

SOUTH BARANGAROO STAGE 1C REMEDIATION AND EARTHWORKS AIR QUALITY IMPACT ASSESSMENT

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PREPARED FOR

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GLOSSARY OF AIR QUALITY TERMS

Air Pollution – The presence of contaminants or pollutant substances in the air that interfere with human health or welfare, or produce other harmful environmental effects.

Air Quality Standards – The level of pollutants prescribed by regulations that are not to be exceeded during a given time in a defined area.

Air Toxics – Any air pollutant for which a national ambient air quality standard (NAAQS) does not exist (i.e. excluding ozone, carbon monoxide, PM-10, sulphur dioxide, nitrogen oxide) that may reasonably be anticipated to cause cancer; respiratory, cardiovascular, or developmental effects; reproductive dysfunctions, neurological disorders, heritable gene mutations, or other serious or irreversible chronic or acute health effects in humans.

Airborne Particulates – Total suspended particulate matter found in the atmosphere as solid particles or liquid droplets. Chemical composition of particulates varies widely, depending on location and time of year. Sources of airborne particulates include dust, emissions from industrial processes, combustion products from the burning of wood and coal, combustion products associated with motor vehicle or non-road engine exhausts, and reactions to gases in the atmosphere.

Area Source – Any source of air pollution that is released over a relatively small area, but which cannot be classified as a point source. Such sources may include vehicles and other small engines, small businesses and household activities, or biogenic sources, such as a forest that releases hydrocarbons, may be referred to as nonpoint source.

Concentration – The relative amount of a substance mixed with another substance. Examples are 5 ppm of carbon monoxide in air and 1 mg/l of iron in water.

Emission – Release of pollutants into the air from a source. We say sources emit pollutants.

Emission Factor – The relationship between the amount of pollution produced and the amount of raw material processed. For example, an emission factor for a blast furnace making iron would be the number of pounds of particulates per ton of raw materials.

Emission Inventory – A listing, by source, of the amount of air pollutants discharged into the atmosphere of a community; used to establish emission standards.

Flow Rate – The rate, expressed in gallons -or litres-per-hour, at which a fluid escapes from a hole or fissure in a tank. Such measurements are also made of liquid waste, effluent, and surface water movement.

Fugitive Emissions – Emissions not caught by a capture system.

Hydrocarbons (HC) – Chemical compounds that consist entirely of carbon and hydrogen.

Hydrogen Sulphide (H₂S) – Gas emitted during organic decomposition. Also, a by-product of oil refining and burning. Smells like rotten eggs and, in heavy concentration, can kill or cause illness.

Inhalable Particles – All dust capable of entering the human respiratory tract.

Nitric Oxide (NO) – A gas formed by combustion under high temperature and high pressure in an internal combustion engine. NO is converted by sunlight and photochemical processes in ambient air to nitrogen oxide. NO is a precursor of ground-level ozone pollution, or smog.

Nitrogen Dioxide (NO₂) – The result of nitric oxide combining with oxygen in the atmosphere; major component of photochemical smog.

Nitrogen Oxides (NO_x) – A criterion air pollutant. Nitrogen oxides are produced from burning fuels, including gasoline and coal. Nitrogen oxides are smog formers, which react with volatile organic compounds to form smog. Nitrogen oxides are also major components of acid rain.

Mobile Sources – Moving objects that release pollution; mobile sources include cars, trucks, buses, planes, trains, motorcycles and gasoline-powered lawn mowers.

Particulates; Particulate Matter (PM-10) – A criteria air pollutant. Particulate matter includes dust, soot and other tiny bits of solid materials that are released into and move around in the air. Particulates are produced by many sources, including burning of diesel fuels by trucks and buses, incineration of garbage, mixing and application of fertilizers and pesticides, road construction, industrial processes such as steel making, mining operations, agricultural burning (field and slash burning), and operation of fireplaces and woodstoves. Particulate pollution can cause eye, nose and throat irritation and other health problems.

Parts Per Billion (ppb)/Parts per Million (ppm) – Units commonly used to express contamination ratios, as in establishing the maximum permissible amount of a contaminant in water, land, or air.

PM10/PM2.5 – PM10 is measure of particles in the atmosphere with a diameter of less than 10 or equal to a nominal 10 micrometers. PM2.5 is a measure of smaller particles in the air.

Point Source – A stationary location or fixed facility from which pollutants are discharged; any single identifiable source of pollution; e.g. a pipe, ditch, ship, ore pit, factory smokestack.

Scrubber – An air pollution device that uses a spray of water or reactant or a dry process to trap pollutants in emissions.

Source – Any place or object from which pollutants are released.

Stack – A chimney, smokestack, or vertical pipe that discharges used air.

Stationary Source – A place or object from which pollutants are released and which does not move around. Stationary sources include power plants, gas stations, incinerators, houses etc.

Temperature Inversion – One of the weather conditions that are often associated with serious smog episodes in some portions of the country. In a temperature inversion, air does not rise because it is trapped near the ground by a layer of warmer air above it. Pollutants, especially smog and smog-forming chemicals, including volatile organic compounds, are trapped close to the ground. As people continue driving and sources other than motor vehicles continue to release smog-forming pollutants into the air, the smog level keeps getting worse.

1 INTRODUCTION

This report has been prepared by Wilkinson Murray Pty Ltd (WMPL) on behalf of Crown Resorts Ltd to accompany a State Significant Development Application (SSDA) for the Stage 1C Remediation and Earthworks at Barangaroo.

SSDA requirements in item 7 are:

Air and Odour

- The EIS must include an Air Quality Impact Assessment (AQIA) that is prepared strictly in accordance with the EPA's Approved Methods for the Modelling and Assessment of Air Pollutants in NSW South Wales 2005.
- The AQIA must also take into make appropriate reference to the EPA's Assessment and Management of Odour from Stationary Sources in NSW: Technical Framework 2006 and Management of Odour from Stationary Source sin New South Wales" Technical Notes 2006
- The AQIA shall include:
 - the identification of all pollutants of concern, including individual toxic air pollutants, dust and odours;
 - the identification and assessment of all relevant fugitive and point source emissions;
 - appropriate coverage of all aspects of remediation, including the excavation, storage, transport and treatment of contaminated material.
 - proposed air quality management and monitoring procedures during remediation; and
 - consideration of the requirements of the Protection of the Environment Operations (Clean Air) Regulation 2010

The remediation and earthworks is proposed in accordance with the approved Barangaroo Concept Plan (as modified) and is located within Barangaroo South.

The Stage 1C remediation and earthworks are described as follows:

- carrying out of remediation and validation within the Stage 1C remediation and earthworks area to ensure it is suitable for the intended future uses of the land;
- construction of a perimeter retention wall system and internal stabilising walls (called the 'Stage 1C groundwater retention wall system') to the west of Block 4B and Block 4C. The Stage 1C groundwater retention wall system would be fully integrated with the Stage 1B retention wall system (as specified by Lend Lease in the EIS for SSD 5897-2013), with direct connections to create a unified groundwater retention wall system across Stage 1B and Stage 1C; and

- bulk excavation within the perimeter of the Stage 1C groundwater retention wall, and the installation of lateral restraining structures to support the perimeter retention wall system.

These works are collectively known as the Stage 1C Remediation and Earthworks.

The land which is the subject of the Stage 1C Remediation and Earthworks SSDA is located in the north-western corner of Barangaroo South, immediately to the west of the Stage 1B development area specified by land Lease in the EIS for SSD 5897-2013.

With reference to the Barangaroo 'development blocks', as identified within the approved Concept Plan Urban Design Controls (MP06_0162 MOD 4), the Stage 1C Remediation and Earthworks area is located to the west of Blocks 4A, 4B and 4C and incorporates part of Globe Harbour.

The following report documents an Air Quality Impact Assessment (AQIA) for the excavation activities associated with Phase 1 (also referred to as Stage 1C Remediation and Earthworks). For the sake of consistency and to aid in comparison of results, many aspects of this assessment are consistent with those in a recent AQIA conducted by AECOM Australia Pty Ltd (AECOM, 2014b).

Dispersion modelling of air pollutants associated with the development was conducted using the CALPUFF model. The modelling and assessment were conducted in general accordance with the following documents:

- *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (DEC, 2005); and
- *Generic Guidance and Optimum Model Setting for the CALPUFF Modelling System for Inclusion into the 'Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales, Australia'* (TRC, 2011).

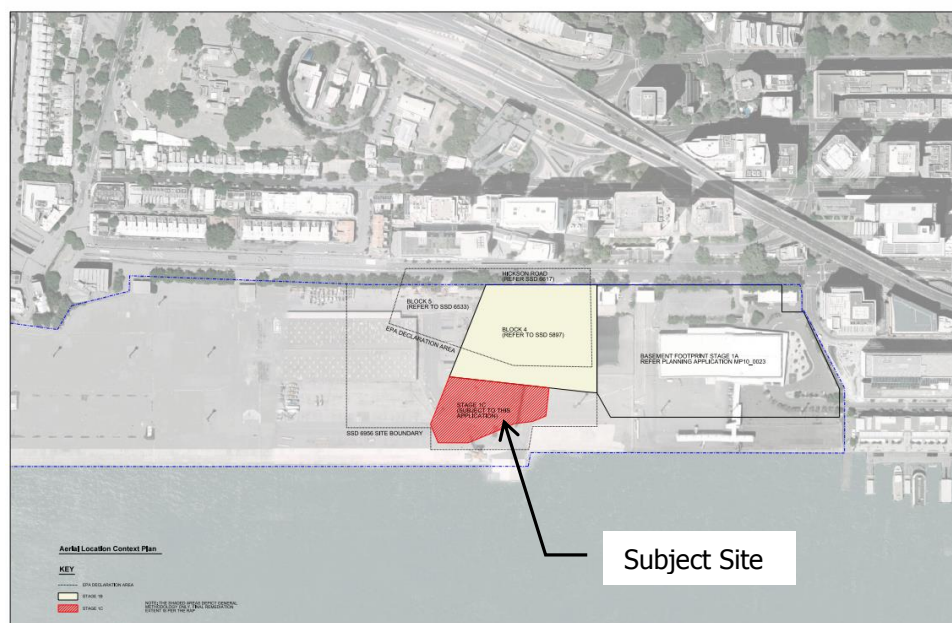
2 SITE DESCRIPTION

Barangaroo is located on the north western edge of the Sydney Central Business District (CBD), bounded by Sydney Harbour to the west and north; the historic precinct of Millers Point (for the northern half), The Rocks and the Sydney Harbour Bridge approach to the east; and a range of new development dominated by large CBD commercial tenants and the King Street Wharf/Cockle Bay precinct to the south.

