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Environmental Impact Statement – Appendix E: Air Quality Assessment

Warragamba Dam Raising

Reference No. 30012078
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Warragamba Dam Raising

Air Quality Assessment

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CONTENTS

List of Figures

List of Tables

1. INTRODUCTION

1.1 Project application

WaterNSW, a New South Wales (NSW) state-owned corporation, is seeking project approval for the Warragamba Dam Raising Project (the project). The approval is sought under Part 5, Division 5.2 (s5.14) (State Significant Infrastructure) of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act).

To support the project approval application, an Environmental Impact Statement (EIS) is being prepared. This report is part of the EIS and has been prepared to assess the project's impact on air quality. The Secretary's Environmental Assessment Requirements (SEARs) that this report addresses are discussed in Section 1.4.

The background to the project is described in the following Section 1.2. A more detailed description of the project is contained in Section 2.

1.2 Project background

As outlined in the State Infrastructure Strategy 2012-2032 (INSW 2012), the flooding history in the Hawkesbury-Nepean Valley can be traced back to the very early years of European settlement. During the 1980s and 1990s evidence emerged that floods significantly larger than any yet historically recorded could occur in the Hawkesbury-Nepean Valley. In 2013, the NSW Government initiated the Hawkesbury-Nepean Valley Flood Management Review to consider flood planning, flood mitigation and flood response in the Hawkesbury-Nepean Valley. The review found that the current flood management and planning arrangements were insufficient in mitigating the risk, and no single mitigation option could address all of the flood risks present in the Hawkesbury-Nepean Valley. The raising of Warragamba Dam to capture inflows was concluded to be the most effective infrastructure measure that could have a major influence on flood levels during those events when the majority of damages occur. The 2015 cost-benefit analysis modelled by INSW demonstrated that Warragamba Dam Raising would provide a 75 percent reduction in flood damages on average and reduce current levels of flood damages from $5 billion to $2 billion (Infrastructure NSW, 2017). Other complementary non-infrastructure options were also identified as essential to mitigate flood risk to life.

WaterNSW is also seeking approval for the installation of environmental flow infrastructure at Warragamba Dam. Warragamba Dam does not currently have the appropriate infrastructure to allow the controlled release of environmental flows into the Warragamba River and the Hawkesbury-Nepean Rivers. Studies undertaken to investigate environmental flow releases from Warragamba Dam demonstrate that there would be substantial downstream water quality and aquatic ecological benefits from environmental flow releases.

1.3 Project location

The assessment areas for the project have been described in the context of both the stage of the works (construction and operation) and geographic extent of possible effects and impacts.

The Study Area includes the areas upstream and downstream of Warragamba Dam that could be affected by the future operation of the project and environmental flow releases.

Upstream of Warragamba Dam this includes Lake Burragorang (i.e. the reservoir formed by Warragamba Dam) and its tributaries and areas of the Blue Mountains National Park, Burragorang State Conservation Area, Nattai National Park, Nattai State Conservation Area and Yerranderie State Conservation Area. Most of the Blue Mountains National Park is also in the Greater Blue Mountains World Heritage Area (GBMWHA) and areas of the GBMWHA would experience increased temporary inundation.

Downstream of Warragamba Dam the Study Area includes the freshwater and estuarine reaches of the river system and its tributaries between Warragamba Dam where it joins the Nepean River near Wallacia (not including the reach of the Nepean River upstream of Wallacia) and Wisemans Ferry as well as the adjacent riparian zone, floodplain and wetland/lagoon waterbodies. During flood events, there are backwater flooding impacts along South Creek which flows into the Hawkesbury River downstream of Windsor and consequently South Creek has been included in the Study Area.

The Construction Area includes the dam and the areas in and around the existing Warragamba Dam, including auxiliary access roads and site buildings. The township of Warragamba and areas immediately upstream and downstream of Warragamba Dam, as well as the immediate road network, are included in the Construction Area because they are likely to be impacted during construction.

1.4 Secretary's Environmental Assessment Requirements

The environmental impact assessment for the project will be subject SEARs (SSI-8441) issued by the former Department of Planning and Environment (DP&E), now the Department of Planning, Industry and Environment (DPIE). The requirements for air quality are given in Table 1-1.

Table 1-1: SEARs relevant to air quality

Key issue and desired performance outcome	Requirements	Guidelines / legislation
The project is designed, constructed and operated in a manner that minimises air quality impacts (including nuisance dust and odour) to minimise risks to human health and the environment to the greatest extent practicable.	1. The Proponent must undertake an air quality impact assessment (AQIA) for construction and operation of the project in accordance with the current guidelines.	Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (DEC, 2017) Approved Methods for the Sampling and Analysis of Air Pollutants in NSW (DEC, 2005) Technical Framework - Assessment and Management of Odour from Stationary Sources in NSW (DEC, 2006)
	2. The Proponent must ensure the AQIA includes a demonstrated ability to comply with the relevant regulatory framework, specifically the Protection of the Environment Operations Act 1997 and the Protection of the Environment Operations (Clean Air) Regulation (2010).	

This air quality assessment comprises of the following components:

- A project description (Section 2).
- Contextual background information on air pollution, and a summary of the air quality assessment criteria that are applicable to the Project (Section 3).
- A description of the existing environment, including background air quality (Section 4).
- The methodology for the assessment of the Project (Section 5).
- The results for assessment of impacts of the Project (Section 6).
- The conclusions from the assessment (Section 8).

2. PROJECT DESCRIPTION

2.1 The Project

Warragamba Dam Raising is a project to provide flood storage capacity in the Lake Burragorang catchment (Warragamba Catchment) to facilitate flood mitigation and to provide environmental flows downstream of Warragamba Dam.

The Project would:

- enable the dam to capture and temporarily hold back inflows from the Warragamba catchment behind the wall
- provide capacity to facilitate flood mitigation by increasing the central spillway by approximately 12 metres and increasing the dam abutments (including access road) by 17 metres, which includes approximately three metres to be resilient to the future impacts of climate change
- provide infrastructure to allow for environmental flows to be released from Warragamba Dam.

The Project would include the following main activities and elements:

- demolition or removal of parts of the existing Warragamba Dam, including the existing drum and radial gates, to allow for the new works
- thickening and raising of the dam abutments
- thickening and raising of the central spillway
- new gates or slots to discharge inflows
- modifications to the auxiliary spillway
- other infrastructure and elements including new roads, bridges and ancillary facilities
- environmental flows infrastructure
- operation of the dam for flood mitigation.

2.1.1 Location

The Project site is located approximately 65 km west of the Sydney Central Business District in the Wollondilly Local Government Area (LGA). To the west of the Project site are the Blue Mountains, various National Parks and State Conservation Areas and the Greater Blue Mountains World Heritage Area (GBMWHA) which make up the catchment of Lake Burragorang - which is the water storage formed by Warragamba Dam. To the east of the Project site are the Warragamba and Silverdale townships and surrounding rural residential areas.

The Construction Area includes Warragamba Dam and the areas around it, including auxiliary access roads, site buildings and other supporting infrastructure. The township of Warragamba and areas immediately upstream and downstream of Warragamba Dam, as well as the immediate road network, are included in the Construction Area because they are potentially impacted during construction.

2.1.2 Construction area

Figure 2-1 shows the construction area for the Project including:

- ancillary facilities such as coffer dams, batch plants, material storage areas and worker facilities
- areas which require clearing of vegetation to allow for construction and access
- areas directly impacted by construction works
- areas that would be used for construction activities but would not be modified by the Project (eg. existing roads, Lake Burragorang).

Figure 2-1: Construction area

2.2 Main activities and elements

The Project works include:

- demolition
- thickening and raising of dam abutments
- thickening and raising of central spillway
- modifications to the auxiliary spillway
- other infrastructure and elements
- environmental flow infrastructure

These are described in greater detail in the following sections.

2.2.1 *Demolition*

Elements of the existing Warragamba Dam would require demolition or removal to enable dam raising construction to proceed. These include:

- the existing road and main spillway bridge across the top of the dam
- the drum and radial gates, and associated mechanical and electrical infrastructure, and portions of the piers within the central spillway
- minor concrete structures to allow the tie-in of the new dam and spillway
- the valve house control room building located at the rear of the valve house

- areas of roads, operational laydown areas, drainage systems and other infrastructure external to but associated with the dam
- the existing gantry crane and associated equipment
- the existing hydroelectric power station equipment to allow for new environmental flow infrastructure
- miscellaneous dam crest services and equipment.

2.2.2 Thickening and raising of the dam abutments

The dam abutments, located either side of the central spillway would be modified:

- the dam abutments would be thickened on the downstream side with additional concrete. The face of the abutments would be smooth as with the existing dam
- the abutment height would be increased by around 17 m
- the left abutment would extend into the surrounding rock to suit the thickening and raising.

2.2.3 Thickening and raising of the central spillway

The existing central spillway would be modified as follows:

- the spillway would be thickened on the downstream face with concrete and it would have a smooth surface
- the spillway crest would be raised to create the flood mitigation zone (FMZ), including the use of post tensioned anchors within the wall for stability
- gated conduits would be constructed within the central spillway to allow for the controlled discharge of inflows. These openings would be located so the flood mitigation zone could be drawn back down to the full supply level
- potentially slots would be constructed within the central spillway crest to allow for the discharge of inflows.

2.2.4 Modification to the auxiliary spillway

The following modifications would be undertaken on the auxiliary spillway:

- removal of the existing fuse plugs (earth/rock embankments designed to wash away in a major flood) and replacement with a concrete spillway crest
- the spillway floor slabs and walls would be modified and reinforced to suit discharging of flood water from the raised dam
- erosion protection would be provided downstream from the auxiliary spillway.

The existing bridge across the auxiliary spillway would be retained for access to the valve house and the base of the dam and spillway.

2.2.5 Other infrastructure elements

Other infrastructure and elements would include:

- A new bridge would be built above the auxiliary spillway crest to provide access to the raised dam.
- The raised abutments and central spillway bridge would allow for vehicle and pedestrian access across the top of the dam. These would connect with the approaches and road network on either side of the dam.

- New control and instrumentation equipment including mechanical, electrical and communications elements.
- New landscaping and urban design features would be provided for areas disturbed by construction and for other areas which require improved integration to the new dam structure.
- Ancillary works to tie existing services into the raised dam.
- The existing two lift towers would be modified to suit the raised dam.
- A drainage line would be modified on the left bank to allow the migration of eels from the river to Lake Burragorang.

2.3 Project construction

This section describes the proposed approach to construction. If the project is approved, further detailed construction planning would take place prior to commencement to inform a Construction Environmental Management Plan (CEMP). This plan would consider methods and the scheduling of activities to minimise impacts on the community and the environment, and would detail mitigation and management measures.

2.3.1 Construction area

The proposed construction area is shown in Figure 2-1. This area may be refined as part of detailed design and construction planning. This includes:

- areas directly impacted by construction
- areas where access for construction is required
- concrete batch plants and material laydown and storage areas
- offices and worker amenities
- visitors and education centre
- other ancillary sites.

2.3.2 Construction program

A preliminary construction program is presented in Figure 2-2 with the project anticipated to be completed between four to five years from commencement.

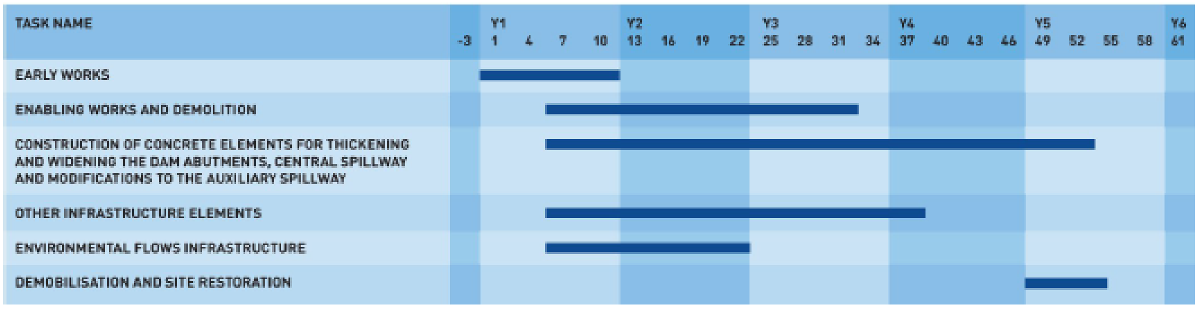

Figure 2-2: Preliminary construction program

2.3.3 Construction workforce

The number of workers would vary over the program. Up to 300 workers would undertake establishment activities including setting up offices and compounds, assembling the concrete batch plants and beginning early and enabling works. The number of workers on site would increase during construction to around 500 during peak construction periods.

2.3.4 Construction hours

The majority of the construction works would take place during standard construction hours for NSW which are:

- 7am to 6pm – Monday to Friday
- 8am to 1pm – Saturday
- no work on Sundays and Public Holidays.

This includes:

- deliveries of materials including concrete, sand and aggregates for concrete production
- demolition work including hydro-blasting (a concrete removal technique that uses high pressure water)
- earthworks, excavations, drilling and blasting

Some activities would need to take place outside of standard construction hours. These activities may include:

- Operation of chilled water plants for cooling and curing of concrete. Continuous cooling of the concrete is required to ensure that heat does not become excessive, and cause cracking and loss of strength of the concrete, during curing.
- Operation of the batching plants for the delivery and pouring of concrete. In warmer periods, concrete pours may not be able to take place in normal working hours. High temperatures may cause thermal issues and cracking during the curing process. Concrete pours may be required at night-time when temperatures are lower.
- Preparatory or emergency works for a flood during the construction period including removing equipment and materials from the construction area, minor earthworks and other activities.
- Work outside the nominated working hours may need to occur in the case of emergencies or unexpected issues.
- The local community would be notified of construction activities including any activities taking place outside of standard construction hours in accordance with the Community Consultation Plan developed by the construction.

2.3.5 Construction methodology

The stages and elements of the construction works include:

- Early works
- Enabling works and demolition
- Construction of concrete elements for thickening and widening the dam abutments, central spillway and modifications to the auxiliary spillway
- Thickening and raising dam abutments
- Thickening and raising of the central spillway
- Auxiliary spillway modifications
- Other infrastructure and elements
- Environmental flows infrastructure
- Demobilisation and site restoration

2.3.6 Construction materials

Raw materials (such as flyash, sand, cement and aggregates) to produce concrete would generate the majority of materials required for the project. The estimated volume and type of concrete for the main components of construction are presented in Table 2-1.

Table 2-1: Volume and type of concrete required

Project element	Cubic metres of concrete
Abutment and central spillway	520,000
Bridges	12,700
Auxiliary Spillway	88,500
Total	621,200

An assessment of potential sources of aggregates, flyash and cement was undertaken for the concept design. Quarries in the Blue Mountains, Southern Highlands, Central Coast and South Coast were identified as capable of supplying coarse aggregates suitable for the project. Flyash would be sourced from coal fired power stations in the region or elsewhere if NSW supplies are running low. Cement would be sourced from suppliers in the Sydney region.

Further assessment during construction planning and detailed design would determine the preferred source locations.

Table 2-2: Weight of materials for concrete production for the duration of the project

Materials	Kilograms per cubic metre of structural concrete	Kilograms per cubic metre of mass concrete	Total weight (tonnes)
Cement	240	100	75,123
Flyash	80	135	89,580
Coarse aggregate	1,100	1,250	846,874
Fine Aggregate (Sand)	800	800	546,656

2.3.7 Spoil and waste management

The project would generate spoil due to the earthworks carried out. Some material may be able to be reused on project for temporary or permanent works, or other off-site projects. Spoil may be temporarily stockpiled before being permanently placed. Once spoil has been placed permanently placed, the area would be covered in topsoil and replanted with suitable native vegetation.

Waste materials would be generated from the demolition of existing dam elements such as the hydro blasting, dam road, radial and drum gates, other electrical and mechanical infrastructure and concrete demolition. These materials would be disposed of off-site.

3. AIR QUALITY CRITERIA

3.1 Impact assessment criteria

The *"Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales"* (Approved Methods) (DEC, 2017) specify air quality assessment criteria relevant for assessing impacts from air pollution. The air quality criteria relate to the total dust burden in the air and not just the dust from proposed activities such as land clearing and construction activities. In other words, consideration of background dust levels needs to be made when using these criteria to assess potential impacts.

Table 3-1 presents the air quality criteria for concentrations of particulate matter that are relevant to this study. For PM_{10} and $PM_{2.5}$, these are consistent with the revised National Environment Protection Measure for Ambient Air Quality (referred to as the Ambient Air-NEPM) (NEPC, 2016). However, the NSW EPA's criteria include averaging periods which are not included in the Ambient Air-NEPM, and reference other measures of air quality, namely TSP.

Table 3-1: NSW EPA air quality criteria for particulate matter concentrations

Pollutant	Standard	Averaging Period	Source
PM_{10}	50 µg/m^3 25 µg/m^3	24-Hour Annual	NSW EPA (2016)
$PM_{2.5}$	25 µg/m^3 8 µg/m^3	24-Hour Annual	NSW EPA (2016)
TSP	90 µg/m^3	Annual	NSW EPA (2016)

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

Table 4.2 shows the maximum acceptable increase in dust deposition over the existing dust levels from an amenity perspective, as well as the maximum total overall dust deposition. These criteria for dust fallout levels are set to protect against nuisance impacts (EPA, 2016).

Table 3-2: NSW criteria for dust deposition (insoluble solids)

Pollutant	Averaging period	Maximum increase	Maximum total
Deposited dust	Annual	2 g/m^2/month	4 g/m^2/month

4. EXISTING ENVIRONMENT

4.1 Local meteorology and sensitive receptors

Dispersion models require information about the meteorology (dispersion characteristics) of a study area. In particular, data are required on wind speed, wind direction, temperature, atmospheric stability class and mixing height.

A nearby available meteorological station was the OEH Bringelly station, which is located approximately 15 kilometres (km) south-east of the project. Five years of wind data were analysed for this site and the results are presented as a time series in Figure 4-1. The analysis shows that 2017 is a representative year and in fact, may even represent a conservative year in terms of background dust levels due to the low rainfall levels. Annual and seasonal wind roses are presented in Appendix A for each year from 2013 – 2017 and are all very similar.

Having determined that 2017 was a representative year, the TAPM (The Air Pollution Model) was used to characterise the meteorological conditions at the project site in 2017. TAPM is a prognostic model that generates meteorological data for each hour of the year, taking into account local terrain against a background of larger scale meteorology provided by synoptic analyses. These data were used in the assessment.

