Westlink – Stage 2 Construction

Air Quality Impact Assessment

ESR Developments (Australia Pty) Ltd

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Basis of Report

This report has been prepared by SLR Consulting Australia (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with ESR Developments (Australia Pty) Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

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1.0 Introduction

SLR Consulting Australia Pty Ltd (SLR) has been commissioned by ESR Developments (Australia) Pty Ltd (ESR) to prepare an Air Quality Impact Assessment (AQIA) for the proposed construction and operation of Stage 2 of the Westlink Project (SSD-46983729) which is a proposed warehousing and distribution development at 1030-1064 Mamre Road and 59-62 & 63 Abbotts Road, Kemps Creek (the Site). The Site is located within the Mamre Road Precinct (MRP).

SLR delivered an AQIA report (610.30983-R03-v1.3-20231102) for the State Significant Development (SSD) application (SSD-46983729) on 3 November 2023 (the Original AQIA).

On 17 October 2024, the NSW Department of Planning, Housing and Infrastructure (DPHI) issued a Request for Additional Information. In relation to air quality, they requested:

> *"… Please provide a quantitative air quality assessment of construction impacts that includes an emissions inventory for the proposed works and a model that includes both annual average and maximum 24-hour average predicted concentrations (PM_{10} and $PM_{2.5}$) and comparison against air quality criteria. The assessment must include site-specific mitigation measures tailored to the outcomes of the assessment that will be implemented during the works, and the implementation of real-time monitoring. The AQIA must consider cumulative impacts from other concurrent construction projects in the precinct."*

This report assesses the air quality impacts of construction activities related to SSD-46983729 (the Project). It presents the methodology and findings of a quantitative (modelling) assessment of construction stage air emissions, details the mitigation measures proposed to be adopted during the construction stage and recommends air quality monitoring and additional management measures to reduce likelihood of exceedances of air quality criteria at surrounding receptors.

This report should be read in conjunction with the Original AQIA, which presents an assessment of operational stage impacts.

2.0 Project Overview

2.1 Site Location and Layout

The Site is located at 1030-1064 Mamre Road and 59-62 & 63 Abbotts Road, Kemps Creek within the Penrith local government area (LGA). The Site location is depicted in **Figure 1**.

Figure 1: Site Location

The proposed site layout is shown in **Figure 2**. An indicative plan of how material would be moved around the Site for the Project bulk earth works required is presented in **Figure 3** and summarised in **Table 1**.

Table 1 Indicative Bulk Material Volume (over 9 Months)

Stage	Cut – Topsoil (m^3)	Cut - Extract (m^3)	Fill - Extracted (m^3)	Fill - Import (m^3)
Stage 2	58,560	597,950	651,890	53,940
Note: This assessment was conducted using anticipated volumes from an earlier revision of civil plans as outlined in Appendix C. The variation is not anticipated to impact the outcomes of the assessment.				

Figure 2 Site Layout

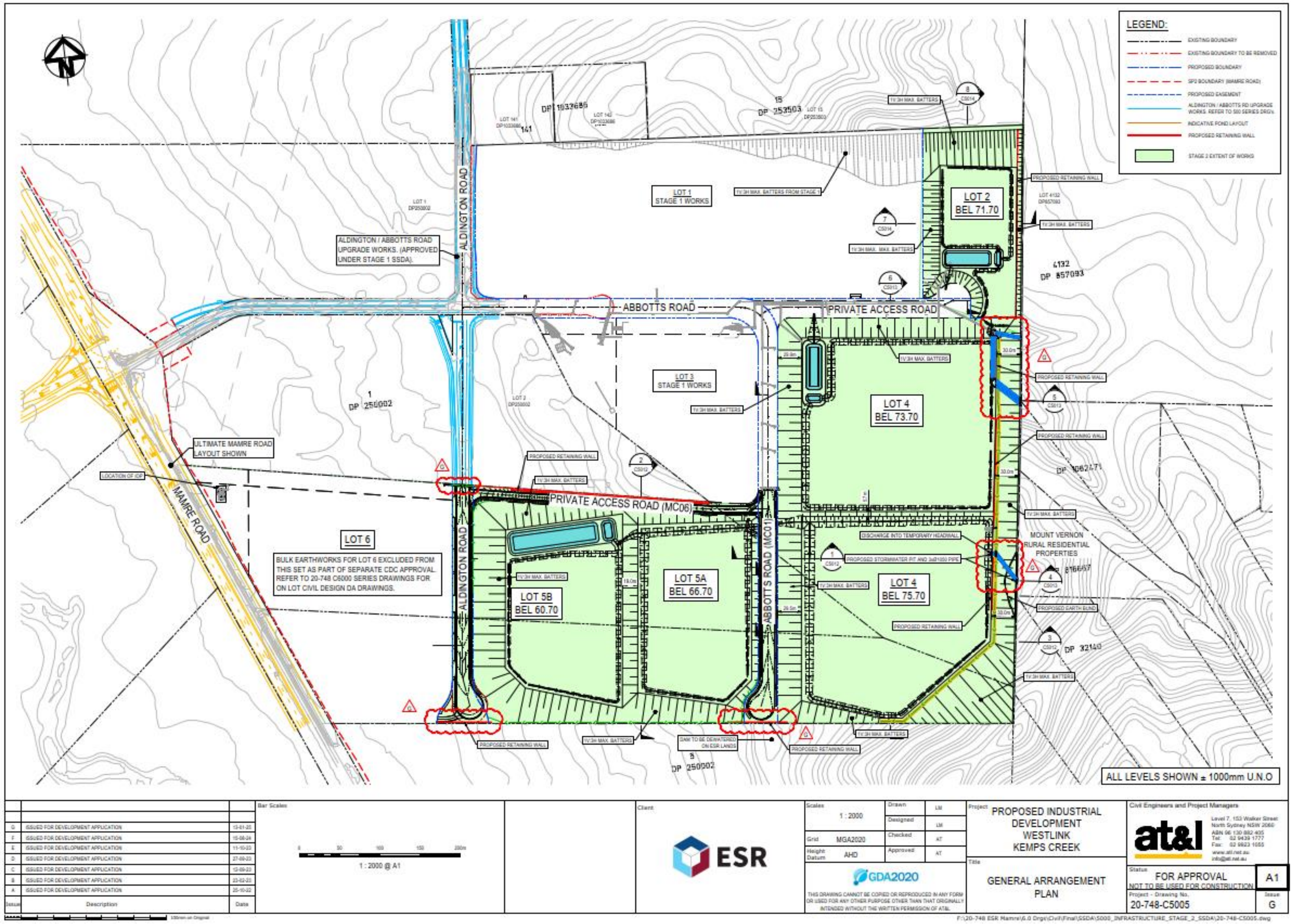
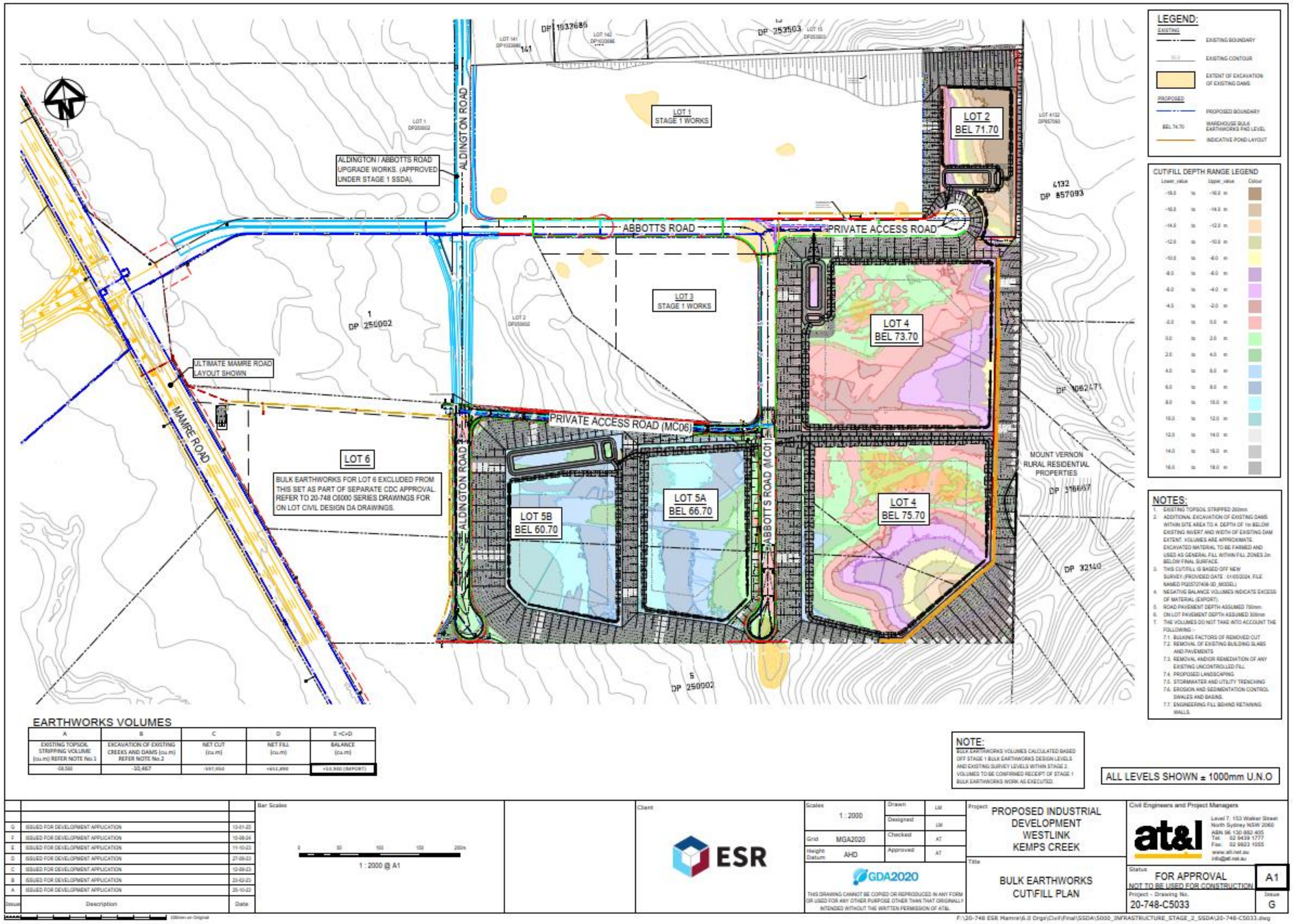


