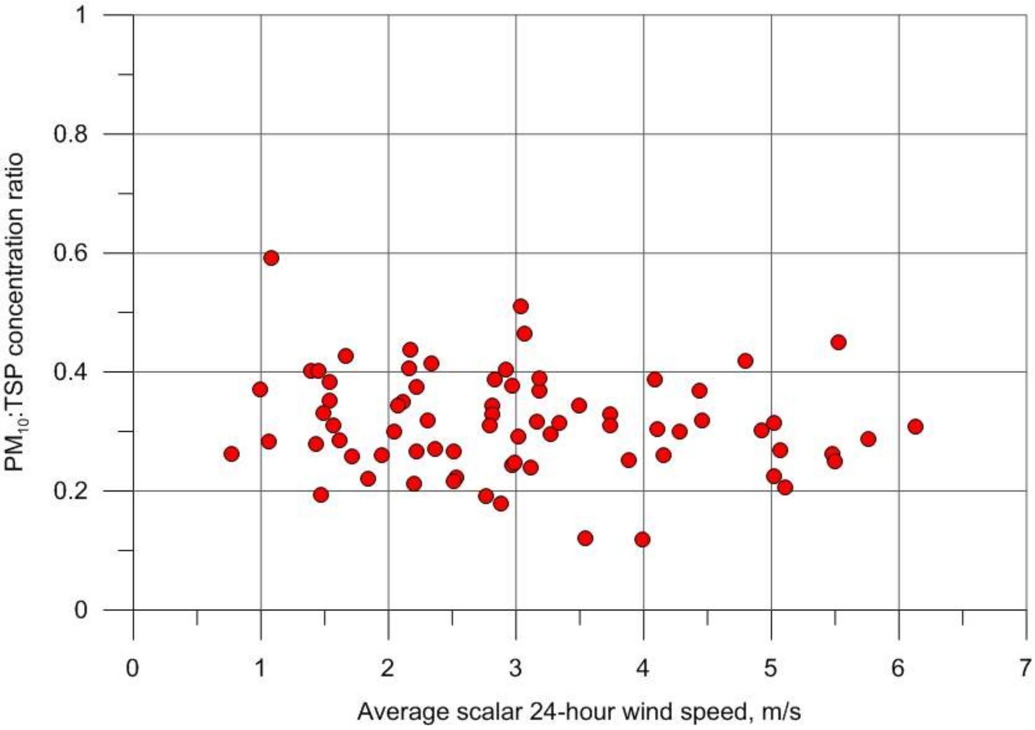

Figure 22: Ratio of PM$_{10}$ to TSP 24-hour average concentration measured at AQMS (1-day-in-6 basis) as a function of daily average wind speed. Showing only days where the wind was blowing from the direction of the Works for at least 11 out of the 24 hours – i.e. Works upwind of AQMS for some or most of the day.

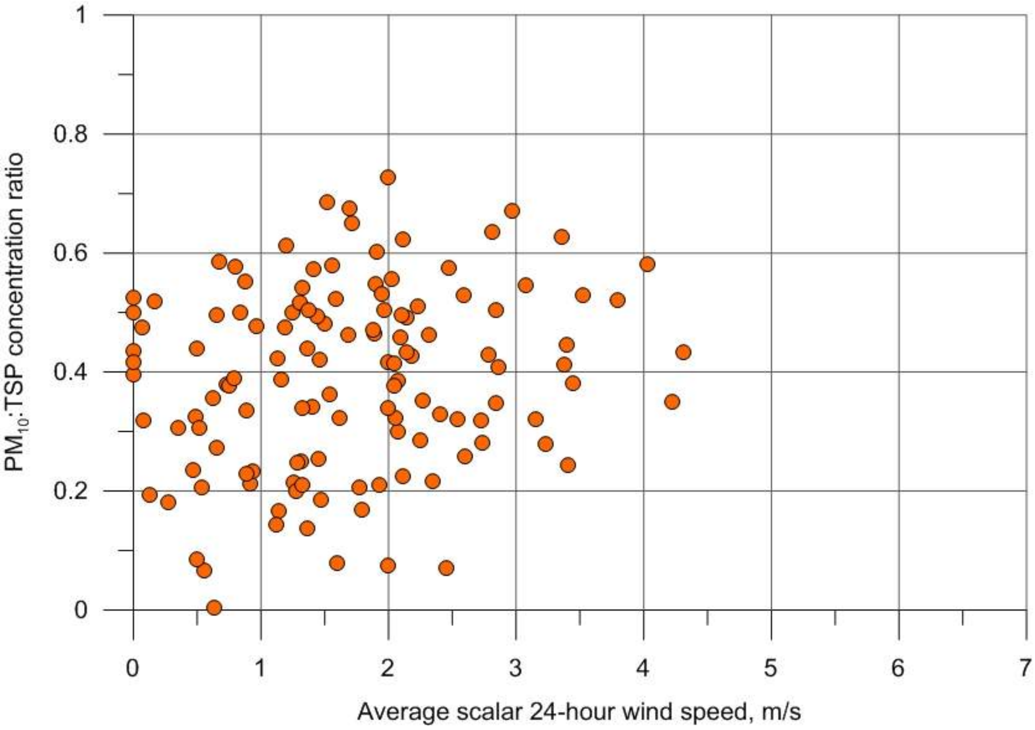

Figure 23: Ratio of PM$_{10}$ to TSP 24-hour average concentration measured at AQMS (1-day-in-6 basis) as a function of daily average wind speed. Showing only days where the wind was blowing from the direction of the Works for no more than 4 out of the 24 hours – i.e. Works *<u>not</u>* upwind of AQMS 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 ($\mu g/m^3$)			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 (OEHHA) California Reference Exposure Level (REL)
7 Acute OEHHA REL, 1-hour average
8 Chronic OEHHA 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), OEHHA 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 4.0.5[8] 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

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[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

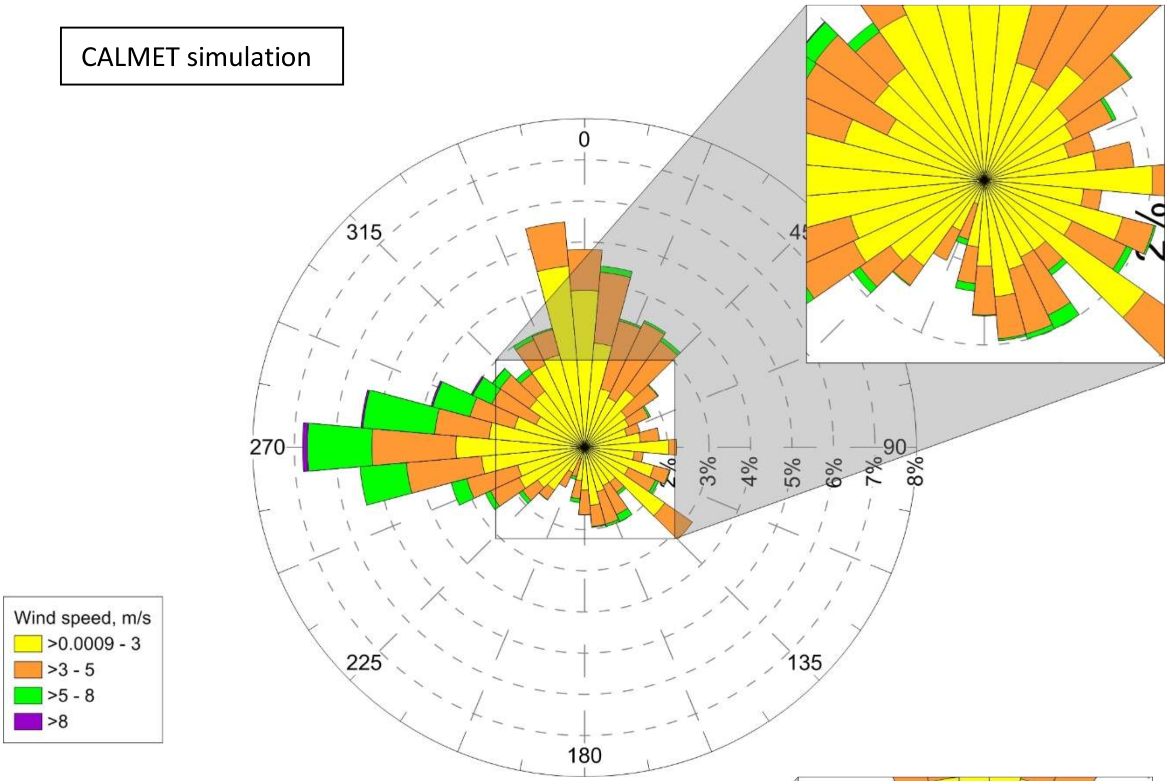
7.5.1 Receptors and Terrain

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.

CALMET simulation



Measured data

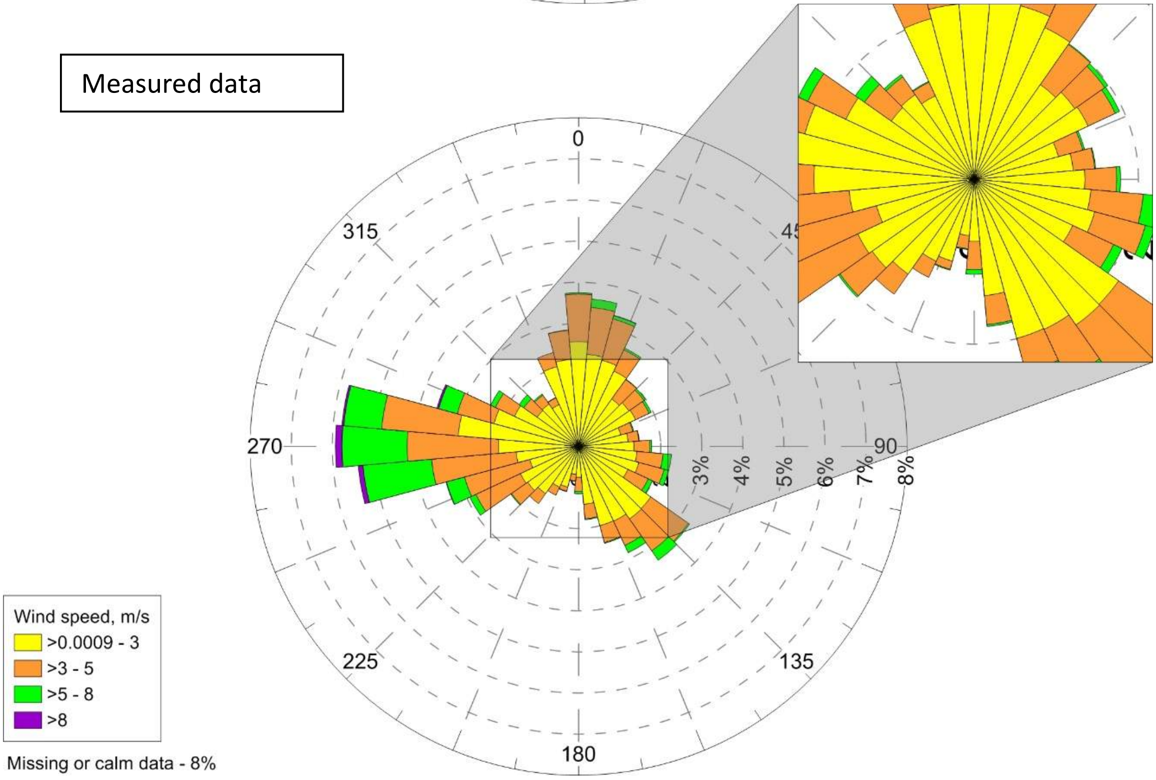


Figure 24: Windrose of meteorological data for Berrima site 2013.
Top – CALMET simulation using fine grid. Bottom – measured data.

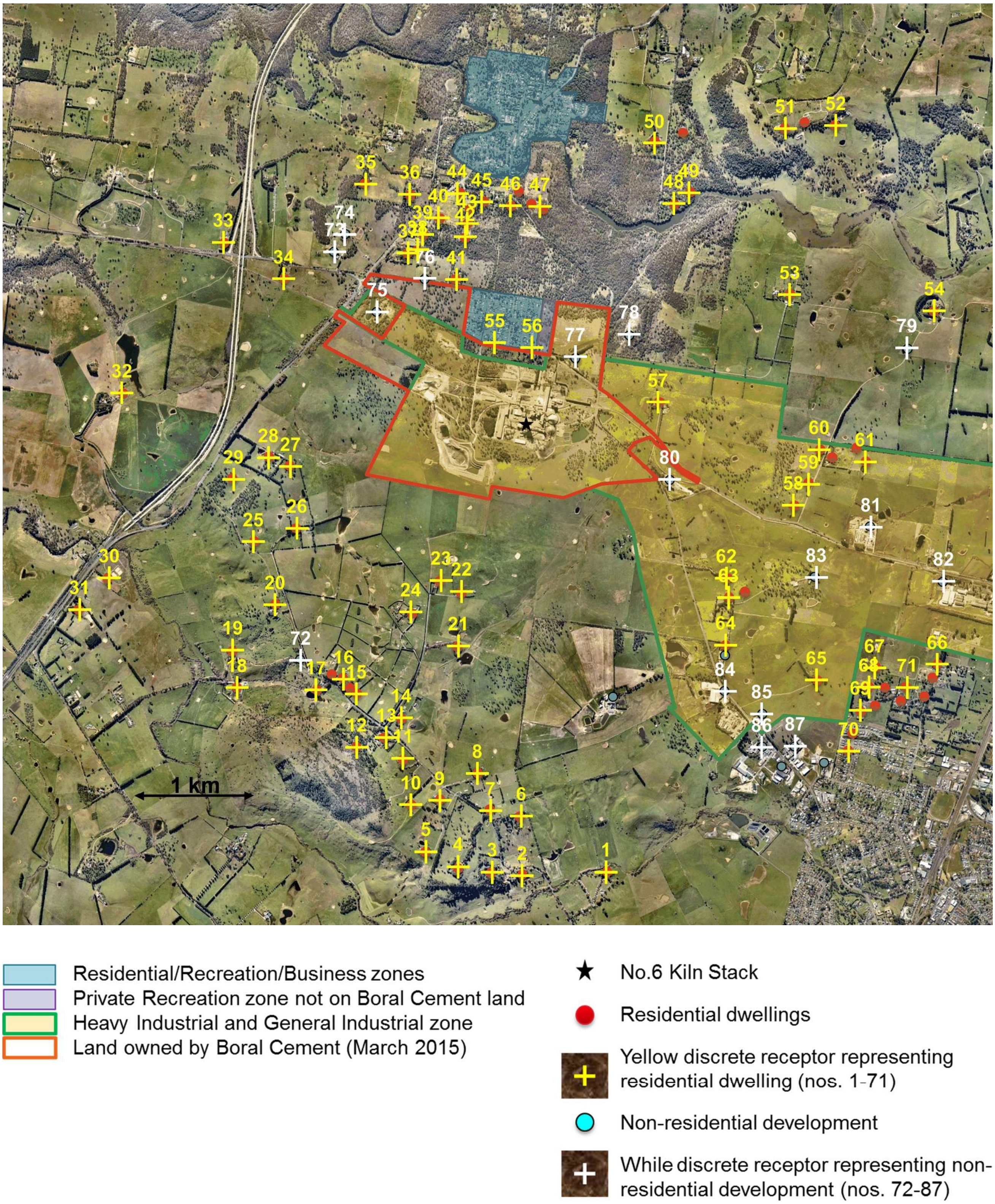
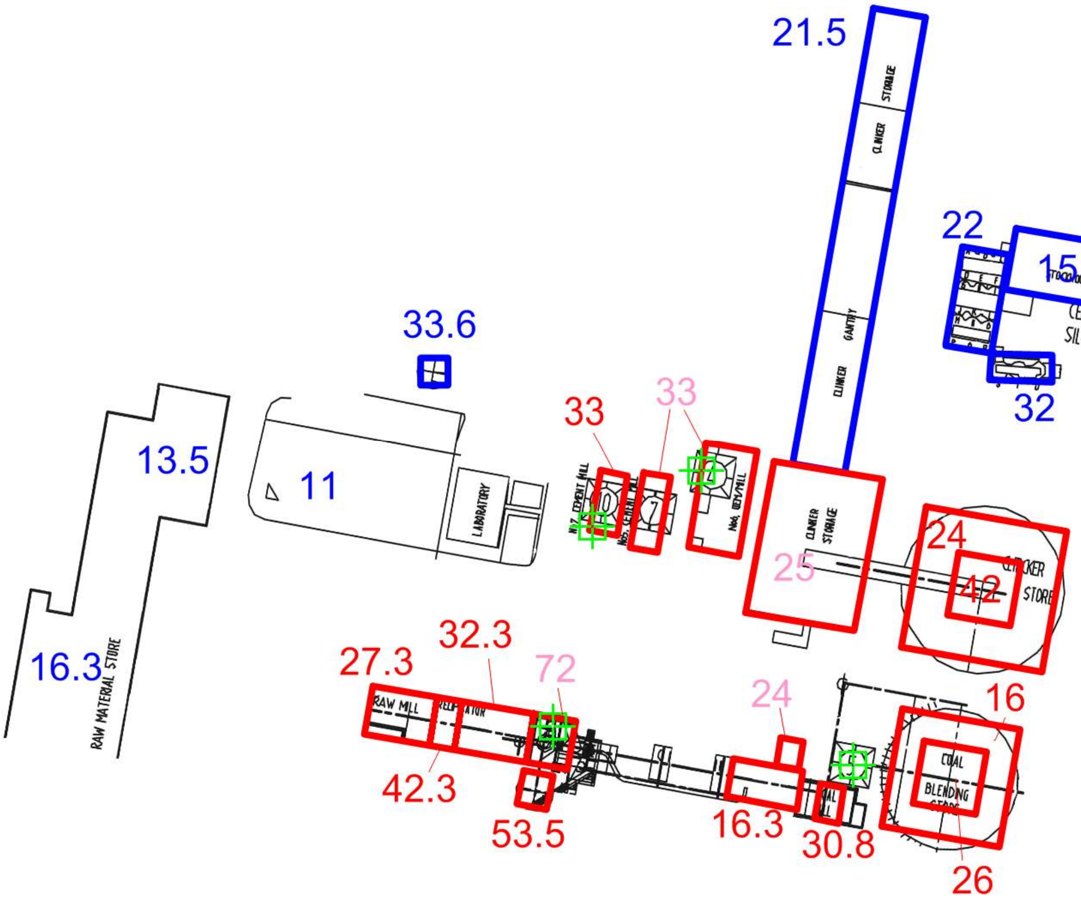