Figure 4-2 shows annual and seasonal wind roses based on this analysis for the project site in the modelling year, 2017. The wind roses show that on an annual basis, prevailing winds are light and from the west southwest quadrant. Winds from this quadrant are dominant throughout the year. The annual average wind speed is 1.7 m/s and the annual percentage of calms (winds less than 0.5 m/s) is 3.5%. Higher wind speeds are most often experienced during the winter months.

Figure 4-3 shows the receptors nearest to the areas of activity. These are representative of receptors which may potentially be most impacted by dust from construction of the project. Most of these sensitive receptors are located within a radius of 1 km, and mainly to the east of, the project construction areas. Many receptors are located downwind of the dominant west southwest winds.

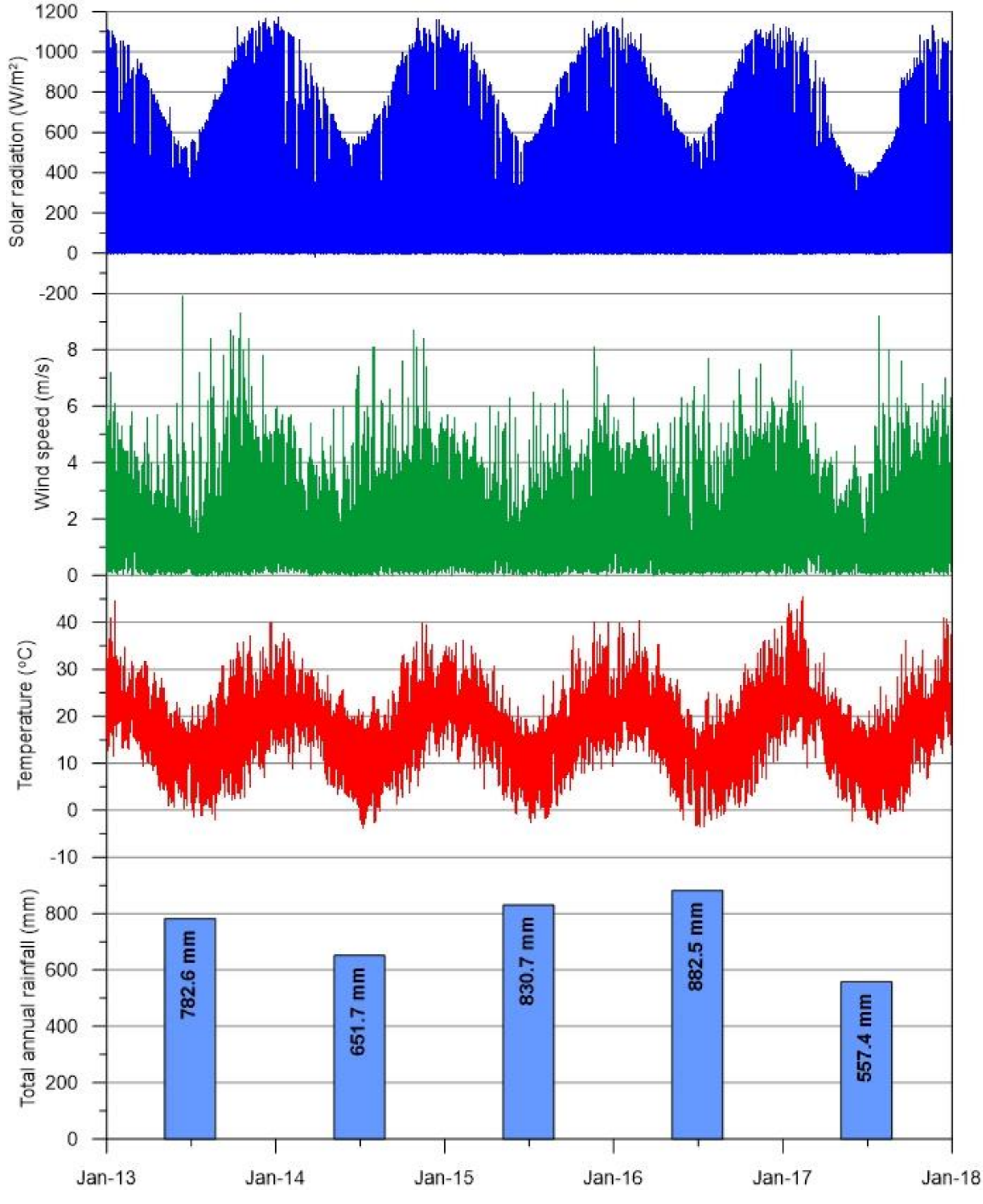

Figure 4-1: Five year data summary for Bringelly (2013 – 2017)

Figure 4-2: Annual and seasonal wind roses for 2017 (TAPM)

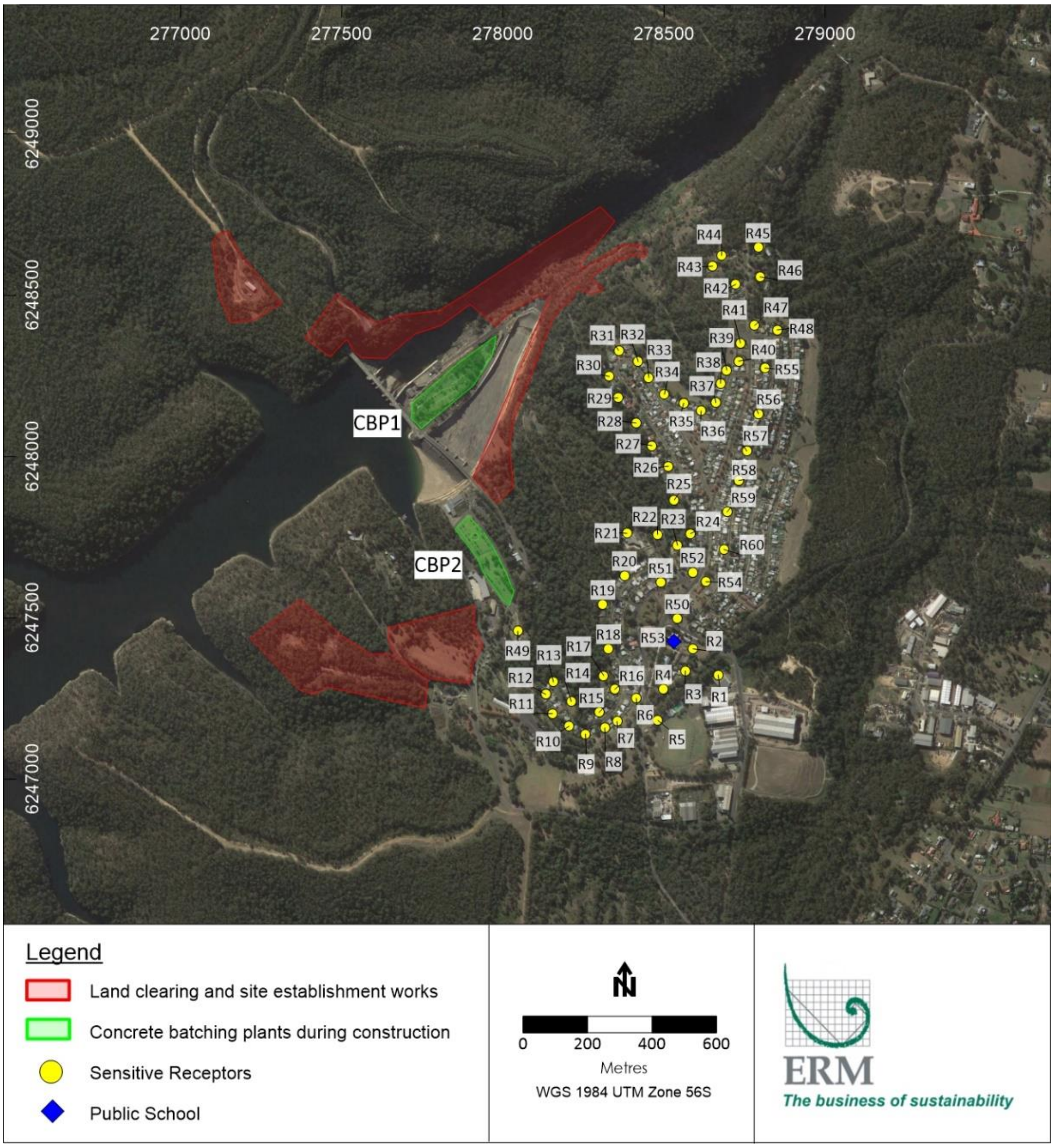

Figure 4-3 Sensitive receptors.

4.2 Existing air quality and background concentrations

Air quality standards and criteria refer to pollutant levels that include the contribution from specific projects and existing sources. To assess impacts against the relevant standards and criteria listed in Section 3, it is necessary to have information or estimates on existing dust concentrations in the area in which the Modification is likely to contribute to these levels.

Air quality monitoring has not been undertaken specifically for the project. However, the NSW Office of Environment and Heritage (OEH) monitors air quality at numerous locations around NSW. Monitoring data collected by the NSW EPA at Bringelly, St. Mary's, Oakdale and Camden stations are some of the closest air quality monitoring sites to the study area. These OEH monitoring stations with the exception of Oakdale are located in residential areas close to road networks and may be likely to record higher PM concentrations than the site given that the project site is less exposed to local sources such as fine particles from vehicle exhaust. The measured values are therefore likely to be conservative when applied as background levels to the site.

Table 4-1 and Table 4-2, as well as Figure 4-4 and Figure 4-5 summarise the PM_{10} and $PM_{2.5}$ monitoring data from Bringelly, St. Mary's, Oakdale and Camden OEH monitoring stations. The highest annual mean PM_{10} and $PM_{2.5}$ concentrations were 19.8 µg/m^3 and 7.5 µg/m^3 respectively. In both cases, the concentrations were below the annual mean air quality criterion of 25 µg/m^3 for PM_{10} and 8 µg/m^3 for $PM_{2.5}$.

In terms of the 24 hour mean PM_{10} and $PM_{2.5}$ concentrations, the highest recorded concentrations were 100.2 µg/m^3 and 93.2 µg/m^3 respectively. In both cases, the concentration exceeded the 24 hour mean air quality criterion of 50 µg/m^3 for PM_{10} and 25 µg/m^3 for $PM_{2.5}$.

Table 4-1: Annual average PM_{10} and $PM_{2.5}$ concentrations (µg/m^3)

Year	Bringelly		St. Mary's		Oakdale		Camden	
	PM_{10} (µg/m3)	**$PM_{2.5}$ (µg/m^3)**	**PM_{10} (µg/m3)**	**$PM_{2.5}$ (µg/m^3)**	**PM_{10} (µg/m3)**	**$PM_{2.5}$ (µg/m^3)**	**PM_{10} (µg/m3)**	**$PM_{2.5}$ (µg/m^3)**
EPA Criterion	***25***	***8***	***25***	***8***	***25***	***8***	***25***	***8***
2014	16.6	n/a	16.7	n/a	13.1	n/a	16	6.3
2015	15.8	n/a	15	n/a	11.4	n/a	14	6.2
2016	16.9	n/a	16.1	n/a	12.2	n/a	14	6.4
2017	19.8	7.5	16.2	7	12.1	6	15	6.7

n/a: No monitoring data was available

Table 4-2: Maximum 24 hour average PM_{10} and $PM_{2.5}$ concentrations (µg/m^3)

Year	Bringelly		St. Mary's		Oakdale		Camden	
	PM_{10} (µg/m3)	**$PM_{2.5}$ (µg/m^3)**	**PM_{10} (µg/m3)**	**$PM_{2.5}$ (µg/m^3)**	**PM_{10} (µg/m3)**	**$PM_{2.5}$ (µg/m^3)**	**PM_{10} (µg/m3)**	**$PM_{2.5}$ (µg/m^3)**
EPA Criterion	***50***	***25***	***50***	***25***	***50***	***25***	***50***	***25***
2014	42.6	n/a	45.0	n/a	56.3	n/a	41.4	18.5
2015	57.0	n/a	53.0	n/a	61.7	n/a	62.4	25.0
2016	61.6	21.6	100.2	93.2	75.9	12.6	43.6	36.0
2017	83.7	52.5	49.8	38.2	49.8	25.5	46.8	27.7

n/a: No monitoring data available

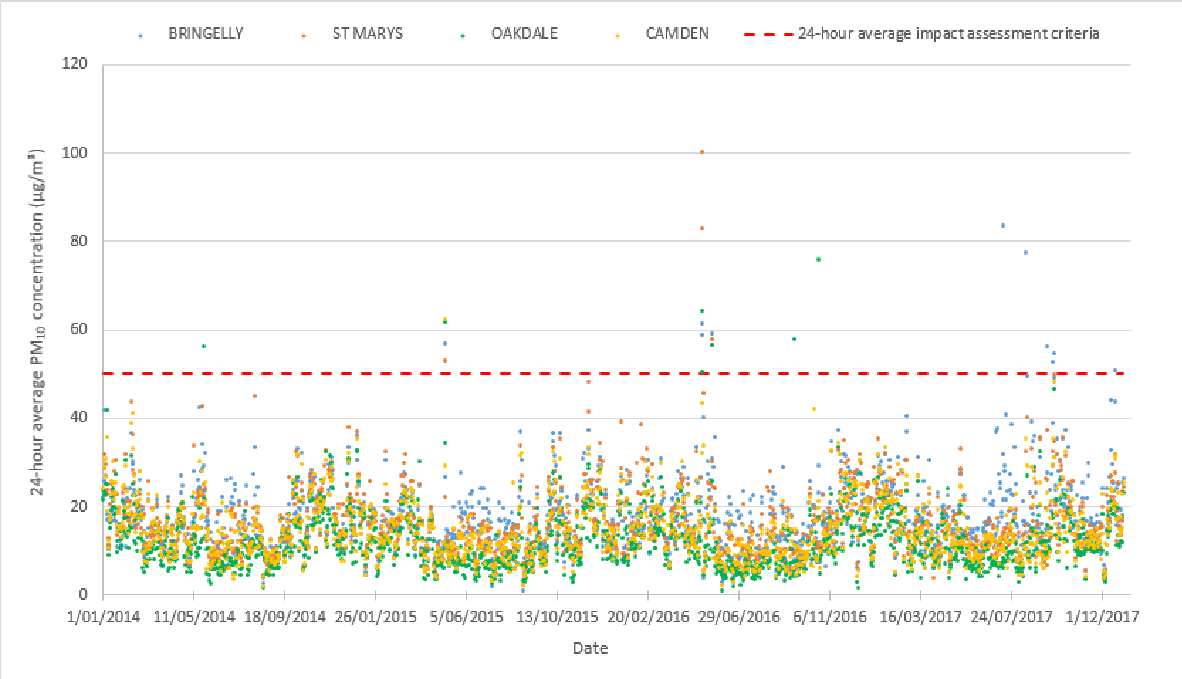

Figure 4-4: 24-hour average PM_{10} concentration (µg/m³).

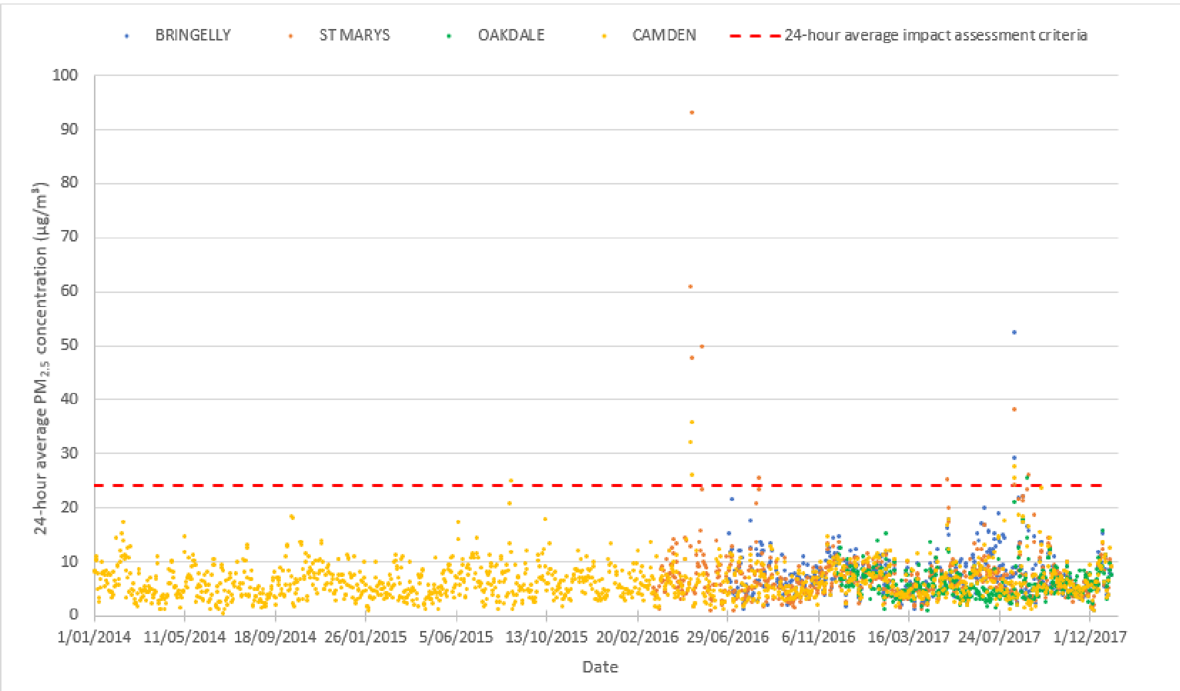

Figure 4-5: 24-hour average $PM_{2.5}$ concentration (µg/m³).

As shown in Table 4-2 and Figures 4-3 and 4-4, the 24 hour mean PM_{10} and $PM_{2.5}$ criterion of 50 µg/m³ and 25 µg/m³ were exceeded at least once between 2014 and 2017. Many of these exceedances are likely attributable to regional events such as bushfires or dust storms rather than specific local sources. Using the maximum monitored concentrations as background levels to which the contribution from the Project can be added is therefore an overly conservative and unrealistic approach, especially in the case of particulate matter, and has therefore not been adopted here.

24-hour average PM_{10} and $PM_{2.5}$ concentrations fluctuate considerably from day to day. To assess the cumulative impacts for short-term impacts a contemporaneous assessment was carried out using monitoring data and model predictions. As the monitoring sites were some distance from the site, the maximum at each of the four sites, for each day, was used to represent conditions at the project location. This showed concentrations exceeded the 24-hour average criterion for PM_{10} and $PM_{2.5}$ on a number of occasions throughout the year.