Figure 3 Indicative Material Movements During the Project Bulk Earthworks



2.2 Identification of Potential Sources of Emissions to Air

The main air quality impacts associated with construction stage impacts relate to emissions of fugitive dust during bulk earthworks. The potential for dust to be emitted during bulk earthworks will be directly influenced by the nature of activities being performed at any given time. Generally, the activities that are most likely to lead to short-term emissions of dust, include:

- Onsite material handling and processing
- Wheel generated dust from onsite vehicle movements
- Wind erosion from exposed areas.

Temporary elevations in local dust levels are most likely to occur when bulk earthworks are undertaken during periods of low rainfall and/or windy conditions. The impact of elevated dust emissions is dependent upon the potential for particulates to become and remain airborne prior to being deposited as dust or experienced as an ambient particulate concentration.

A number of environmental factors may affect the generation and dispersion of dust emissions, including:

- Wind direction - determines whether dust and suspended particles are transported in the direction of the sensitive receptors.
- Wind speed - determines the potential suspension and drift resistance of particles.
- Surface type - more erodible surface material types have an increased soil or dust erosion potential.
- Surface material moisture - increased surface material moisture reduces soil or dust erosion potential.
- Rainfall or dew - rainfall or heavy dew that wets the surface of the soil reduces the risk of dust generation.

2.2.1 Pollutants of Interest

SLR Consulting has conducted a large number of assessments for construction across Australia. The results of these assessments have indicated that the key pollutants for determining compliance with relevant air quality criteria from these types of operations are suspended particulate matter (TSP, PM_{10} and $PM_{2.5}$) and dust deposition.

While emissions of pollutants associated with the combustion of diesel fuel, including nitrogen oxides (NOx), sulphur dioxide (SO_2), carbon monoxide (CO) and Volatile Organic Compounds (VOCs), will be generated by the proposed construction activities for the Project, these emissions are unlikely to compromise air quality goals at the closest receptors, given the nature and scale of the operation. They have therefore not been considered further.

Suspended Particulate Matter

Airborne contaminants that can be inhaled directly into the lungs can be classified on the basis of their physical properties as gases, vapours or particulate matter. In common usage, the terms “dust” and “particulates” are often used interchangeably. The health effects of particulate matter are strongly influenced by the size of the airborne particles. Smaller particles can penetrate further into the respiratory tract, with the smallest particles having a greater impact on human health as they penetrate to the gas exchange areas of the lungs.

Larger particles primarily cause nuisance associated with coarse particles settling on surfaces.

The term “particulate matter” refers to a category of airborne particles, typically less than 30 microns (μm) in diameter and ranging down to 0.1 μm and is termed total suspended particulate (TSP). Particulate matter with an aerodynamic diameter of 10 microns or less is referred to as PM_{10}. The PM_{10} size fraction is sufficiently small to penetrate the large airways of the lungs, while $PM_{2.5}$ (2.5 microns or less) particulates are generally small enough to be drawn in and deposited into the deepest portions of the lungs. Potential adverse health impacts associated with exposure to PM_{10} and $PM_{2.5}$ include increased mortality from cardiovascular and respiratory diseases, chronic obstructive pulmonary disease and heart disease, and reduced lung capacity in asthmatic children.