The 22ha Barangaroo site is generally rectangular in shape and has a 1.4 kilometre harbour foreshore frontage, with an eastern street frontage to Hickson Road. The site has been divided into three distinct redevelopment areas (from north to south) – the Headland Park, Barangaroo Central and Barangaroo South, and has been subject to multiple investigations that detail the physical and natural characteristics of the site.

The 1C area is located within Barangaroo South as shown in Figure 2-1. The SSDA Site extends over land at the North Western end of the site. Blocks 4 and 5 are directly east of the Stage 1C works.

Figure 2-1 South Barangaroo Site Plan



2.1 Surrounding Land Use and Sensitive Receptors

The site is bounded to the north and west by Sydney Harbour, to the east by Hickson Road and to the south by Shelley Street. The nearest sensitive receptors to the development are located immediately to the east of the site, along Hickson Road. These receptors comprise a mix of residential and commercial uses.

For consistency and ease of comparing results, the receptors under consideration in this AQIA have been adopted from a recent AQIA conducted by AECOM Australia Pty Ltd (AECOM, 2014b), which assessed air quality impacts associated with construction works carried out at Barangaroo by Lend Lease. Additionally residential building R8 and commercial building T2 have been added as receptors. As R8 and T2 are high rise buildings they have been modelled at various heights. The receptors are shown in Figure 2-1 and are tabulated in Appendix A.

2.2 Scope of the Report

This report documents the assessment of air quality impacts associated with bulk excavation works for this development. The excavation works are planned to occur during over the period September 2015 and April 2017.

Additionally, assessment is made of cumulative NO₂ and dust/ particulate matter impacts associated with this development and other submitted and approved construction works within the Barangaroo precinct being Block 4 and 5 remediation works.

Figure 2-1 Nearby Sensitive Receptors



3 PROJECT DESCRIPTION

3.1 Project Overview

The works the subject of the SSDA are termed the Stage 1C remediation and earthworks. The land which is the subject of the Stage 1C remediation and earthworks SSDA comprises approximately 6,300 m² located in the north-western corner of Barangaroo South. With reference to the Barangaroo 'development blocks', as identified within the approved Concept Plan Urban Design Controls (MP06_0162 MOD 6), the Stage 1C remediation and earthworks area is located to the west of Blocks 4A, 4B and 4C and incorporates part of Globe Harbour.

The Stage 1C remediation and earthworks are described as follows:

- carrying out of remediation and validation within the Stage 1C remediation and earthworks area to ensure it is suitable for the intended future uses of the land;
- construction of a perimeter retention wall system and internal stabilising walls (called the 'Stage 1C groundwater retention wall system') to the west of Block 4B and Block 4C. The Stage 1C groundwater retention wall system would be fully integrated with the Stage 1B retention wall system (as specified by Lend Lease in the EIS for SSD 5897-2013), with direct connections to create a unified groundwater retention wall system across Stage 1B and Stage 1C; and
- bulk excavation within the perimeter of the Stage 1C groundwater retention wall, and the installation of lateral restraining structures to support the perimeter retention wall system.:

3.2 Remediation and Earthworks

3.2.1 Bulk Earthworks

A "worst case" air quality assessment has been conducted assuming that the bulk earthworks associated with the basement excavations are carried out using excavators and dozers to extract material. Excavators would be used to load the material into trucks with would then remove it from site for appropriate re-use or disposal.

It should be noted that alternative excavation and building options are being considered, however this assessment considers the "worst case" excavation methodology for the purpose of assessment of air quality impacts.

3.2.2 Timing and Work Hours

The excavation works are expected to occur between September 2015 and April 2017. Works are expected to be conducted within standard construction hours. The proposed construction hours for the works are between 7.00am and 6.00pm Monday – Friday and between 7.00am and 5.00pm on Saturdays. It is noted that the proposed hours for Saturdays are outside the EPA's standard hours of construction. However, this extended period of remediation hours will enable the major noise and vibration generating activities to be carried out in a more efficient manner, thereby shortening the overall construction period to which sensitive receptors will be exposed. This represents an approach already approved under South Barangaroo Project Approval MP 10 0023. No construction / remediation work is proposed to be undertaken outside the proposed

Construction/Remediation hours, including on Sundays or Public Holidays.

4 AIR QUALITY ASSESSMENT CRITERIA

4.1 Introduction

The NSW EPA's *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (DEC, 2005) sets out applicable impact assessment criteria for a number of air pollutants.

Air quality criteria are benchmarks set to protect the general health and amenity of the community in relation to air quality. The sections below identify the pollutants of interest in this study and the application air quality criteria for each pollutant.

4.2 Pollutants of Interest

The proposed works will generate particulate emissions associated with both excavation and materials handling. Heavy metals detected within the soil may be released to the air attached to the dust. The works will primarily use electrical and diesel-powered plant and equipment. The combustion of diesel fuel generates a range of pollutant emissions, primarily oxides of nitrogen (NO_x) and particulate matter (including PM₁₀ and TSP), as well as volatile organic compounds (VOCs) (particularly benzene, toluene, ethylbenzene, and xylenes, which are known collectively as BTEX). Other emissions, such as carbon monoxide and sulfur dioxide, are also emitted from combustion engines, but were not assessed as they were considered to be lower risk than particulate and NO_x emissions due to their generally higher trigger values. When exposed to air, the contaminated material is also expected to generate gaseous emissions of the contaminants and associated odours.

For the purposes of this AQIA, pollutants of interest were defined as chemicals that have been detected on the site in concentrations greater than relevant human health screening criteria. The pollutants assessed were:

- Nitrogen dioxide (NO₂);
- Particulate matter;
- Heavy metals (cadmium, chromium VI, copper, lead, mercury, nickel, zinc);
- VOCs (specifically BTEX, naphthalene and phenol);
- PAHs; and
- Odour.

4.3 Assessment Criteria

The ambient air quality criteria for the pollutants considered in this assessment are shown in Table 4-1, for combustion products, dust and soil contaminants. The pollutants considered are consistent with the latest Barangaroo air quality impact assessment AECOM (2014b).

Table 4-1 Impact Assessment Criteria - Criteria Pollutants

Pollutant	Averaging Period	Criteria ($\mu\text{g}/\text{m}^3$)
Combustion Products and Dust		
Nitrogen dioxide (NO_2)	1 hour	246
	Annual	62
Total suspended particulates (TSP)	Annual	90
Fine particulate matter (PM_{10})	24 hours	50
	Annual	30
Soil Contaminants		
Arsenic	1 hour	0.09
Benzene	1 hour	29
Beryllium	1 hour	0.004
Cadmium	1 hour	0.018
Chromium VI	1 hour	0.09
Copper (dust and mist)	1 hour	18
Cyanide	1 hour	90
Ethylbenzene	1 hour	8,000
Lead	Annual	0.5
Manganese	1 hour	18
Mercury (organic)	1 hour	0.18
Naphthalene	1 hour	440*
Nickel	1 hour	0.18
Phenol	1 hour	20
Polycyclic aromatic compounds (PAHs) (as benzo[a]pyrene)	1 hour	0.4
Toluene	1 hour	360
Xylenes	1 hour	190
Zinc (as zinc chloride fumes)	1 hour	18
*As adopted for previous Barangaroo assessments undertaken by AECOM (e.g. AECOM, 2010b). Criterion is equivalent to the odour threshold for naphthalene.		

A number of soil contaminants identified within the site have the potential to cause nuisance odours. Odour in a regulatory context needs to be considered in two similar, but different ways depending on the situation.

NSW legislation prohibits emissions that cause offensive odour to occur at any off-site receptor. Offensive odour is evaluated in the field by authorised officers, who are obliged to consider the odour in the context of its receiving environment, frequency, duration, character and so on and to determine whether the odour would unreasonably interfere with the comfort and repose of the normal person. In this context, the concept of offensive odour is applied to operational facilities

and relates to actual emissions in the air.

However, in the approval and planning process for proposed new operations or modifications to existing projects, no actual odour exists and it is necessary to consider hypothetical odour. In this context, odour concentrations are used and are defined in odour units. The number of odour units represents the number of times that the odour would need to be diluted to reach a level that is just detectable to the human nose. Thus by definition, odour less than odour unit (1 OU), would not be detectable to most people.

The range of a person's ability to detect odour varies greatly in the population, as does their sensitivity to the type of odour. Therefore there can be a wide range of variability in the way odour response is interpreted. As a result the assessment of odour impacts and the application of specific air quality goals related to odour is a challenging aspect of air science.

It should be noted that odour refers to complex mixtures of odours, and not 'pure' odour arising from a single chemical. Odour from a single, known chemical very rarely occurs (when it does, it is best to consider that specific chemical in terms of its concentration in the air). In most situations, odour will be comprised of a cocktail of many substances that is referred to as a complex mixture of odorous pollutants, or more simply odour.

For developments with potential for odour it may be necessary to predict the likely odour impact that may arise. This is done by using air dispersion modelling which can calculate the level of dilution of odours emitted from the source at the point that it reaches surrounding receptors. This approach allows the air dispersion model to produce results in terms of odour units.

The NSW criteria for acceptable levels of odour range from 2 to 7 OU, with the more stringent 2 OU criteria applicable to densely populated urban areas and the 7 OU criteria applicable to sparsely populated rural areas, as outlined below.

Table 4-2 presents the relevant impact assessment criteria for complex mixtures of odorous pollutants.

Table 4-2 Impact Assessment Criteria –Complex Mixtures of Odorous Pollutants

Population of Affected Community	Impact Assessment Criteria (OU)*
Urban ($\geq \sim 2000$) and/or schools and hospitals	2.0
~500	3.0
~125	4.0
~30	5.0
~10	6.0
Single rural residence ($\leq \sim 2$)	7.0

*99th percentile nose-response time

The area surrounding the site is highly populated, and therefore; the applicable impact assessment criteria for odour is 2.0 OU/m³.