As there were no measured TSP or dust deposition data available, it was assumed that PM_{10} was approximately 40% of TSP. This relationship was obtained from data collected by co-located TSP and PM_{10} monitors operated for reasonably long periods of time in the Hunter Valley (NSW Minerals Council, 200). A conservative assumption of background dust deposition was also used, at 2 g/m²/month.

A summary of the background concentrations used is provided in Table 4-3.

Table 4-3: Summary of background concentrations

Pollutant	Background concentration	
	Annual mean	**24-hour mean**
$PM_{2.5}$	7.5 µg/m³	Daily varying
PM_{10}	19.8 µg/m³	Daily varying
TSP	49.5 µg/m³	N/A
Deposited dust	2 g/m²/month	N/A

5. METHODOLOGY

Emissions of particulate matter (TSP, PM_{10} and $PM_{2.5}$) are expected to occur as a result of the site establishment works and construction stages of the Project. Activities related to the operation of the dam are not expected to contribute emissions to air to any significant degree and are not assessed in this report. These may include, emissions from vehicles through engine exhausts including carbon monoxide (CO), minor quantities of sulphur dioxide (SO_2) and nitrogen dioxide (NO_2).

Sources potentially affecting air quality because of activities related to the site establishment and construction may include the following:

- Surface clearance.
- Demolition, blasting and construction works.
- Operation of the two concrete batching plants.

In terms of potential impacts to air quality, this is a site clearing and construction project where the dominant pollutant is dust. It is likely that any odour from flooding would be upstream where there are no identified receptors and so odour has not been assessed further in this report.

5.1 Approach to assessment

The overall approach to the assessment follows the Approved Methods (NSW EPA, 2016) using the Level 2 assessment methodology. The Approved Methods specify how assessments based on the use of air dispersion models should be completed. They include guidelines for the preparation of meteorological data to be used in dispersion models and the relevant air quality criteria for assessing the significance of predicted concentration and deposition rates from proposals.

AERMOD was chosen as the most suitable model due to the source types, location of nearest receptors and nature of local topography. AERMOD is the US-EPA's recommended steady-state plume dispersion model for regulatory purposes and it is an accepted model of the NSW EPA. AERMOD replaced the Industrial Source Complex (ISC) model for regulatory purposes in the US in December 2006 as it provides more realistic results. Ausplume, a steady state Gaussian plume dispersion model developed by the Victorian EPA and frequently used in Australia for simple near-field applications is based on ISC, which has now been replaced by AERMOD.

Even though the terrain is relatively hilly in the project construction area, the sources are non-buoyant and ground-based and the receptors are in close proximity and AERMOD is appropriate in this case.

A significant feature of AERMOD is that the Pasquill-Gifford stability based dispersion is replaced with a turbulence-based approach that uses the Monin-Obukhov length scale to account for the effects of atmospheric turbulence based dispersion.

The AERMOD system includes AERMET, used for the preparation of meteorological input files and AERMAP, used for the preparation of terrain data. Terrain data were sourced from NASA's Shuttle Radar Topography Mission (SRTM) Data (~30m resolution) and processed within AERMAP to create the necessary input files.

5.1.1 Scenarios

There are two significant dust generating stages for this project. These are the initial site establishment works and the general construction works. Figure 5-1 shows the general areas of dust generating activity for each of these scenarios.

The activities associated with each of the stages and relevant for dust emissions are listed below:

- Site establishment works (Scenario 1)
  - Land clearing

  - Topsoil removal and land levelling
  - Spoil and material excavation, loading and stockpiling
  - Truck movements
  - Dozer activity and grading
- Construction (Scenario 2)
  - Blasting
  - Concrete batching
  - Delivery of material to concrete batching plants
  - Truck movements.

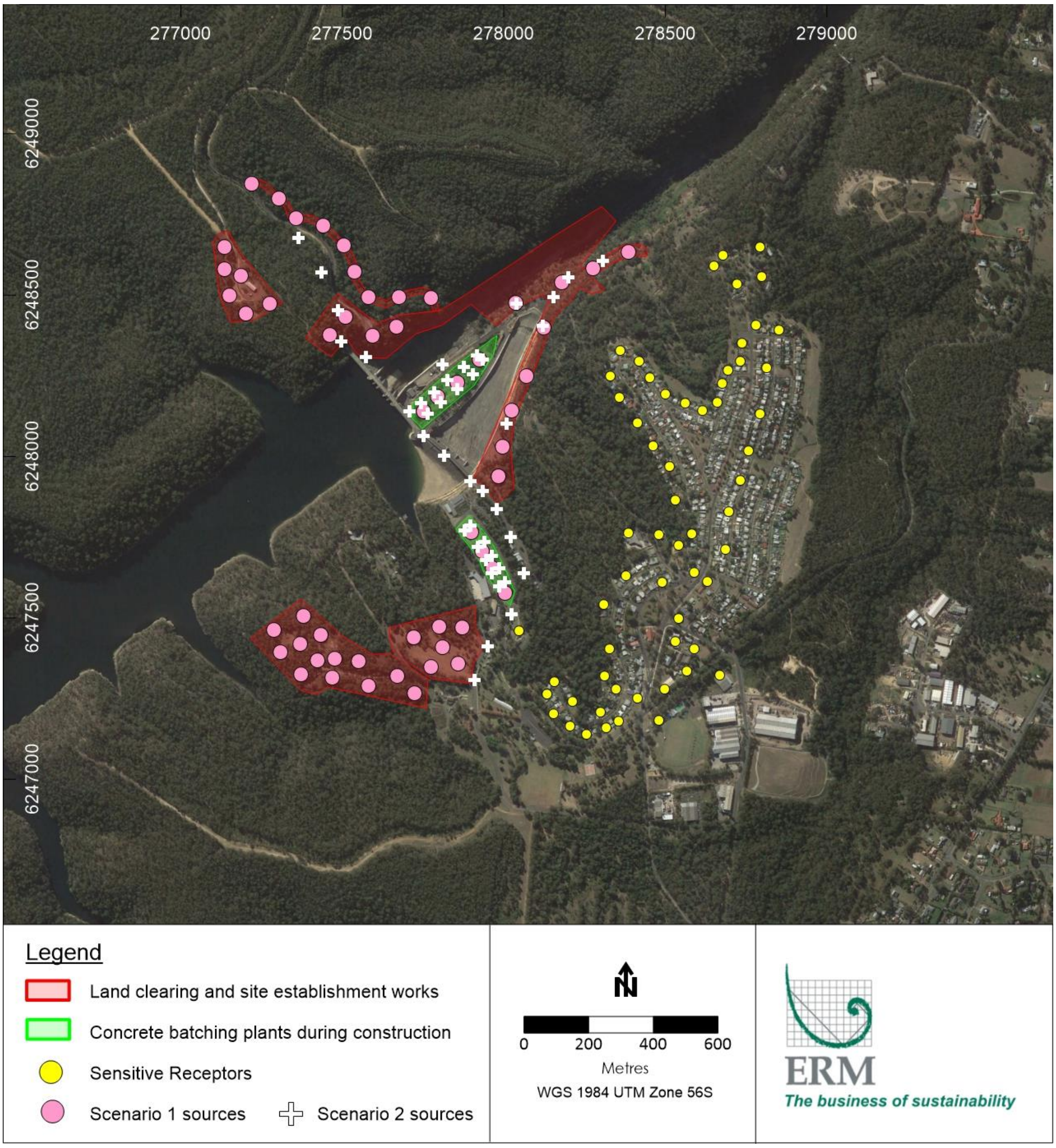

Figure 5-1: Location of dust generating activity for each scenario

5.2 Emissions to Air

The main sources of particulate emissions and their estimated contribution are listed in Table 5-1 and Table 5-2. A summary of calculations is provided in Appendix B. As shown in the tables below and also in Section 6.2, emissions and resulting concentrations are much lower for the construction scenario than for the site establishment works, and well below the criteria. It is noted also that even though the emissions for the site establishment works are noted in kg/y, these are emitted over a much shorter period and so the annual emissions for the modelling have been increased accordingly.

Table 5-1: Estimated emissions for site establishment work scenario

Activity	TSP (kg/y)	PM_{10} (kg/y)	$PM_{2.5}$ (kg/y)
Scrapers stripping topsoil	1,001	252	25
Scraper hauling topsoil to stockpiles	1,601	403	40
Loading topsoil to stockpiles	19	9	1.4
Dozers pushing spoil	5,289	1,166	555
Excavators loading haul trucks	131	62	9
Hauling spoil to stockpiles	4,974	1,065	106
Unloading spoil at stockpiles	131	62	9
Grading roads	5,121	1,789	159
Wind erosion - Exposed cleared land	26,280	13,140	1,971
Total	**44,547**	**17,948**	**2,875**

Table 5-2: Estimated emissions for construction scenario

Activity	TSP (kg/y)	PM_{10} (kg/y)	$PM_{2.5}$ (kg/y)
Hauling of material by aggregate and sand delivery trucks onsite-sealed roads	1,384	266	94
Hauling of material by flyash and cement delivery trucks onsite-sealed roads	162	31	11
Hauling of material by other trucks onsite-sealed roads	232	45	16
Material handling - trucks to aggregate storage bins	177	84	13
Material handling - Conveying aggregate to silos	353	167	25
Residual from de-dusted air loading cement and fly-ash bag house	70	70	4
Blasting	3,703	1,926	111
Total	**6,081**	**2,589**	**274**

Predictions were made at each sensitive receptor, shown in **Figure 4-3**, using the modelling package AERMET / AERMOD. Predictions were also made across a grid which covered a wider area of approximately 3 km x 3 km.

5.3 Crystalline silica

Silica (SiO_2) is a naturally occurring mineral composed of silicon and oxygen. It exists in crystalline and amorphous forms depending on the structural arrangement of the oxygen and silicon atoms. Only the crystalline forms are known to be fibrogenic (causes the formation of fibres) and only the respirable particles (those which are capable of reaching the gas exchange region of the lungs) are considered in determining health effects of crystalline silica.

Human exposure to crystalline silica occurs most often during occupational activities that involve the working of materials containing crystalline silica products (e.g. masonry, concrete, sandstone) or use or manufacture of crystalline silica-containing products. Activities that involve cutting, grinding or breaking of these materials can result in the liberation of particles in multiple size ranges.

Crystalline silica dust is found everywhere in the environment (i.e. not just in an occupational context) due to natural, industrial and agricultural activities as it comprises 12% of the earth's crust (EOG Resources 2014).

Whilst the long term inhalation of silica dust may lead to the formation of scar tissue in the lungs, which can result in the serious lung disease silicosis, this is regarded exclusively as a work place exposure issue that is associated with long-term exposure to high levels of respirable crystalline silica (RCS).

The World Health Organization's Concise International Chemical Assessment Document on Crystalline Silica, Quartz (CICAD, 2000) states that "there are no known adverse health effects associated with the non-occupational exposure to quartz".

In addition, an Australian Government Senate Committee (2005) report identified that there are no reports in the international literature of individuals developing silicosis as a result of exposure to non-occupational levels (i.e. outside the work place) of silica dust, and an expert appearing before the committee confirmed the potential for such an occurrence as being very remote.

A literature review on the potential impacts to health from exposure to crustal material in Port Hedland, WA, states "exposure to airborne quartz carries the risk of silicosis, but only with prolonged exposure to concentrations greater than 200 µg/m^3" (Department of Health, 2007).

In Australia, the occupational exposure standards for respirable crystalline silica are defined by Safe Work Australia. The national exposure standard for respirable crystalline silica is 100 µg/m^3 (Time Weighted Average (TWA)).

Although the occupational standard is not applicable to the assessment of the ambient air quality, the risk of silicosis among people living in areas surrounding activities such as quarrying would therefore be considered minimal provided the concentration of respirable particles at the source was acceptable in terms of occupational safety.

NSW EPA has not set any impact assessment criteria for crystalline silica. The Victorian EPA has adopted an ambient assessment criterion for mining and extractive industries of 3 µg/m^3 (annual average as $PM_{2.5}$) (VEPA, 2007). This has been derived from the Reference Exposure Level (REL)[1] set by the California EPA Office of Environmental Health Hazard Assessment of 3 µg/m^3 (annual average as PM_4) (OEHHA, 2005), at or below which *"no adverse effects are expected for indefinite exposure".*

As will be shown in Section 6, predicted annual average PM_{10} concentrations are well below this level and RCS levels will only be a fraction of this.

[1] RELs are used by the California Environmental Protection Agency as indicators of potential adverse health effects. An REL is a concentration level (g/m^3) or dose (mg/kg/day) at (or below) which no adverse health effects are anticipated for a specified time period. RELs are generally based on the most sensitive adverse health effect reported in the medical and toxicological literature. RELs are designed to protect the most sensitive individuals in the population by the inclusion of margins of safety.

6. MODELLING RESULTS

This section presents tables with the receptor showing the predicted ten highest TSP, Dust Deposition, PM_{10} and $PM_{2.5}$ concentrations for both modelled scenarios – site establishment works and blasting and concrete batching during construction. In addition, predicted levels for each scenario are presented as contour plots. Contours for TSP, dust deposition, PM_{10} and $PM_{2.5}$ are presented for both scenarios.

As shown in the contour plots, the predicted levels of dust and deposition due to the project activities are very low for both scenarios. All levels are well below the assessment criteria for the project alone and even when added to conservative background estimates these are also still below their relevant criteria.

It is also noted that vehicle emissions are not explicitly modelled in this assessment as it is not likely to be a significant component of the total particulates emissions. In terms of total emissions, the more significant sources for this project are the activities mechanically generating dust during earthworks, blasting, land clearing, wheel generated dust, stockpiling and windblown dust.

6.1 Site establishment works

Table 6-1 lists the ten highest concentrations for each pollutant and averaging time, the corresponding receptor ID and location. The table lists the annual average predicted concentrations due to the project only and the total cumulative level in brackets. Project only values are presented for 24-hour averages and further analysis done for cumulative values in Section 6.1.2. The cumulative results are also presented as contours (annual averages).

Table 6-1: Predictions for top ten receptors

Receptor ID	X (m)	Y (m)	Annual average				24-hr mean	
			TSP (µg/m³)	Dust Deposition (g/m²/month)	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)
R11	278154	6247203	N/A	N/A	0.3 (20.1)	0.1 (7.6)	N/A	N/A
R12	278133	6247263	0.3 (49.8)	0.1 (2.1)	0.4 (20.2)	0.1 (7.6)	N/A	N/A
R13	278157	6247301	0.3 (49.8)	0.1 (2.1)	0.4 (20.2)	0.1 (7.6)	N/A	0.5
R14	278212	6247241	N/A	N/A	0.3 (20.1)	0.1 (7.6)	N/A	N/A
R19	278310	6247541	0.3 (49.8)	N/A	0.3 (20.1)	0.1 (7.6)	N/A	N/A
R28	278413	6248104	0.3 (49.8)	0.1 (2.1)	N/A	N/A	N/A	N/A
R29	278357	6248182	0.4 (49.9)	0.1 (2.1)	0.3 (20.1)	0.1 (7.6)	2.3	0.5
R30	278330	6248248	0.4 (49.9)	0.2 (2.2)	0.3 (20.1)	0.1 (7.6)	2.8	0.6
R31	278359	6248329	0.4 (49.9)	0.2 (2.2)	0.3 (20.1)	0.1 (7.6)	2.7	0.6
R32	278420	6248294	0.3 (49.8)	0.1 (2.1)	0.3 (20.1)	0.1 (7.6)	2.3	0.6
R33	278453	6248245	0.3 (49.8)	0.1 (2.1)	N/A	N/A	2.1	0.5
R34	278501	6248193	N/A	0.1 (2.1)	N/A	N/A	N/A	N/A
R42	278723	6248534	N/A	N/A	N/A	N/A	1.8	0.4
R43	278651	6248590	N/A	N/A	N/A	N/A	2.3	0.5
R44	278679	6248623	N/A	N/A	N/A	N/A	2.2	0.5
R45	278792	6248648	N/A	N/A	N/A	N/A	1.7	N/A
R49	278046	6247459	0.9 (50.4)	0.3 (2.3)	0.9 (20.7)	0.2 (7.7)	2.9	0.9

N/A: The predicted level at the indicated receptor is outside the top ten for that pollutant and averaging time

6.1.1 Annual averages

Figure 6-1, Figure 6-2, Figure 6-3 and Figure 6-4 present the cumulative annual average predictions for $PM_{2.5}$, PM_{10}, TSP and deposition, respectively, for the site establishment works scenario.

Predicted levels for all pollutants are small and well below their respective air quality assessment criteria and unlikely to cause any additional exceedances for the duration of the works.