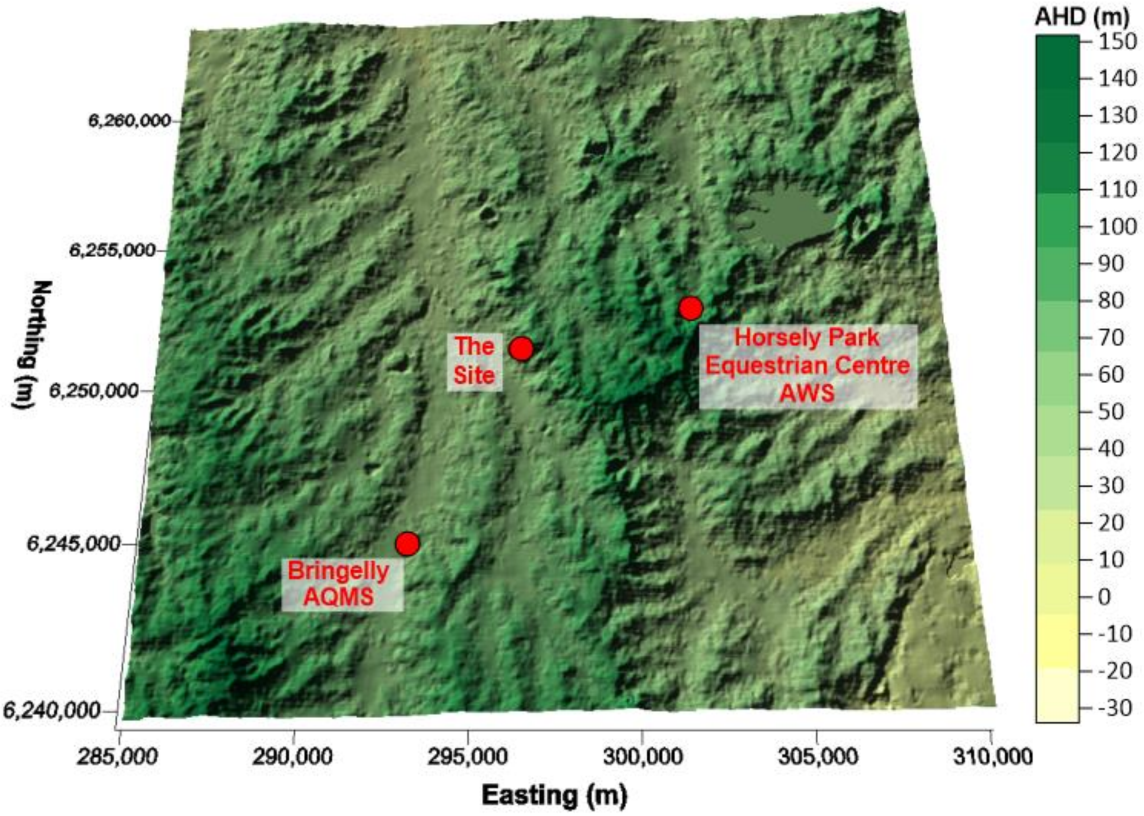
3.0 Existing Air Environment

3.1 Surrounding Topography

Local topography is important in air quality studies as local atmospheric dispersion can be influenced by night-time katabatic (downhill) drainage flows from elevated terrain or channelling effects in valleys or gullies.

The topography of the Site and near surrounds is relatively flat, with an elevation of the approximately 45 m Australian Height Datum (AHD). A pseudo-three-dimensional representation of the region surrounding the Site is presented in **Figure 4**. The locations of Badgerys Creek automatic weather station (AWS; refer **Section 3.4**) and Bringelly air quality monitoring station (AQMS; refer **Section 3.5**) are also indicated.

Figure 4 Regional Topography



Project Number:	610.V30893
Location:	Kemps Creek, NSW
Source:	ICSM - Elvis
Projection:	SRTM-derived Smoothed 1 Second Digital Elevation Model V1.0
Date:	13/11/2025

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ESR Developments (Australia) Pty Ltd

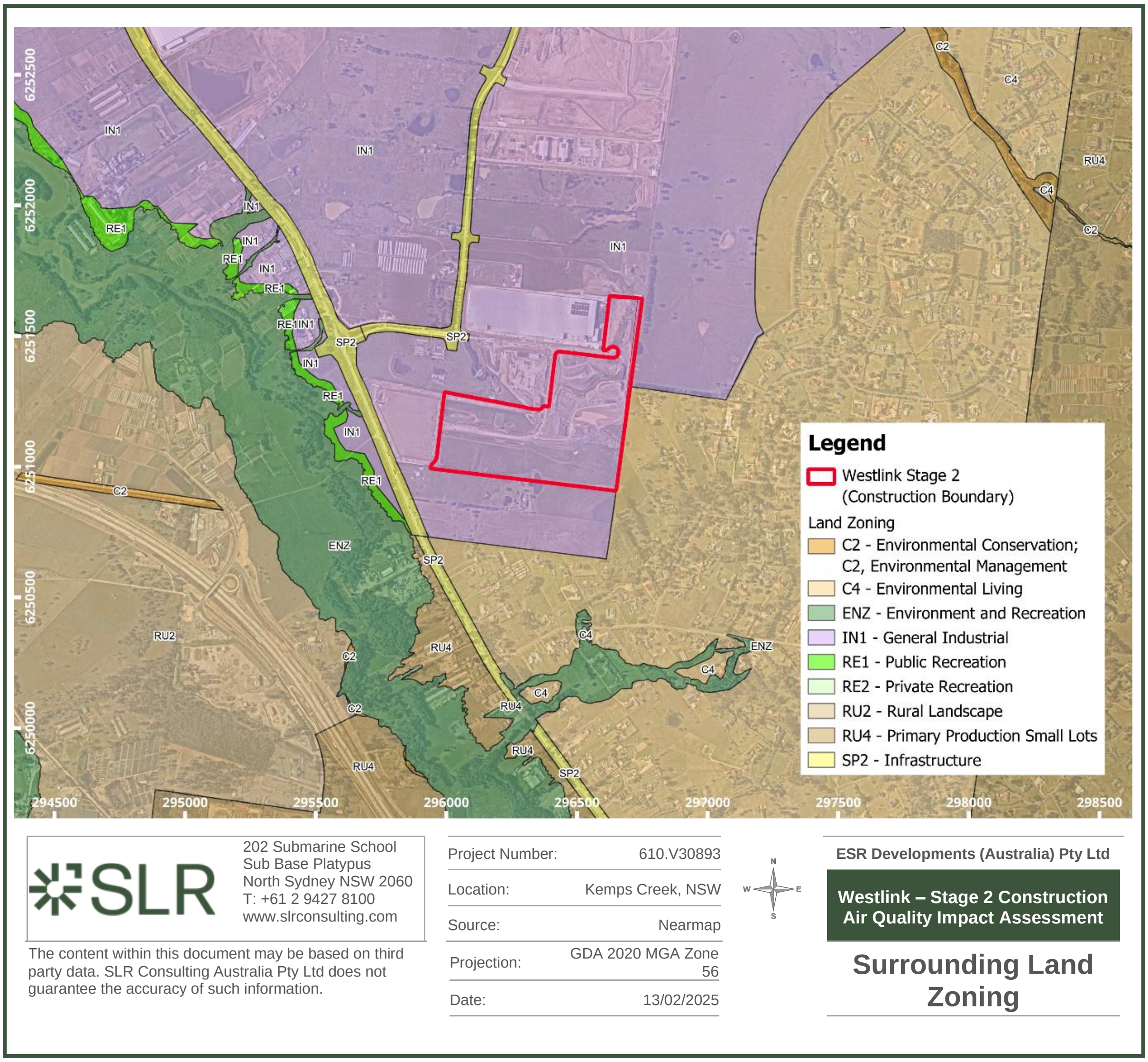
Westlink – Stage 2 Construction
Air Quality Impact Assessment