5 EXISTING ENVIRONMENT

5.1 Local Climate

Long-term meteorological data for the surrounding area is available from the Bureau of Meteorology (BoM) operated Automatic Weather Stations (AWS) at Observatory Hill and Fort Denison. The Observatory Hill AWS is located approximately 300m east of the site and records observations of a number of meteorological data including temperature, humidity and rainfall. There is no anemometer at Observatory Hill, and therefore; observations of wind speed and direction are taken from the Fort Denison AWS, located approximately 2km east of the site.

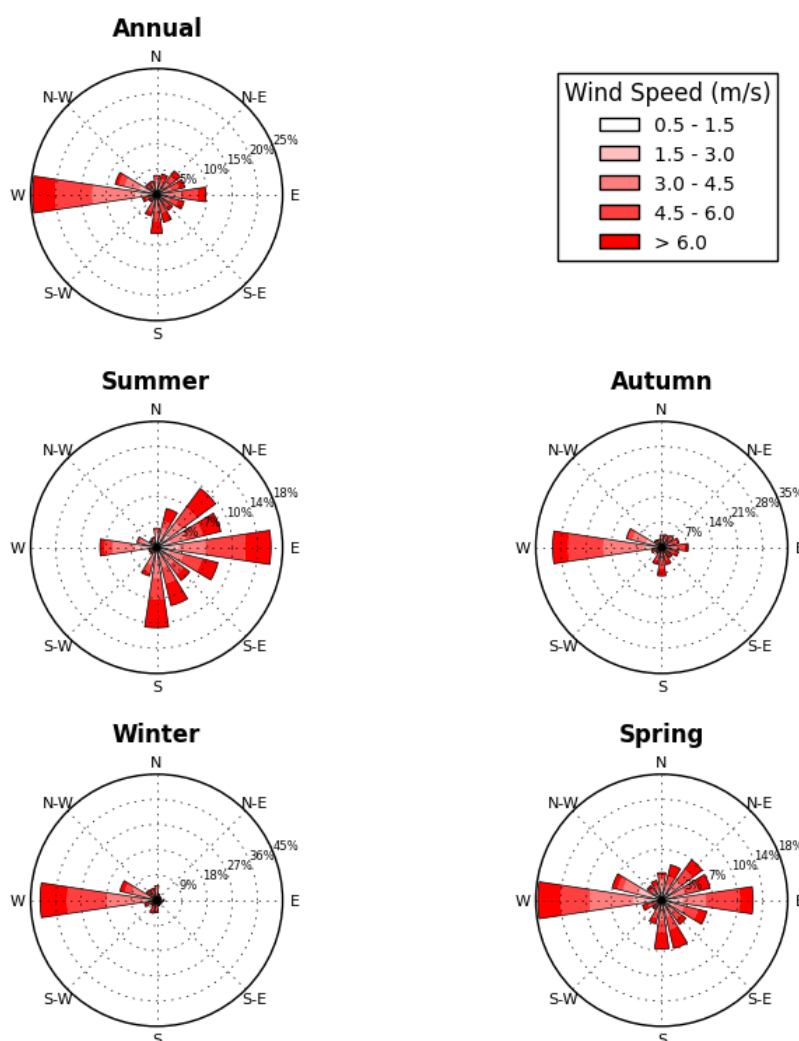
Long-term climate statistics are presented in Table 5-1. Temperature data recorded at the Observatory Hill AWS indicates that January is the hottest month of the year, with a mean daily maximum temperature of 25.9°C. July is the coolest month with a mean daily minimum temperature of 8.1°C. June is the wettest month with an average rainfall of 132 mm falling over almost 9 days. There are on average 100 rain days per year, yielding 1213 mm of rain.

Table 5-1 Long-term Climate Averages for Observatory Hill

Observation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
9am Mean Observations													
Temperature (°C)	22.5	22.3	21.1	18.2	14.6	11.9	10.9	12.5	15.7	18.5	19.9	21.6	17.5
Humidity (%)	71	74	74	72	74	74	71	66	62	61	66	67	69
3pm Mean Observations													
Temperature (°C)	24.8	24.9	24.0	22.0	19.4	16.9	16.4	17.5	19.2	20.7	22.1	23.8	21.0
Humidity (%)	62	64	62	59	57	57	51	49	51	56	58	59	57
Daily Minimum and Maximum Temperatures													
Minimum (°C)	18.7	18.8	17.6	14.7	11.6	9.3	8.1	9.0	11.1	13.6	15.6	17.5	13.8
Maximum (°C)	25.9	25.8	24.8	22.4	19.5	17.0	16.3	17.8	20.0	22.1	23.6	25.2	21.7
Rainfall													
Rainfall (mm)	101.1	118.0	129.7	127.1	119.9	132.0	97.4	80.7	68.4	76.9	84.3	77.3	1212.6
Rain days	8.6	9.0	9.8	9.0	8.7	8.7	7.5	7.2	7.2	7.9	8.4	8.0	100.0

Windrose plots showing the distribution of wind direction and wind speed at the Fort Denison BoM AWS between 2008 and 2013 and presented in Figure 5-1.

Figure 5-1 Windrose Plots – Fort Denison Bom AWS, 2008 – 2013



5.2 Local Air Quality

The NSW Office of Environment and Heritage (OEH) operates a network of air quality monitoring sites across the state. The nearest OEH air quality monitoring station to the Barangaroo site is located at Rozelle, approximately 3 km to the west.

Ambient pollution concentrations recorded at the Rozelle site between 1 July 2013 and 30 June 2014 have been used to establish the existing local air quality for this assessment and are summarised in Table 5-2.

Table 5-2 Existing Ambient Pollutant Concentrations – Rozelle Monitoring Station

Pollutant	Averaging Period	Background Concentration ($\mu\text{g}/\text{m}^3$)	Impact Assessment Criteria ($\mu\text{g}/\text{m}^3$)
NO ₂	1 hour Maximum	130	246
	Annual Average	22	62
PM ₁₀	24 hour Maximum	59	50
	Annual Average	19	30
TSP ¹	Annual Average	39	90
Ozone ²	1 hour Maximum	164	214
	Annual Average	36	-

1 Scaled from PM₁₀ concentrations

2 Not assessed. Used to calculate NO₂ transformation

Detailed plots of PM₁₀, NO₂ and O₃ concentrations from the Rozelle monitoring station are included in Appendix B. The detailed plot of PM₁₀ concentrations indicate that the existing 24 hour PM₁₀ levels measured by the Rozelle monitoring station exceed the goal of 50 $\mu\text{g}/\text{m}^3$ on three occasions during the period 1 July 2013 to 30 June 2014.

In addition to the air quality data from the Rozelle monitoring site, the Barangaroo Air Quality Monitoring System has existing levels of PM₁₀ in the area surrounding the development with Barangaroo construction in progress. The mean PM₁₀ concentrations across the three monitors on the Barangaroo site were calculated for the period 1 July 2013 to 30 June 2014 and are summarised in Table 5-3.

Table 5-3 Existing 24 hour PM₁₀ Concentrations at Barangaroo

Pollutant	Averaging Period	Background Concentration ($\mu\text{g}/\text{m}^3$)	Impact Assessment Criteria ($\mu\text{g}/\text{m}^3$)
PM ₁₀	24 hour Maximum	76	50
	Annual Average	27	30

A detailed plot of PM₁₀ concentrations at the Barangaroo site are included in Appendix B. This plot indicates that the existing 24 hour PM₁₀ levels measured by the Barangaroo air quality monitoring system exceeded the goal of 50 $\mu\text{g}/\text{m}^3$ on 14 occasions during the period 1 July 2013 to 30 June 2014. The Barangaroo Air Quality Monitoring station has more exceedances than Rozelle likely to be caused by the existing construction works at Barangaroo. It should be noted that since the dust monitors are located within the Barangaroo site, they are significantly closer to dust generating construction activities than nearby receptors.

6 AIR QUALITY MODELLING

6.1 Introduction

Based on staging information provided by Lend Lease, the following concurrent activities are expected to represent the worst-case emissions during the Stage 1C Remediation and Earthworks at Barangaroo, and were assessed through dispersion modelling:

- Block 5 excavation;
- Block 4 remediation activities; and
- Operation of the on-site water treatment plant.

The potential impacts of the proposed works were assessed through the analysis of a single operational scenario, which represented the expected highest activity levels of all on-site activities that may be occurring during the Stage 1C Remediation and Earthworks works.

Other activities on the Barangaroo site, including works associated with Barangaroo South and the operation of a concrete batching plant, which were addressed in previous assessments, are expected to be completed when the Stage 1C Remediation and Earthwork commence.

Some other minor works such as those associated with the building construction may overlap some stages of the Stage 1C Remediation and Earthwork works, the emissions from these activities are expected to be in minor nature. As such, these activities were not included in the operational scenario modelled.

6.2 Meteorological Modelling

6.2.1 TAPM

Prognostic meteorological data was generated using The Air Pollution Model (TAPM), developed by the CSIRO. The prognostic modelling domain was centred at 31° 51.5' S, 105° 12' E and involved four nesting grids of 30 km, 10 km, 3 km and 1km with 35 vertical levels

Observations of wind speed and direction from the BoM AWS at Fort Denison and the on-site anemometer at the Barangaroo site were assimilated into the TAPM model to refine details of local winds.

6.2.2 CALMET

The three dimensional prognostic wind field from the TAPM simulation was incorporated in a CALMET model as the initial guess wind field. CALMET was run using the 'No-Observations Approach' recommended by TRC (2011).

The CALMET domain was 10 x 10 km with a grid resolution of 0.1 km. Local land use and topographical data (SRTM 3) were used to produce realistic fine scale flow fields in the area surrounding the site.

6.3 Dispersion Modelling

6.3.1 CALPUFF

CALPUFF is a non-steady state Gaussian puff dispersion model, developed for the US EPA and approved for use in DEC (2005). CALPUFF is considered an advanced dispersion model and is intended for use in situations where less advanced Gaussian plume models are not appropriate. CALPUFF is most often used in areas exhibiting one or more of the following features:

- Complex terrain;
- Recirculating coastal sea breezes;
- High frequency of calm winds; and,
- Buoyant line sources.

CALPUFF was chosen for this assessment as the site is located in a coastal area with complex terrain.

6.3.2 Pollutant Transformation

During combustion in engines, high-temperature chemical processes cause the nitrogen in the fuel air mixture to oxidise, creating various 'oxides of nitrogen' or NO_x . Nitric oxide (NO) makes up the majority of NO_x emissions from engines, with NO_2 contributing a small percentage.