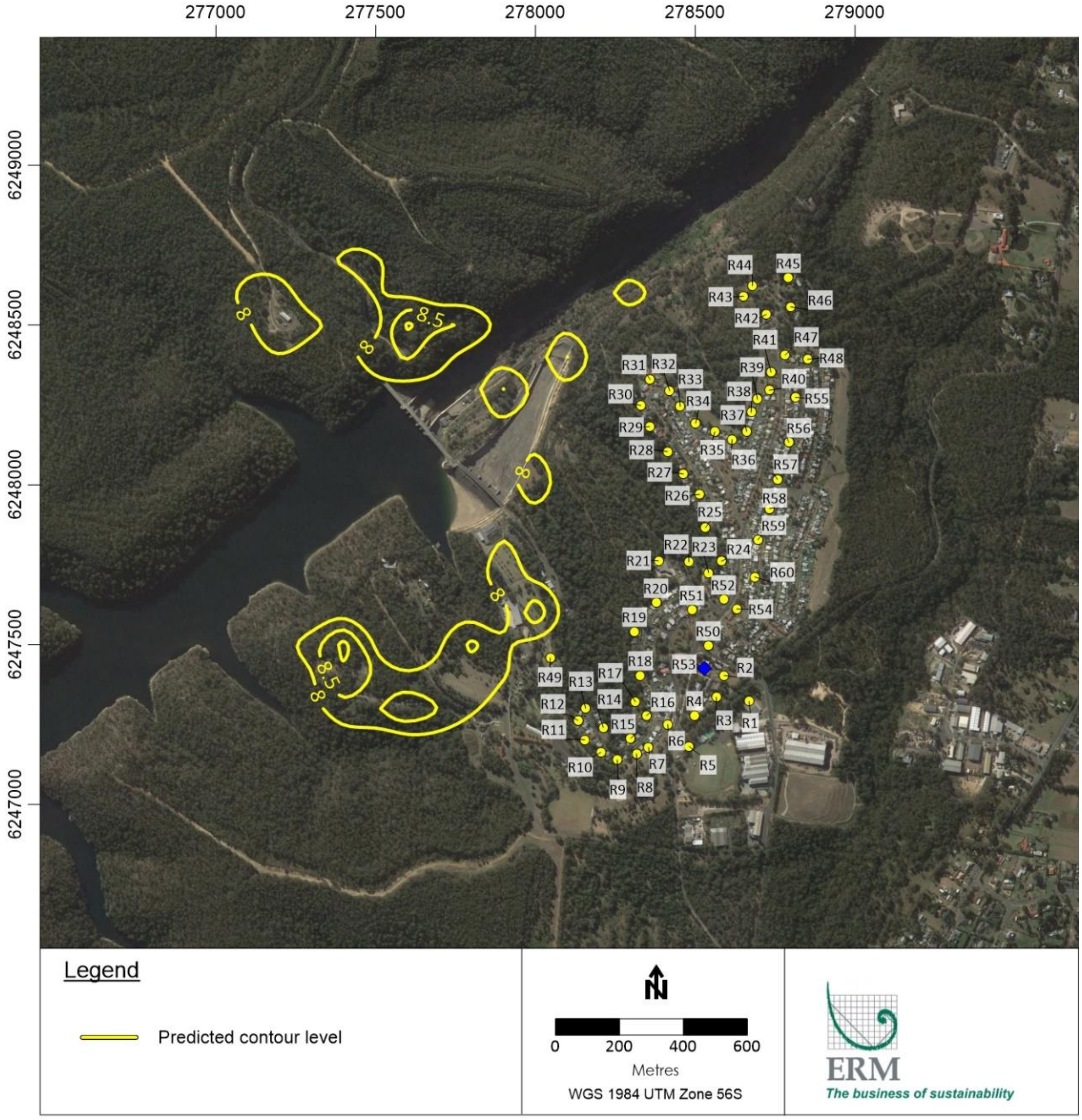

Figure 6-1: Predicted annual average cumulative $PM_{2.5}$ concentrations due to emissions from site establishment works activities (µg/m^3)

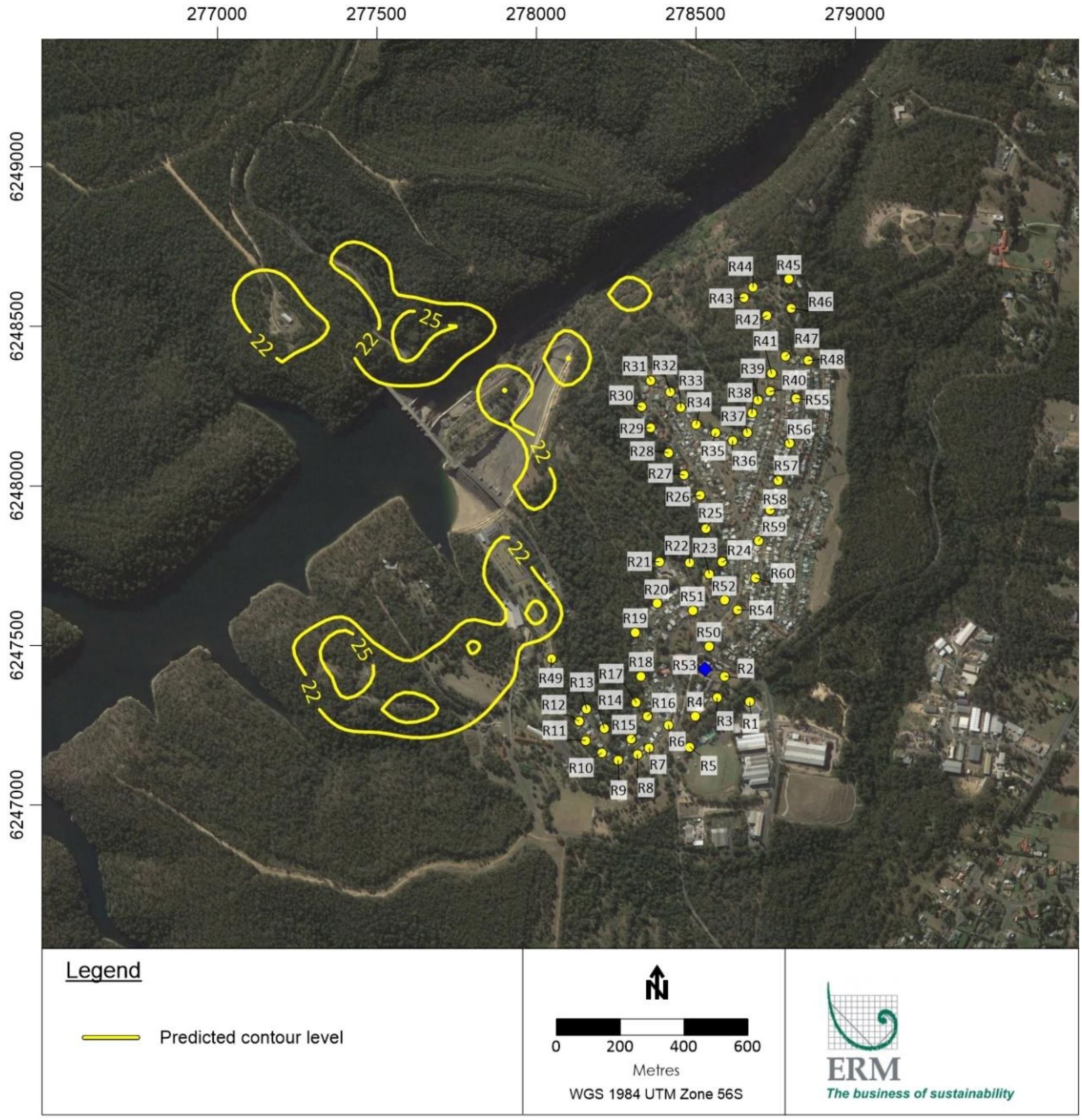

Figure 6-2: Predicted annual average PM_{10} cumulative concentrations due to emissions from site establishment works activities (µg/m^3)

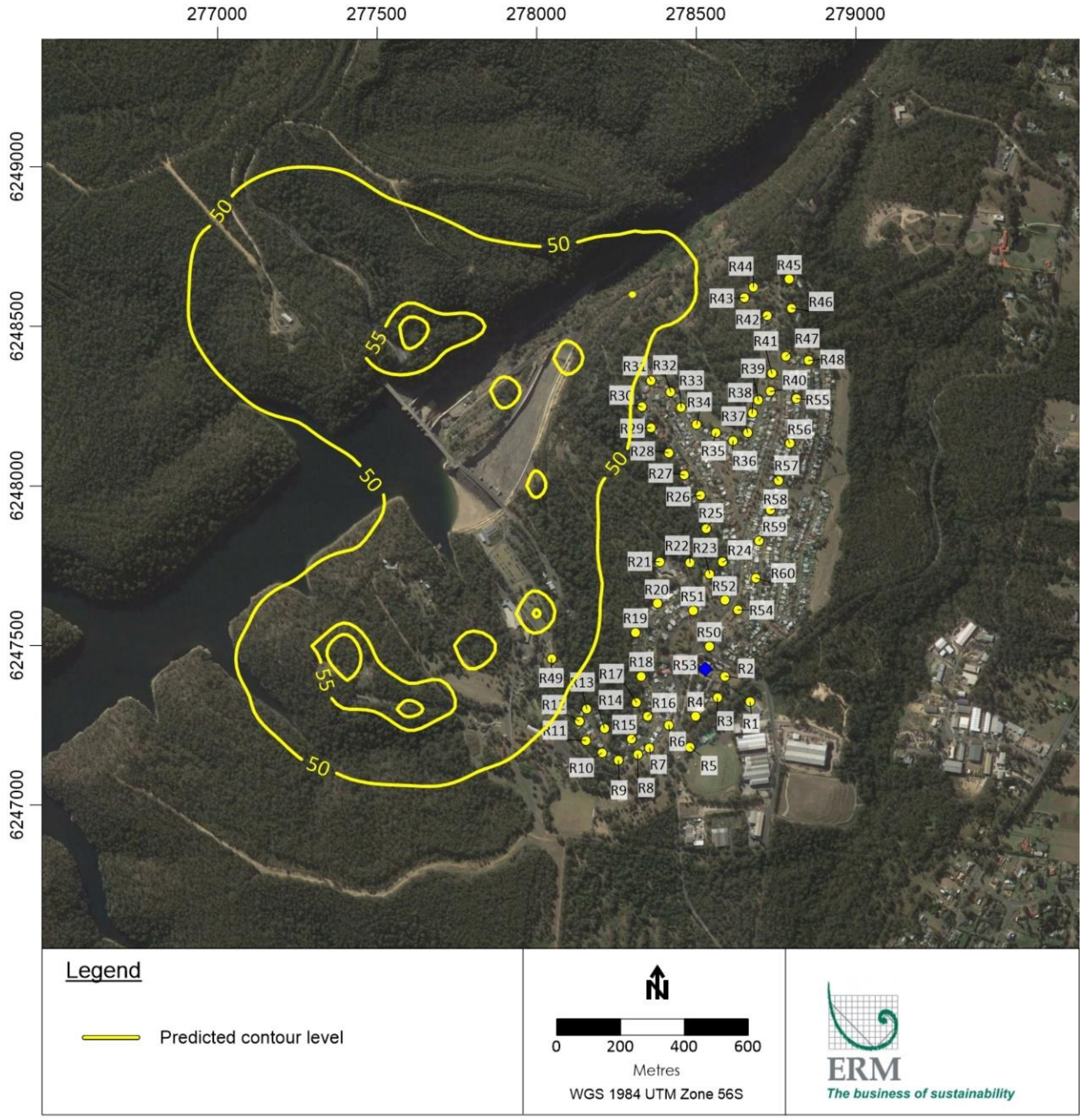

Figure 6-3: Predicted annual average TSP cumulative concentrations due to emissions from site establishment works activities (µg/m3)

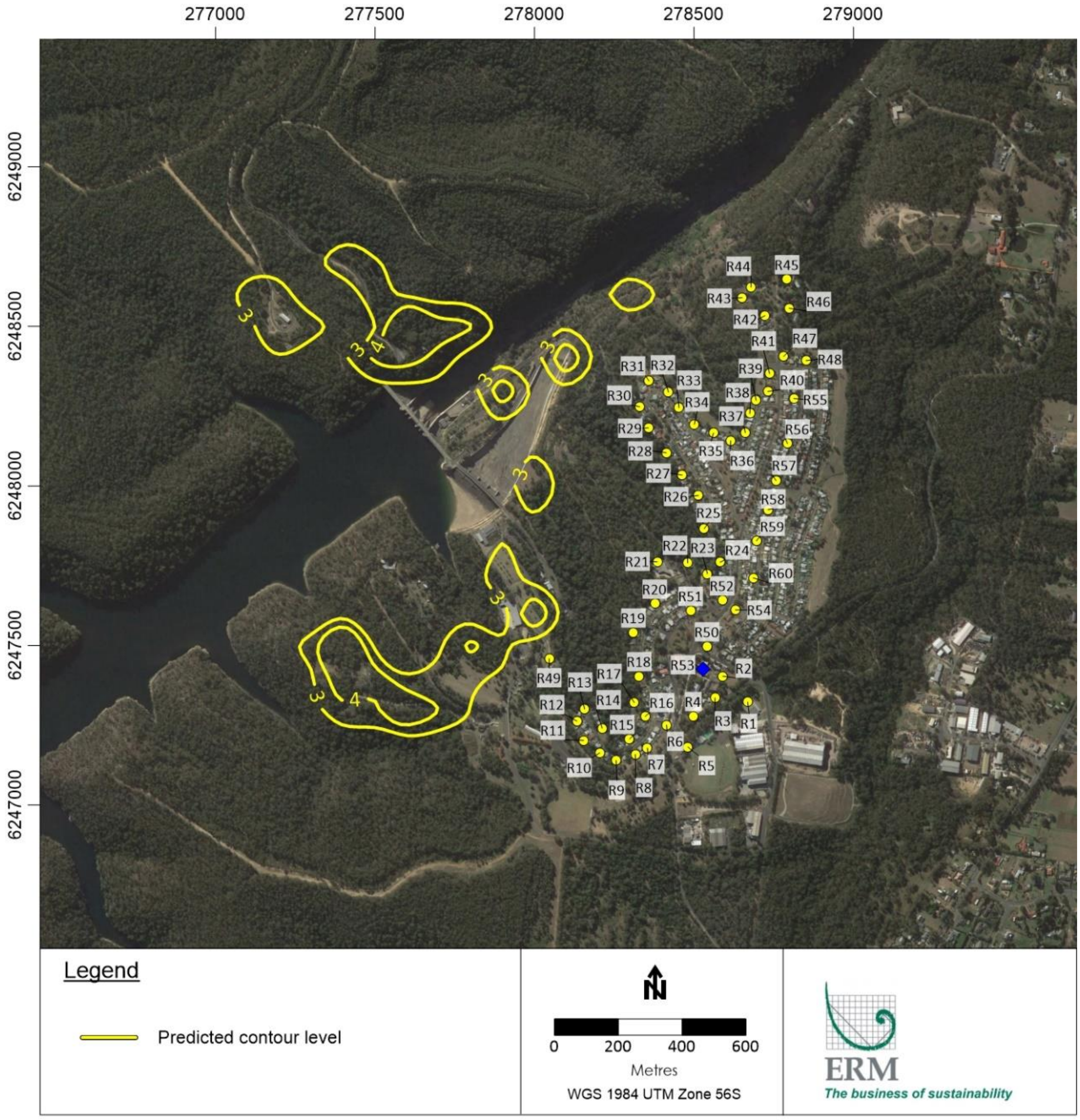

Figure 6-4: Predicted annual average cumulative dust deposition levels due to emissions from site establishment works activities (µg/m³)

6.1.2 Maximum 24-hour averages

Figure 6-5 and Figure 6-6 show the maximum 24-hour average $PM_{2.5}$ and PM_{10} levels, respectively, predicted at the nearest sensitive receptors. Maximum $PM_{2.5}$ levels are estimated to be below 2 µg/m^3 and PM_{10} levels below 5 µg/m^3. These are both well below their respective impact assessment criterion and are unlikely to result in any additional exceedances due to the project.

Further analysis was carried out to predict potential cumulative impacts at the most affected receptor, R49. Results for maximum 24-hour $PM_{2.5}$ concentrations at R49 are shown in Figure 6-7 and results for 24-hour PM_{10} are presented in Figure 6-8. There are five measured exceedances of the 24-hour average $PM_{2.5}$ criterion in the measured background, however, there are no additional exceedances predicted due to emissions from the project at the most affected receptors. For PM_{10}, there is one additional exceedance predicted. However, it is noted that the background value was 49.9 µg/m^3 and combined with a predicted value of only 1.5 µg/m^3 this is only slightly above the criterion. As shown in Figure 6-8 background PM_{10} levels are predominantly below 30 µg/m^3 and exceedances of the criterion are rare and the result of elevated regional dust events.

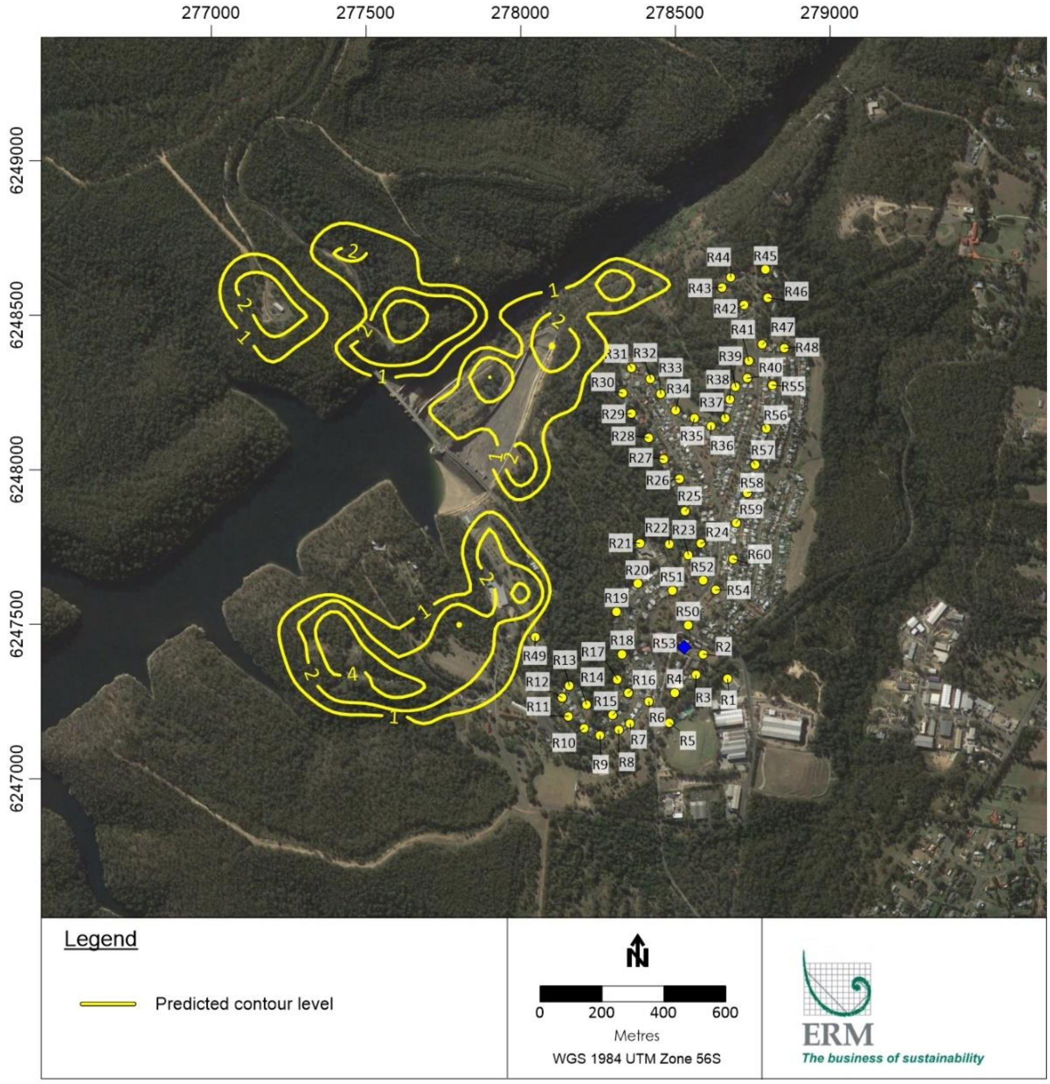

Figure 6-5: Predicted maximum 24-hour average $PM_{2.5}$ concentrations due to emissions from site establishment works activities (µg/m^3)