Topography

3.2 Surrounding Land Uses

As shown in **Figure 5**, the Site and its adjacent areas to the north, south, and west are zoned as General Industrial (IN1), the areas southeast of the Site are zoned as Environmental Living (C4).

Figure 5 Surrounding Land Zoning



3.3 Sensitive Receptors

There are several residential and commercial receptors located in all directions from the Site, with the closest sensitive receptor is located approximately 40 m to the south. **Table 2** outlines the location of the sensitive receptors included in the assessment and their approximate distance to the nearest Site boundary.

Figure 6 Surrounding Receptors

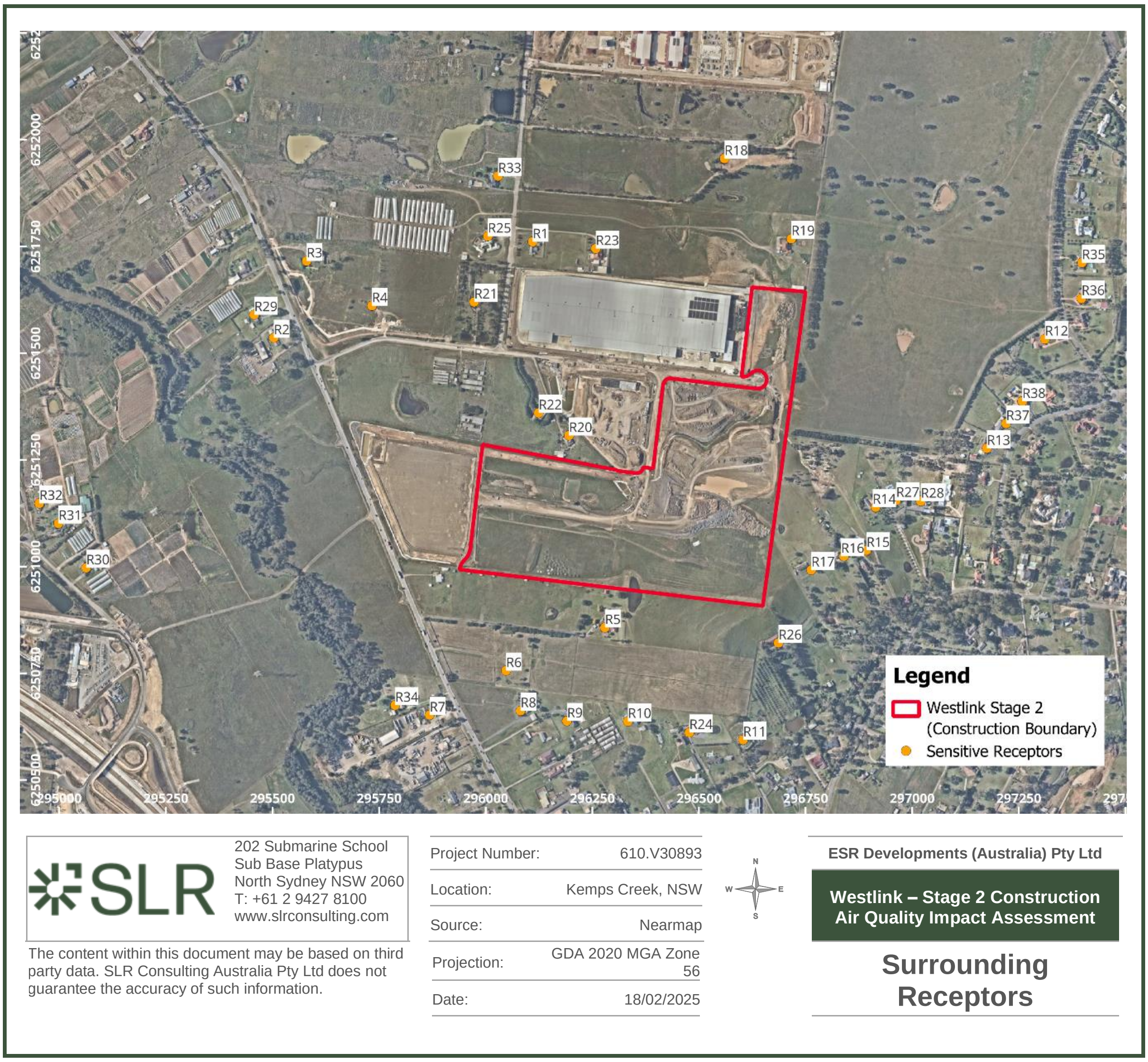


Table 2 Sensitive Receptor Locations

Map ID	Easting (m)	Northing (m)	Direction from Site Boundary	Distance from Closest Site Boundary (m)
R1	296,110	6,251,761	Northwest	450
R2	295,503	6,251,536	Northwest	500
R3 [a]	295,580	6,251,716	Northwest	600
R4 [a]	295,733	6,251,611	Northwest	410
R5	296,280	6,250,857	South	95
R6 [b]	296,048	6,250,756	South	200
R7	295,868	6,250,652	Southwest	330
R8	296,082	6,250,662	South	310