When NO enters the plume, it reacts with atmospheric ozone (O_3) and is converted to NO_2 . A number of methods exist to model the transformation of NO_x to NO_2 , ranging from very simple to rather complex.

This assessment makes use of the US EPA's Ozone Limiting Method (OLM) to predict ground level concentration of NO_2 . The OLM assumes that all the available atmospheric O_3 will react with NO in the plume until either all of the O_3 or all the NO is used up.

The OLM is one of the three methods recommended in DEC (2005) for modelling the conversion of NO to NO_2 .

6.3.3 Peak to Mean Ratios

To account for the time-averaging limitations of the dispersion model, peak-to-mean ratios have been incorporated into all odour flux rates in accordance with DEC (2005). Peak-to-mean ratios for various source types, as prescribed by DEC (2005), are presented in Table 6-1.

Table 6-1 Peak-to-Mean Ratios

Source Type	Pasquill-Gifford Stability Class	P/M60	
		Near-Field	Far-Field
Area	A,B,C,D	2.5	2.3
	D,E	2.3	1.9
Line	A-F	6	6
Surface wake-free point	A,B,C	12	4
	D,E,F	25	7
Tall wake-free point	A,B,C	17	3
	D,E,F	35	6
Wake-affected point	A-F	2.3	2.3
Volume	A-F	2.3	2.3

*Ratio of peak 1-second average concentrations to mean 1-hour average concentrations

6.4 Emissions Estimation for Stage 1C Remediation and Earthworks

An inventory of emissions for the pollutants of interest in this assessment has been developed based on information supplied by the client regarding the expected activities associated with the development.

6.4.1 NO_x Emissions

The primary sources of NO_x emission associated with this development are those from combustion in earthmoving equipment and trucks. NO_x emissions were estimated using emissions factors published in NPI (2008). Estimated NO_x emission rates from the basement excavation works are presented in Table 6-2. A detailed inventory of NO_x emissions is included in Appendix C.

6.4.2 Dust and Particulate Emissions

Emissions of TSP and PM₁₀ associated with this development will be generated by excavation works, wind erosion and haulage. TSP and PM₁₀ emissions have been estimated using emissions factors published in US EPA (1985 and updates). A control factor of 50% has been applied to trucks on haul roads as the majority of the haul route on the Barangaroo site will be sealed. Estimated TSP and PM₁₀ emission rates from the basement excavation works are presented in Table 6-2. A detailed inventory of dust and particulate emissions is included in Appendix C.

Table 6-2 Emissions Estimates – NO_x, TSP and PM₁₀

Activity	Emissions (kg/day)		
	NO _x	TSP	PM ₁₀
Trucks entering site empty	3.45	0.81	0.21
Excavators/dozers on overburden	23.5	0.617	0.292
Excavators loading trucks	6.53	0.617	0.292
Trucks leaving site loaded	3.45	1.15	0.30
Wind Erosion	-	5.40	2.70
Total	36.88	8.59	3.79

6.4.3 Toxic Pollutant Emissions

Emissions of individual and principal toxic air pollutants have not been estimated directly. Rather, the ground level concentrations of these substances resulting from the proposed excavation works will be calculated by scaling the maximum predicted 1 hour PM₁₀ concentrations at nearby receptors by the maximum detected soil concentration of each substance as per AECOM (2014a).

The soil test results in AECOM (2014a) indicated that the soil concentrations of a number of pollutants under investigation in this study were below their respective thresholds of detection. Where this was identified to be the case, the soil concentration of these pollutants was assumed to be half their respective detection thresholds. This assumption is considered to be conservative.

6.4.4 Odour

There is potential for odour emissions to occur during the excavation works due to exposed soil which contains some level of contamination. Ratios of odour flux to soil concentration were established for a number of soil contaminants in a previous AQIA for earthworks within the Baraganroo site (AECOM 2014b) and have been adopted in this assessment to estimate the odour flux rate from the excavation area.

The odour flux rate calculation is presented in Table 6-3 and is based on the maximum detected concentrations of soil contaminants within the excavation area. The total flux rate includes a peak-to-mean ratio of 2.3.

Consistent with the assessment of toxic pollutants, odorous pollutants with soil concentrations below their respective detection limits were assumed to be present at a concentration of half the detection limit.

Table 6-3 Odour Flux Rate Estimates

Pollutant	Odour Flux to Soil Concentration Ratio*	Maximum Detected Soil Concentration	Odour Flux (OU.m⁻².s⁻¹)
Benzene	1.15E-02	0.3	3.45E-03
Toluene	1.51E-03	0.25	3.78E-04
Naphthalene	1.22E-06	4.22	2.27E-03
Ethylbenzene	5.54E-04	0.25	1.39E-04
Total xylenes	4.00E-06	0.5	2.00E-06
2-methylphenol	1.40E-01	0.25	3.51E-02
4-chloro-3-methylphenol	5.00E-04	0.25	1.25E-04
Phenol	1.00E-03	0.8	8.00E-04
Dibenzofuran	1.00E-05	0.25	2.50E-06
1,2,4-trimethylbenzene	1.00E-03	0.25	2.50E-04
1,3,5-trimethylbenzene	4.29E-04	0.25	1.07E-04
Isopropylbenzene	6.00E-03	0.25	1.50E-03
Styrene	2.00E-03	0.25	5.00E-04
Sub-total			4.08E-02
Total (including peak-to-mean ratio)			9.37E-02

*AECOM (2014a)

It should be noted that the soil concentrations of all odorous pollutants identified in Table 6-3 were found to be less than their detection limits. To be conservative it was assumed that the odorous pollutants would range between a quarter and a half the detection limit. This is considered conservative as many of the pollutants are likely not to be present at all.

6.5 Emissions Estimation for Block 4, Block 5 and Water Treatment Plant

All emissions data Block 4, Block 5 and Water Treatment Plant have been sourced from the *Air Quality Impact Assessment: Remediation Development Application, Barangaroo Block 5, EPA Declaration Area No 2112, Hickson Road, Millers Point, NSW*, AECOM Australia Pty Ltd, July 2014 (AECOM (2014b)) and are summarised below.

6.5.1 Block 5

Details of the emission rates for the Block 5 excavation odour control system are provided in Table 6-4 and stack characteristics are presented in Table 6-5.

Table 6-4 Treatment Tent Stack Emission Rates

Pollutant	Total Emission Rates After filtration
NO _x (g/s)	0.69
PM ₁₀ (g/s)	0.011
TSP (g/s)	0.034
Odour (OU/s)	51
VOCs combustion emissions (g/s)	0.00054
Benzene	0.0001
Ethylbenzene	0.00008
Toluene	0.00014
Total xylenes	0.0003
Naphthalene	0.0066
Phenol	0.0004

Table 6-5 Block 5 Excavation OCS Stack Characteristics

Details	Value	Units
Tent height	14	m
Stack height	4	m
Velocity	25	m/s
Diameter	0.7	m
Volumetric flow rate	11.2	m ³ /s
Temperature	25	°C

Details of the truck emissions associated with the Block 5 are provided in Table 6-6.

Table 6-6 Block 5 Truck Emissions

Pollutant	ER (g/s/source)
NO _x	0.0003
PM ₁₀	0.00002
TSP	0.00002
VOC	0.00003

6.5.2 Block 4

Details of the emission rates for the Block 4 excavation odour control system are provided in Table 6-7 and stack characteristics are presented in Table 6-8.

Table 6-7 Block 4 Excavation OCS Stack Emission Rates

Pollutant	Total Emission Rates After filtration
NO _x (g/s)	0.69
PM ₁₀ (g/s)	0.029
TSP (g/s)	0.096
Combustion VOC (g/s)	0.011
Odour (OU/s)*	106.4
Benzene	0.00010
Ethylbenzene	0.00008
Toluene	0.00014
Total xylenes	0.0003
Naphthalene	0.007
Phenol	0.0004

Table 6-8 Block 4 Excavation OCS Stack Characteristics

Details	Value	Units
Tent height	14	m
Stack height	4	m
Velocity	25	m/s
Exit area	0.45	m ²
Diameter	0.76	m
Volumetric flow rate	11.2	m ³ /s
Temperature	25	°C

Details of the truck emissions associated with the Block 5 are provided in Table 6-9.

Table 6-9 Block 4 Truck Emissions

Pollutant	ER (g/s/source)
NO _x	0.00014
PM ₁₀	0.000009
TSP	0.000009
VOCs	0.000013

6.5.3 Water Treatment Plant

The Water Treatment Plant (WTP) will have two point sources:

- the inlet tank displacement valve (ITDV); and
- the air strippers discharge stack (ASDS).

Details of these sources are provided in Table 6-10.

Table 6-10 Water Treatment Plant Stack Characteristics

Source	Base Elevation (m)	Stack Height (m)	Stack Temp (°C)	Diameter (m)	Stack Velocity (m/s)	Source VFR (m ³ /s)
ITDV	6	2.77	15.6	0.10	3.2	0.03
ASDS	6	2.77	15.6	0.42	8.2	1.13

As described in AECOM (2014b), the primary pollutants of interest associated with the operation of the WTP are VOCs (BTEX) (as a surrogate for odour) and naphthalene. Emission rates for the two associated point sources are provided in Table 6-11.

Table 6-11 Water Treatment Plant Emission Rates

Pollutant	Emission Rate (g/s)	
	ITDV	ASDS
Benzene	0.0010	0.009
Toluene	0.0004	0.004
Ethylbenzene	0.0001	0.001
Xylenes	0.0002	0.001
Naphthalene	0.0071	0.062

The emission rates correspond to a stripping efficiency of 99 % and a water flow rate of 25 L/s.

7 ASSESSMENT OF IMPACTS

The following section presents the predicted incremental and cumulative impacts on air quality at nearby receptors based on the results of the dispersion modelling and the best available data represented the existing local air quality.

The highest project contributions (pollutant concentrations associated with the project) predicted at any sensitive receptor assessed are provided in Table 7-1. These contributions represent the 100th percentile for NO₂, PM₁₀ and TSP and the 99.9th percentile for benzene, ethylbenzene, toluene, xylenes, naphthalene and phenol in accordance with DEC (2005a). Cumulative pollutant concentrations, which represent the project contribution plus background pollutant concentrations, are provided for NO₂, PM₁₀ and TSP as required by the EPA. For TSP, the ambient concentration was estimated from the PM₁₀ concentration as described in **Section 5.2**.