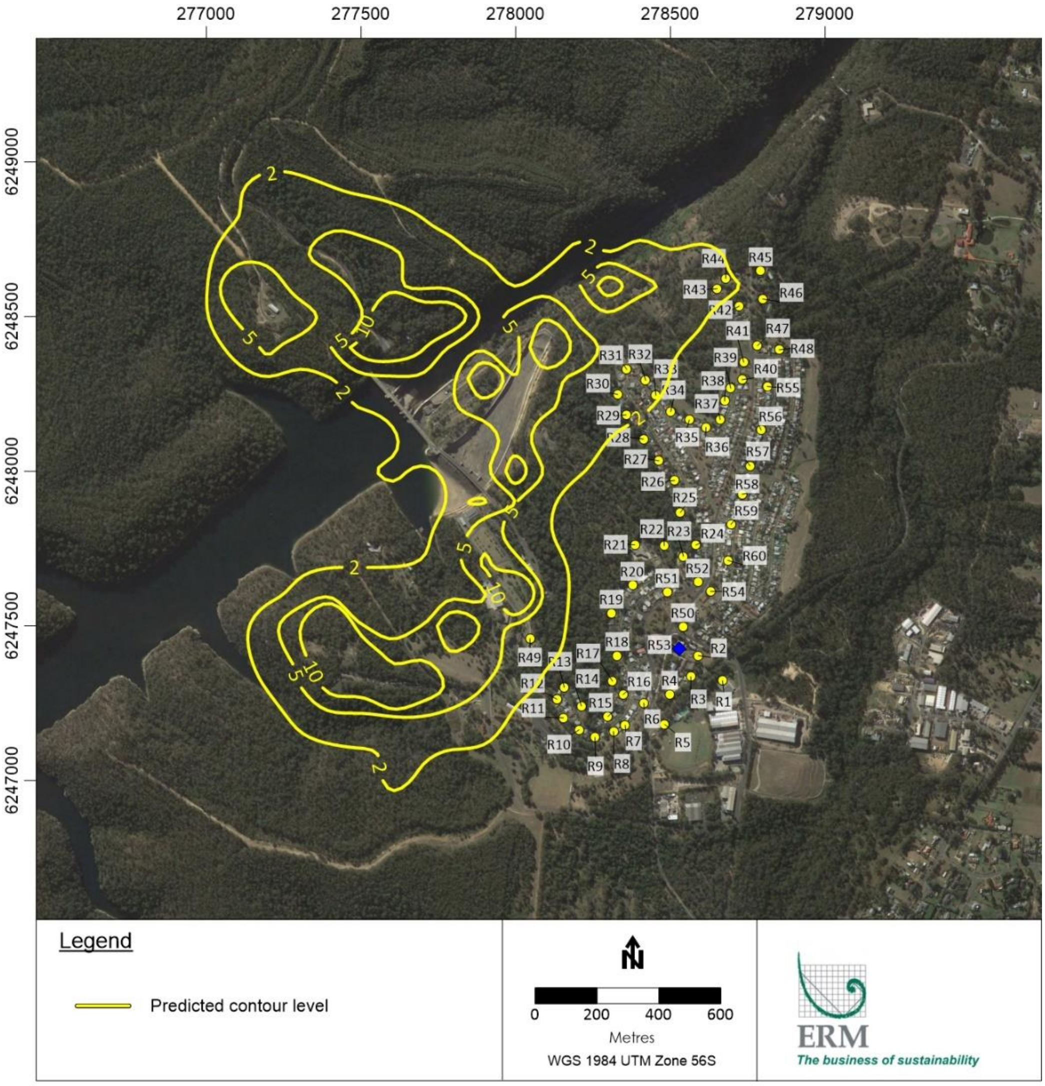

Figure 6-6: Predicted maximum 24-hour average PM_{10} concentrations due to emissions from site establishment works activities (µg/m^3)

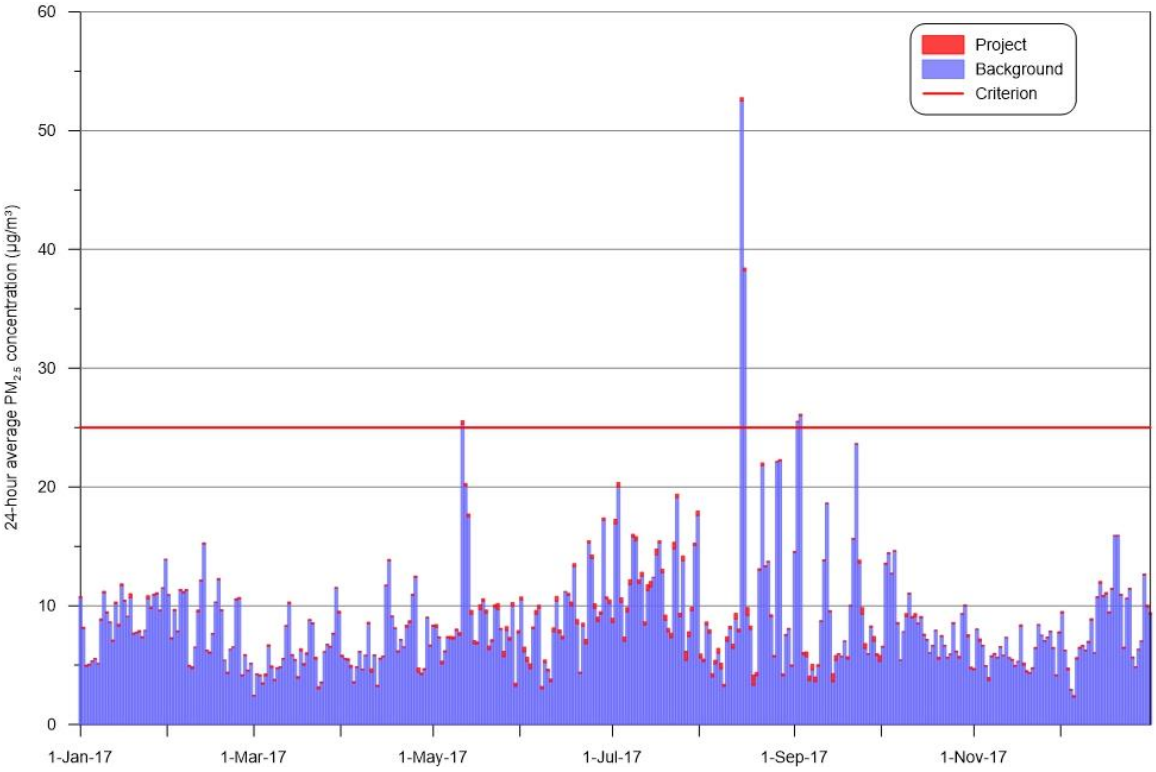

Figure 6-7: Predicted cumulative 24-hour average $PM_{2.5}$ concentrations at R49 due to emissions from site establishment works activities (µg/m³)

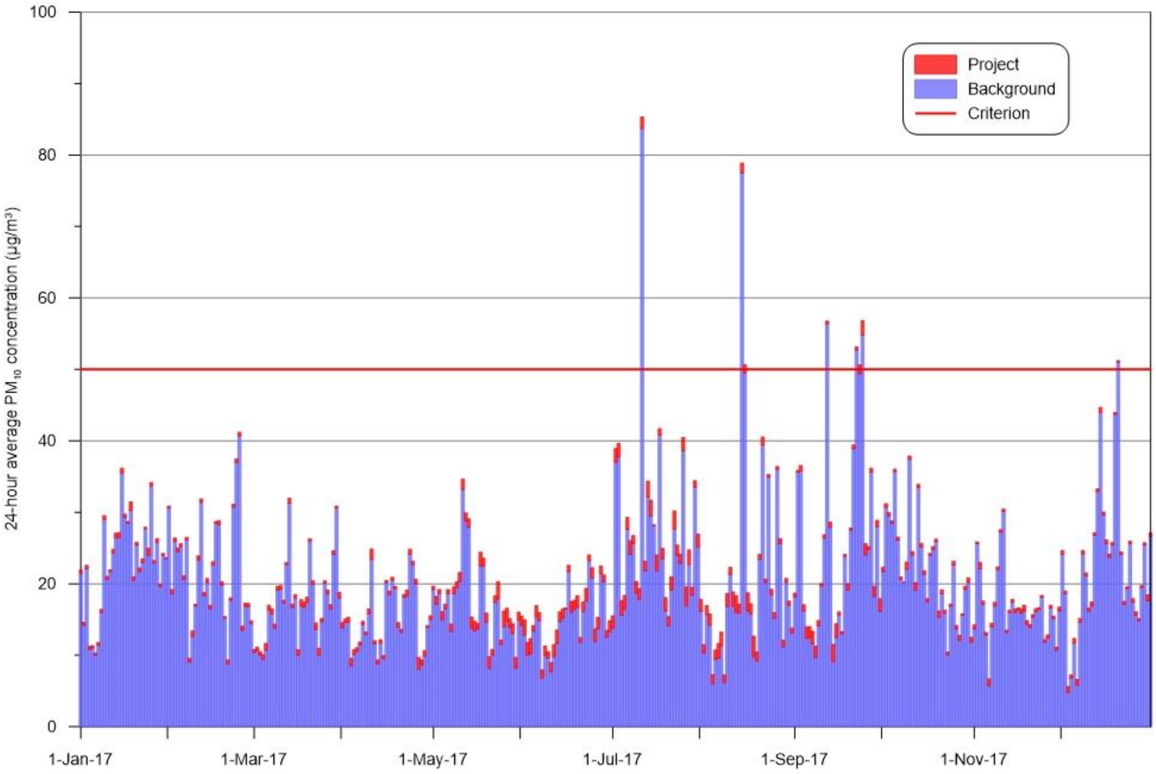

Figure 6-8: Predicted cumulative 24-hour average PM_{10} concentrations at R49 due to emissions from site establishment works activities (µg/m³)

6.2 Construction scenario

Table 6-2 shows the ten highest predicted concentrations for each pollutant and averaging time, the corresponding receptor ID and location. The table lists the annual average predicted concentrations due to the project only and the cumulative level in brackets. Project only values are presented for 24-hour averages and further analysis done for cumulative values in Section 6.2.2. The cumulative results are also presented as contours (annual averages).

Table 6-2: Top 10 highest concentrations

Receptor ID	X (m)	Y (m)	Annual mean				24-hr mean	
			TSP (µg/m^3)	Dust Deposition (g/m^2/month)	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)
R3	278566	6247336	N/A	N/A	N/A	N/A	N/A	0.057
R4	278498	6247279	N/A	N/A	N/A	N/A	0.353	0.061
R11	278154	6247203	N/A	N/A	N/A	N/A	N/A	0.054
R12	278133	6247263	N/A	N/A	N/A	0.01 (7.5)	N/A	0.058
R13	278157	6247301	N/A	N/A	N/A	0.01 (7.5)	N/A	0.061
R18	278328	6247404	N/A	N/A	N/A	N/A	0.346	N/A
R19	278310	6247541	0.05 (49.5)	N/A	N/A	0.01 (7.5)	0.437	0.069
R20	278377	6247631	N/A	N/A	N/A	0.01 (7.5)	0.418	0.053
R21	278385	6247762	N/A	N/A	N/A	0.01 (7.5)	N/A	N/A
R27	278463	6248034	N/A	N/A	N/A	N/A	0.343	N/A
R28	278413	6248104	0.05 (49.5)	0.03 (2.0)	0.05 (19.8)	N/A	N/A	N/A
R29	278357	6248182	0.06 (49.6)	0.04 (2.0)	0.06 (19.9)	0.01 (7.5)	N/A	N/A
R30	278330	6248248	0.08 (49.6)	0.04 (2.0)	0.07 (19.9)	0.01 (7.5)	0.332	N/A
R31	278359	6248329	0.08 (49.6)	0.05 (2.0)	0.07 (19.9)	0.01 (7.5)	N/A	N/A
R32	278420	6248294	0.06 (49.6)	0.04 (2.0)	0.06 (19.9)	0.01 (7.5)	0.321	N/A
R33	278453	6248245	0.05 (49.6)	0.03 (2.0)	0.05 (19.9)	N/A	N/A	N/A
R42	278723	6248534	N/A	0.02 (2.0)	N/A	N/A	N/A	N/A
R43	278651	6248590	0.06 (49.6)	0.03 (2.0)	0.05 (19.9)	N/A	N/A	N/A
R44	278679	6248623	0.06 (49.6)	0.03 (2.0)	0.05 (19.9)	N/A	0.339	N/A
R45	278792	6248648	N/A	N/A	0.04 (19.9)	N/A	0.319	N/A
R49	278046	6247459	0.28 (49.8)	0.09 (2.1)	0.15 (20.0)	0.05 (7.6)	0.762	0.260
R50	278541	6247498	N/A	N/A	N/A	N/A	N/A	0.057
R53	278530	6247426	N/A	N/A	N/A	N/A	N/A	0.0634

NA: The predicted level at the indicated receptor is outside the top ten for that pollutant and averaging time.

6.2.1 Annual averages

Predicted concentrations during the construction scenario are significantly lower than for the site establishment works as shown in the cumulative plots in Figure 6-9 to Figure 6-12.

There are not predicted to be any exceedances of the air quality criteria under the construction scenario.

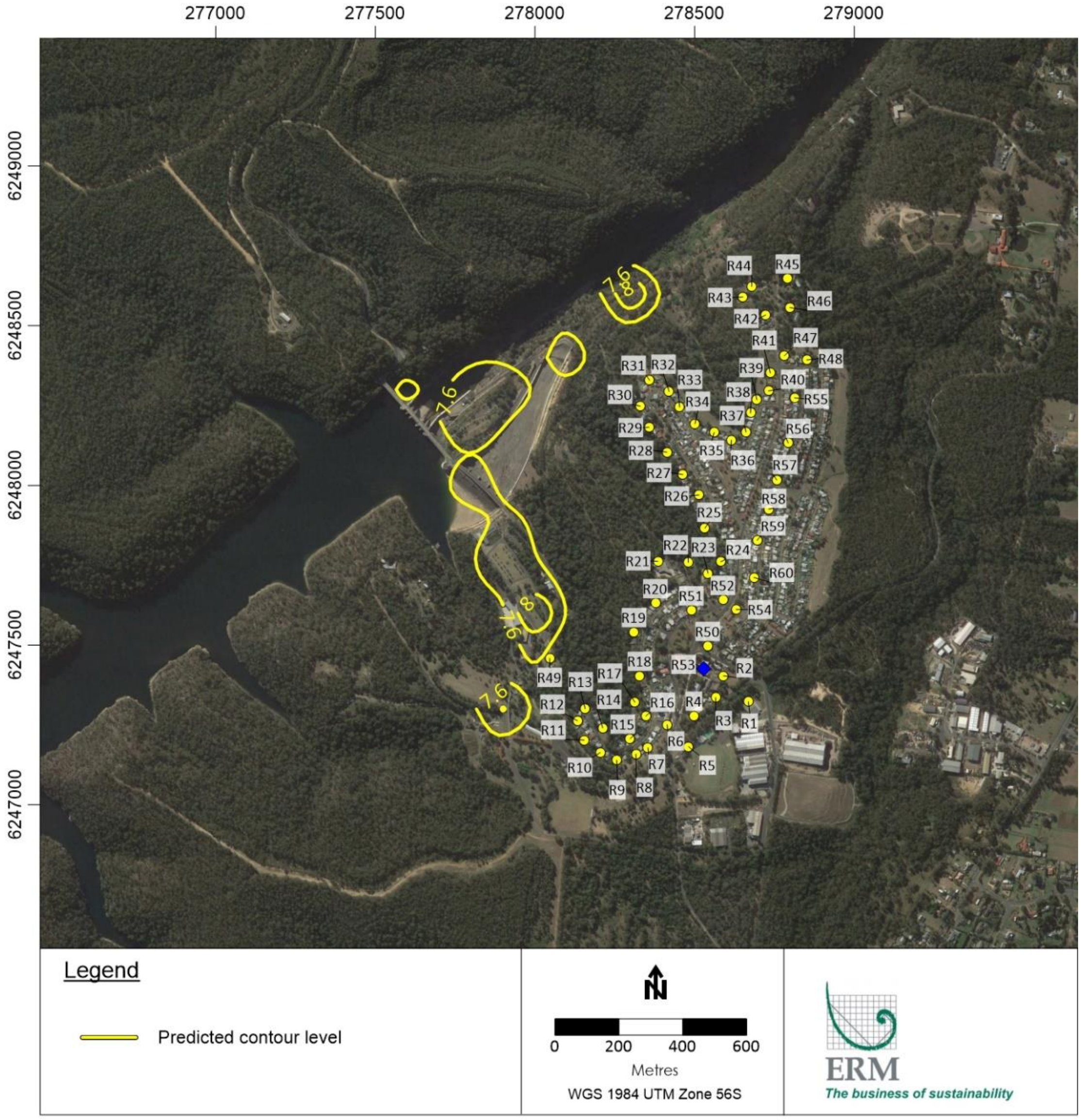

Figure 6-9: Predicted annual average cumulative $PM_{2.5}$ concentrations due to emissions from construction activities (µg/m^3)