Figure 25: Discrete receptors representing potentially sensitive locations.

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.



Grid north ↑
(Map Grid of Australia (MGA) co-ordinate system)

Legend
🟥 Building or group of structures included in model
🟦 Building not significant height, so not included in model
⌖ Stack/vent locations
Red font Structure height (above local ground level), from site drawings or stack testing report
Pink font Elevation best estimate based on known heights of nearby buildings
Blue font Elevation of building not included in model due to relatively small height or large separation distance from sources

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, PM_{10} 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 PM_{10}, $PM_{2.5}$, SO_2, NO_2, Lead and Hydrogen Fluoride

Assessment criteria for PM_{10}, NO_2, SO_2, 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 EPA[10].

Table 42: Impact assessment criteria for PM_{10}, $PM_{2.5}$, NO_2, SO_2, lead and hydrogen fluoride

Pollutant	Averaging period	Ambient Air Concentration ($\mu g/m^3$)	
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.

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[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 µg/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 in 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), µg/m^3	ESL*, µg /m^3 Short term (1-hour average)	ESL*, µg /m^3 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
xylenes	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 (≥~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 (≤~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 (µg/m^3) or elsewhere*
Heavy metals^	
Arsenic	0.09
Beryllium	Not listed in "Approved Methods". ESL = 0.02 µg/m^3 for "beryllium – particulate" **
Cadmium	0.018
Chromium (III)	9
Chromium (VI)	0.09
Cobalt	Not listed in "Approved Methods". ESL = 0.2 µg/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 µg/m^3 for "selenium and compounds" **
Thallium	Not listed in "Approved Methods". ESL = 1 µg/m^3 for "thallium and compounds" **
Vanadium	Not listed in "Approved Methods". ESL = 0.5 µg/m^3 ** WHO ambient air goal (24-hour average) = 1 µg/m^3 $
Tin	Not listed in "Approved Methods". ESL = 20 µg/m^3 for "tin compounds: metal, oxide, and inorganic" **
Other pollutants	
Dioxins	0.000002 (2 ng/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 PM_{10} 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, NO_2, SO_2 and PM_{10} 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 station[11], 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 NO_2 (and SO_2, 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 NO_2, higher concentrations of ozone, and slightly lower concentrations of PM_{10} in most statistics categories.

Compared to Bargo, the Bringelly and Camden sites showed higher PM_{10} 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 PM_{10} measured at Bargo was caused by a major bushfire and is considered to be an outlier. The Camden site showed lower NO_2 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

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[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, NO_2, SO_2 and PM_{10} for Bargo were purchased from the NSW EPA for 2013 for this assessment. Hourly measurements of ozone, NO, NO_2, $PM_{2.5}$ and PM_{10} 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: 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).

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

	Bringelly	Bargo	Macarthur/ Campbelltown West	Oakdale	Camden (from Oct 2012 only)
NO_2 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
75th percentile	0.6	0.7	1.2	0.3	0.6
90th percentile	0.8	1.0	1.5	0.4	0.8
95th percentile	0.9	1.2	1.7	0.4	0.9
98th percentile	1.0	1.3	1.9	0.5	0.9
99th percentile	1.1	1.5	2.0	0.6	1.0
99.5th percentile	1.2	1.6	2.0	0.6	1.1
99.9th percentile	1.5	1.8	2.3	0.7	1.2
Maximum	1.6	2.4	2.8	0.8	1.2
SO_2 24-hour average (pphm)					
Mean	0.02	0.02	0.04		
Median	0	0	0		
75th percentile	0	0	0.1		
90th percentile	0.1	0.1	0.1		
95th percentile	0.1	0.1	0.1		
98th percentile	0.1	0.1	0.2		
99th percentile	0.2	0.1	0.2		
99.5th percentile	0.2	0.2	0.2		
99.9th percentile	0.2	0.2	0.3		
Maximum	0.3	0.3	0.4		
PM_{10} 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
75th percentile	19.7	17.2	18.3	14.7	19.8
90th percentile	25.5	22.6	23.9	20.5	25.7
95th percentile	29.1	26.4	27.9	24.3	29.5
98th percentile	33.8	30.5	31.6	28.9	32.6
99th percentile	37.9	35.5	35.3	31.7	35.6
99.5th percentile	41.8	42.5	37.1	36.6	40.5
99.9th percentile	76.3	62.5	51.3	80.8	61.8
Maximum	97.2	208.9 (2nd highest 89.7)	58.7	99.0	97.5
$PM_{2.5}$ 24-hour average (µg/m³)					
Mean					6.52
Median					5.8
75th percentile					8.3
90th percentile					10.9
95th percentile					12.7
98th percentile					14.8
99th percentile					18.2
99.5th percentile					20.7
99.9th 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
75th percentile	2.1	2.4	2.0	2.8	2.4
90th percentile	2.5	2.8	2.4	3.2	2.8
95th percentile	2.7	3	2.7	3.6	3.1
98th percentile	3.2	3.4	3.1	4.0	3.4
99th percentile	3.3	3.6	3.4	4.3	3.6
99.5th percentile	3.7	3.8	3.7	4.6	3.9
99.9th 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 NO$_2$, PM$_{10}$, PM$_{2.5}$ and TSP

Annual average concentrations of NO$_2$ and PM$_{10}$ 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 PM$_{10}$ events during bushfires, which may explain the higher annual average concentrations reported for 2012 and 2013. Annual average PM$_{2.5}$ and PM$_{10}$ data from Camden for 2013 and 2014 (first years of Camden operation) is also provided in the table.

Table 47: Annual average concentrations of NO$_2$ and PM$_{10}$ 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/m^3 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/m^3.

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 PM$_{10}$). However, the calculated annual average concentrations of TSP at the Berrima monitoring site (Table 37) over the last four years are 35-43 µg/m^3, less than half of the annual average criteria for TSP of 90 µg/m^3 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 PM_{10} and $PM_{2.5}$ 24-hour Average Data

Figure 28 shows the daily variation in 24-hour average PM_{10} 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 PM_{10} 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 period[12], 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 PM_{10} "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.

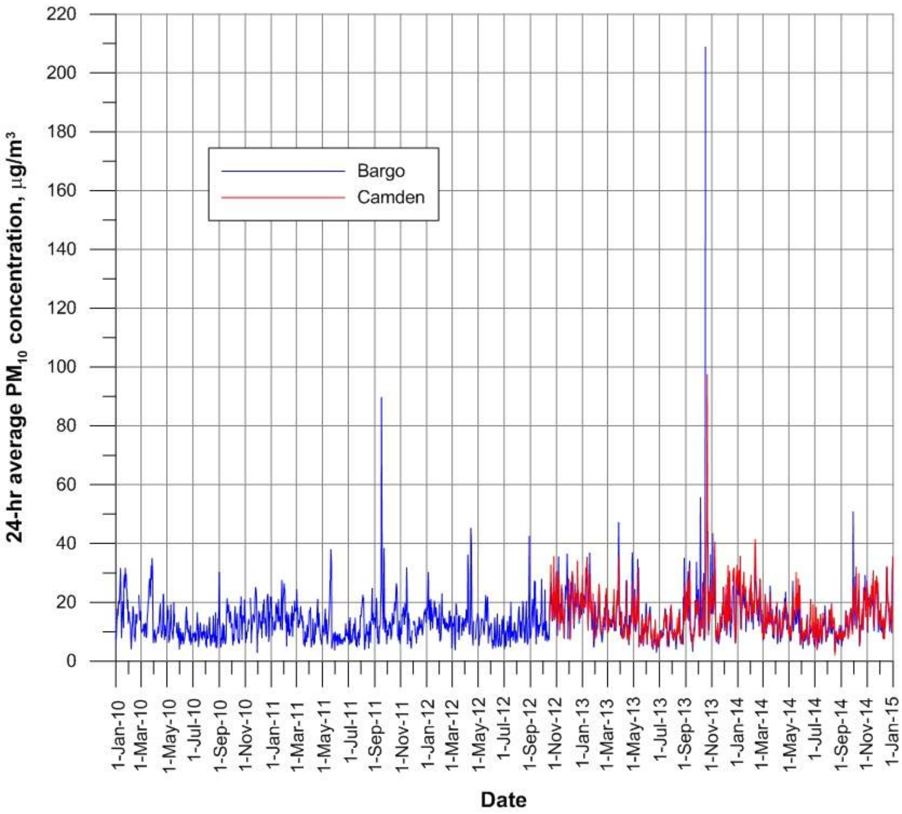

Figure 28: Daily variation in 24-hour average PM_{10} concentration at Bargo and Camden monitoring sites, from 1 January 2010 to 31 December 2014. Data source: OEH website.

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[12] "New South Wales Air Quality Statement 2013", NSW EPA http://www.environment.nsw.gov.au/resources/aqms/140057nswairqual13.pdf, page 3

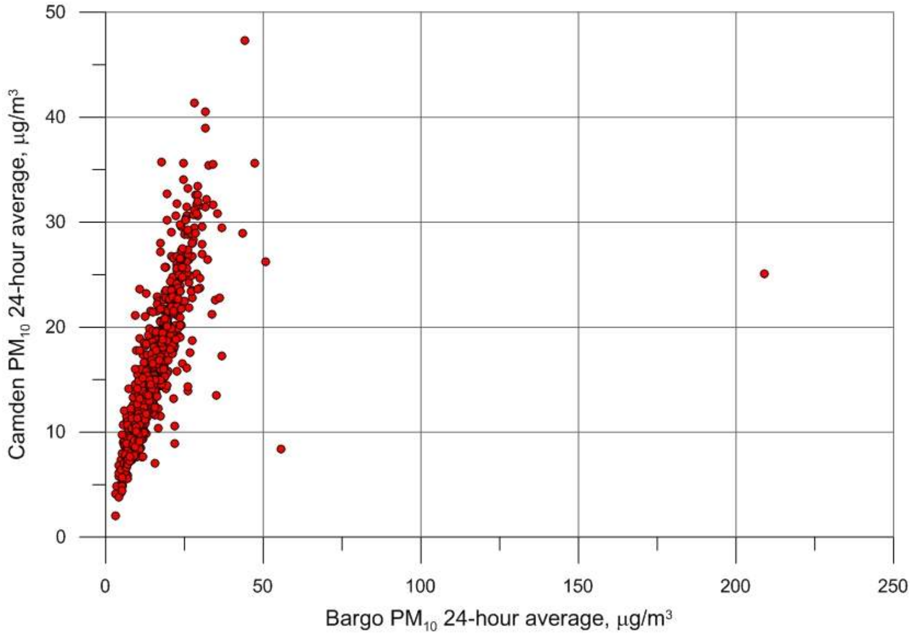

Figure 29: Scatter plot showing contemporaneous Bargo and Camden PM_{10} data (24-hour average, October 2012 to December 2014).

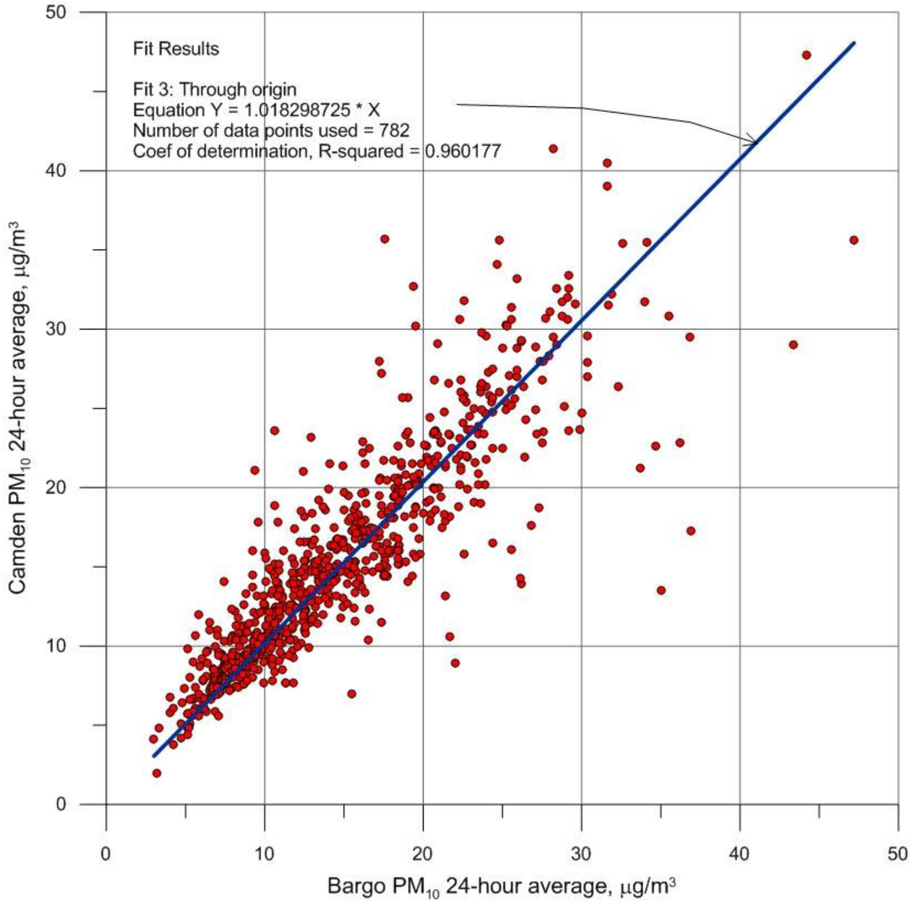

Figure 30: Scatter plot showing contemporaneous Bargo and Camden PM_{10} data (24-hour average, October 2012 to December 2014), showing only Bargo data <50 µg/m³.