The EPA criteria for air toxics apply at and beyond the boundary of the facility. The concentrations reported below represent the highest 99.9th percentile concentrations for any sensitive receptor assessed, which include receptors located on the boundary.

As shown, no exceedances of the EPA criteria were predicted to occur at any sensitive receptor location assessed.

Table 7-1 Dispersion Modelling Results

Pollutant	Averaging Period	Units	Maximum Predicted Project Contribution	Total Cumulative Concentration	Criteria
NO ₂	Max 1 hour average	(µg/m ³)	142	221	246
	Annual average	(µg/m ³)	13	30	62
PM ₁₀	Max 24 hour average	(µg/m ³)	32	69	50
	Annual average	(µg/m ³)	5.0	24	30
TSP	Annual average	(µg/m ³)	3.7	46	90
Benzene	99.9 th 1 hour	(µg/m ³)	1.61E-04	2.5	29
Ethylbenzene	99.9 th 1 hour	(µg/m ³)	1.34E-04	0.3	8,000
Toluene	99.9 th 1 hour	(µg/m ³)	1.34E-04	1.1	360
Xylenes	99.9 th 1 hour	(µg/m ³)	2.68E-04	0.3	190
Naphthalene	99.9 th 1 hour	(µg/m ³)	2.27E-03	17.5	440
Phenol	99.9 th 1 hour	(µg/m ³)	4.29E-04	0.1	20

For 1 hour NO₂ and 24 hour PM₁₀, contemporaneous assessments were undertaken, where the measured background pollutant concentrations for each hour/24 hours of the modelling period were matched to the hourly/24 hour modelling predictions.

The total impact on 1 hour NO₂ was calculated via a contemporaneous assessment using monitoring data from the OEH monitoring station at Rozelle. Hourly concentrations of NO₂ and O₃ from Rozelle were combined with hourly dispersion model predictions at each receptor to calculate the total hourly concentrations of NO₂ via the Ozone Limiting Method, as described in Section 6.3.2. Rozelle is the nearest OEH air quality monitoring station to the site and provides the best available indication of existing levels of NO₂ and O₃ in the area surrounding the site.

The total impact on annual average NO₂ concentrations was calculated as the mean value of the total 1 hour NO₂ concentrations at the most affected off-site receptor during the simulation period.

Figure 7-1 provides a graphical representation of the contemporaneous NO₂ assessment and the relative contribution of the proposed works on 1 hour NO₂ levels.

The total impact on 24 hour PM₁₀ concentrations was established by conducting a contemporaneous assessment based on data from the Rozelle air quality monitoring system during the simulation period of 1 July 2013 to 30 June 2014. The total 24 hour PM₁₀ concentration was calculated by adding the predicted incremental 24 hour PM₁₀ concentration to the existing level.

As outlined in Section 5.2, the existing 24 hour PM₁₀ levels at Rozelle were found to exceed the criterion of 50 µg/m³ on three occasions during the simulation period. It is therefore expected that the total impact would also exceed the criterion. Detailed analysis of the contemporaneous 24 hour PM₁₀ assessment indicates that the proposed excavation works are predicted to result in no additional exceedances of the criterion.

Figure 7-2 provides a graphical representation of the contemporaneous PM₁₀ assessment and the relative contribution of the proposed works on 24 hour PM₁₀ levels.

Figure 7-1 1 hour NO₂ Contemporaneous Assessment

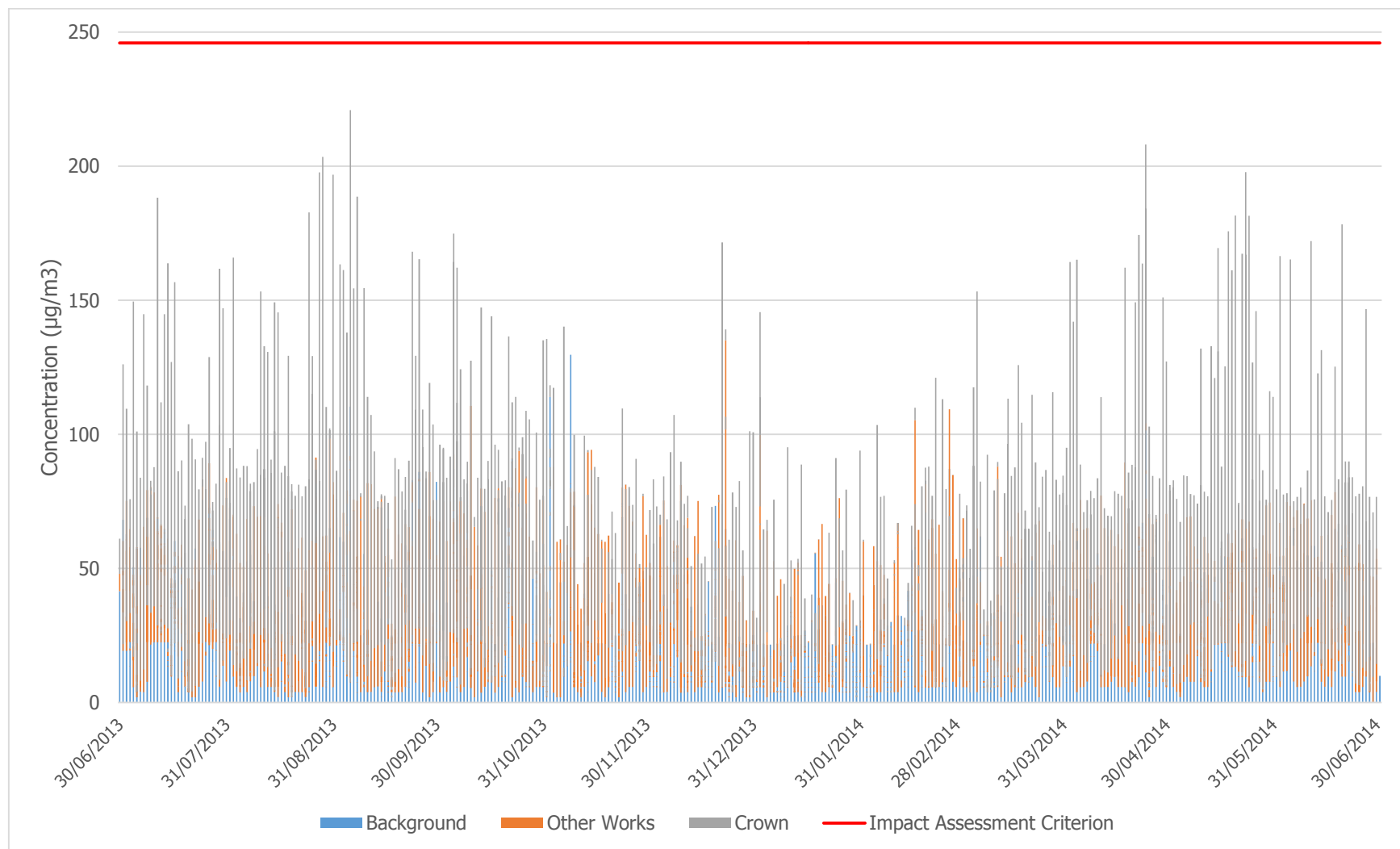
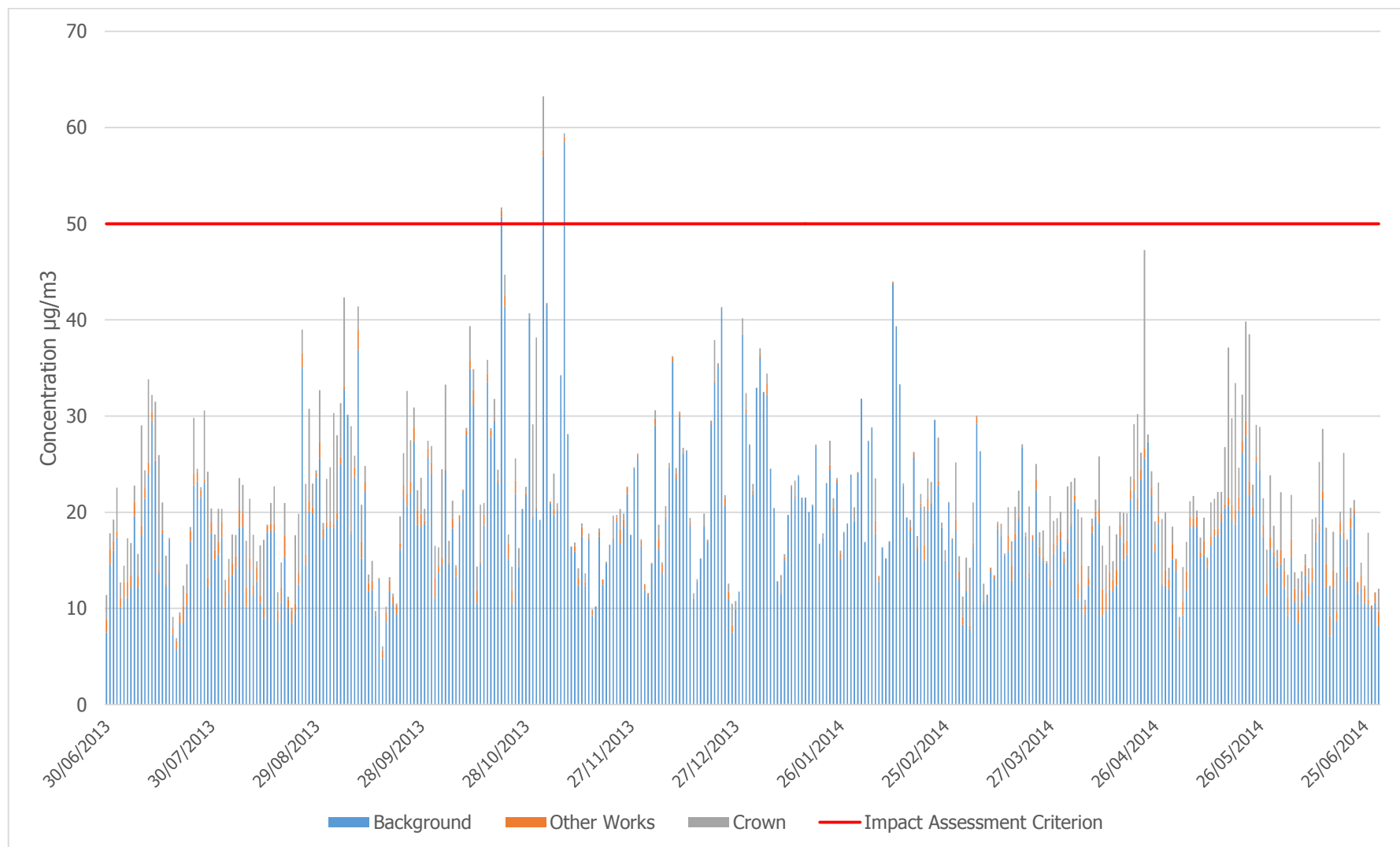


Figure 7-2 24 hour PM₁₀ Contemporaneous Assessment



7.1 Metals, PAHs and Cyanide

The predicted impact of metals, PAHs and cyanide are presented in Table 7-2. All values presented in Table 7-2 correspond to the maximum predicted levels at off-site receptors.