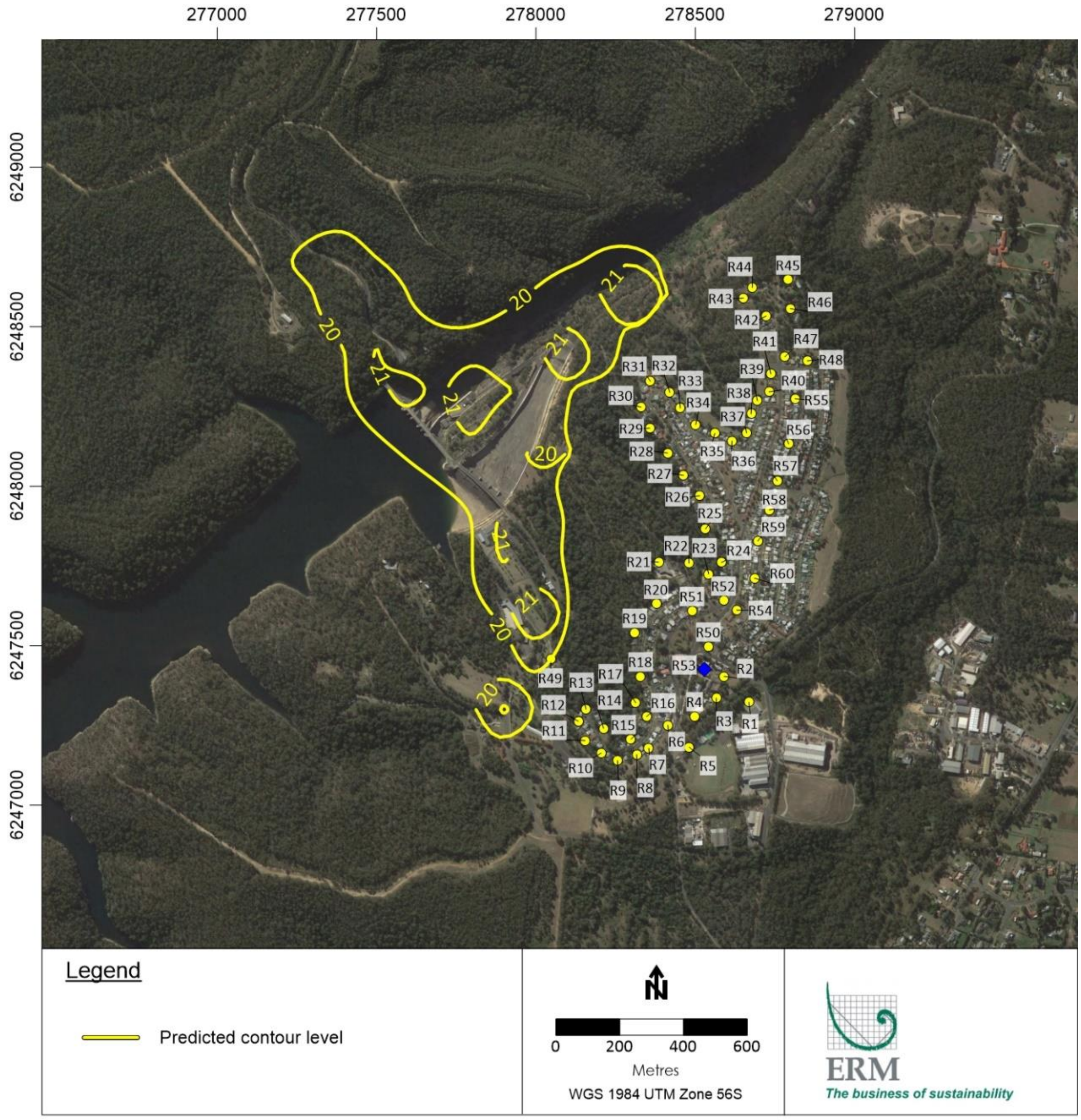

Figure 6-10: Predicted annual average cumulative PM_{10} concentrations due to emissions from main construction activities (µg/m³)

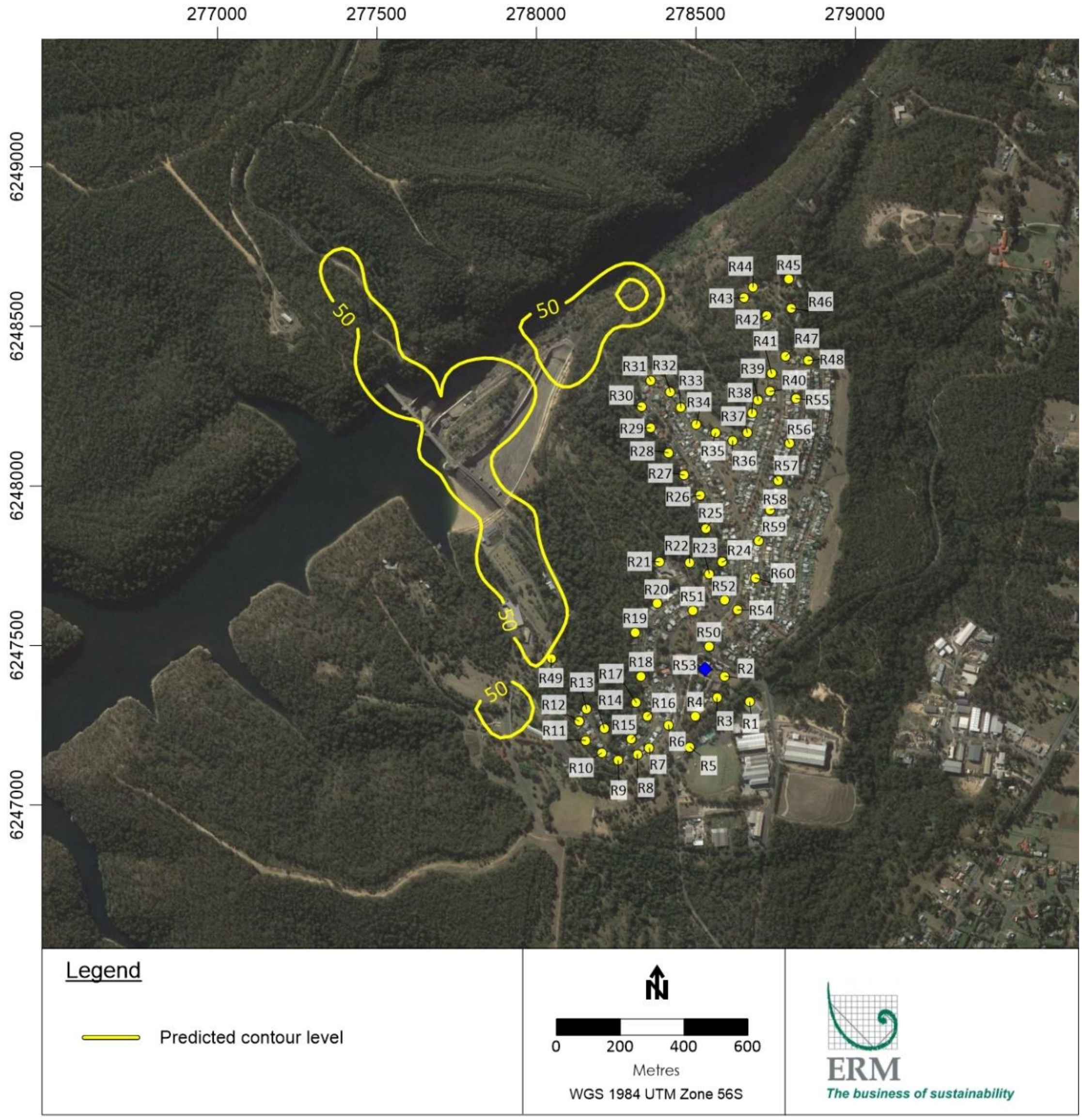

Figure 6-11: Predicted annual average cumulative TSP concentrations due to emissions from main Construction activities (µg/m³)

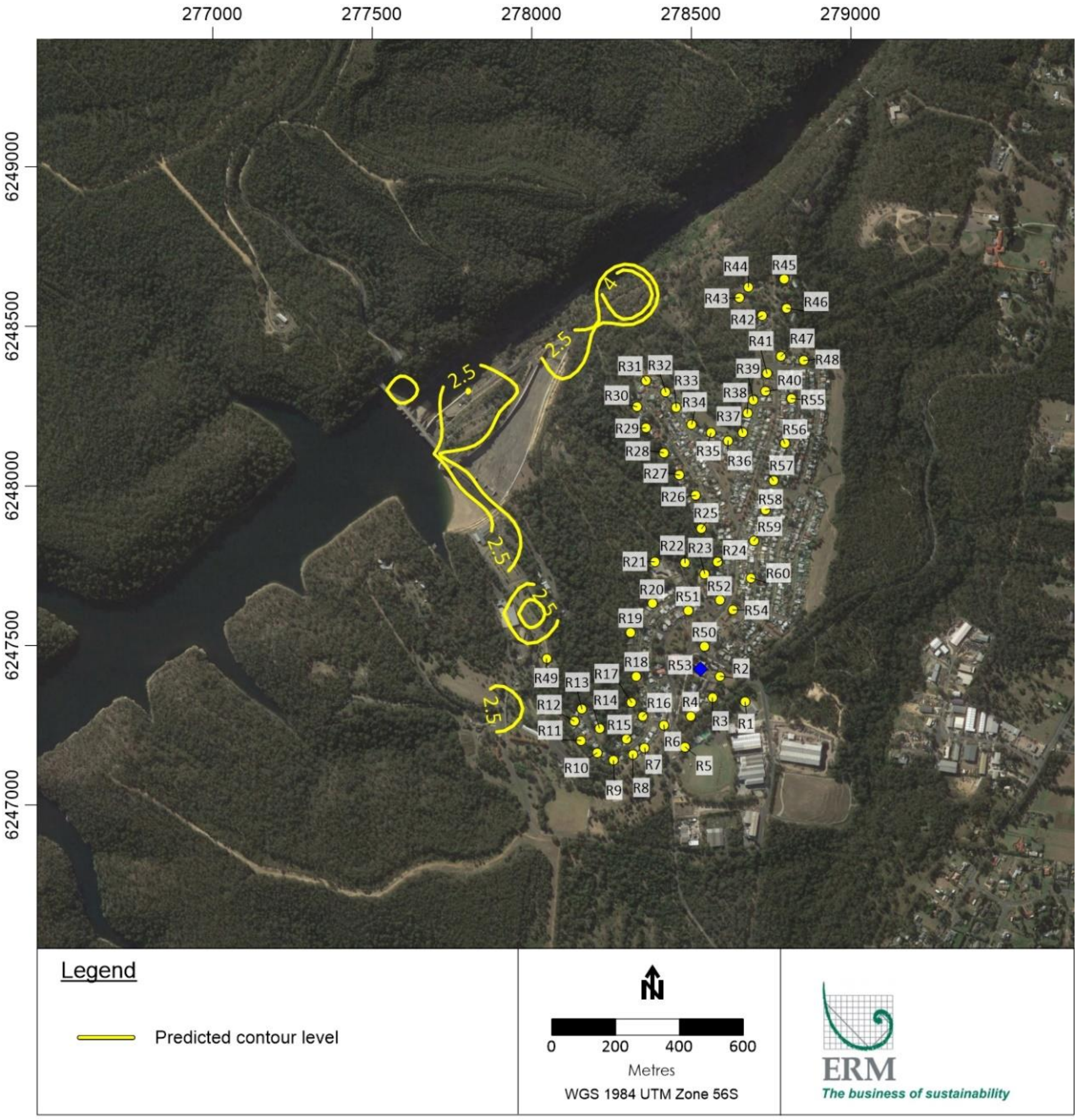

Figure 6-12: Predicted annual average cumulative dust deposition due to emissions from construction activities (µg/m^3)

6.2.2 Maximum 24-hour averages

Figure 6-13 and Figure 6-14 show the maximum 24-hour average $PM_{2.5}$ and PM_{10} levels, respectively, predicted at the nearest sensitive receptors. Maximum $PM_{2.5}$ levels are estimated to be below 0.5 µg/m^3 and PM_{10} levels below 1 µg/m^3. These are both well below the impact assessment criterion and are unlikely to result in any additional exceedances due to the project.

Further analysis was carried out to predict potential cumulative impacts at the most affected receptor, R49. The results for maximum 24-hour $PM_{2.5}$ concentrations are shown in Figure 6-15 for $PM_{2.5}$ and Figure 6-16 for PM_{10}, and present the measured background (maximum of four nearest monitoring sites) and the predicted levels due to the project. There are no predicted additional exceedances.

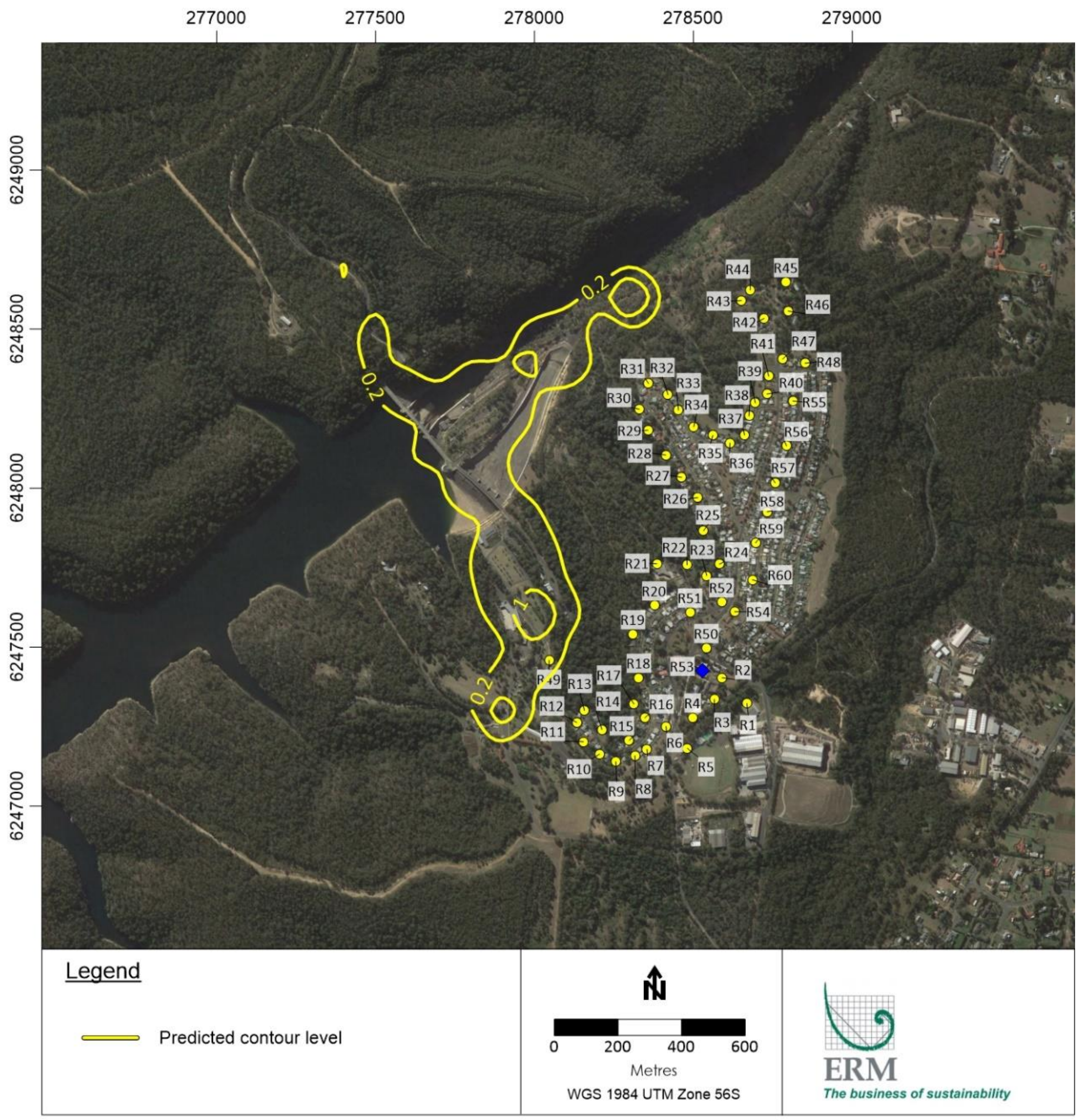

Figure 6-13: Predicted maximum 24-hour average $PM_{2.5}$ concentrations due to emissions from construction activities (µg/m^3)

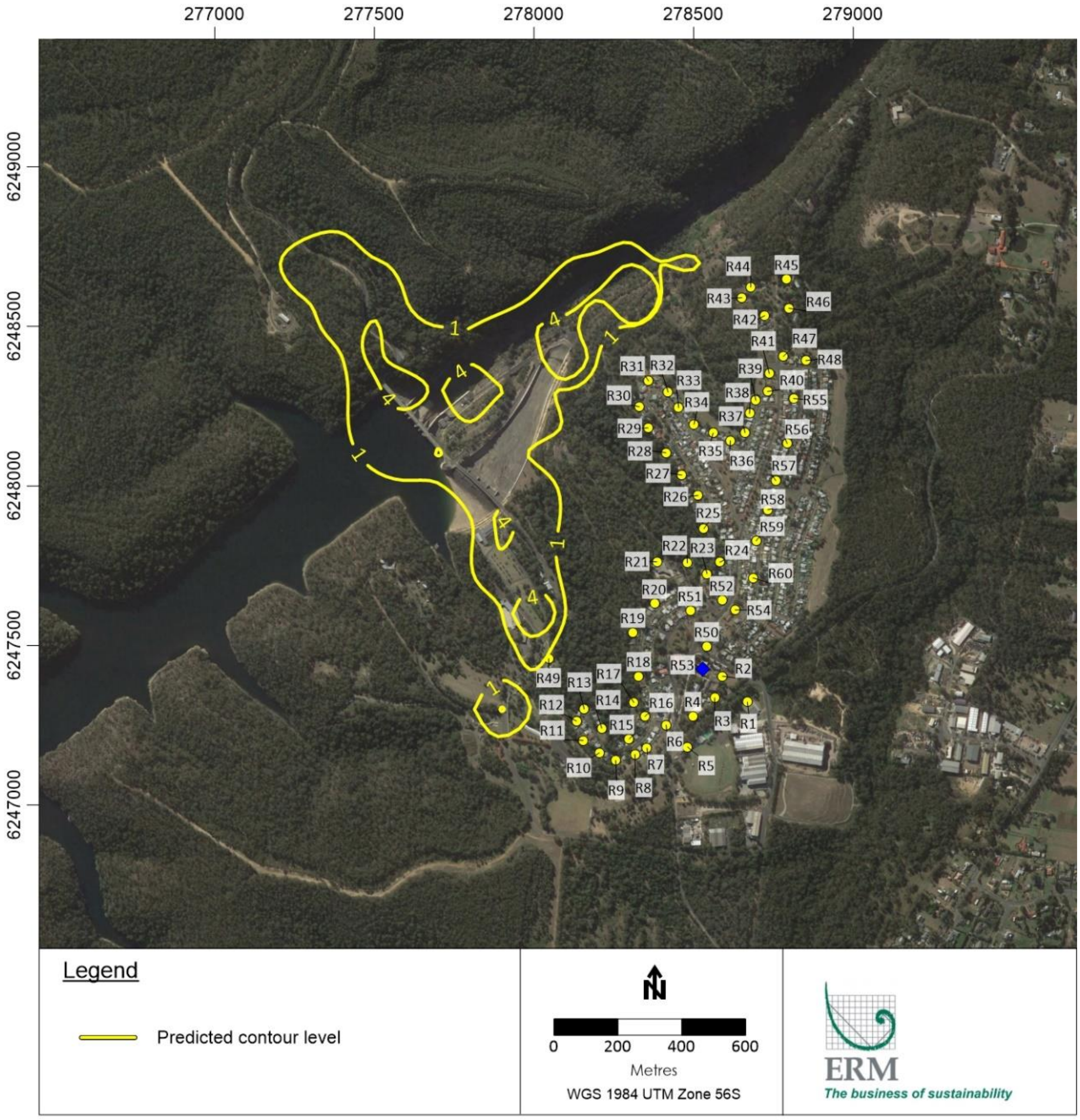

Figure 6-14: Predicted maximum 24-hour average PM_{10} concentrations due to emissions from construction activities (µg/m³)