Map ID	Easting (m)	Northing (m)	Direction from Site Boundary	Distance from Closest Site Boundary (m)
R9	296,191	6,250,638	South	320
R10	296,333	6,250,637	South	305
R11	296,604	6,250,594	South	315
R12	297,311	6,251,533	Northeast	560
R13	297,175	6,251,277	East	470
R14	296,914	6,251,139	East	230
R15	296,893	6,251,038	East	220
R16	296,840	6,251,024	East	170
R17	296,764	6,250,992	East	100
R18 [c]	296,560	6,251,956	North	315
R19	296,717	6,251,768	North	115
R20	296,195	6,251,307	Northwest	55
R21	295,973	6,251,620	Northwest	335
R22	296,124	6,251,360	Northwest	95
R23	296,258	6,251,745	Northwest	350
R24	296,477	6,250,611	South	315
R25	296,005	6,251,774	Northwest	535
R26	296,687	6,250,821	Southeast	95
R27 [d]	296,962	6,251,155	East	280
R28	297,020	6,251,153	East	335
R29	295,457	6,251,590	Northwest	610
R30	295,063	6,250,997	West	870
R31	294,998	6,251,101	West	945
R32	294,953	6,251,148	West	1,000
R33	296,029	6,251,915	Northwest	615
R34	295,787	6,250,675	Southwest	335
R35 [e]	297,398	6,251,712	Northeast	650
R36	297,397	6,251,628	Northeast	645
R37	297,220	6,251,335	East	510
R38	297,258	6,251,387	East	535

a Owned by ESR, currently vacant
b Owned by Gibb Group, currently vacant
c Owned by Stockland and fife, currently vacant
d Owned by Anric, currently vacant
e Owned by Icon Oceania, currently vacant

3.4 Local Meteorology

Local wind speed and direction influence the dispersion of air pollutants. Wind speed determines both the distance of downwind transport and the rate of dilution as a result of 'plume' stretching. Wind direction, and the variability in wind direction, determines the general path pollutants will follow and the extent of crosswind spreading. Surface roughness (characterised by features such as the topography of the land and the presence of buildings, structures and trees) affects the degree of mechanical turbulence, which also influences the rate of dispersion of air pollutants.

The Bureau of Meteorology (BoM) maintains and publishes data from weather stations across Australia. The closest such station to the Site is Horsley Park Equestrian Centre Automatic Weather Station (AWS) (Station no. 67119), which is located approximately 5 km to the east of the Site. Considering the distance, terrain and land cover between the Site and Horsley Park Equestrian Centre AWS, wind conditions at the AWS are likely to be a reasonable representation of those at the Site.

The Horsley Park Equestrian Centre AWS was commissioned in 1997, sits at an elevation of 100 m and has data available for the following parameters:

- wind speed (m/s) and wind direction (degrees)
- temperature (°C)
- rainfall (mm)
- relative humidity (%).

A review of the long-term climate data collected at this station is provided in the following sections.

3.4.1 Rainfall

Rainfall statistics for Horsley Park Equestrian Centre AWS are summarised in **Figure 7**. The average monthly rainfall is distributed evenly throughout the year. The lowest mean monthly rainfall of 37.6 mm/month was recorded during September. The highest average monthly rainfall of 122.3 mm/month occurred in February. The maximum mean number of rain days occurs in December, with an average of 12.2 rain days recorded in this month. Maximum rainfall of 461.8 mm and minimum rainfall of 0 mm have been recorded.

3.4.2 Relative Humidity

Available humidity statistics (9 am and 3 pm monthly averages) for Horsley Park Equestrian Centre AWS are summarised in **Figure 8**. Morning humidity levels range from an average of around 61% in mid spring to around 81% in early autumn. Afternoon humidity levels are lower at around 42% in early spring, and around 55% in mid-winter.

3.4.3 Temperature

Available temperature statistics for Horsley Park Equestrian Centre AWS are summarised in **Figure 9**. Mean maximum temperatures range from 17.6°C in winter to 29.9°C in summer, while mean minimum temperatures range from 5.9°C in winter to around 18.0°C in summer. Maximum temperatures of 47°C and minimum temperatures of -2.3°C have been recorded.