Table 7-2 Maximum Predicted Impact – Principal Toxic Air Pollutants

Pollutant	Averaging Period	Predicted Incremental Impact (mg/m ³)	Predicted Cumulative Impact	Impact Assessment Criteria (µg/m ³)
Arsenic and compounds	1 hour	5.90E-03	6.30E-03	9.00E-02
Polycyclic aromatic hydrocarbons (as benzo[a]pyrene)	1 hour	3.08E-03	5.08E-03	4.00E-01
Beryllium and beryllium compounds	1 hour	2.68E-04	3.18E-04	4.00E-03
Cadmium and cadmium compounds	1 hour	2.68E-04	3.38E-04	1.80E-02
Chromium VI compounds	1 hour	6.21E-03	8.21E-03	9.00E-02
Copper	1 hour	1.77E-02	2.27E-02	1.80E+01
Cyanide	1 hour	1.95E-03	3.95E-03	9.00E+01
Lead	1 hour	5.73E-04	2.26E-02	5.00E-01
Manganese	1 hour	1.07E-01	1.29E-01	1.80E-01
Mercury	1 hour	1.21E-04	1.51E-04	1.80E-01
Nickel	1 hour	9.16E-03	1.03E-02	1.80E-01
Zinc	1 hour	4.75E-04	1.15E-02	1.80E+01

a Gas volumes are expressed at 25°C and at an absolute pressure of 1 atmosphere (101.325 kPa)

Review of Table 7-2 indicates that the predicted concentrations of metals, PAHs and cyanide at the most affected off-site receptors, due to the proposed excavation works, are well below the applicable impact assessment criteria.

7.2 Odour

The predicted 99th percentile odour impact at the most affected off-site receptor due to the proposed excavation works was calculated to be 0.92 OU/m³, and is below the established impact assessment criterion of 2.0 OU/m³.

It is noted that the method of estimating odour emissions from the excavation was conservative and assumed the presence of a number of odorous pollutants which may in fact not be present in the excavated soil.

8 CONCLUSION

An Air Quality Impact Assessment (AQIA) has been prepared by Wilkinson Murray Pty Ltd on behalf of Crown Resorts Ltd to accompany a State Significant Development Application (SSDA) for the Crown Sydney Hotel Resort at Barangaroo.

The AQIA assessed the likely air quality impacts on nearby sensitive receptors resulting from the basement excavation works associated with the proposed Stage 1C remediation and earthworks. For consistency, many aspects of this assessment are consistent with those in a recent AQIA conducted by AECOM Australia Pty Ltd (AECOM, 2014a).

Dispersion modelling of air pollutants associated with the development was conducted using the CALPUFF regulatory model. The modelling and assessment were conducted in general accordance with the following documents:

- *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (DEC, 2005); and
- *Generic Guidance and Optimum Model Setting for the CALPUFF Modelling System for Inclusion into the 'Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales, Australia'* (TRC, 2011).

A contemporaneous assessment of 1 hour NO₂ impacts was conducted using the best available background data. This data included 1 hour concentrations of NO₂ and O₃ from the OEH monitoring station at Rozelle. The 'Ozone Limiting Method' was used to model the transformation of NO_x to NO₂. The contemporaneous assessment of 1 hour NO₂ concentrations indicated no impacts associated with the proposed excavation works.

Monitoring data across the period 1 July 2013 to 30 June 2014 from the Rozelle OEH monitoring station indicated that existing PM₁₀ concentrations exceeded the 24 hour PM₁₀ impact assessment criterion on three occasions. The dispersion modelling predictions indicated that the additional PM₁₀ emissions associated with the proposed works do not result in any additional exceedances of the 24 hour PM₁₀ impact assessment criterion at the most affected off-site receptor.

Soil contaminant concentrations identified in the Remedial Action Plan (AECOM 2014a) were used to predict concentrations of toxic air pollutants at air receptors due to the excavation of contaminated soil. The predicted concentrations of all toxic air pollutants were well below the applicable impact assessment criteria.

Odour impacts associated with the excavation of contaminated soil were assessed in a manner consistent with previous assessments at Barangaroo (AECOM 2014a) and the modelling indicated that odour nuisance from the development is unlikely.

9 REFERENCES

AECOM (2014a), *Remedial Action Plan: Crown Hotel Development (Part of ORWN Area), Barangaroo South*, AECOM Australia Pty Ltd, May 2014

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NPI (2008), *Emission Estimation Technique Manual for Combustion Engines, Version 3.0*, National Pollutant Inventory, June 2008

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US EPA (1985 and updates), *Compilation of Air Pollutant Emission Factors, AP-42, Fourth Edition*, United States Environmental Protection Agency

APPENDIX A

SENSITIVE RECEPTORS

Table A-9-1 Sensitive Receptors

Receptor ID	Coordinates		Flagpole Height (m)
	x (m)	y (m)	
R_1	333778	6251503	0
R_2	333796	6251497	18
R_3	333789	6251493	0
R_4	333795	6251466	0
R_5	333793	6251457	0
R_6	333823	6251476	25
R_7	333822	6251462	25
R_8	333800	6251439	0
R_9	333828	6251447	48
R_10	333825	6251436	50
R_11	333803	6251418	0
R_12	333805	6251400	0
R_13	333812	6251361	8
R_14	333809	6251339	12
R_15	333813	6251328	15
R_16	333792	6251319	0
R_17	333788	6251299	35
R_18	333769	6251307	35
R_19	333757	6251311	0
R_20	333775	6251290	40
R_21	333756	6251293	48
R_22	333738	6251287	40
R_23	333724	6251286	0
R_24	333714	6251272	10
R_25	333706	6251246	15
R_26	333695	6251260	10
R_27	333674	6251251	12
R_28	333664	6251260	0
R_29	333643	6251251	15
R_30	333616	6251255	0
R_31	333632	6251884	0
R_32	333773	6251949	0
R_33	333776	6251874	0
R_34	333812	6251839	0
R_35	333785	6251806	0
R_36	333777	6251775	0
R_37	333776	6251718	0
R_38	333776	6251718	30

Receptor ID	Coordinates		Flagpole Height (m)
	x (m)	y (m)	
R_39	333821	6251707	0
R_40	333821	6251707	20
R_41	333821	6251707	40
R_42	333821	6251707	60
R_43	333798	6251641	0
R_44	333798	6251641	20
R_45	333785	6251606	0
R_46	333785	6251606	20
R_47	333785	6251606	30
R_48	333816	6251631	0
R_49	333816	6251631	20
R_50	333816	6251631	40
R_51	333816	6251631	60
R_52	333793	6251504	0
R_53	333793	6251504	20
R_104	333733	6251786	0
R_55	333822	6251500	20
R_56	333822	6251500	40
R_57	333822	6251500	60
R_58	333822	6251500	80
R_59	333702	6251273	0
R_105	333736	6251750	0
R_61	333792	6251516	0
R_62	333792	6251521	0
R_63	333791	6251528	0
R_64	333790	6251536	0
R_65	333789	6251542	0
R_66	333817	6251537	0
R_67	333817	6251537	20
R_68	333817	6251537	40
R_69	333819	6251521	60
R_70	333795	6251551	0
R_71	333795	6251564	0
R_72	333794	6251579	0
R_73	333794	6251593	0
R_74	333785	6251606	10
R_75	333785	6251606	30
R_76	333785	6251606	50
R_77	333780	6251635	0
R_78	333780	6251635	20

Receptor ID	Coordinates		Flagpole Height (m)
	x (m)	y (m)	
R_79	333780	6251635	40
R_80	333779	6251663	0
R_81	333786	6251667	20
R_82	333786	6251667	40
R_83	333781	6251676	30
R_84	333781	6251676	10
R_85	333774	6251765	0
R_86	333770	6251785	0
R_87	333768	6251796	0
R_89	333775	6251840	0
R_88	333773	6251750	0
R_90	333768	6251897	0
R_91	333766	6251926	0
R_92	333796	6251908	10
R_93	333804	6251817	20
R_94	333754	6251851	0
R_95	333751	6251895	0
R_96	333748	6251935	0
R_97	333744	6251976	0
R_98	333741	6252010	0
R_99	333763	6251979	0
R_100	333762	6251963	10
R_101	333765	6251936	0
R_102	333756	6252058	0
R_103	333737	6252055	0
R_106	333742	6251711	0
R_110 (Residential R8)	333641	6251462	0
R_111 (Residential R8)	333641	6251462	20
R_112 (Residential R8)	333641	6251462	40
R_113 (Commercial T2)	333655	6251499	0
R_114 (Commercial T2)	333655	6251499	20
R_115 (Commercial T2)	333655	6251499	40
R_116 (Commercial T2)	333655	6251499	60