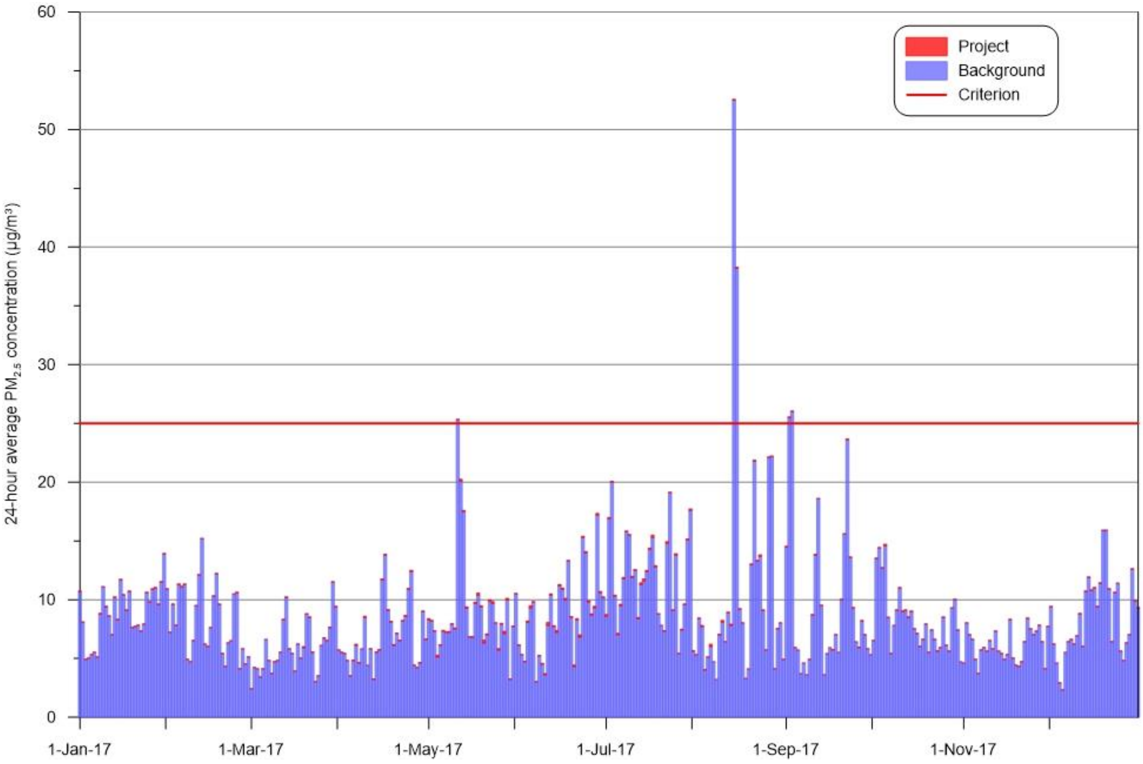

Figure 6-15: Predicted cumulative 24-hour average $PM_{2.5}$ concentrations at R49 due to emissions from construction activities (µg/m³)

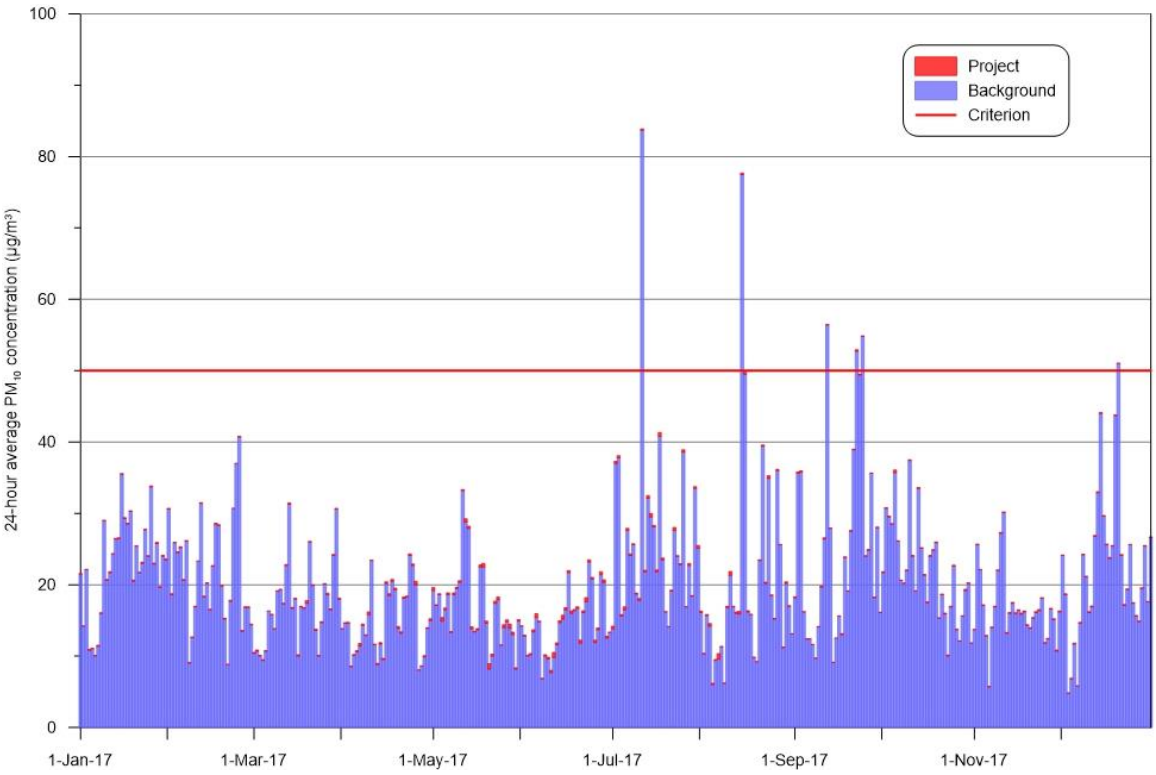

Figure 6-16: Predicted cumulative 24-hour average PM_{10} concentrations at R49 due to emissions from construction activities (µg/m³)

7. MITIGATION MEASURES

A Dust Management Plan should be produced to cover all construction phases of the project. This would contain details of the site-specific mitigation measures to be applied. Recommended mitigation measures are provided in Table 7-1.

Additional guidance on the control of dust at construction sites in NSW is provided as part of the NSW EPA Local Government Air Quality Toolkit[2]. Detailed guidance is also available from the UK (GLA, 2006) and the United States (Countess Environmental, 2006). For precise requirements, reference should be made to the Baseline Conditions of Approval for the project.

Table 7-1: Mitigation Measurements

Prior to works commencing
Develop and implement a stakeholder communications plan to inform and engage the community before work commences on site.
Develop and implement a Dust Management Plan (DMP), which includes measures to control dust emissions as well as identifying roles and responsibilities for operational dust management.
Site management and monitoring
Regular communication with sensitive receptors (residences and schools) in proximity to ensure that measures are in place to manage cumulative dust impacts.
Carry out regular site inspections to monitor compliance with the DMP and for potential dust issues. The site inspection, and issues arising, will be recorded. Increase frequency of inspections when on-site activities with high potential to produce dust are being carried out during prolonged dry or windy conditions.
Record dust and air quality complaints, identify cause(s), take appropriate measures to reduce emissions in a timely manner, and record the measures taken. Recording exceptional incidents may also help to identify causes for complaints.
Preparing and maintaining the site
Land clearing and stockpiling activities with the potential to generate dust will be modified or ceased during unfavourable weather conditions (such as high winds towards receptors) to reduce the potential for dust generation.
Measures to reduce potential dust generation, such as the use of water carts, will be implemented within project sites as required.
Speed limits will be reduced on unsealed roads to reduce dust generation.
Storage of materials that have the potential to result in dust generation will be minimised within project sites at all times. These may include stockpiles of cleared material during site establishment works, or storage of raw materials during concrete batching. Exposed surface areas should be kept to a minimum.
Suitable dust suppression and/or collection techniques, such as mist sprays, will be used during cutting, grinding or sawing activities likely to generate dust in close proximity to sensitive receptors. Drill rig curtains should also be used during the drilling of blast holes.
All vehicles loads will be covered to prevent escape of loose materials during transport.
Unsealed hauling routes and active dozer areas will be treated with water carts and monitored during earthworks operations, ceasing works if necessary during high winds where dust controls are not effective.
Ensure cleared vegetation is removed before it is allowed to rot and become odorous.

[2] http://www.epa.nsw.gov.au/air/lgaqt.htm

8. CONCLUSIONS

This report presents the methodology and results for the assessment of potential air quality impacts from the site establishment and construction activity required for the raising of the Warragamba Dam. Types of activity, as well as quantities of material excavated, transferred and stockpiled have been used to estimate dust emissions from the proposed site establishment and construction activities.

The dispersion modelling showed that there are anticipated to be minor increases in both 24-hour and annual average concentrations. However, the magnitude of these increases is low and unlikely to result in any measureable differences in air quality or exceedances of the EPA air quality assessment criteria at the nearest receptors.

Background monitoring shows that there have been, from time to time, exceedances of these criteria, but these are the result of regional events such as bushfires, dust storms or hazard reduction burning as is also shown in elevated levels in regional data at these times. These events would occur regardless of the project and the project is unlikely to contribute to any significant additional exceedances.

However, it is recommended that a Dust Management Plan be produced to cover the site establishment works, and recommendations for elements of this plan have been provided in the form of suggested management and mitigation measures.

There are no expected changes in air quality due to the operation of the project. The dust generating activities will occur during site clearing and construction and not to any significant extent during the operational phase.

9. REFERENCES

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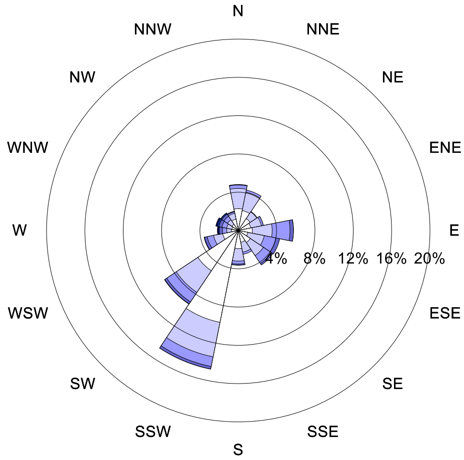
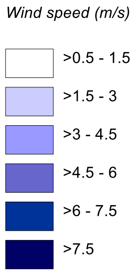
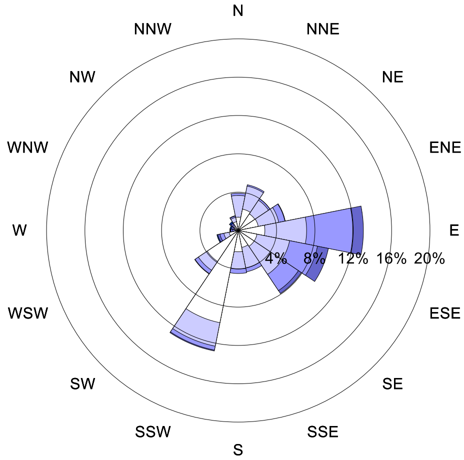
APPENDIX A ANNUAL AND SEASONAL WIND ROSES FOR 2013, 2014, 2015, 2016 AND 2017