Figure 7 Monthly Rainfall Data for Horsley Park Equestrian Centre AWS

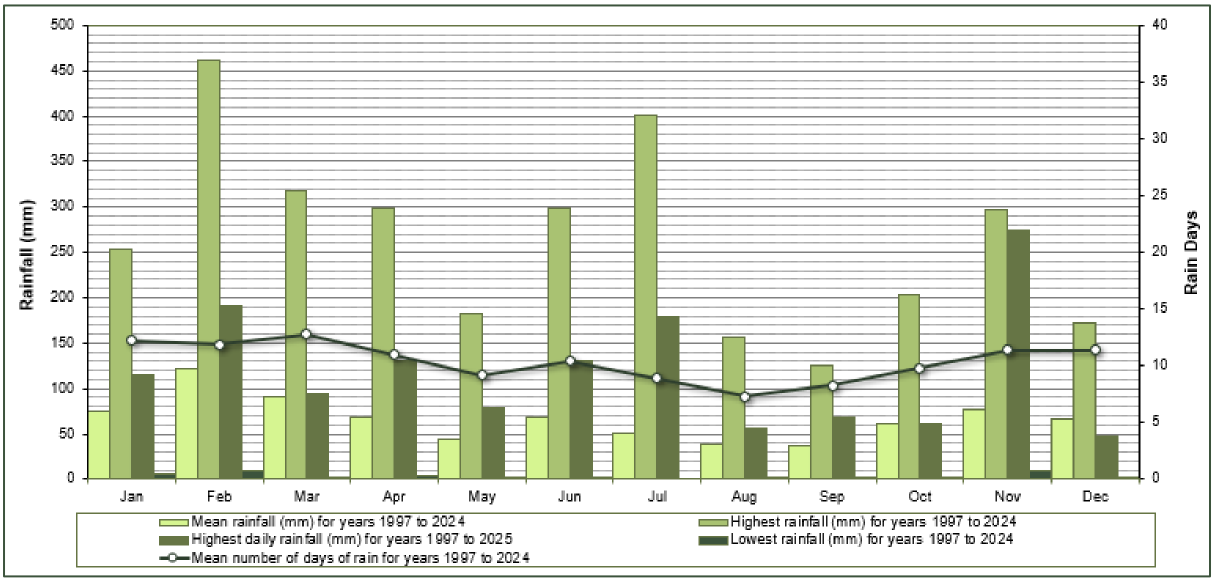


Figure 8 Humidity Data for Horsley Park Equestrian Centre AWS

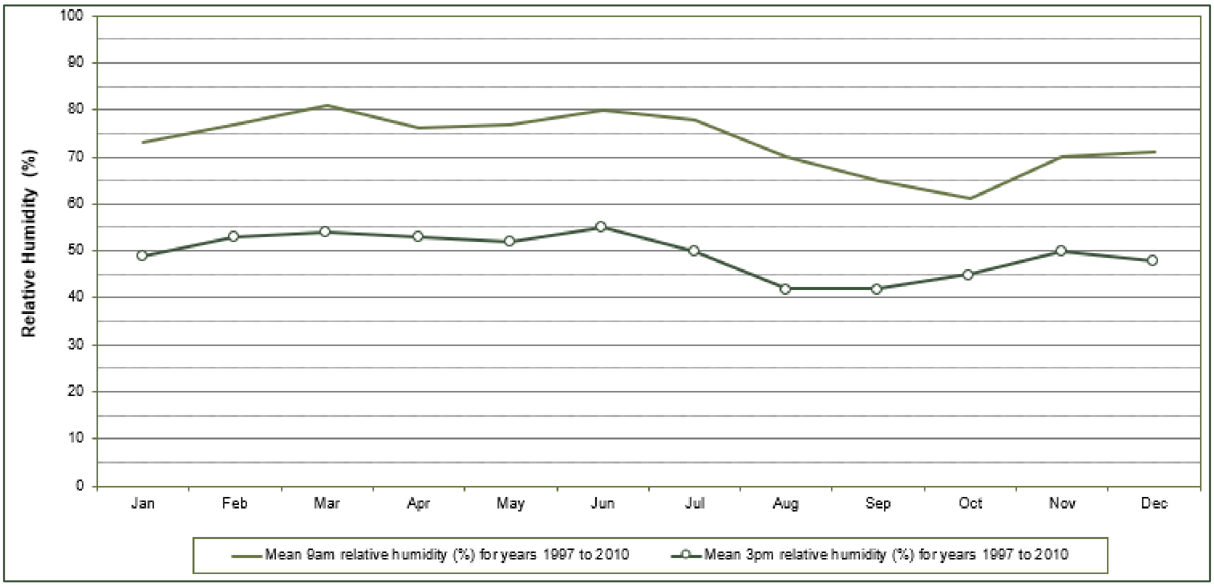
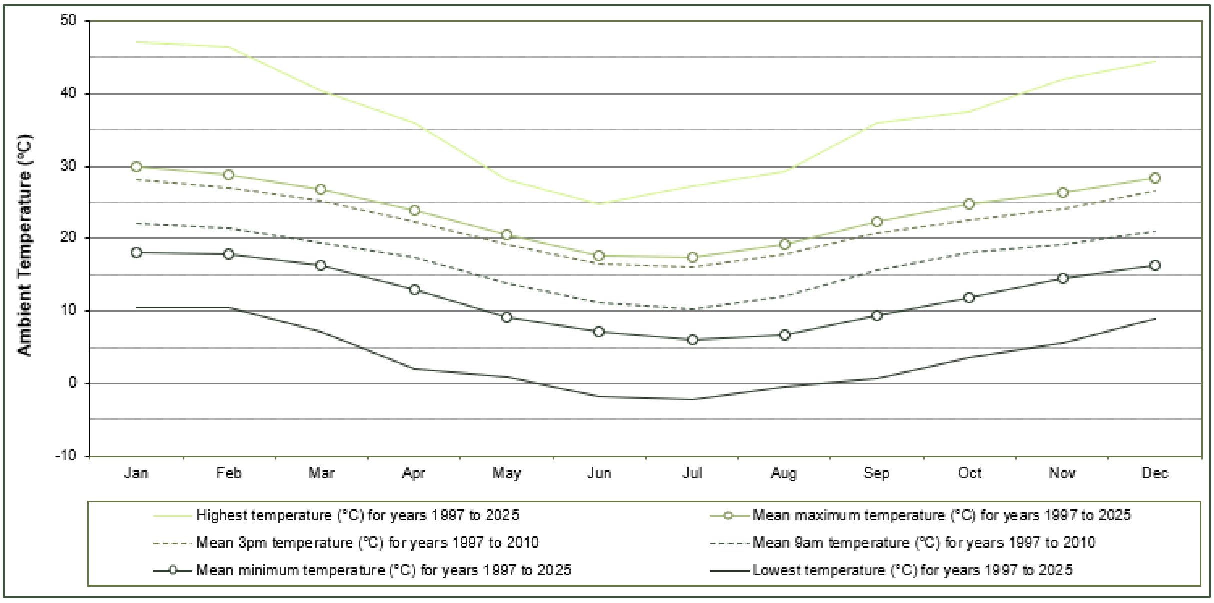


Figure 9 Temperature Data for Horsley Park Equestrian Centre AWS



3.4.4 Wind Speed and Direction

Local wind speed and direction influence the dispersion of air pollutants. Wind speed determines both the distance of downwind transport and the rate of dilution as a result of 'plume' stretching. Wind direction, and the variability in wind direction, determines the general path pollutants will follow and the extent of crosswind spreading. Surface roughness (characterised by features such as the topography of the land and the presence of buildings, structures and trees) will also influence dispersion.

Annual and seasonal wind roses for the five-year period from 2020 to 2024, compiled from data recorded by the Horsley Park Equestrian Centre AWS are presented in **Figure 10**. Wind roses show the frequency of occurrence of winds by direction and strength. The bars correspond to the 16 compass points (degrees from North). The bar at the top of each wind rose diagram represents winds blowing from the north (i.e. northerly winds), and so on. The length of the bar represents the frequency of occurrence of winds from that direction, and the widths of the bar sections correspond to wind speed categories, the narrowest representing the lightest winds. Thus, it is possible to visualise how often winds of a certain direction and strength occur over a long period, either for all hours of the day, or for particular periods during the day.

There are times when the wind is calm (defined as being from zero to 0.5 metres/second), and the percentage of the time that winds are calm are shown as a note on the wind rose. **Table 3** outlines the wind scale used to describe the wind speed.

Table 3 Wind Scale Descriptions

Description	km/h	m/s	Description on land
Calm	0-1.8	0-0.5	Smoke rises vertically
Light air	1.8-5.5	0.5-1.5	Smoke drift indicates wind direction
Light breeze	5.4-10.8	1.5-3	Wind felt on face, leaves rustle, light flags extended, ordinary vanes moved by wind
Gentle breeze	10.8-19.8	3-5.5	Leaves and small twigs in constant motion; light flags extended.
Moderate winds	19.8-28.8	5.5-8.0	Raises dust and loose paper, small branches are moved
Fresh winds	28.8-37.8	8.0-10.5	Small trees in leaf begin to sway, crested wavelets form on inland waters
Strong winds	>37.8	>10.5	Large branches in motion, whistling heard in telephone wires; umbrellas used with difficulty

The annual wind rose indicates that winds blow from all directions, with the least frequent winds coming from the northeastern quadrant and the most frequent winds coming from the southwestern quadrant. Calm wind conditions (wind speed less than 0.5 m/s) were recorded to occur 18.5% of the time throughout the investigated period. The average seasonal wind roses for the year 2020-2024 indicate that:

- In summer, winds blow from all directions except the northwestern quadrant, where winds occur infrequently. Calms were recorded approximately 16% of the time during the summer months.
- In autumn, winds predominantly blow from the southwestern quadrant, with the least frequent winds originating from the northeastern quadrant. Calms were recorded approximately 20% of the time during the autumn months.
- In winter, winds predominantly blow from the southwestern and northwestern quadrant, with the least frequent winds originating from the northeastern and southeastern quadrants. Calms were recorded 21% of the time.
- In spring, winds blow almost evenly from all directions. Calms were recorded approximately 16% of the time during spring.