A cumulative frequency plot of the Bargo and Camden daily PM_{10} concentrations is compared with a similar plot for PM_{10} 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 the either the Bargo site or the Camden site would be a suitable proxy site for background PM_{10} 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.

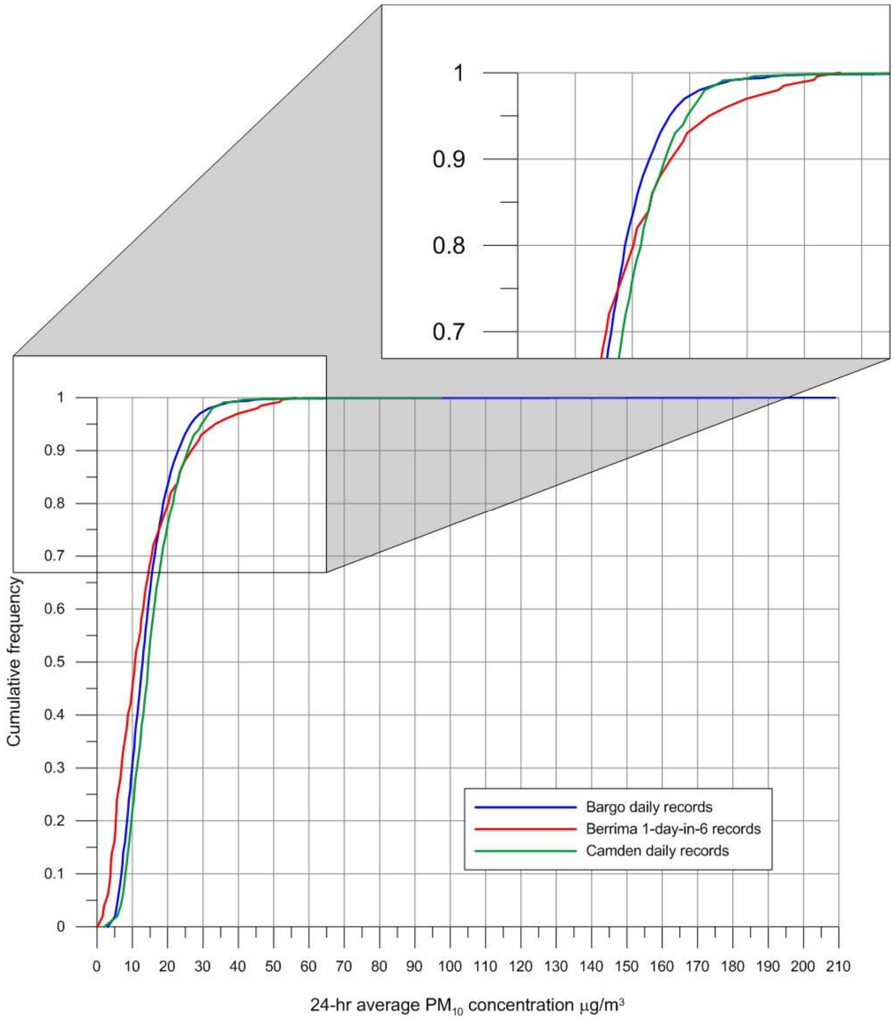

Figure 31: Comparison of cumulative frequency of PM_{10} ambient monitoring data at Berrima (24-hour average, 1-day-in-6 sampling) and Bargo and Camden (daily sampling); January 2011 to December 2014 (Berrima and Bargo); October 2012 to December 2014 (Camden).

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**
75th percentile	17.4	17.5	19.8
90th percentile	26.7	23.0	25.7
95th percentile	33.4	26.5	29.5
98th percentile	45.4	31.7	32.6
99th percentile	50.2	36.7	35.6
99.5th percentile	52.1	43.6	40.5
99.9th 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 PM_{10} 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 PM_{10} background concentration of 209 µg/m^3 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/m^3.

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 PM_{10} 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/m^3 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 PM_{10}, which specifies a 24-hour PM_{10} concentration standard of 50 µg/m^3 with 5 exceedances allowed annually[13]. 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 PM_{10}, no "Level 1" impact assessment was carried out. The assessment instead focussed on a "Level 2" approach with contemporaneous background data.

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[13] The NEPM for Air Quality (1998) is currently under review by the federal government. The review may result in a change to the PM_{10} 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 PM_{10}, following the presentation of the incremental PM_{10} dispersion model results.

Table 49: Five highest daily average PM_{10} concentrations measured in Bargo for each of the calendar years 2010-2014

Rank	2010	2011	2012	2013	2014
1st	34.9	89.7	45.2	208.9	50.8
2nd	32.4	43.6	42.5	55.7	34.1
3rd	31.6	38.4	39.8	47.2	31.9
4th	31.6	38.0	36.5	44.2	31.6
5th	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/m^3 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
1st	61.9	18.5
2nd	34.1	18.2
3rd	27.5	17.3
4th	24.7	15.3
5th	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/m^3). One femtogram is 1 x 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.

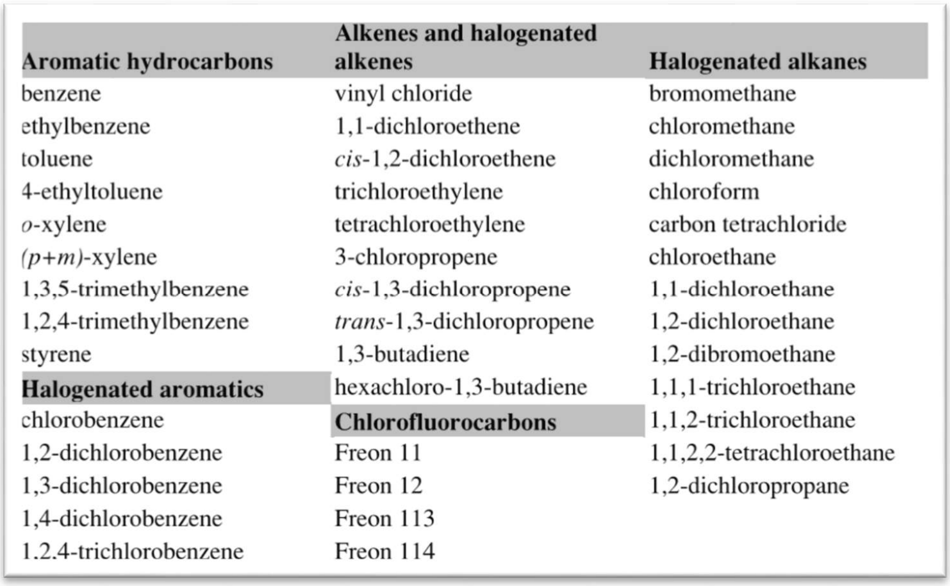
However it is noted that the very low concentrations measured during the NSW EPA study are negligible compared with the dioxin assessment criteria in the "Approved Methods" guideline, which is 2x10^{-9} mg/m^3 or 2,000 fg/m^3.

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	*cis*-1,2-dichloroethene	dichloromethane
4-ethyltoluene	trichloroethylene	chloroform
o-xylene	tetrachloroethylene	carbon tetrachloride
(*p+m*)-xylene	3-chloropropene	chloroethane
1,3,5-trimethylbenzene	*cis*-1,3-dichloropropene	1,1-dichloroethane
1,2,4-trimethylbenzene	*trans*-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.

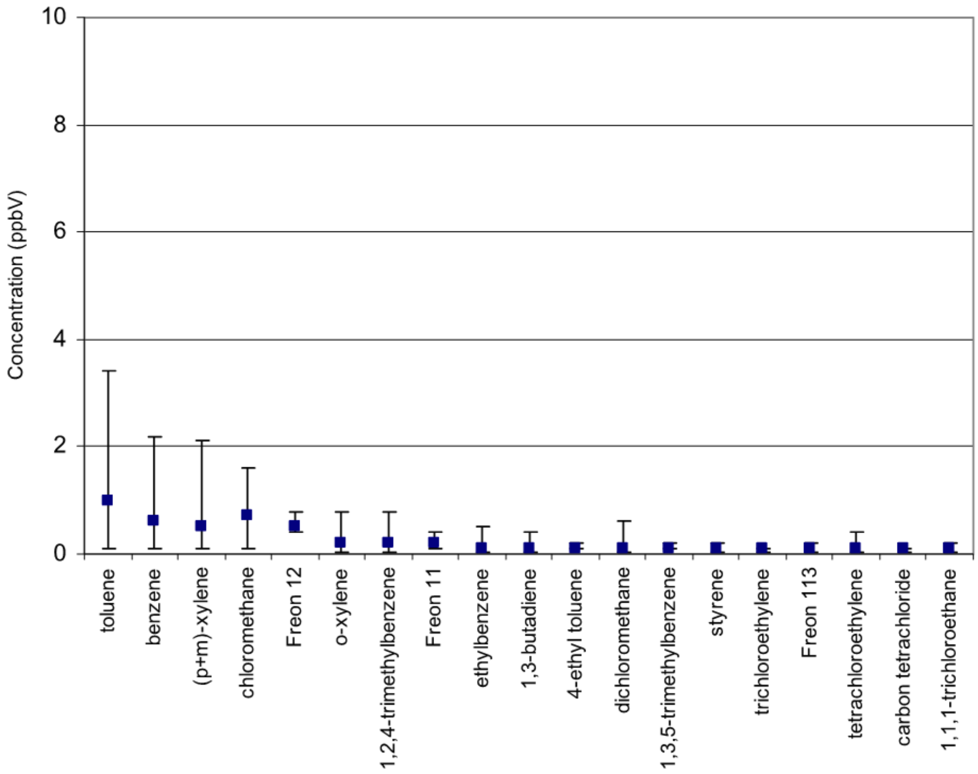


Figure 33: Overall average, minimum 24-hour average and maximum 24-hour average concentrations of organics measured in Wollongong, 1997-2001 (from NSW EPA, 2004a).

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/m^3 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.

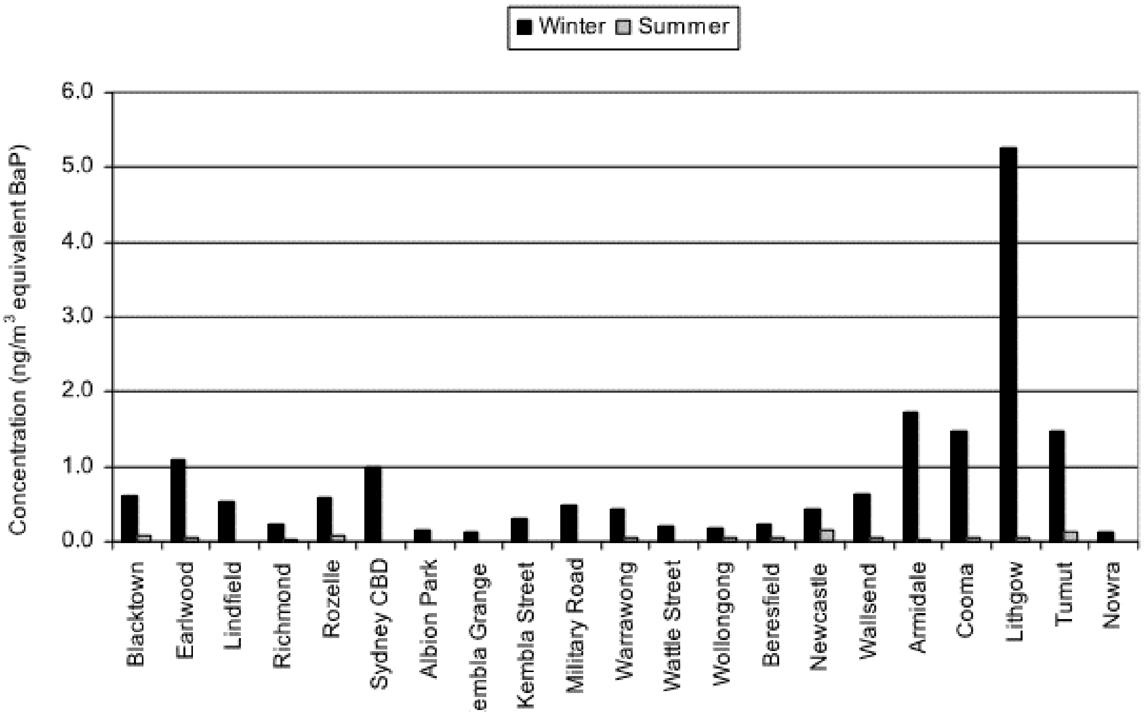


Figure 34: Average 24-hour PAH concentrations reported in NSW EPA (2004b) by site and season. Concentrations expressed as BaP-TEQ.

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/m^3 (or 0.004 µg/m^3).

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. PM_{10}) 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/m^3 or less at all sites.
- Antimony and arsenic were detected at less than 5 ng/m^3 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/m^3 in the Shetland Islands and Norway, 0.6 ng/m^3 in northwest Canada, 1–140 ng/m^3 in continental Europe, 20–70 ng/m^3 in Japan, and 45–67 ng/m^3 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/m^3 (24-hour background level) to 156.8 ng/m^3 (urban annual average); the maximum concentration determined in the United States in any one measurement was about 684 ng/m^3 (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/m^3; urban areas: 4–70 ng/m^3, and industrial areas 5–200 ng/m^3* ".

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/m^3 [5-10 ng/m^3] 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/m*^{3}*, with a typical concentration of 0.04 ng/m*^{3}*. Concentrations of thallium in Chadron, Nebraska reportedly ranged from 0.04 to 0.48 ng/m*^{3}*, and geometric mean concentrations measured during 1985-1986 in Genoa, Italy were about 0.015 µg/m*^{3} *[15 ng/m*^{3}*]."* 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/m*^{3} *for urban air compared to 0.01-0.05 µg/m*^{3} *for rural air. The concentrations of zinc in the air of remote areas range from <0.003 to 0.027 µg/m*^{3}*."*

7.7.6 Hydrogen Fluoride

Background concentrations for hydrogen fluoride were assumed to be negligible.

7.8 NO_x to NO_2 Oxidation Calculations

Emission data for both NO and NO_2 discharged from the No.6 Kiln Stack is available. To calculate ambient concentrations of NO_2 that could occur as a result of these discharges, it is necessary to estimate the oxidation of NO into NO_2 in the atmosphere after discharge from the stack.

For the calculation of NO_2 dynamics, in order to compare the model results to the assessment criteria in Table 42, an assessment of NO-to-NO_2 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 NO_2 concentrations were within the NSW EPA assessment criteria.

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[14] The ATSRD, 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 NO_2

All NO_x and NO_2 model results discussed in this section assume a constant NOx emission concentration of 1000 mg/Nm^3 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 NO_2 concentrations from the No.6 Kiln stack, for the NO_2 discharged from the stack in NO_2 form (i.e. at 1.78 g/s as per Table 31). This figure does not show any NO_2 calculated from atmospheric conversion of NO to NO_2.