APPENDIX B

LOCAL AIR QUALITY

Figure B-1 Background 1 hour NO₂ Concentration – Rozelle OEH Monitoring Station

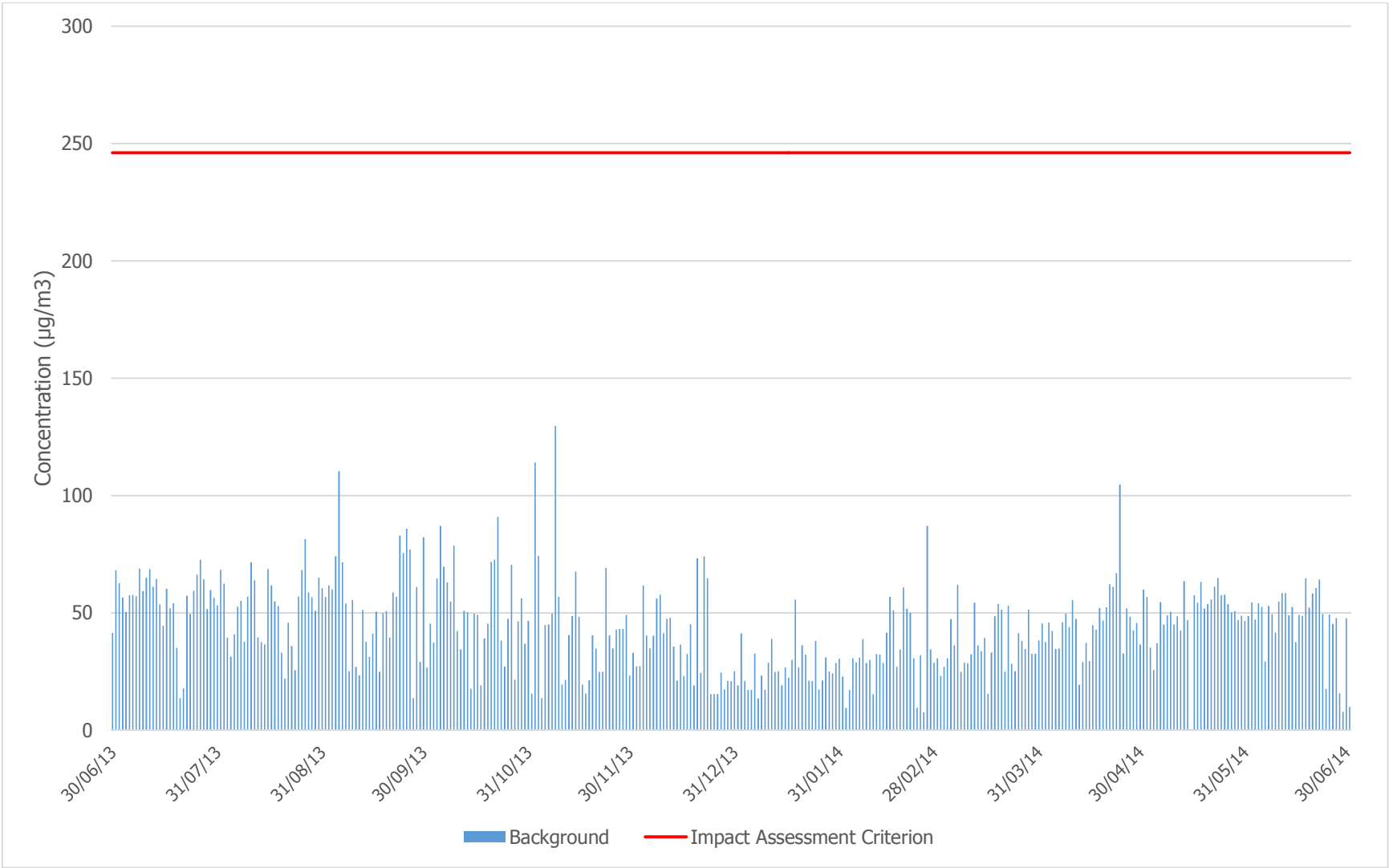


Figure B-2 Background 1 hour O₃ Concentration – Rozelle OEH Monitoring Station

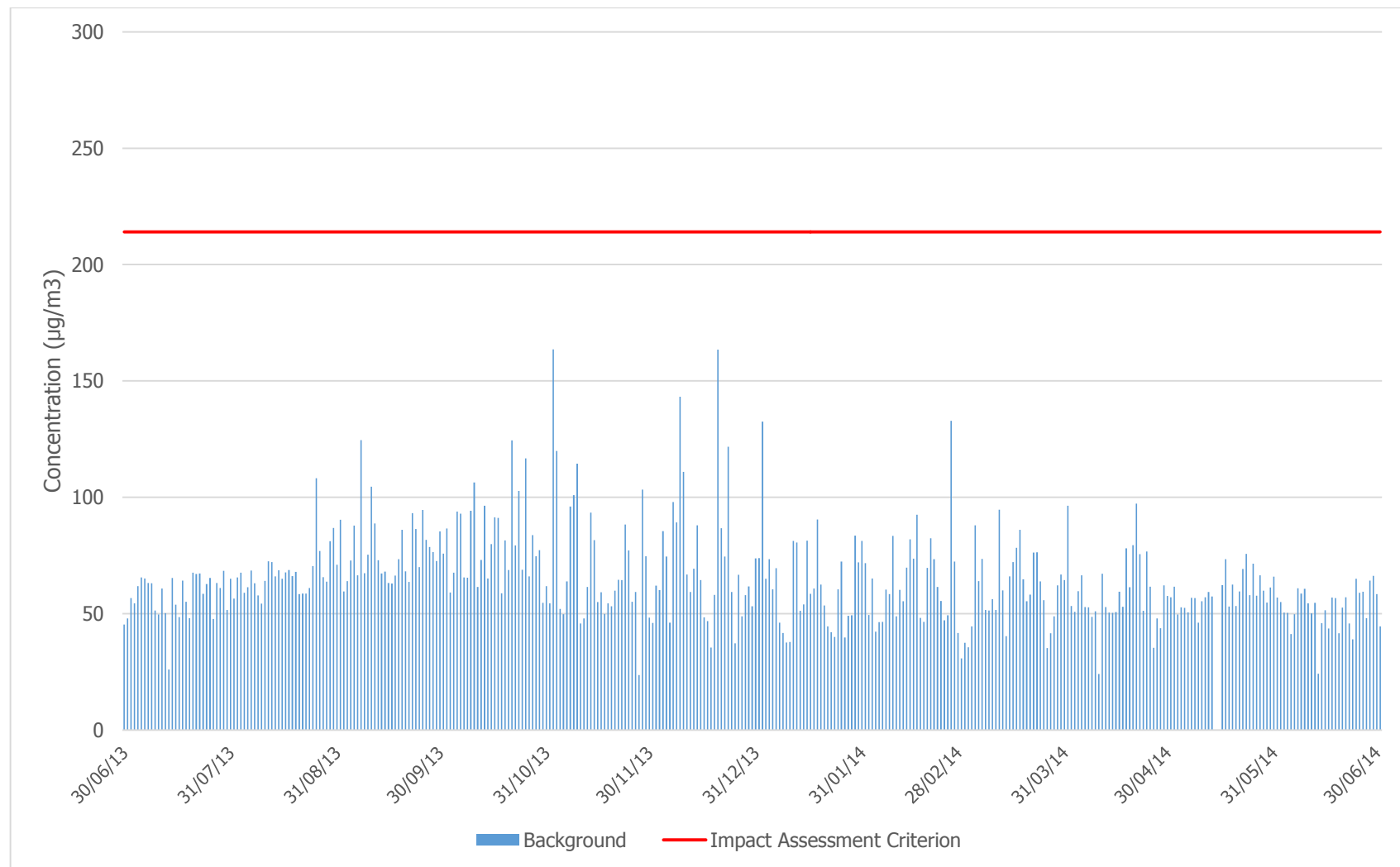


Figure B-3 Background 24 hour PM10 Concentration – Rozelle OEH Monitoring Station