Wind erosion of dust from exposed surfaces is usually initiated when wind speeds exceed the threshold friction velocity for a given surface or material, however a general rule of thumb is that wind erosion can be expected to occur above approximately 5.5 m/s. The frequency of wind speeds for the period of 2020-2024 is presented in **Figure 11**. The plot shows that the frequency of wind speeds exceeding 5.5 m/s for the period 2020-2024 at Horsley Park Equestrian Centre AWS was approximately 2% of the time.

Figure 10 Horsley Park Equestrian Centre AWS Seasonal and Annual Wind Roses (2020 – 2024)

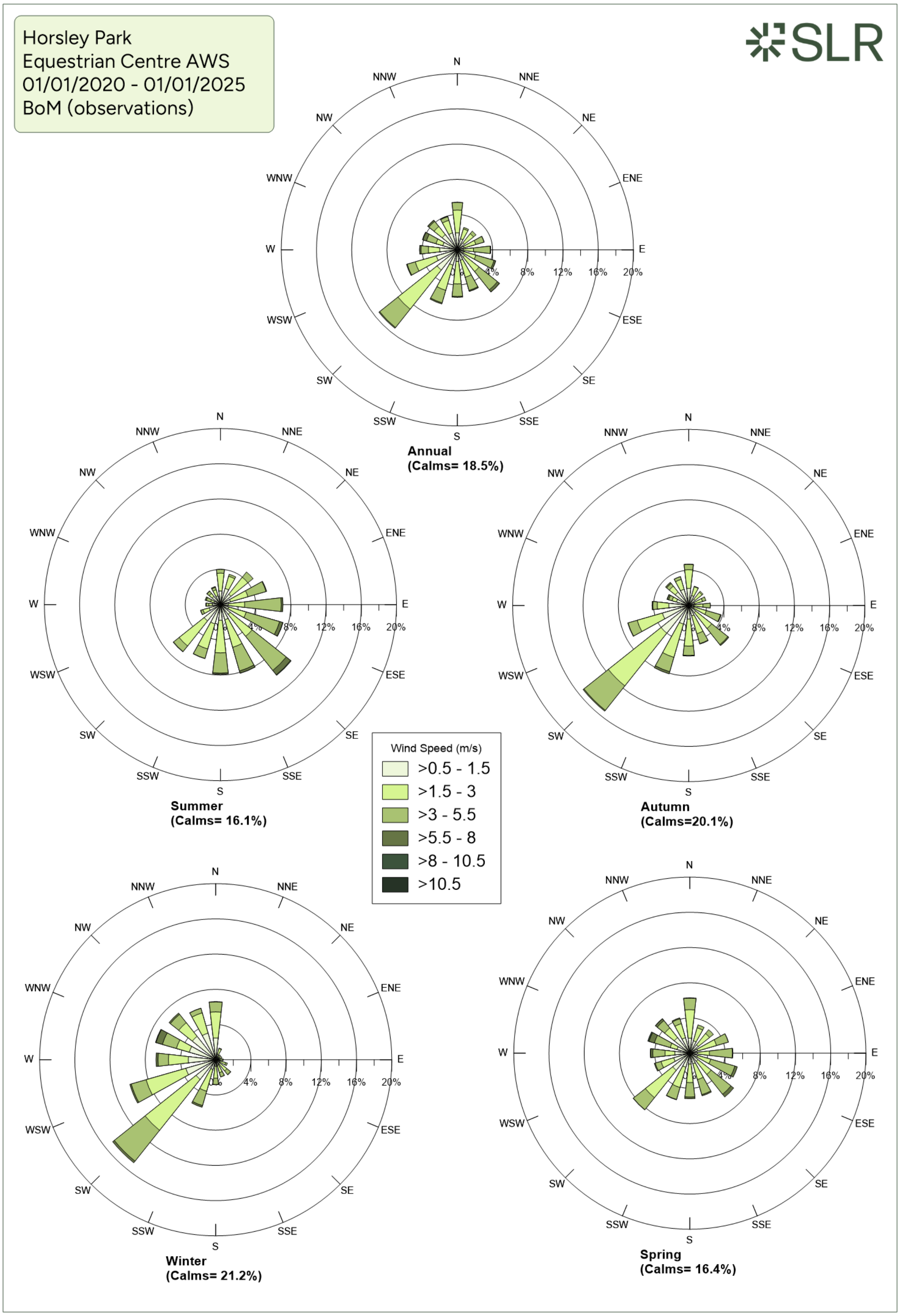
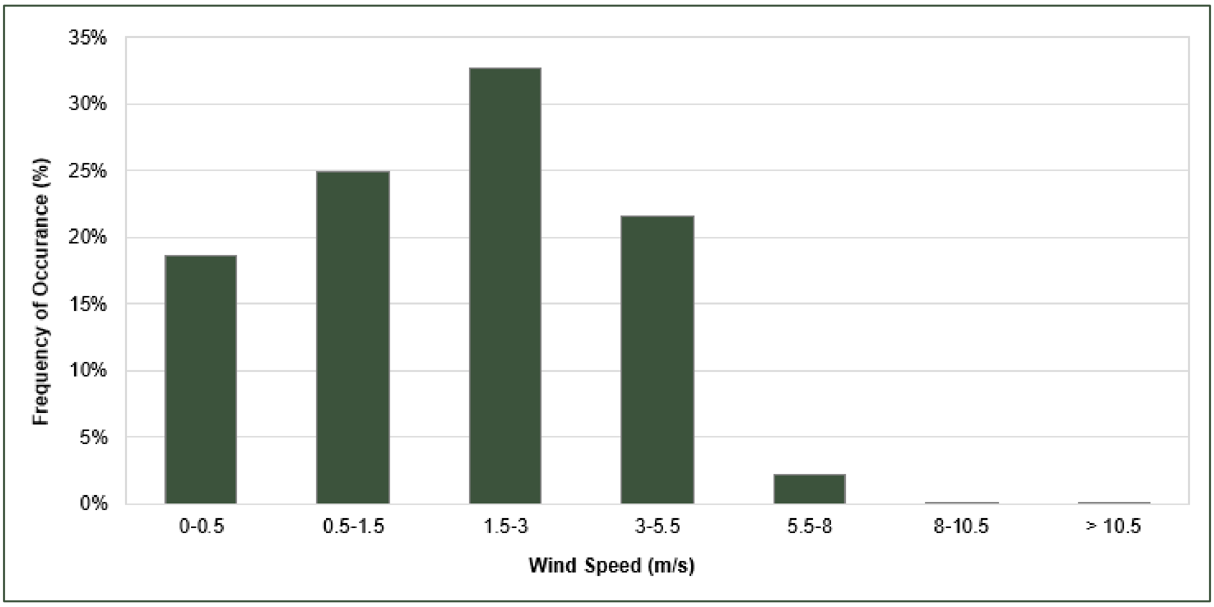


Figure 11 Wind Speed Frequency Chart for Horsley Park Equestrian Centre AWS – 2020-2024



3.5 Regional Air Quality

Air quality monitoring is performed by the NSW Department of Climate Change, Energy, the Environment and Water (DCCEW) at a number of monitoring stations across NSW. The closest station to the Site is the Bringelly Air Quality Monitoring Station (AQMS), located approximately 7.5 km to the southwest (see Section 3.1).