Calculation of the cumulative NO_2 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-NO_2 conversion using Method 1

"Method 1" for NO-to-NO_2 conversion specified in the "Approved Methods" guidelines requires the assumption that 100% of the NO_x emitted is converted to NO_2. This is a highly simplistic and conservative method. Using this method, incremental NO_2 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-NO_2 conversion using Method 2 - "Ozone Limiting Method"

Method 2 for NO-to-NO_2 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 NO_2 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 NO_2
2. Assume that ozone data measured at Bargo can be used contemporaneously for hour-by-hour OLM conversions
3. Calculate converted NO_2 concentration as minimum of either incremental NO_2 concentration or (46/48 × ozone) concentration.
4. Add modelled incremental NO_2 concentration from kiln discharge.
5. Add contemporaneous background NO_2 from Bargo[15], converted from ppmh to ug/m3 using Berrima temperature and pressure data.
6. As a sensitivity check, the total NO_2 concentration was also calculated using contemporaneous background NO_2 data from Camden.

This procedure is slightly different to the equation specified in the “Approved Methods” guidelines, because here the actual NO_2 stack discharge has been added to the NO_2 concentration from converted NO. In the “Approved Methods” guidelines, an assumption is made that 10% of the discharged NO_x is in the NO_2 form, which is an appropriate assumption only if emission rates of actual NO_2 are not available.

The maximum incremental concentrations (i.e. no background NO_2 contributions) of 1-hour NO_2 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 NO_2 discharged as NO_2 from the kiln stack. The maximum off-site incremental concentration of 1-hour average NO_2 beyond the site boundary at an existing or likely future off-site sensitive receptor using Method 2 is 180 $\mu g/m^3$ 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 NO_2 of 246 $\mu g/m^3$.

The maximum cumulative concentrations of 1-hour NO_2 using the Bargo or Camden contemporaneous background concentrations are listed in Table 55. The table also shows the calculated cumulative NO_2 concentrations after editing the Bargo data file to remove peak NO_2 concentrations occurring over the period 17-21 October 2013, and editing the Camden data file to remove peak NO_2 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 NO_2 beyond the site boundary at an existing or likely future off-site sensitive receptor using Method 2 is 210 $\mu g/m^3$, occurring at both receptors 59 and 60. This cumulative concentration is less than the NSW EPA criteria of 246 $\mu g/m^3$. 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 $\mu g/m^3$ at receptor 68[16].

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[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 $\mu g/m^3$ 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 NO_2 beyond the site boundary at an existing or likely future off-site sensitive receptor using Method 2 is 209 µg/m^3, occurring at receptor 68. This cumulative concentration is less than the NSW EPA criteria of 246 µg/m^3. 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 NO_2 at potentially sensitive discrete receptors. NO-to-NO_2 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

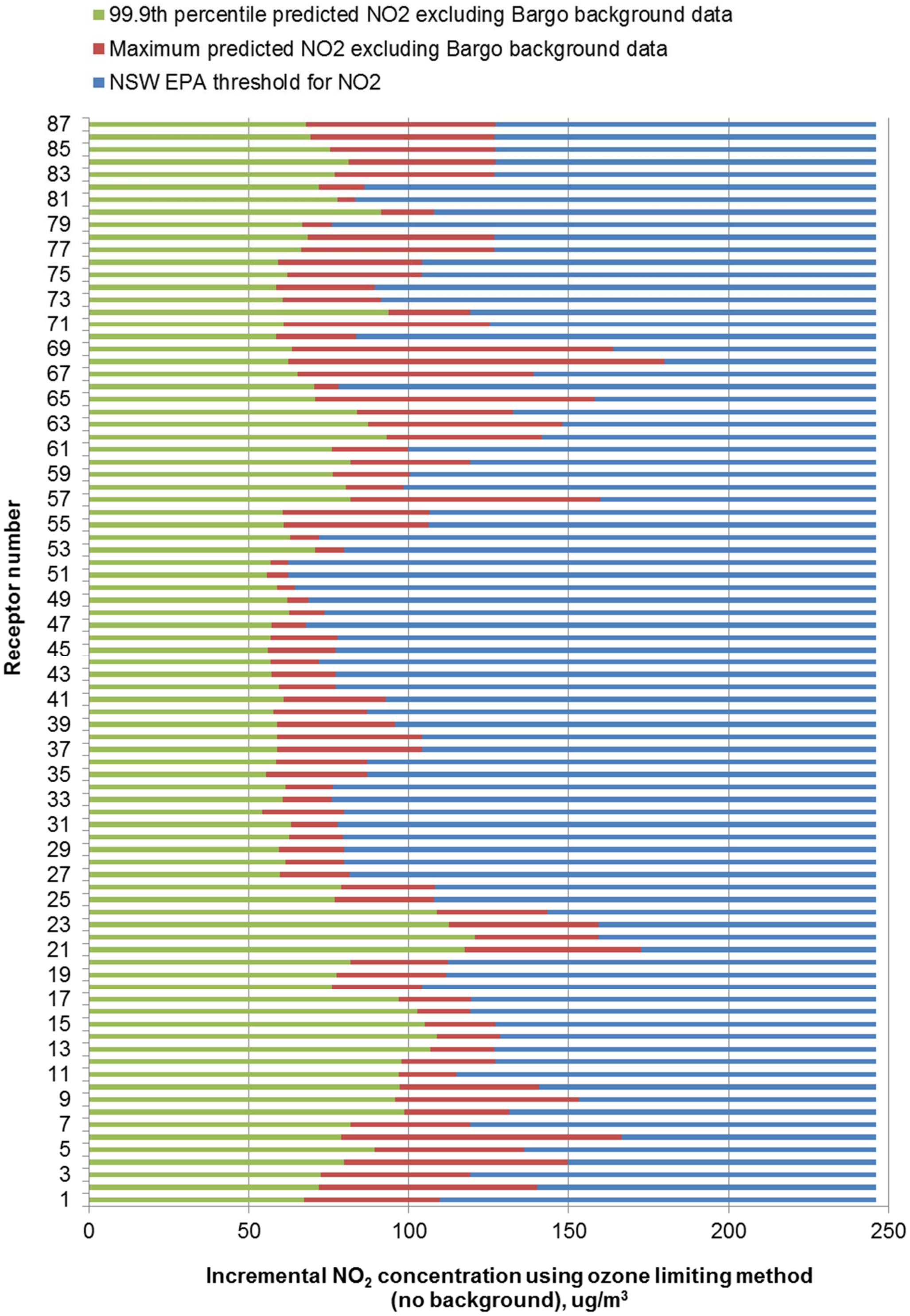


Figure 35: Incremental NO_2 concentrations in ambient air predicted at each discrete receptor using ozone limiting method; 1-hr average, both maximum and 99.9th percentile values shown compared to NSW EPA ambient air quality assessment threshold for NO_2.

Data excludes background contribution of NO_2 but includes NO_2 emissions from stack plus NO_2 converted from NO after discharge from stack using Method 2 (ozone limiting method).

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.

Receptor no.	1-hr avg NO_2 (µg/m^3) Bargo background data	1-hr avg NO_2 (µg/m^3) Bargo data excl. 17-21 Oct peaks	1-hr avg NO_2 (µg/m^3) Camden background data	1-hr avg NO_2 (µg/m^3) 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) Bargo background data	1-hr avg NO_2 (µg/m^3) Bargo data excl. 17-21 Oct peaks	1-hr avg NO_2 (µg/m^3) Camden background data	1-hr avg NO_2 (µg/m^3) 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

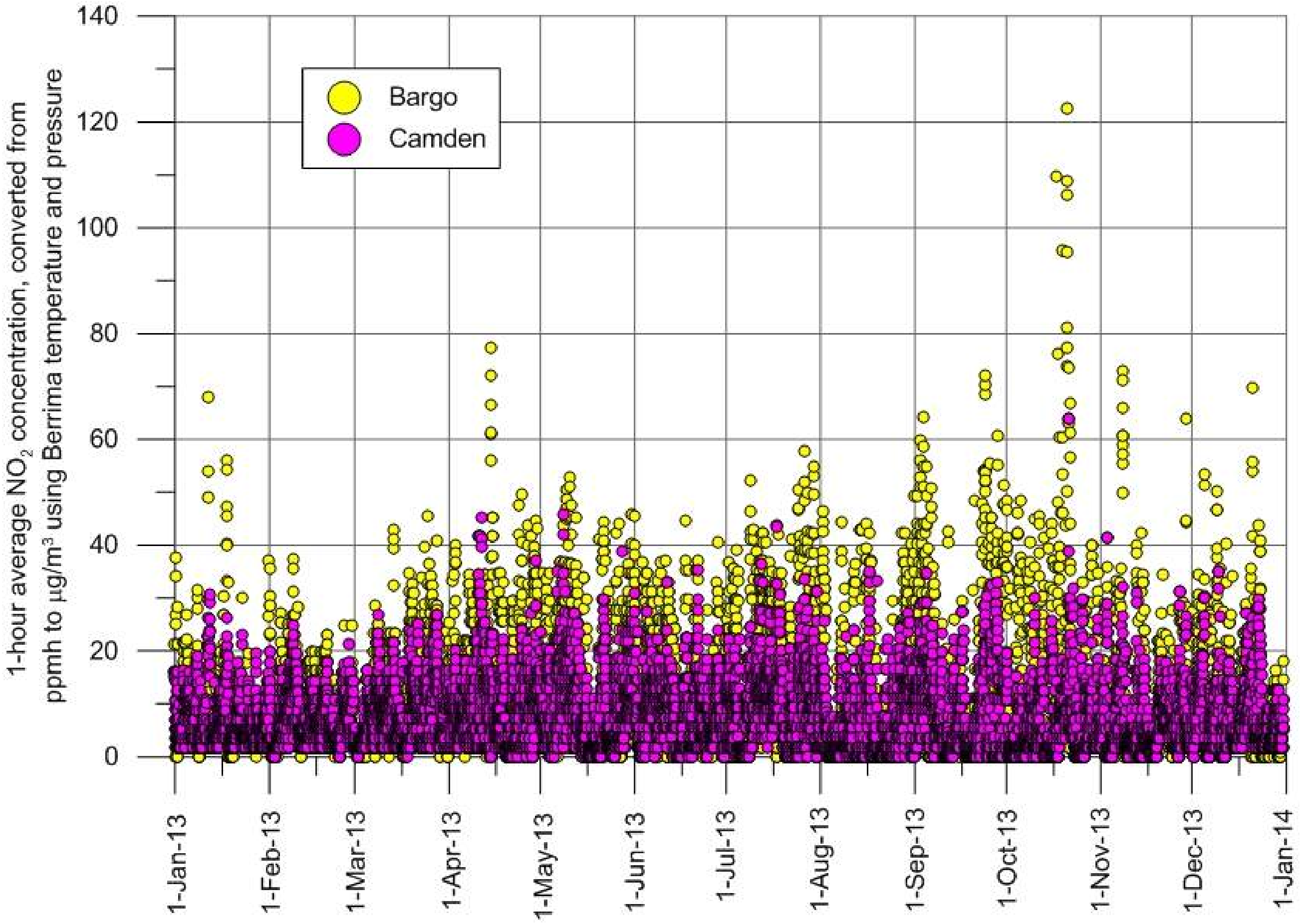


Figure 36: Bargo and Camden 1-hour average NO_2 concentration data used for contemporaneous background assessment.

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 NO_2 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.

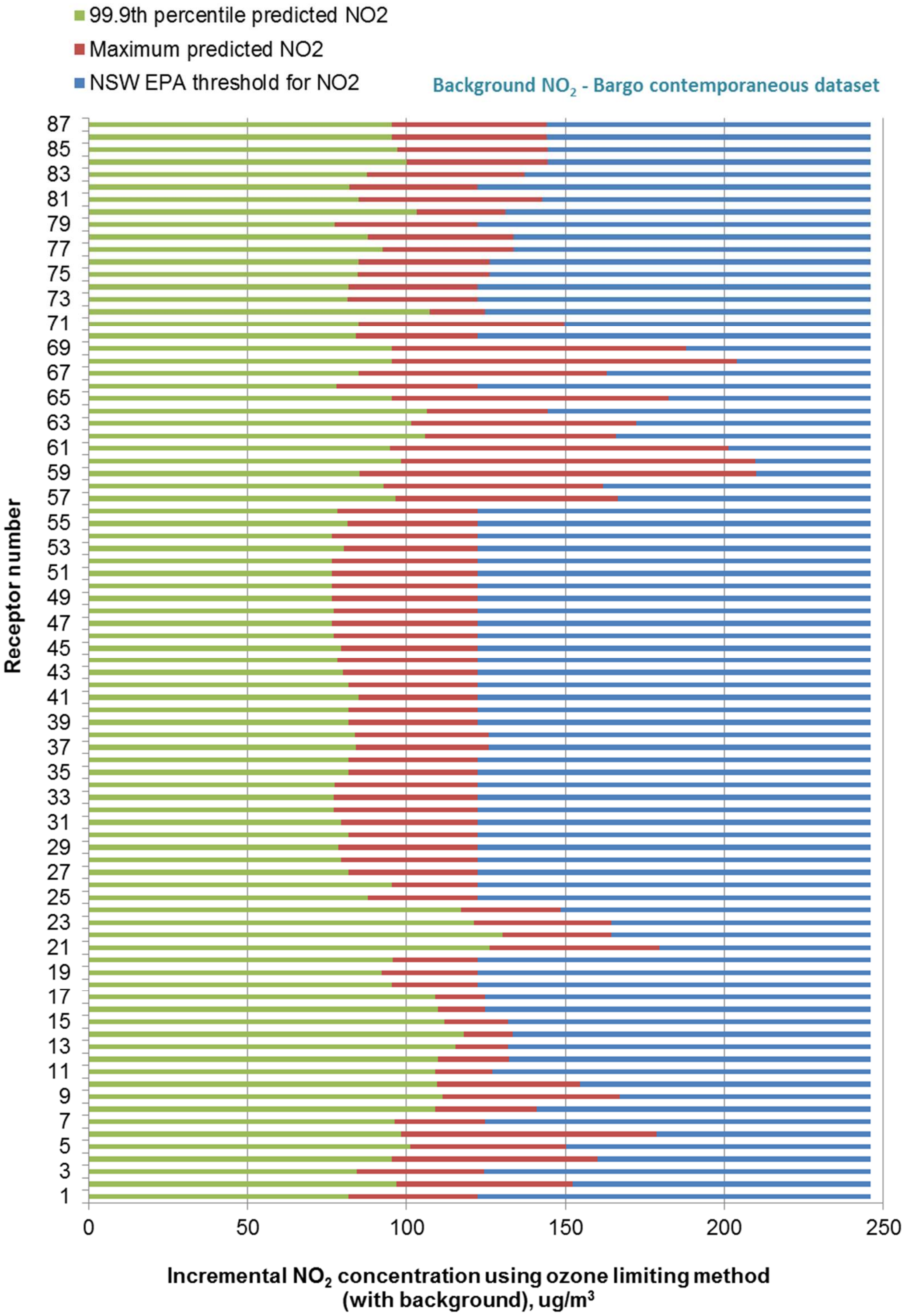


Figure 37: Cumulative NO_2 concentrations in ambient air predicted at each discrete receptor using ozone limiting method; 1-hr average, both maximum and 99.9th percentile values shown compared to NSW EPA ambient air quality assessment threshold for NO_2.

Data <u>includes</u> background contribution of NO_2 using contemporaneous hourly data from Bargo.