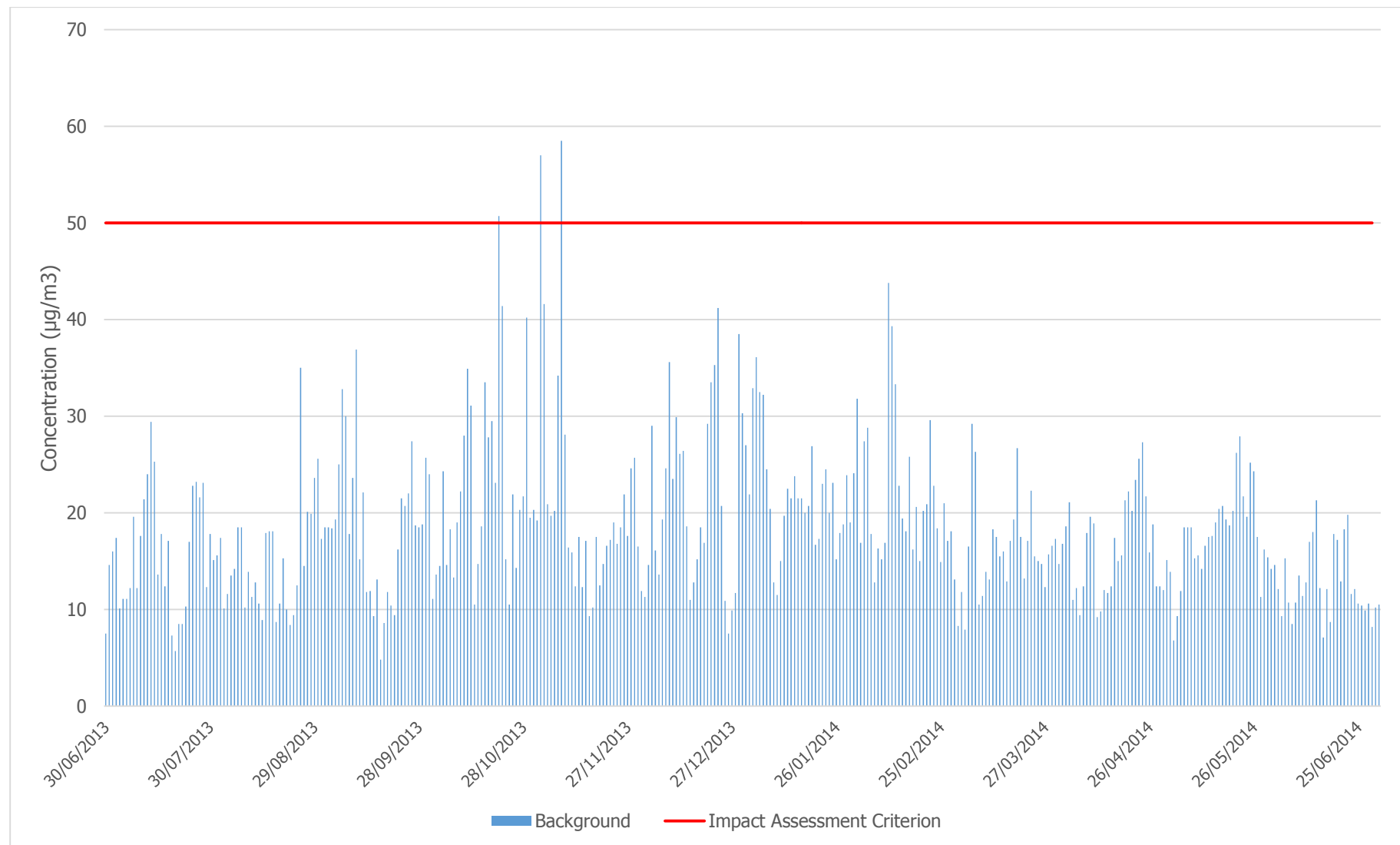
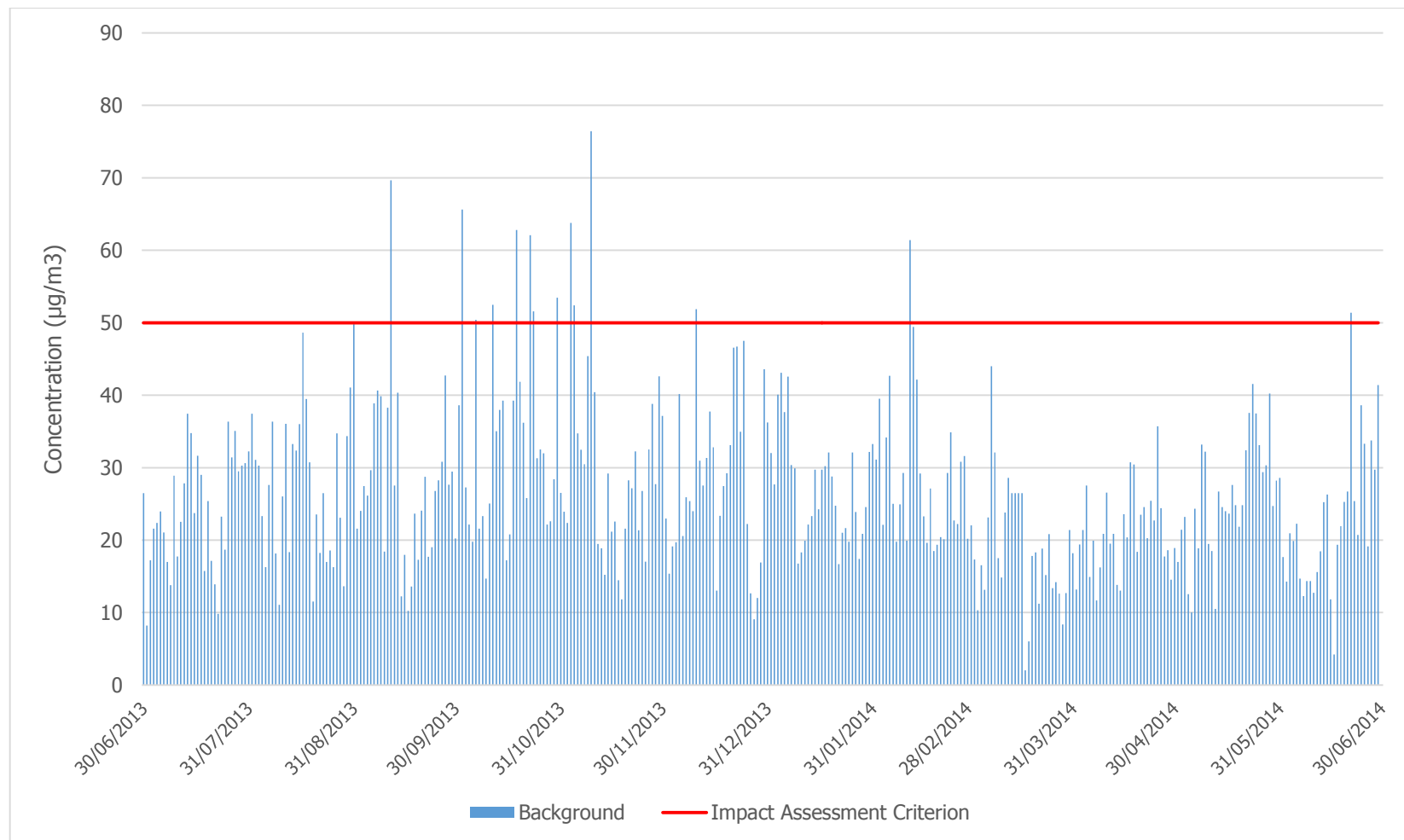


Figure B-3 Background 24 hour PM₁₀ Concentration – Barangaroo On-site Monitoring System



APPENDIX C

EMISSIONS INVENTORY

C.1 Particulate Emission Factor Equations

Haul roads

Wheel generated particulate emissions associated with material haulage are estimated using the following US EPA emission factors (US EPA, 1985 and updates):

$$E[kg/VKT] = 0.2819 \times a \times \left(\frac{s}{12}\right)^b \times \left(\frac{1.1023 \times W}{3}\right)^{0.45}$$

Where:

a = 4.9 for TSP, 1.5 for PM₁₀ and 0.15 for PM_{2.5}

b = 0.7 for TSP and 0.9 for PM₁₀ and PM_{2.5}

s = silt content [%] of road surface

W = weight of vehicle [t]

Particulate emissions from vehicles travelling along sealed haul roads have been estimated using the above equations, and including a control factor of 90% to reflect that the majority of the haul road is sealed.

Loading / unloading / transferring material

Each tonne of material handles will generate quantities of particulate matter that will depend on the wind speed and the moisture content of the material according to the US EPA emission factor (US EPA, 1985 and updates) shown below:

$$E[kg/t] = k \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2.0}\right)^{1.4}} \right)$$

Where:

k = 0.74 for TSP, 0.35 for PM₁₀ and 0.053 for PM_{2.5}

U = wind speed [ms⁻¹]

M = moisture content [%]

The wind speed is taken as the average wind speed from the TAPM dataset.

Dozers and excavators on overburden

Particulate emissions for excavators and dozers on overburden have been estimated using US EPA emission factor equations (US EPA, 1985 and updates) for dozers on overburden as follows:

$$E[kg/h] = a \times \left(\frac{s^b}{M^c} \right)$$

Where:

a = 2.6 for TSP, 0.8775 for PM_{10} and 0.273 for $PM_{2.5}$

b = 1.2 for TSP, 1.5 for PM_{10} and 1.2 for $PM_{2.5}$

c = 1.3 for TSP, 1.4 for PM_{10} and 1.3 for $PM_{2.5}$

s = silt content [%]

M = moisture content [%]

Wind erosion

Particulate emission factors for wind erosion, taken from the NPI (NPI, 2012), are 0.4 kg/ha/h for TSP and 0.2 kg/ha/h for PM_{10}

C.2 NO_x Emission Equation

NO_x emissions from various diesel powered vehicles and plant have been estimated using the following NPI emission factor equation (NPI, 2008):

$$E_{NO_x}[kg/day] = P \times T_{operating} \times LF \times EF_{NO_x}$$

Where:

P = average rated engine power [kW]

$T_{operating}$ = vehicle operating time [h/day]

LF = load factor to describe operational duty cycle of vehicle

EF_{NO_x} = engine and fuel specific emission factor [kg/kWh]

C.3 Emission Estimates

Table C-1 Summary of NO_x Emissions

Activity	Emission [kg/day]	Intensity	Units	Emission Factor	Units	Variable 1	Units	Variable 2	Units	Variable 3	Units	Control [%]
Trucks	6.89	0.167	hours per day	0.011	kg/kWh	375	power [kW]	0.25	load factor	40	units operating / day	0
Dozers	16.94	8	hours per day	0.011	kg/kWh	350	power [kW]	0.55	load factor	1	units operating / day	0
Excavators	13.06	8	hours per day	0.010	kg/kWh	170	power [kW]	0.50	load factor	2	units operating / day	0
Total [kg/day]	36.88											
Total [g/s]	0.427											

Table C-2 Summary of TSP Emissions

Activity	Emission [kg/day]	Intensity	Units	Emission Factor	Units	Variable 1	Units	Variable 2	Units	Variable 3	Units	Variable 4	Units	Control [%]
Trucks entering site empty	0.81	40	trucks/day	0.403	kg/truck	0	km/trip (one way)	1.344	kg/VKT	10	unladen vehicle mass [t]	5	silt content [%]	90
Excavators/dozers on overburden	0.617	453	t/day	0.001	kg/t	2	wind speed [m/s]	2	moisture content [%]					0
Excavators loading trucks	0.617	453	t/day	0.001	kg/t	2	wind speed [m/s]	2	moisture content [%]					0
Trucks leaving site loaded	1.15	40	trucks/day	0.575	kg/truck	0	km/trip (one way)	1.917	kg/VKT	22	laden vehicle mass [t]	5	silt content [%]	90
Wind Erosion	5.40	24	hours/day	0.225	kg/h	1	area [ha]	0.400	kg/ha/h					
Total [kg/day]	8.59													
Total [g/s]	0.099													

Table C-3 Summary of PM₁₀ Emissions

Activity	Emission [kg/day]	Intensity	Units	Emission Factor	Units	Variable 1	Units	Variable 2	Units	Variable 3	Units	Variable 4	Units	Control [%]
Trucks entering site empty	0.21	40	trucks/day	0.104	kg/truck	0.3	km/trip (one way)	0.345	kg/VKT	10	unladen vehicle mass [t]	5	silt content [%]	90
Excavators/dozers on overburden	0.292	453	t/day	0.001	kg/t	2.5	wind speed [m/s]	2.000	moisture content [%]					0
Excavators loading trucks	0.292	453	t/day	0.001	kg/t	2.5	wind speed [m/s]	2	moisture content [%]					0
Trucks leaving site loaded	0.30	40	trucks/day	0.148	kg/truck	0.3	km/trip (one way)	0.493	kg/VKT	22	laden vehicle mass [t]	5	silt content [%]	90
Wind Erosion	2.70	24	hours/day	0.113	kg/h	0.6	area [ha]	0.200	kg/ha/h					
Total [kg/day]	3.79													
Total [g/s]	0.044													