Annual and seasonal windroses for OEH Bringelly January - December 2013

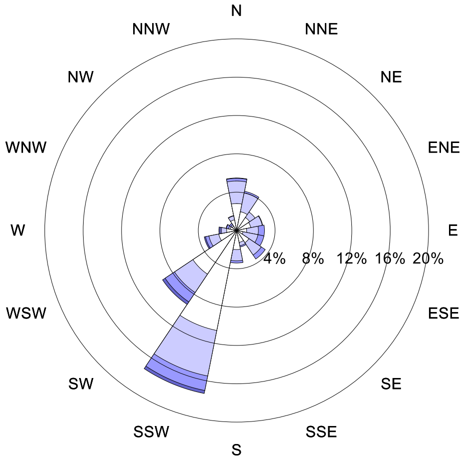


Annual
Calms = 28.7%

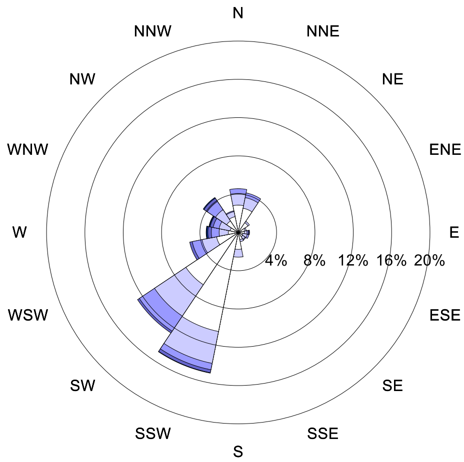




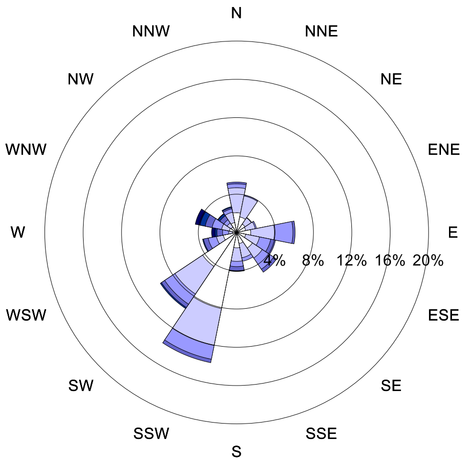
Summer
Calms = 17.8%



Autumn
Calms = 35.2%

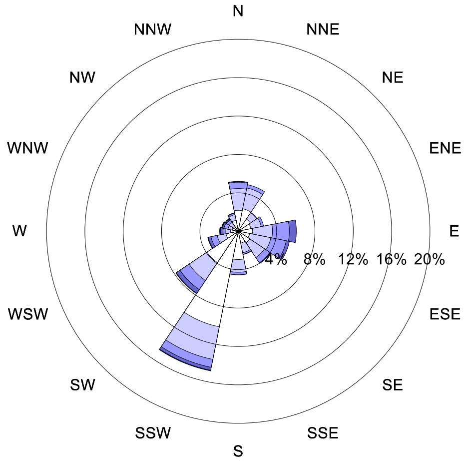


Winter
Calms = 36.1%

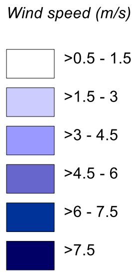


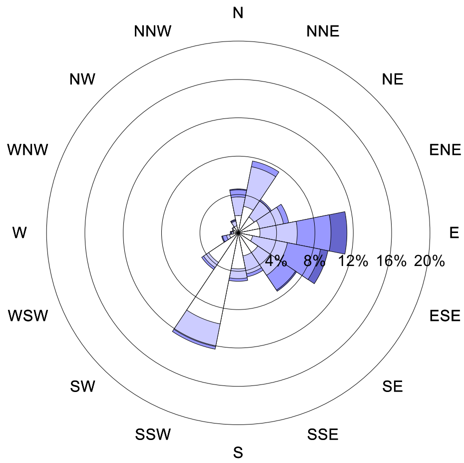
Spring
Calms = 25.2%

Annual and seasonal windroses for OEH Bringelly January - December 2014

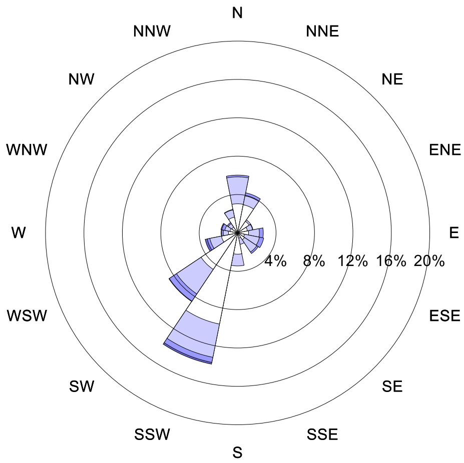


Annual
Calms = 29.1%

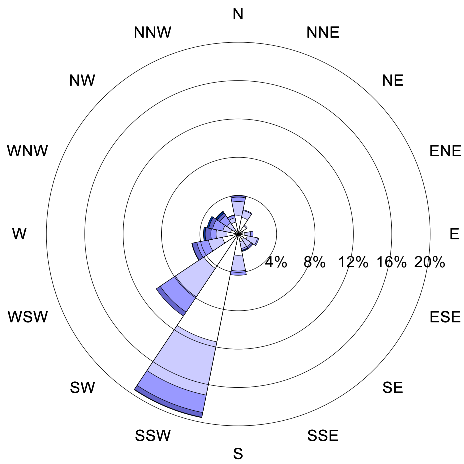




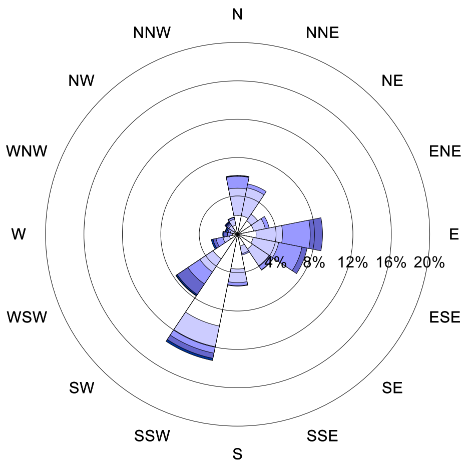
Summer
Calms = 17.9%



Autumn
Calms = 40.5%

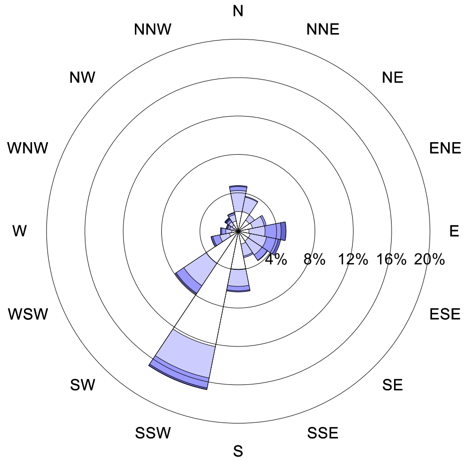


Winter
Calms = 33.5%

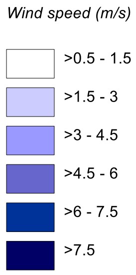


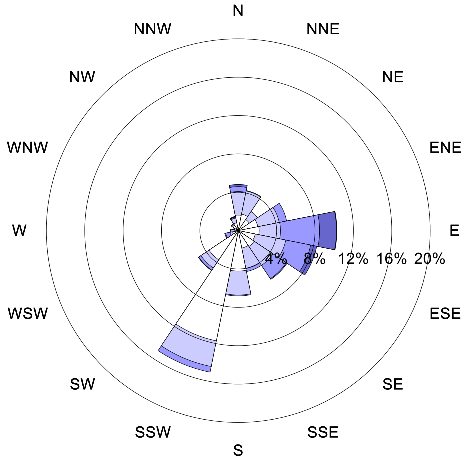
Spring
Calms = 24.1%

Annual and seasonal windroses for OEH Bringelly January - December 2015

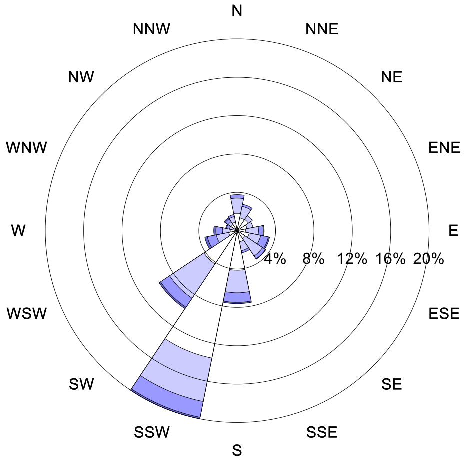


Annual
Calms = 29.7%

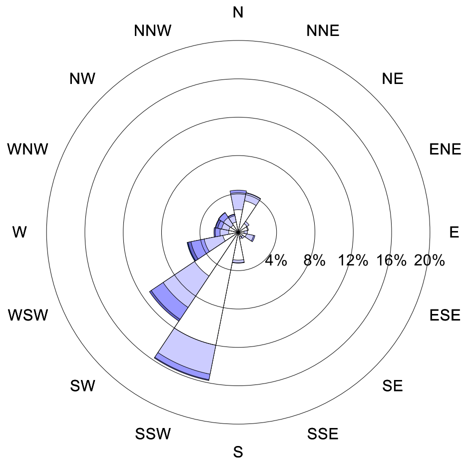




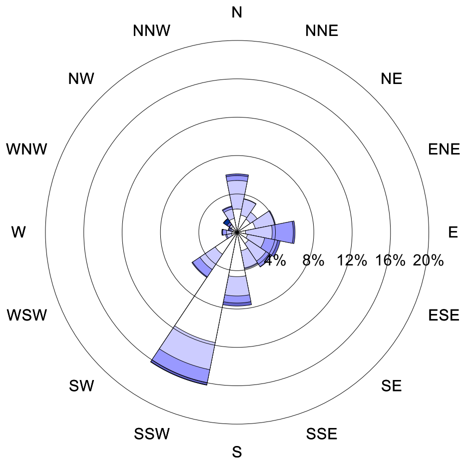
Summer
Calms = 22.3%



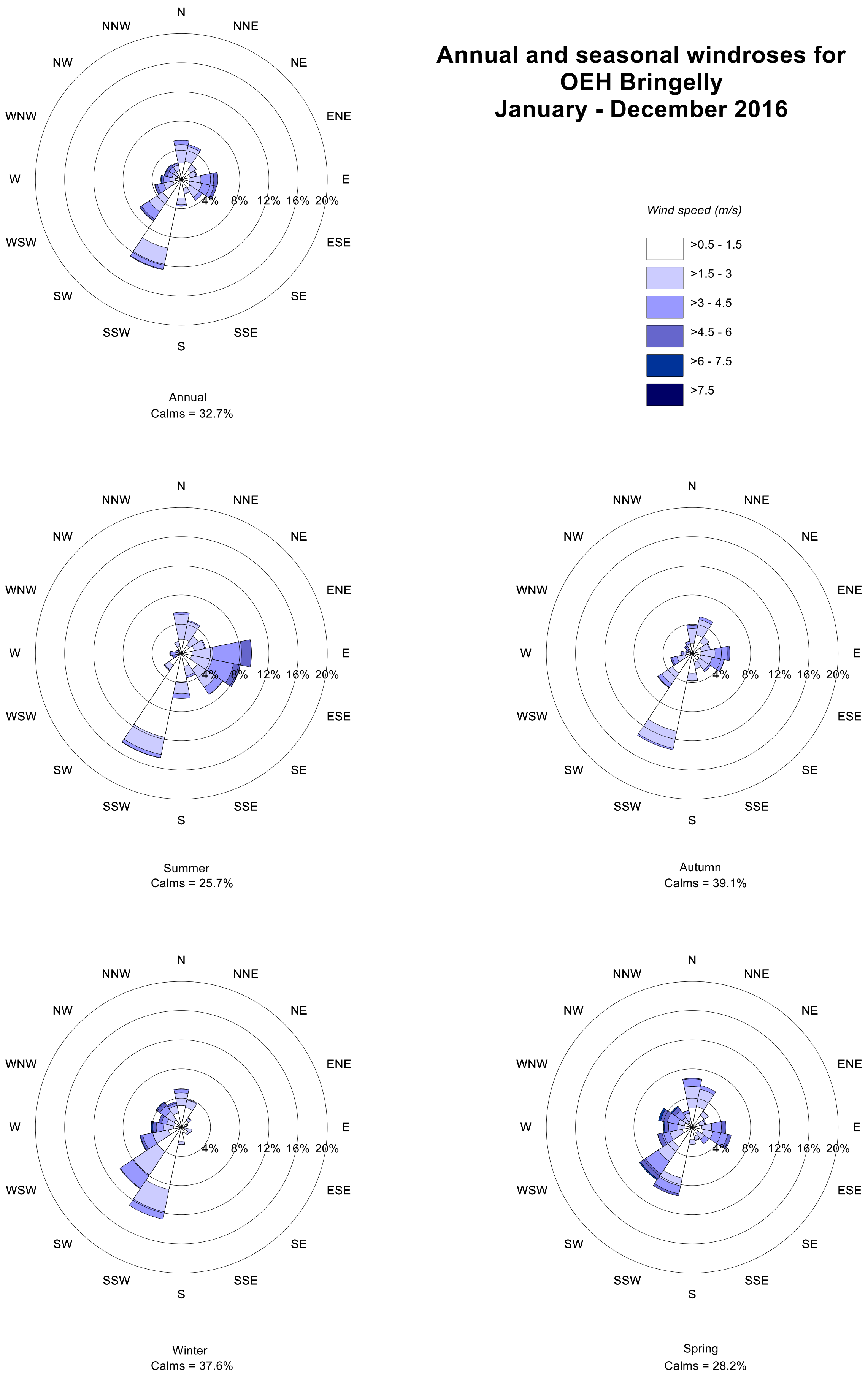
Autumn
Calms = 29.6%



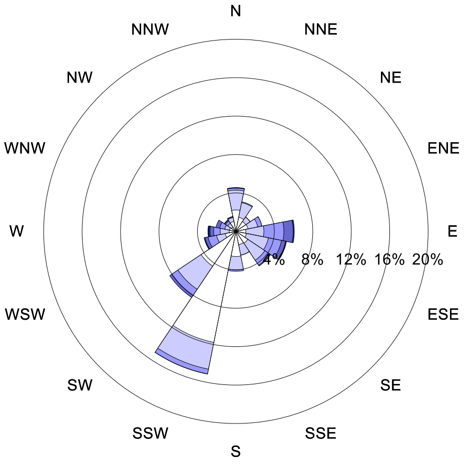
Winter
Calms = 39.8%



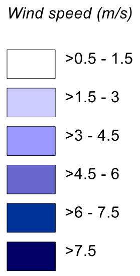
Spring
Calms = 26.9%

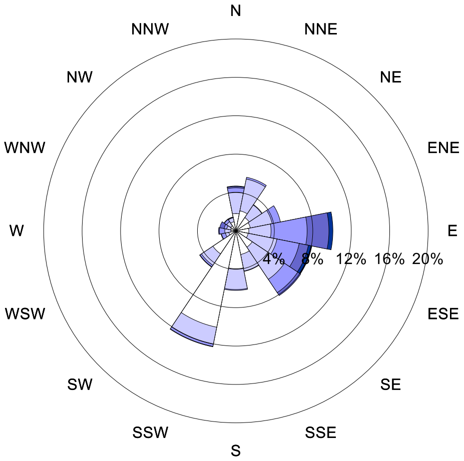

Annual and seasonal windroses for
OEH Bringelly
January - December 2016
Wind speed (m/s)
>0.5 - 1.5
>1.5 - 3
>3 - 4.5
>4.5 - 6
>6 - 7.5
>7.5
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
4%
8%
12%
16%
20%
Annual
Calms = 32.7%
Summer
Calms = 25.7%
Autumn
Calms = 39.1%
Winter
Calms = 37.6%
Spring
Calms = 28.2%

Annual and seasonal windroses for OEH Bringelly January - December 2017

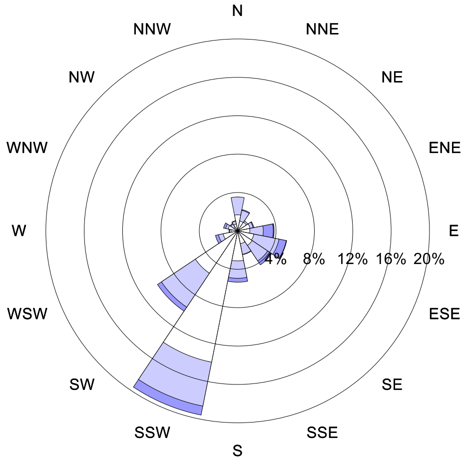


Annual
Calms = 30.4%

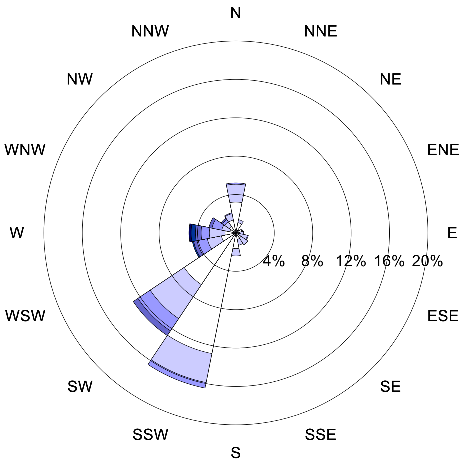




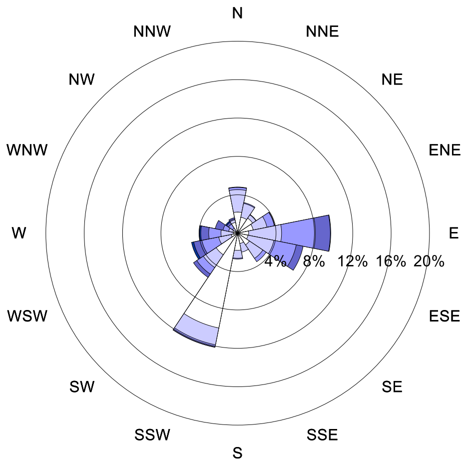
Summer
Calms = 20.0%



Autumn
Calms = 33.7%



Winter
Calms = 39.3%



Spring
Calms = 28.6%

APPENDIX B EMISSION ESTIMATES

Summary of emissions calculations for Scenario 1 – Site Establishment Works

Emission calculations

Activity	Annual emissions (kg/y) TSP	Annual emissions (kg/y) PM10	Annual emissions (kg/y) PM2.5	Control (%)	Intensity	Units	Emission factors TSP Factor	Units	Emission factors PM10 Factor	Units	Emission factors PM2.5 Factor	Units
Topsoil - Scrapers stripping topsoil	1,001	252	25	50	69,000	t/y	0.029	kg/t	0.0073	kg/t	0.001	kg/t
Topsoil - Scraper hauling topsoil to stockpiles	1,601	403	40	20	69,000	t/y	0.029	kg/t	0.0073	kg/t	0.001	kg/t
Topsoil - Emplacing topsoil at stockpiles	19	9	1.4	0	69,000	t/y	0.000279	kg/t	0.000132	kg/t	0.000020	kg/t
Dozers pushing spoil	5,289	1,166	555	50	2,080	h/y	5.1	kg/h	1.121	kg/h	0.53	kg/h
Excavators loading haul trucks	131	62	9	0	230,000	t/y	0.000570	kg/t	0.000269	kg/t	0.000041	kg/t
Hauling spoill to stockpiles	4,974	1,065	106	50	230,000	t/y	0.04325	kg/t	0.00926	kg/t	0.00093	kg/t
Unloading spoil at stockpiles	131	62	9	0	230,000	t/y	0.000570	kg/t	0.000269	kg/t	0.000041	kg/t
Grading roads	5,121	1,789	159	50	16,640	km	0.6155	kg/VKT	0.2150	kg/VKT	0.0191	kg/VKT
Wind erosion - Exposed cleared land	26,280	13,140	1,971	0	30.0	ha	876.0	kg/ha/y	438.0	kg/ha/y	65.7	kg/ha/y

Activity	Variables: Area (m2)	(ws/2.2)^1.3	Moisture (%)	Drop distance (m)	kg/VKT (TSP)	kg/VKT (PM10)	kg/VKT (PM2.5)	payload (t)	GVM (t)	km/trip	Silt (%)	Speed (km/h)	h/year	Silt loading (g/m2)
Topsoil - Scrapers stripping topsoil	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Topsoil - Scraper hauling topsoil to stockpiles	-	-	-	-	0.078	0.011	0.001	26.5	29.25	1	2	-	-	-
Topsoil - Emplacing topsoil at stockpiles	-	0.849	5	-	-	-	-	-	-	-	-	-	-	-
Dozers pushing spoil	-		5	-	-	-	-	-	-	-	10	-	2080	-
Excavators loading haul trucks	-	0.849	3	-	-	-	-	-	-	-	-	-	-	-
Hauling spoill to stockpiles	-	-	-	-	1.146	0.245	0.025	26.5	29.25	1	2	-	-	-
Unloading spoil at stockpiles	-	0.849	3	-	-	-	-	-	-	-	-	-	-	-
Grading roads	-	-	-	-	-	-	-	-	-	-	-	8	2,080	-
Wind erosion - Exposed cleared land	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Summary of emissions calculations for Scenario 2 – Concrete batching

Concrete Batching Plant 2

Activity - Annual Average	Emission (kg/y)	Intensity	units	Emission factor	units	Variable 1	units	Variable 2	units	Variable 3	units	Variable 4	units	Variable 5	units		Source
Hauling of material by aggregate and sand delivery trucks onsite-sealed roads	93	6636	trucks/year	0.00931	kg/VKT	26.5	payload (tonnes)	29.25	Gross vehicle mass (tonnes)	1.5	km/Return trip	0.0093081	kg/VKT	0.4	g/m2 silt loading	0	%control
Hauling of material by flyash and cement delivery trucks onsite-sealed roads	11	777	trucks/year	0.00931	kg/VKT	26.5	payload (tonnes)	29.25	Gross vehicle mass (tonnes)	1.5	km/Return trip	0.0093081	kg/VKT	0.4	g/m2 silt loading	0	%control
Hauling of material by **OTHER TRUCKS** onsite-sealed roads	16	1112	trucks/year	0.00931	kg/VKT	26.5	payload (tonnes)	29.25	Gross vehicle mass (tonnes)	1.5	km/Return trip	0.0093081	kg/VKT	0.4	g/m2 silt loading	0	%control
Material handling - trucks to aggregate storage bins	41.8	175857	t/y	0.0005	kg/t	0.85	average of (wind speed/2.2)^1.3 in m/s	2	moisture content in %							50	%control
Material handling - Conveying aggregate to silos	84	175857	t/y	0.0005	kg/t	0.85	average of (wind speed/2.2)^1.3 in m/s	2	moisture content in %							0	%control
Residual from de-dusted air loading cement and fly-ash-Bag house	35	20593	t/y	0.05	g/Nm3	34	Nm3/minute	1	minutes/t	26.5	t/truck	777	truck/y			0	%control
Total	**279**	**380833**															

Concrete Batching Plant 1

Activity - Annual Average	Emission (kg/y)	Intensity	units	Emission factor	units	Variable 1	units	Variable 2	units	Variable 3	units	Variable 4	units	Variable 5	units		Source
Hauling of material by aggregate and sand delivery trucks onsite-sealed roads	173	6636	trucks/year	0.0093	kg/VKT	26.5	payload (tonnes)	29.25	Gross vehicle mass (tonnes)	2.8	km/Return trip	0.0093081	kg/VKT	0.4	g/m2 silt loading	0	%control
Hauling of material by flyash and cement delivery trucks onsite-sealed roads	20	777	trucks/year	0.0093	kg/VKT	26.5	payload (tonnes)	29.25	Gross vehicle mass (tonnes)	2.8	km/Return trip	0.0093081	kg/VKT	0.4	g/m2 silt loading	0	%control
Hauling of material by **OTHER TRUCKS** onsite-sealed roads	29	1112	trucks/year	0.0093	kg/VKT	26.5	payload (tonnes)	29.25	Gross vehicle mass (tonnes)	2.8	km/Return trip	0.0093081	kg/VKT	0.4	g/m2 silt loading	0	%control
Material handling - trucks to aggregate storage bins	41.8	175857	t/y	0.0005	kg/t	0.85	average of (wind speed/2.2)^1.3 in m/s	2	moisture content in %							50	%control
Material handling - Conveying aggregate to silos	84	175857	t/y	0.0005	kg/t	0.85	average of (wind speed/2.2)^1.3 in m/s	2	moisture content in %							0	%control
Residual from de-dusted air loading cement and fly-ash-Bag house	35	20593	t/y	0.05	g/Nm3	34	Nm3/minute	1	minutes/t	26.5	t/truck	777	truck/y			0	%control
Total	**383**	**380833**															

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