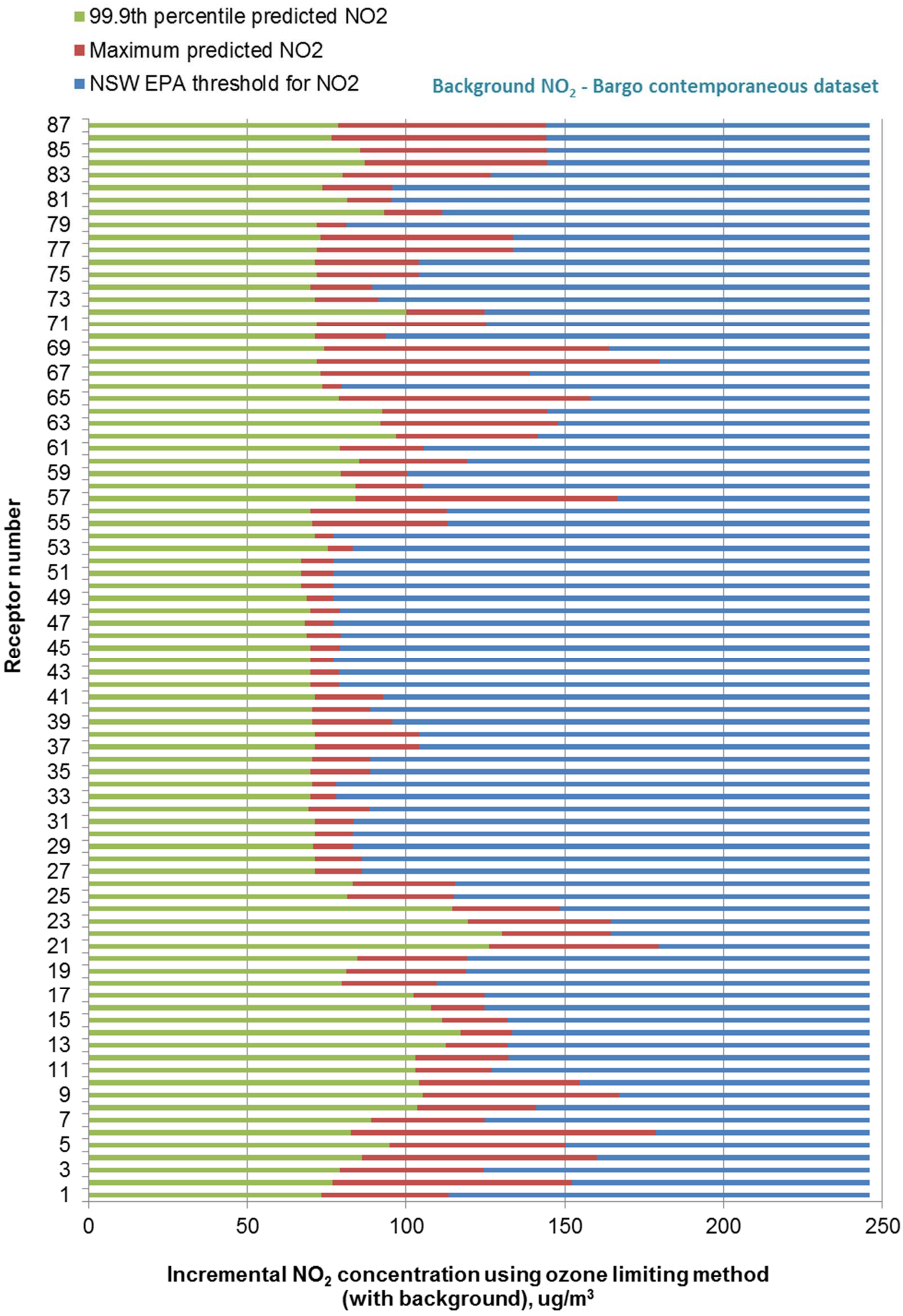


Figure 38: Cumulative NO_2 concentrations in ambient air predicted at each discrete receptor using ozone limiting method; 1-hr average, both maximum and 99.9th percentile values shown compared to NSW EPA ambient air quality assessment threshold for NO_2.

Data <u>includes</u> background contribution of NO_2 using contemporaneous hourly data from Bargo but with peak background concentrations occurring on 17-21 October removed.

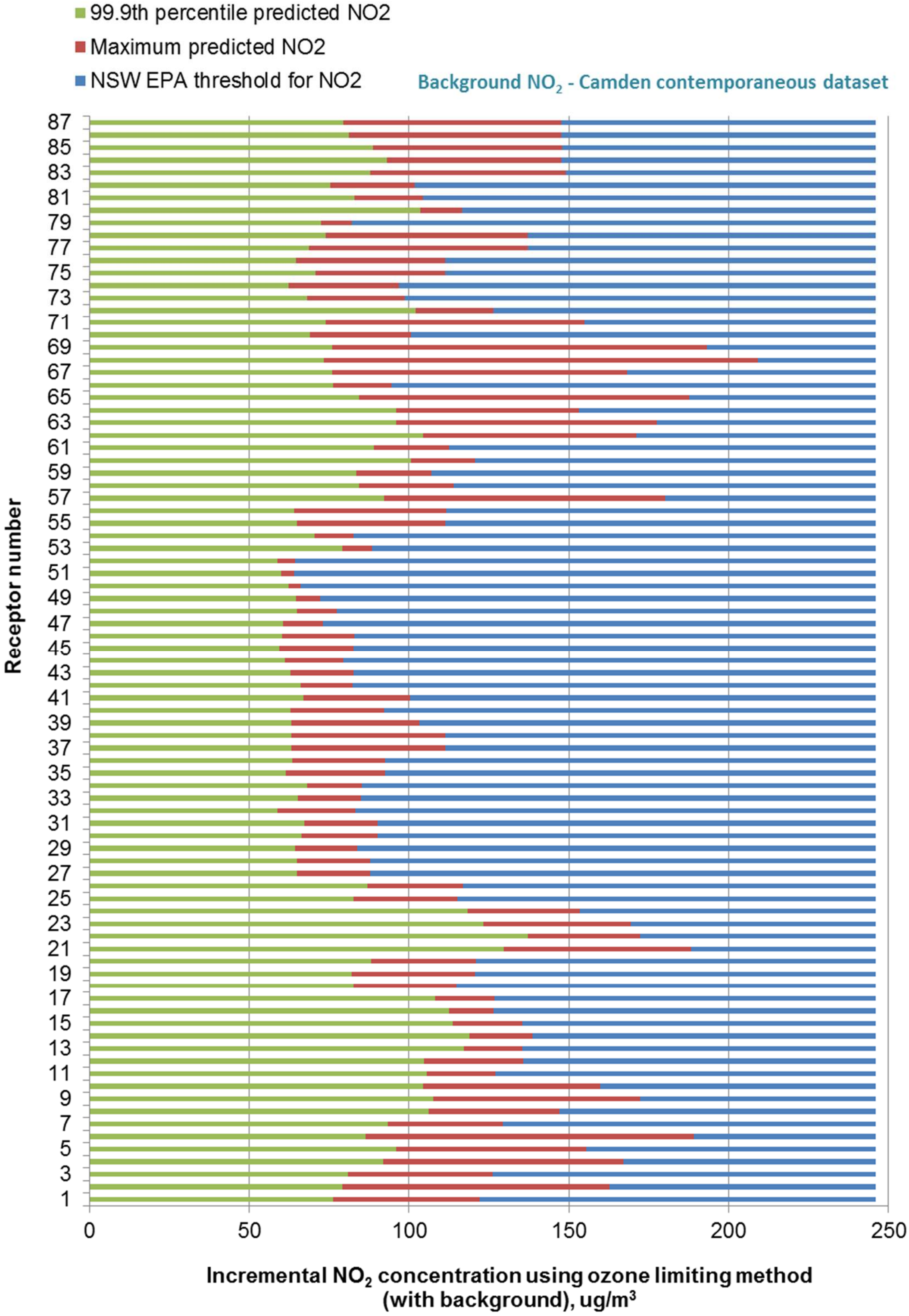


Figure 39: Cumulative NO$_2$ concentrations in ambient air predicted at each discrete receptor using ozone limiting method; 1-hr average, both maximum and 99.9th percentile values shown compared to NSW EPA ambient air quality assessment threshold for NO$_2$.

Data includes background contribution of NO$_2$ using contemporaneous hourly data from Camden.

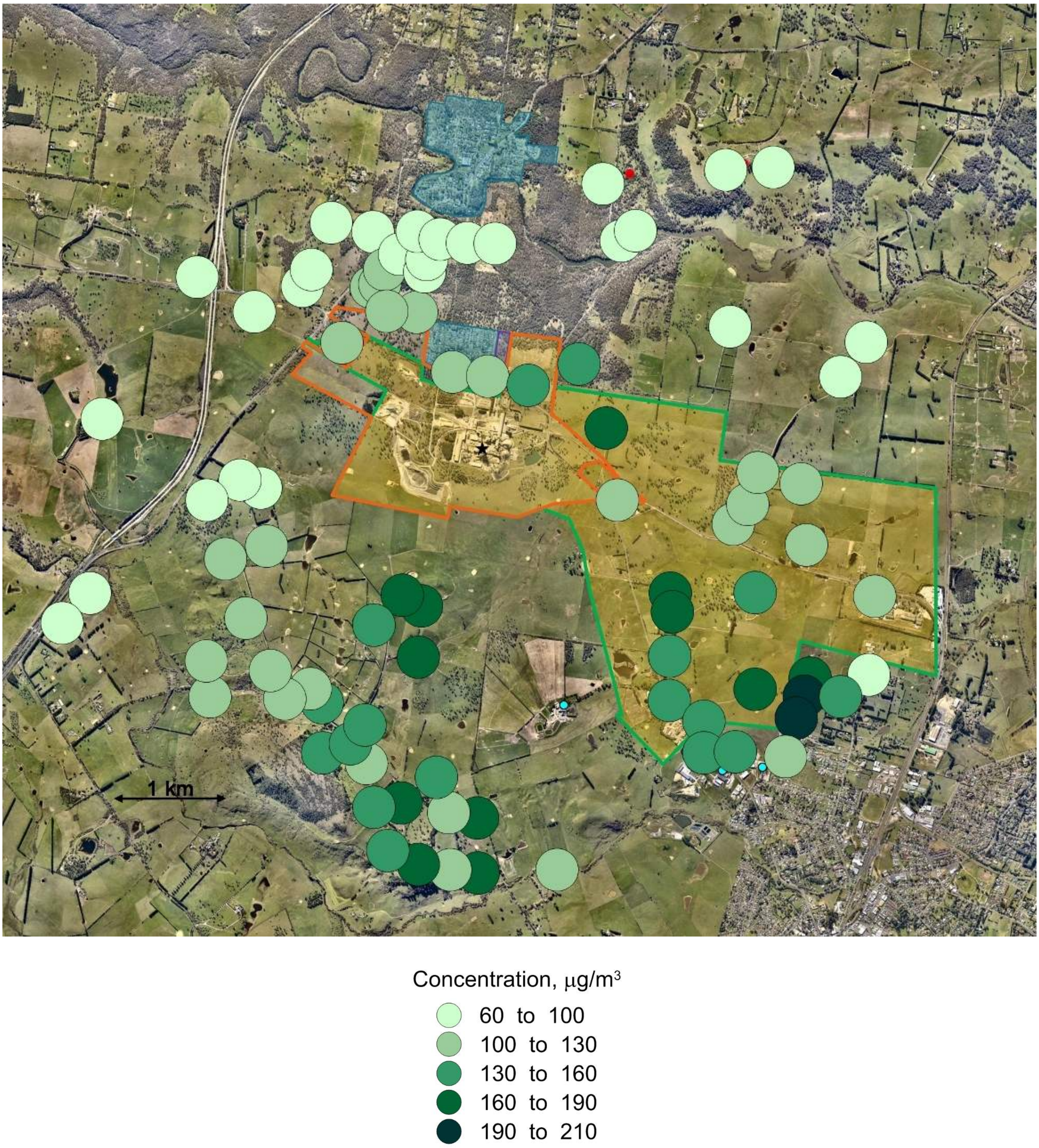


Figure 40: Spatial distribution of cumulative NO_2 concentrations in ambient air using ozone limiting method; 1-hr average, including contemporaneous background data contribution from Bargo (including background data measured 17-21 October 2013).

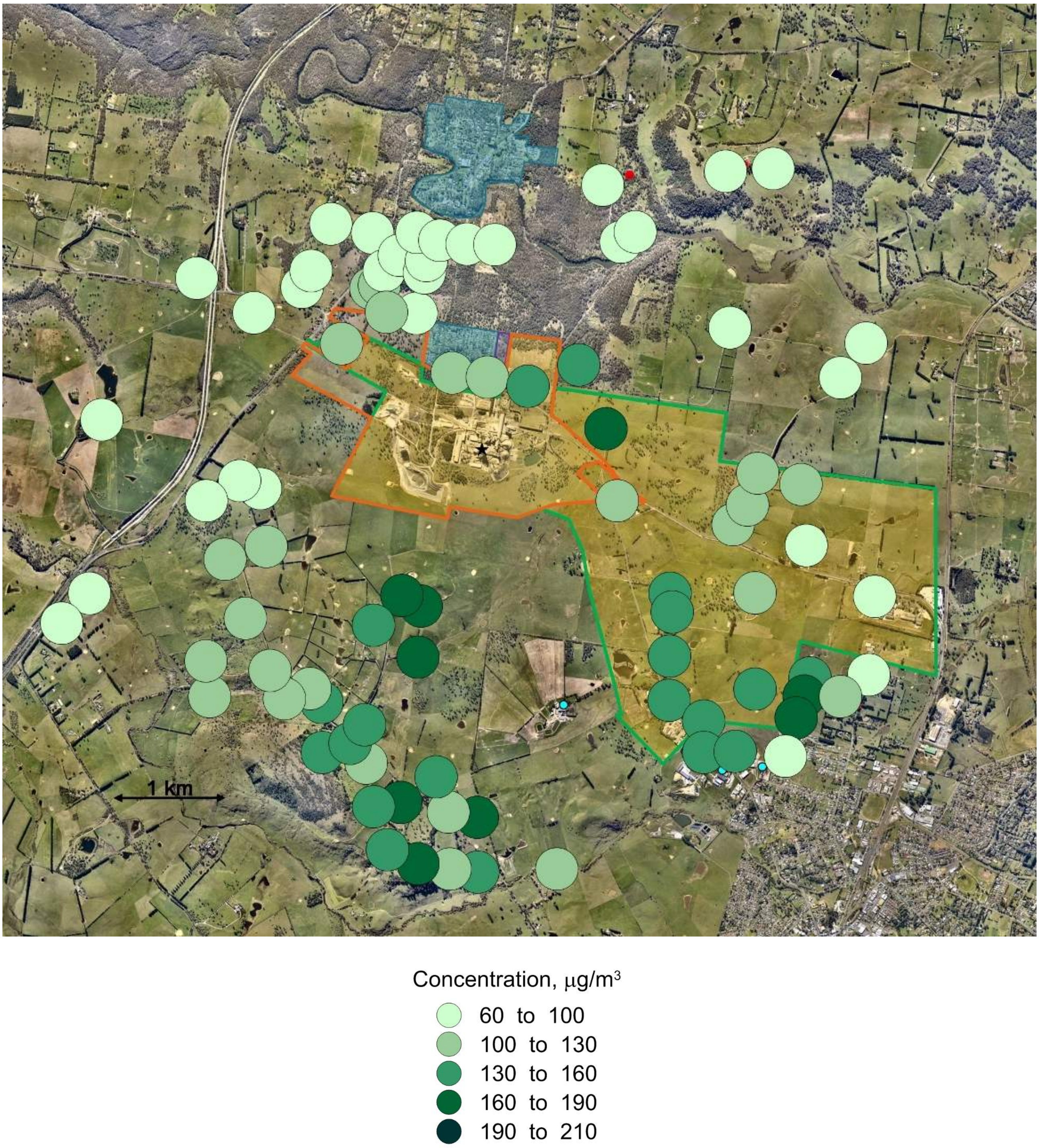


Figure 41: Spatial distribution of cumulative NO_2 concentrations in ambient air using ozone limiting method; 1-hr average, including contemporaneous background data contribution from Bargo (excluding background data measured 17-21 October 2013).

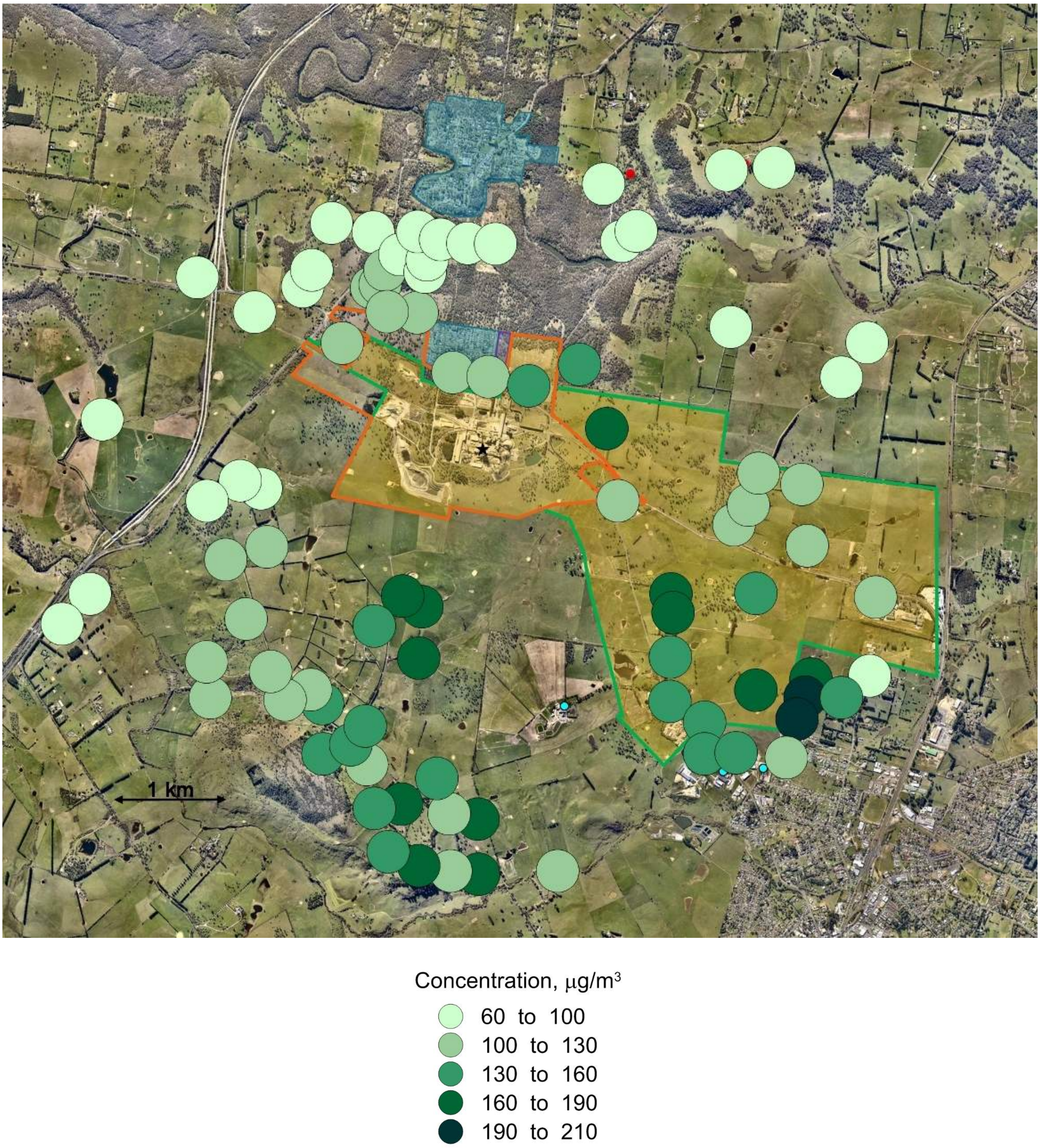
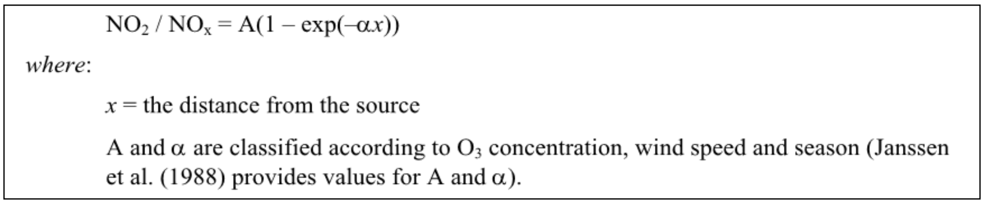


Figure 42: Spatial distribution of cumulative NO_2 concentrations in ambient air using ozone limiting method; 1-hr average, including contemporaneous background data contribution from Camden.

8.1.4 NO-to-NO_2 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"):



$$NO_2 / NO_x = A(1 - \exp(-\alpha x))$$

where:

x = the distance from the source

A and α are classified according to O_3 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/m^3 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 NO_2 concentrations at each of these locations was as follows:

1. Extract time series (hourly estimates) of NO concentrations and NO_2 concentrations (due to discharge of NO and NO_2 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:NO_2 ratio for each receptor.
4. Convert NO concentrations in the time series to NO_X and then multiply by the NO_X:NO_2 ratio to get NO_2 contribution from NO emissions.
5. Add NO_2 contribution due to NO_2 discharged from No.6 Kiln Stack for that hour, plus corresponding background NO_2 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 NO_2 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 NO_2 discharged as NO_2 from the kiln stack. The maximum off-site incremental concentration of 1-hour average NO_2 beyond the site boundary at an existing or likely future off-site sensitive receptor using the Janssen method is 124 µg/m^3 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 NO_2 of 246 µg/m^3.

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.

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

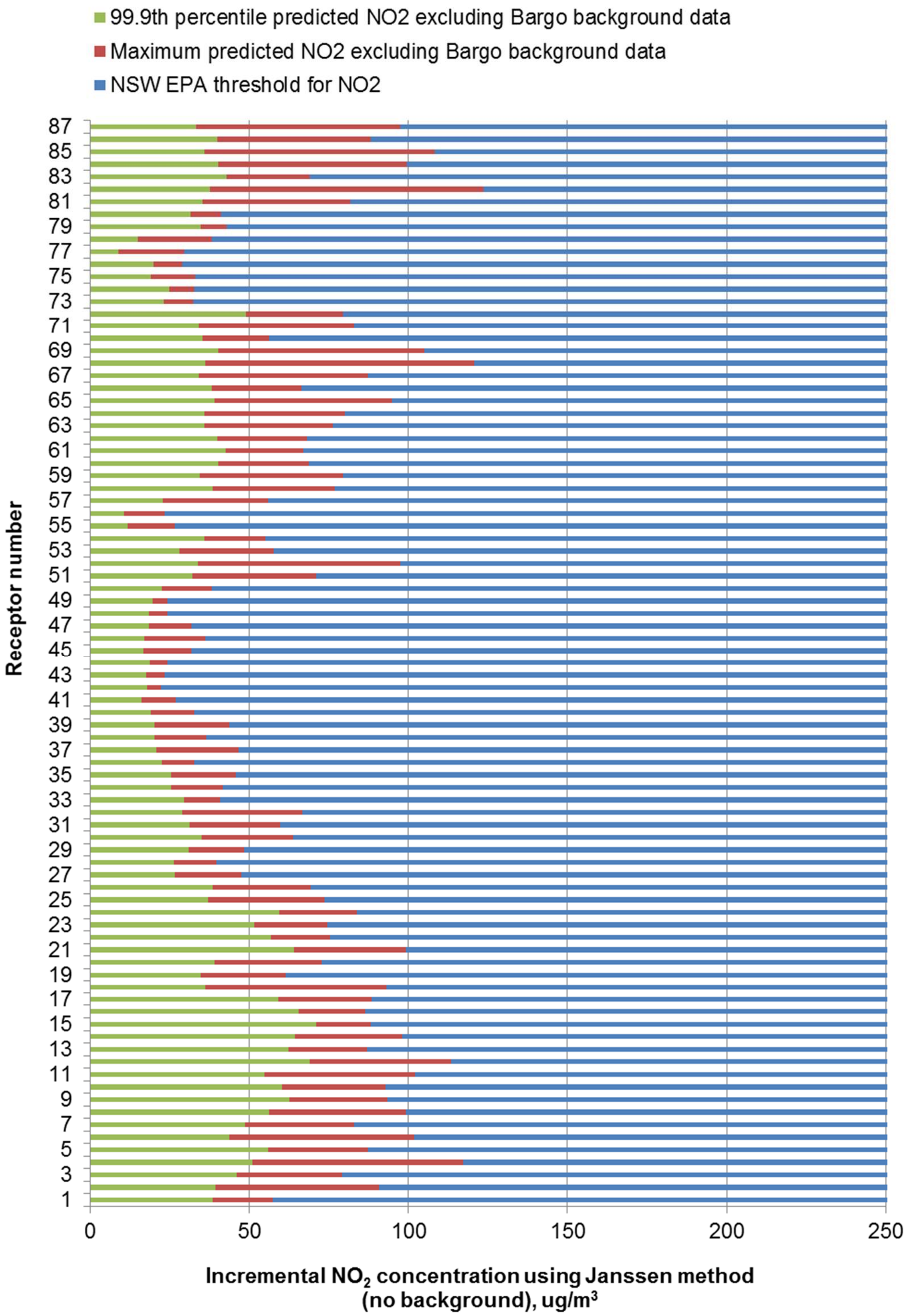


Figure 43: Incremental NO_2 concentrations in ambient air predicted at each discrete receptor using Method 3 (Janssen method); 1-hr average, both maximum and 99.9th percentile values shown compared to NSW EPA ambient air quality assessment threshold for NO_2.

Data <u>excludes</u> background contribution of NO_2 but includes NO_2 emissions from stack plus NO_2 converted from NO after discharge from stack using Method 3.

The maximum cumulative concentrations of 1-hour NO_2 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 NO_2 of 246 µg/m^3.

Using the Bargo background data excluding the October peak records, the maximum off-site cumulative (incremental + background) concentration of 1-hour average NO_2 beyond the site boundary at an existing or likely future off-site sensitive receptor using Method 3 is 128 µg/m^3, occurring at receptor 4. This cumulative concentration is just over 50% of the NSW EPA criteria of 246 µg/m^3.

Using the Camden background data, the maximum off-site cumulative (incremental + background) concentration of 1-hour average NO_2 beyond the site boundary at an existing or likely future off-site sensitive receptor using Method 3 is 150 µg/m^3, occurring at receptor 68. This cumulative concentration is 61% of the NSW EPA criteria of 246 µg/m^3.

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.

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).

Receptor no.	1-hr avg NO_2 ($\mu g/m^3$) Bargo background data	1-hr avg NO_2 ($\mu g/m^3$) Camden background data	Receptor no.	1-hr avg NO_2 ($\mu g/m^3$) Bargo background data	1-hr avg NO_2 ($\mu g/m^3$) 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			

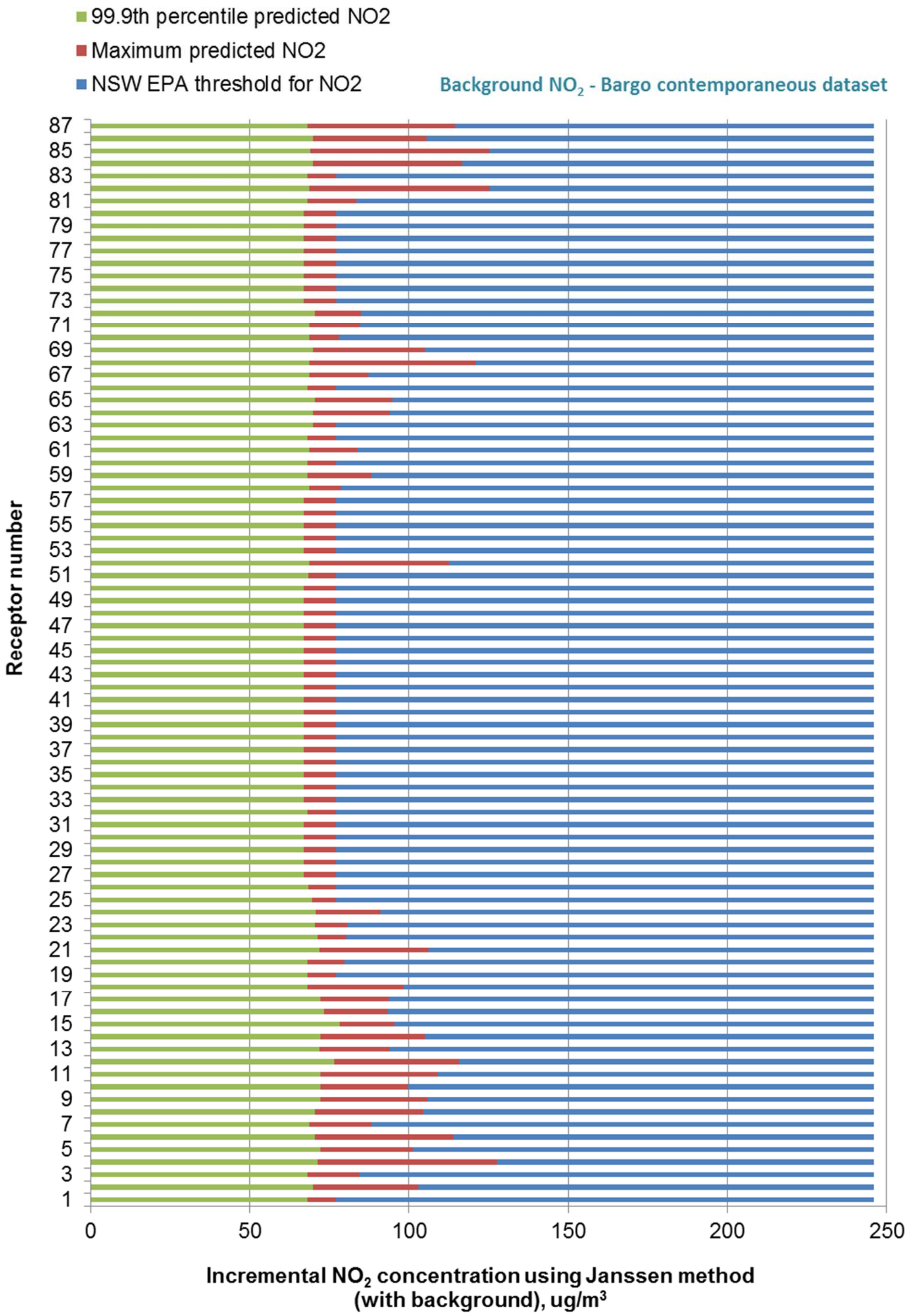


Figure 44: Cumulative NO_2 concentrations in ambient air predicted at each discrete receptor using Janssen method; 1-hr average, both maximum and 99.9th percentile values shown compared to NSW EPA ambient air quality assessment threshold for NO_2.

Data includes background contribution of NO_2 using contemporaneous hourly data from Bargo but with peak background concentrations occurring on 17-21 October removed.

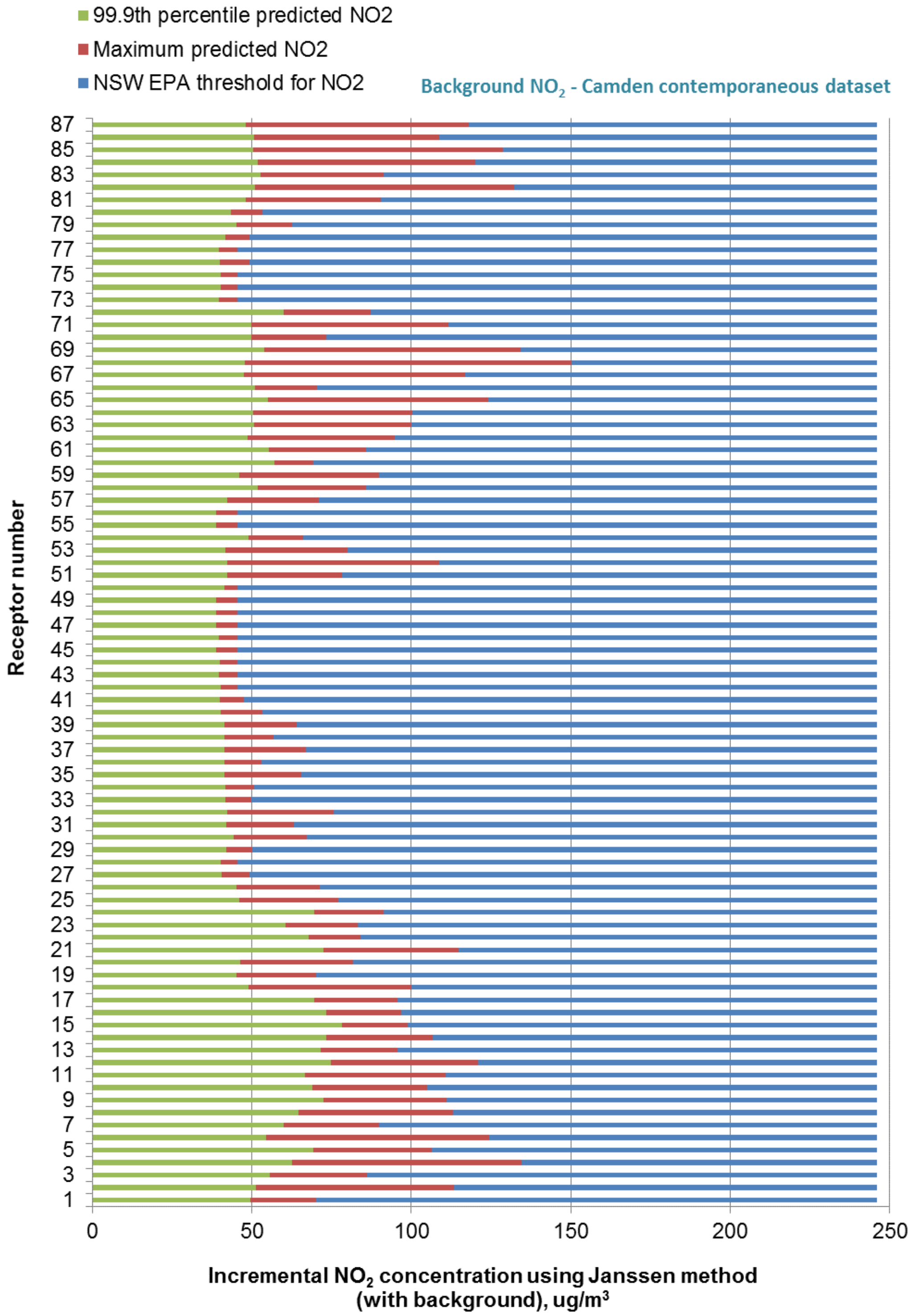


Figure 45: Cumulative NO₂ concentrations in ambient air predicted at each discrete receptor using ozone limiting method; 1-hr average, both maximum and 99.9th percentile values shown compared to NSW EPA ambient air quality assessment threshold for NO₂.

Data <u>includes</u> background contribution of NO₂ using contemporaneous hourly data from Camden.

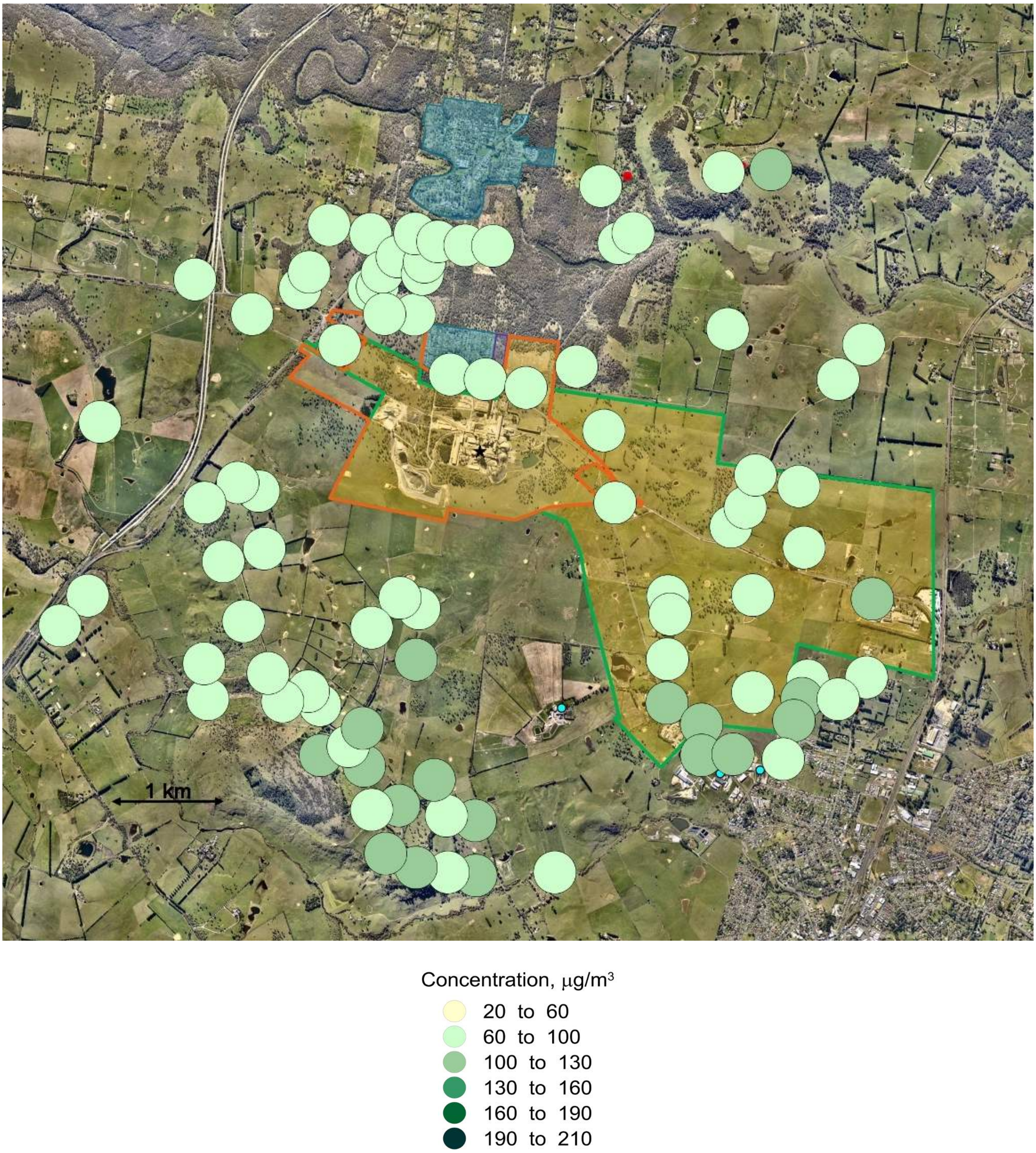


Figure 46: Spatial distribution of cumulative NO_2 concentrations in ambient air using Janssen method; 1-hr average, including contemporaneous background data contribution from Bargo (excluding background data measured 17-21 October 2013).

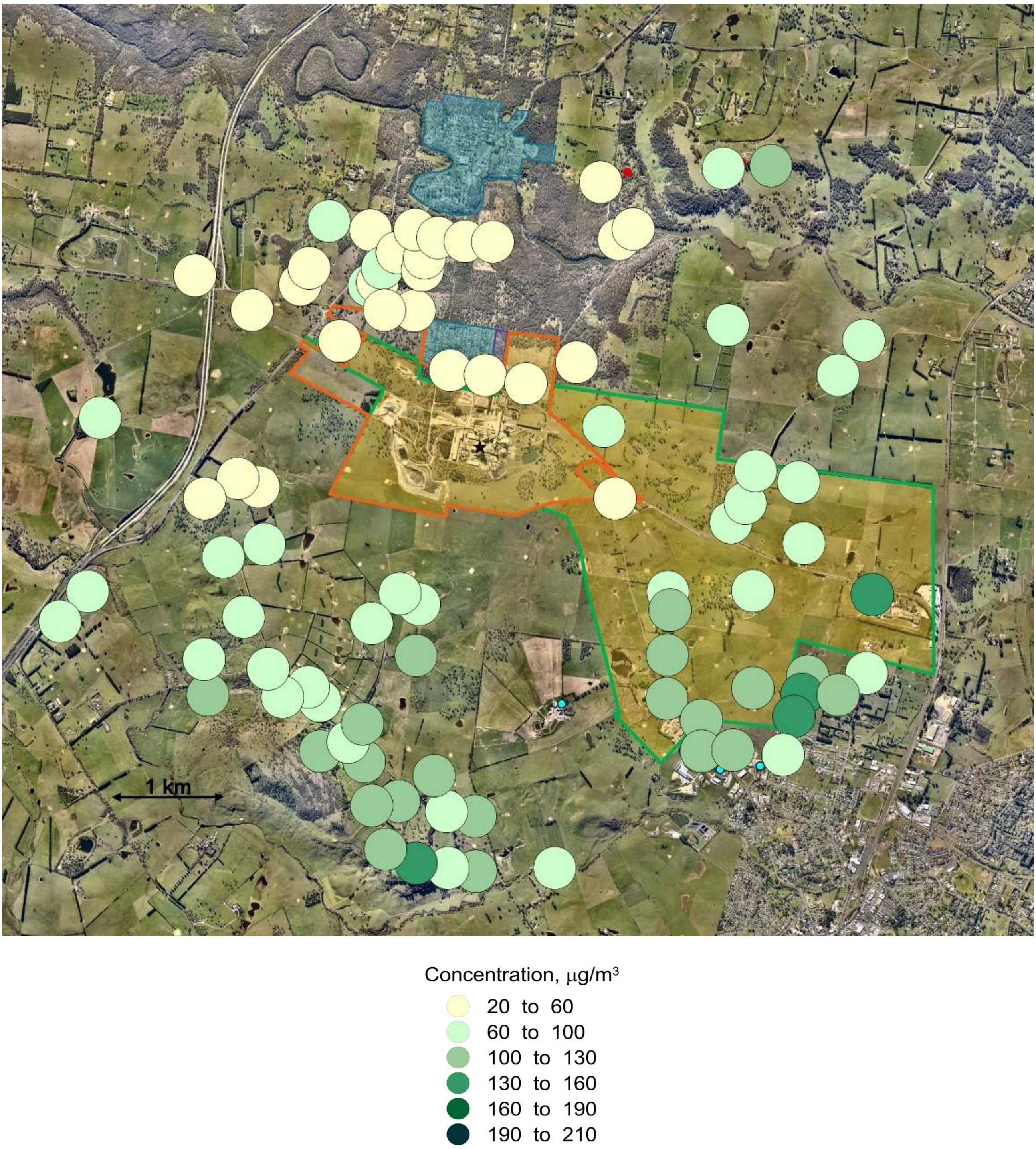


Figure 47: Spatial distribution of cumulative NO_2 concentrations in ambient air using Janssen method; 1-hr average, including contemporaneous background data contribution from Camden.

8.1.5 Annual Average

The incremental annual average NO_2 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-NO_2 conversion Method 2 or Method 3.

The annual average incremental NO_2 concentrations predicted at each receptor using Methods 2 and 3 are shown in Table 58.

The maximum off-site incremental concentration of annual average NO_2 at the discrete receptors is 3.34 µg/m^3 (receptor 60) using Method 2, and 0.98 µg/m^3 (receptor 38) using Method 3. These incremental concentrations are very small compared to the NSW EPA criteria of 62 µg/m^3.

The annual average cumulative (incremental + background) NO_2 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 NO_2 at the discrete receptors is summarised as follows:

NO-to-NO_2 calculation method	***Source of contemporaneous background data***	***Maximum predicted annual concentration***	***Discrete receptor where this concentration occurs***
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 NO_2 predicted using any of the methods and background data is 13.1 µg/m^3 (receptor 38) using Method 2. This cumulative concentration is only 21% of the NSW EPA criteria of 62 µg/m^3.

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).

Receptor no.	Incremental annual avg NO_2 (µg/m³)	Incremental annual avg NO_2 (µg/m³)	Receptor no.	Incremental annual avg NO_2 (µg/m³)	Incremental annual avg NO_2 (µg/m³)
	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 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).

Receptor no.	Annual avg NO_2 ($\mu g/m^3$) Method 2 Bargo data excl. 17-21 Oct peaks	Annual avg NO_2 ($\mu g/m^3$) Method 3 Bargo data excl. 17-21 Oct peaks	Annual avg NO_2 ($\mu g/m^3$) Method 2 Camden background data	Annual avg NO_2 ($\mu g/m^3$) Method 3 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/m³) Method 2 Bargo data excl. 17-21 Oct peaks	Annual avg NO_2 (μg/m³) Method 3 Bargo data excl. 17-21 Oct peaks	Annual avg NO_2 (μg/m³) Method 2 Camden background data	Annual avg NO_2 (μg/m³) Method 3 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 NO_2 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 NO_2 impact assessment criteria will be exceeded at any time if the proposed 24-hour average emission concentration of 1000 mg/Nm^3 during burning of NSF is incorporated into the EPL.

8.2 SO_2

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 SO_2 concentrations from the No.6 Kiln stack. The Kiln stack is the only significant source of SO_2 emissions at the site.

The maximum incremental concentrations (i.e. no background SO_2 contributions) of 1-hour, 24-hour and annual average SO_2 at each of the discrete receptors 1-87 are listed in Table 54. The maximum off-site incremental concentration of 1-hour average SO_2 beyond the site boundary at an existing or likely future off-site sensitive receptor is 29 µg/m^3 at receptor 57. The maximum off-site incremental concentration of 24-hour average SO_2 beyond the site boundary at an existing or likely future off-site sensitive receptor is 3.8 µg/m^3 at receptor 12. The maximum off-site incremental concentration of annual-average SO_2 beyond the site boundary at an existing or likely future off-site sensitive receptor is 0.23 µg/m^3 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 SO_2 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 SO_2 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:

Averaging period	*NSW EPA Criteria*	*Cumulative concentration*	*Discrete receptor where this concentration occurs*
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 NO_2 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 SO_2 at potentially sensitive discrete receptors.

Receptor no.	SO_2 (µg/m³) Incremental 1-hour average	SO_2 (µg/m³) Incremental 24-hour average	SO_2 (µg/m³) 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 SO_2 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/Nm^3 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/m^3 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 (µg/m^3) Incremental Kiln 6 stack only	Annual average TSP (µg/m^3) Incremental Cement mills and cooler stack only	Annual average TSP (µg/m^3) Incremental 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 (µg/m³) Incremental Kiln 6 stack only	Annual average TSP (µg/m³) Incremental Cement mills and cooler stack only	Annual average TSP (µg/m³) Incremental 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 PM_{10} 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 µg/m^3. This predicted worst case concentration is much less than the TSP impact assessment criteria of 90 µg/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 µg/m^3 to 42.8 µg/m^3. The GLC for annual average TSP at this location predicted by the model is about 19 µg/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 µg/m^3.

Location of receptor 88 (new house under construction as at 22 May 2014)

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 µg/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 (µg/m³) Fugitive sources only	Annual average TSP (µg/m³) Fugitive sources plus point sources	Receptor no.	Annual average TSP (µg/m³) Fugitive sources only	Annual average TSP (µg/m³) 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 PM_{10}

All PM_{10} model results for the Kiln 6 stack discussed in this section assume a constant PM_{10} emission concentration which is calculated from a constant TSP concentration of 50 mg/Nm^3 (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_{10} fraction of 70% of TSP.

Using the same approach as for TSP emissions, the calculated maximum PM_{10} 24-hour average emission concentration was converted into a very conservative equivalent 1-hour PM_{10} 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 PM_{10} 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 PM_{10} 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:

Averaging period	***Emission sources***	***Maximum predicted concentration at a discrete receptor***	***Discrete receptor where this concentration occurs***
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 µg/m^3. This predicted PM_{10} concentration is only 25% of the NSW EPA ambient air quality assessment threshold criteria of 50 µg/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 µg/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 µg/m^3.

Table 64: 24-hour average incremental ground level concentration of PM_{10} 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 PM_{10} at potentially sensitive discrete receptors, point sources only.

Receptor no.	Annual avg incremental PM_{10} (µg/m³)	Annual avg incremental PM_{10} (µg/m³)	Receptor no.	Annual avg incremental PM_{10} (µg/m³)	Annual avg incremental PM_{10} (µg/m³)
	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 PM_{10} 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/m^3. A contribution of about 7 µg/m^3 from background PM_{10} 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 PM_{10} estimate for open sources subject to wind erosion, when combined with the other PM_{10} emissions from fugitive sources and the point sources, yielded a predicted 24-hour PM_{10} concentration at the AQMS site of about 42 µg/m^3 (with the background contribution to be added to that). This scaling factor was used in all subsequent cumulative PM_{10} assessments.

8.4.3 Fugitive and Point Sources Combined

Appendix 10 shows incremental 24-hour average PM_{10} 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 PM_{10} 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 PM_{10} 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 PM_{10}, such as a 50% increase over and above the emission rate used in this report, without impacting on the maximum PM_{10} impacts occurring beyond the site boundary.

The 24-hour concentrations occurring at each discrete receptor for the model shown in Figure A10h (all PM_{10} 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 PM_{10} 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} ($\mu g/m^3$)	Receptor no.	Max 24-hr avg PM_{10} ($\mu g/m^3$)	Receptor no.	Max 24-hr avg PM_{10} ($\mu g/m^3$)
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 PM_{10} at potentially sensitive discrete receptors, fugitive and point sources combined (Kiln 6 stack emissions at proposed Licence limit).

Receptor no.	Annual avg PM_{10} ($\mu g/m^3$)	Receptor no.	Annual avg PM_{10} ($\mu g/m^3$)	Receptor no.	Annual avg PM_{10} ($\mu g/m^3$)
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 PM_{10} Cumulative Assessment and Comparison with Ambient Air Quality Assessment Threshold Criteria

The maximum off-site incremental annual-average concentration of PM_{10} at any potentially sensitive receptor is 5.2 µg/m^3 occurring at receptor 75. This predicted worst case concentration is 17% of the PM_{10} impact assessment criteria of 30 µg/m^3 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/m^3 to 15.7 µg/m^3 for PM_{10} 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/m^3 to 15.1 µg/m^3. The annual average incremental PM_{10} concentration of 5.2 µg/m^3 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/m^3 is added to the worst case annual average background concentration of 15.7 µg/m^3, the total cumulative concentration of 20.9 µg/m^3 is 70% of the impact assessment criteria of 30 µg/m^3.

8.4.5 24-hour Average PM_{10} 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 PM_{10} incremental 24-hour concentrations to exceed NSW EPA criteria of 50 µg/m^3 at the southwest edge of New Berrima (receptor 88) and on the Berrima sewage treatment plant site (receptor 75). These hypothetical PM_{10} 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 PM_{10} 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 PM_{10} emission rates and thus there will be no effective change to off-site air quality impacts of PM_{10} due to the Project.

Despite the comments above about the conservative nature of predicted PM_{10} 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 PM_{10} 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/m^3 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 PM_{10} 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 PM_{10} (over 100 µg/m^3) 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 µg/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 µg/m^3 measured on 27 March 2013.

In the Camden background data file, the 50 µg/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 µg/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 µg/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 µg/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 PM_{10} (50 $\mu g/m^3$) at each discrete receptor – cumulative concentrations of PM_{10} 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 $\mu g/m^3$

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 µg/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 µg/m^3 (excluding days where background exceeds 47 µg/m^3) is 10.4 µg/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 µg/m^3 (excluding days where background exceeds 47 µg/m^3) is 17.2 µg/m^3. The associated cumulative GLC only just breaches the 50 µg/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 µg/m^3 (excluding days where background exceeds 47 µg/m^3) range from 34.6 to 64.6 µg/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 µg/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 µg/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 µg/m^3 (excluding days where background exceeds 47 µg/m^3) range from 17.3 to 52.5 µg/m^3 , with the majority of those incremental concentrations exceeding 44.4 µg/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 µg/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 µg/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 $\mu g/m^3$ or exceeding 47 $\mu g/m^3$

Rank of 24-hour cumulative GLC (1 = highest)	Analysis based on Bargo background data (all concentrations in $\mu g/m^3$)			Analysis based on Camden background data (all concentrations in $\mu g/m^3$)		
	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 Summary

Annual average

Cumulative annual average concentrations of PM_{10} from both fugitive and point sources at the Works, including background concentrations, are below the Approved Methods assessment criteria of 90 µg/m^3 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_{10} concentrations due to the Project.

24-Hour average

For most of the discrete receptors, no additional exceedances of the 24-hour average PM_{10} air quality criteria are generated due to PM_{10} 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/m^3 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/m^3 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 PM_{10} emission rates and thus there will be no effective change to off-site local air quality impacts of PM_{10} 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/Nm^3 (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 71 and Table 72. The maximum concentrations are as follows:

Averaging period	***Emission sources***	***Maximum predicted concentration at a discrete receptor***	***Discrete receptor where this concentration occurs***
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 71: 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 72: Annual average incremental ground level concentration of $PM_{2.5}$ at potentially sensitive discrete receptors, point sources only.

Receptor no.	Annual avg incremental $PM_{2.5}$ ($\mu g/m^3$)	Annual avg incremental $PM_{2.5}$ ($\mu g/m^3$)	Receptor no.	Annual avg incremental $PM_{2.5}$ ($\mu g/m^3$)	Annual avg incremental $PM_{2.5}$ ($\mu g/m^3$)
	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/m^3. This predicted $PM_{2.5}$ concentration is only 22% of the NSW EPA ambient air quality assessment threshold criteria of 25 µg/m^3, 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/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. Despite this degree of conservatism, the maximum predicted incremental concentration is only 7% of the NSW EPA assessment criteria of 8 µg/m^3.

8.5.2 Handling of Fugitive Emissions

Fugitive $PM_{2.5}$ emissions were modelled as outlined in Section 5.2.1, with $PM_{2.5}$:PM_{10} 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 PM_{10} 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 PM_{10} emission sources) are listed in Table 73. The annual average concentrations occurring at each discrete receptor for the same model are listed in Table 74.

Table 73: 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 $PM_{2.5}$ ($\mu g/m^3$)	Receptor no.	Max 24-hr avg $PM_{2.5}$ ($\mu g/m^3$)	Receptor no.	Max 24-hr avg $PM_{2.5}$ ($\mu g/m^3$)
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 74: 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/m³)	Receptor no.	Annual avg $PM_{2.5}$ (µg/m³)	Receptor no.	Annual avg $PM_{2.5}$ (µg/m³)
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 74, the maximum off-site incremental annual-average concentration of $PM_{2.5}$ at any potentially sensitive receptor is 1.0 µg/m^3 occurring at receptor 57. This predicted worst case GLC is 13% of the $PM_{2.5}$ impact assessment criteria of 8 µg/m^3 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/m^3 to 6.5 µg/m^3 for over the two years of operation to date (2013 and 2014). The maximum annual average incremental PM_{10} concentration of 1.0 µg/m^3 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/m^3 is added to the worst case annual average background concentration of 6.5 µg/m^3, the total cumulative concentration of 7.5 µg/m^3 is below the impact assessment criteria of 8 µg/m^3, 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 PM_{10}. 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/m^3 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/m^3 measured on 19 October 2013.

Table 75 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/m^3 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 75: Number of exceedances of NSW EPA criteria for 24-hour average $PM_{2.5}$ (25 $\mu g/m^3$) 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 $\mu g/m^3$

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 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/m^3 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/m^3 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 PM_{10}, 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

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/m^3.

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/m^3 are provided in Table 76. 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.

Table 76: 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

The applicable assessment criteria are not exceeded for any of the individual NMHC species.

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 µg/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.

8.7 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/Nm^3 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/m^3 (24 fg/m^3). This concentration is 83,000 times less than the NSW EPA criteria of 2 ng/m^3, 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/m^3 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/Nm^3 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 µg/m^3. This is only 0.004% of the NSW EPA air quality criteria of 0.4 µg/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 µg/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 ng/m^3 (0.0299 µg/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 µg/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 mg/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 µg/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 µg/m^3 (sum of maximum background plus maximum GLC) is only 6% of the NSW EPA criteria of 0.5 µg/m^3. Therefore adverse impacts from discharges of lead from the Works are anticipated to be negligible.

8.9.2 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 mg/Nm^3, each metal was assumed to have a constant maximum emission concentration of 0.025 mg/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 g/s. The resulting GLCs are provided in Table 77 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 77: Heavy metal GLCs and comparison to assessment criteria

Heavy metal	Highest 99.9th percentile incremental GLC beyond site boundary, μg/m^3	Air quality assessment criteria, μg/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

8.10 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 78 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 μg/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/Nm^3 (at 10% O_2) 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/Nm^3 (at 10% O_2) 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/m^3 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/Nm^3 (at 10% O_2) 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/m^3 which is 0.1% of the NSW EPA assessment criteria.

Table 78: Halide and other chemical species GLCs, and comparison to assessment criteria

Chemical species	Highest 99.9th 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/Nm^3 during burning of NSF. The highest GLC occurring beyond the site boundary is 0.11 µg/m^3. 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 79.

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 Adelaide[17]:

> *"We have been using very significant volumes of a PEF at our Birkenhead site for more than 10 years. The receival 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.*

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[17] Email from Michael Jones (Adelaide Brighton Cement) to Aleksandra Wnorowski (Boral Cement) on 23/3/15.

Table 79: 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

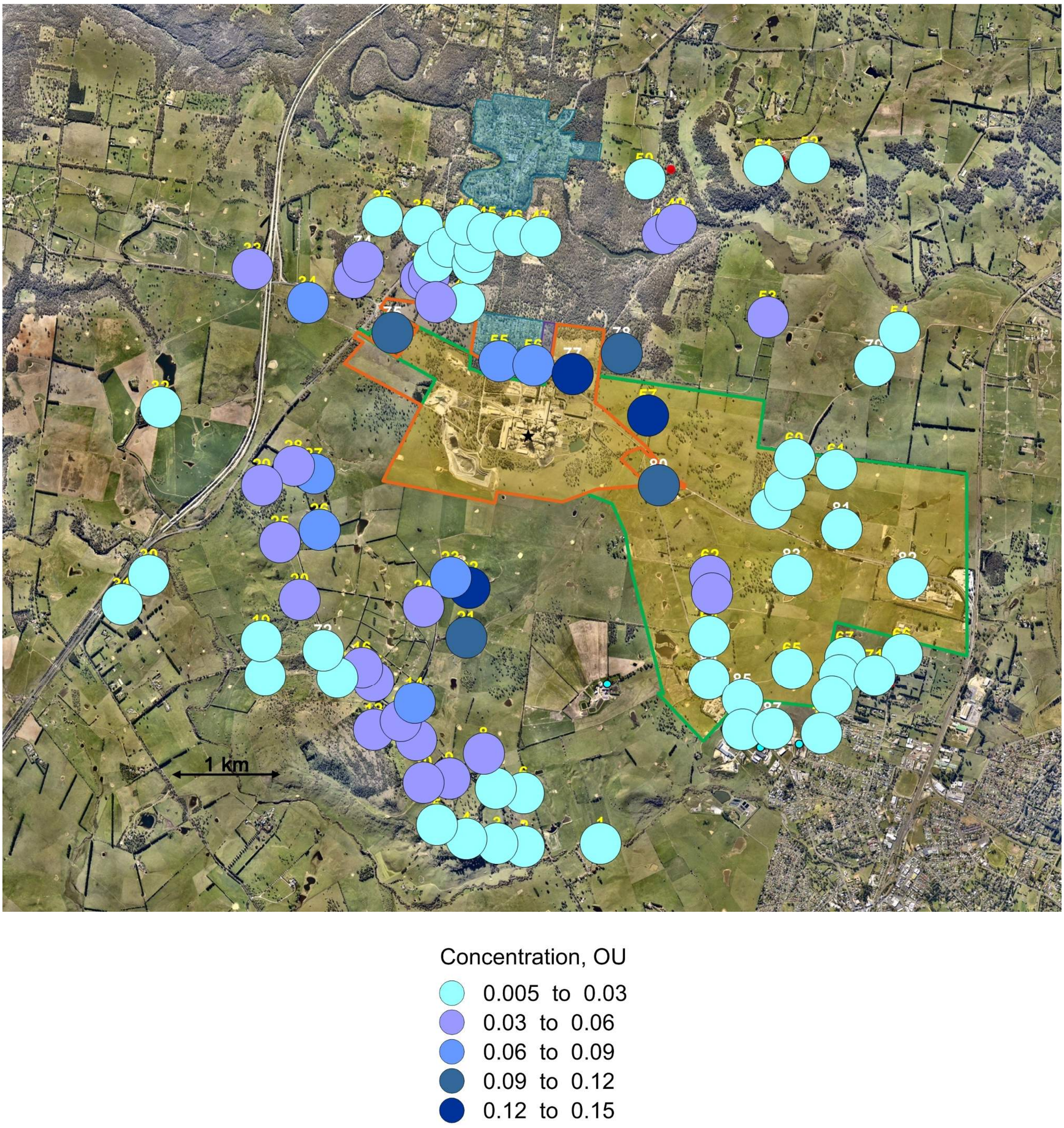

Figure 49: Spatial distribution of 99th percentile odour concentrations at discrete receptors.

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% O_2):

- TSP: 50 mg/Nm^3, calculated over a midday-to-midday 24-hour basis
- NO_x: 1000 mg/Nm^3, 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, PM_{10}, $PM_{2.5}$, NO_2, SO_2, 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, PM_{10} 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 PM_{10}, 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 NO_2 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 PM_{10}, for most of the discrete receptors, no additional exceedances of the 24-hour average PM_{10} 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 PM_{10} 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 PM_{10} measured data from the local ambient air quality monitoring station indicates that PM_{10} 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 PM_{10} due to the Project as the model results are insensitive to Kiln 6 stack PM_{10} emission rates at the equivalent TSP emission concentrations proposed during the burning of NSF.

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