The following air pollutants are monitored at this station:

- Fine particles as $PM_{2.5}$
- Fine particles as PM_{10}

A summary of the monitored pollutant concentrations for the last five years (2020-2024) is presented in **Table 4** and the data are presented graphically in **Figure 12** to **Figure 13**.

No TSP monitoring is conducted by the Bringelly AQMS. In the absence of any monitoring data for TSP, daily varying ambient TSP concentrations have been estimated from the PM_{10} concentrations recorded by the Bringelly AQMS using a PM_{10}/TSP ratio of 0.4 [1], which is typical for industrial areas in Australia. Therefore, for cumulative analysis purposes, the annual average background TSP concentration was estimated to be 37.5 µg/m^3.

No background dust deposition monitoring is conducted by the Bringelly AQMS. Dust deposition monitoring is currently conducted for Westlink Stage 1, however it is anticipated that the Stage 1 construction works would be completed prior to the commencement of the of the Project. Therefore, the existing Stage 1 monitoring data would not be representative of the background dust deposition from the Project activities.

[1] This is conservative as when this ratio is determined from the total PM_{10} and TSP emissions to area in Sydney as detailed in the 2013 Calendar Year Air Emissions Inventory for the Greater Metropolitan Region in NSW, the ratio is 0.6, which would result in a concentration was estimated to be 25.0 µg/m^3. This includes the following sources of emissions: natural, commercial, domestic-commercial, industrial, off-road mobile, on-road mobile.

In the absence of suitably representative dust deposition monitoring data, a background dust deposition rate of 2 g/m^2/month has been assumed for this assessment, which is typical for residential/industrial areas in Australia. This results in the cumulative assessment criterion of 4 g/m^2/month being the defining criterion for the Project.

Table 4 Summary of Air Quality Monitoring Data at Bringelly AQMS (2020-2024)

Pollutant	PM_{10}		$PM_{2.5}$	
Averaging Period	**Maximum 24-hour**	**Annual**	**Maximum 24-hour**	**Annual**
Units	**µg/ m^3**	**µg/ m^3**	**µg/ m^3**	**µg/ m^3**
2020	241.8 (11)	18.1	78.1 (12)	8.2
2021	69.0 (1)	15.0	57.4 (3)	7.2
2022	28.7	11.9	17.8	5.0
2023	53.2 (1)	15.7	45.4 (3)	6.7
2024	58.1 (1)	15.9	17.2	6.6
Criteria	50	25	25	8
# numbers in brackets represent number of exceedances of relevant criteria recorded each year.				

Exceedances of the 24-hour average PM_{10} criteria were recorded by the Bringelly AQMS each year over the period analysed except for 2022. $PM_{2.5}$ criteria exceedances were recorded by in the years 2020, 2021, and 2023. Exceedances of the annual average $PM_{2.5}$ criterion were also recorded for the years 2019 and 2020. Exceedances of the annual average $PM_{2.5}$ criterion were also recorded for 2020.

A review of the available compliance monitoring reports indicates that the PM_{10} and $PM_{2.5}$ exceedances during these years were primarily due to exceptional events such as bushfire emergencies, dust storms and hazard reduction burns (NSW DPIE 2020) (NSW DPE 2021). The high number of exceedances recorded in 2020 were due to bushfire smoke that affected Sydney and the surrounding areas for a significant number of days in early 2020 (the ‘Black Summer’ bushfire event). The NEPM compliance report for 2023 shows that the single PM_{10} exceedance in 2023 was a non-exceptional exceedance due to local dust (DCCEEW 2025). The NEPM compliance report for 2024 has not been published at the time of this assessment and the cause of the single PM_{10} exceedance in 2024 is unknown.

Figure 12 Measured 24-Hour Average PM_{10} Concentrations at Bringelly AQMS (2020-2024)

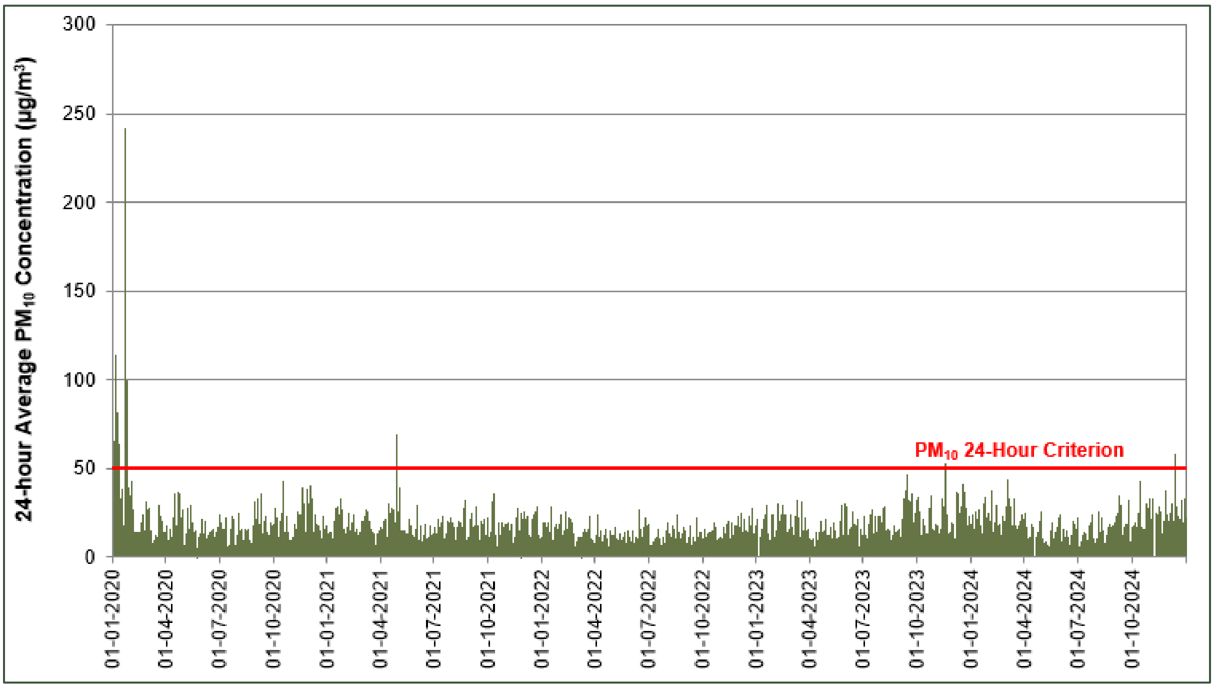
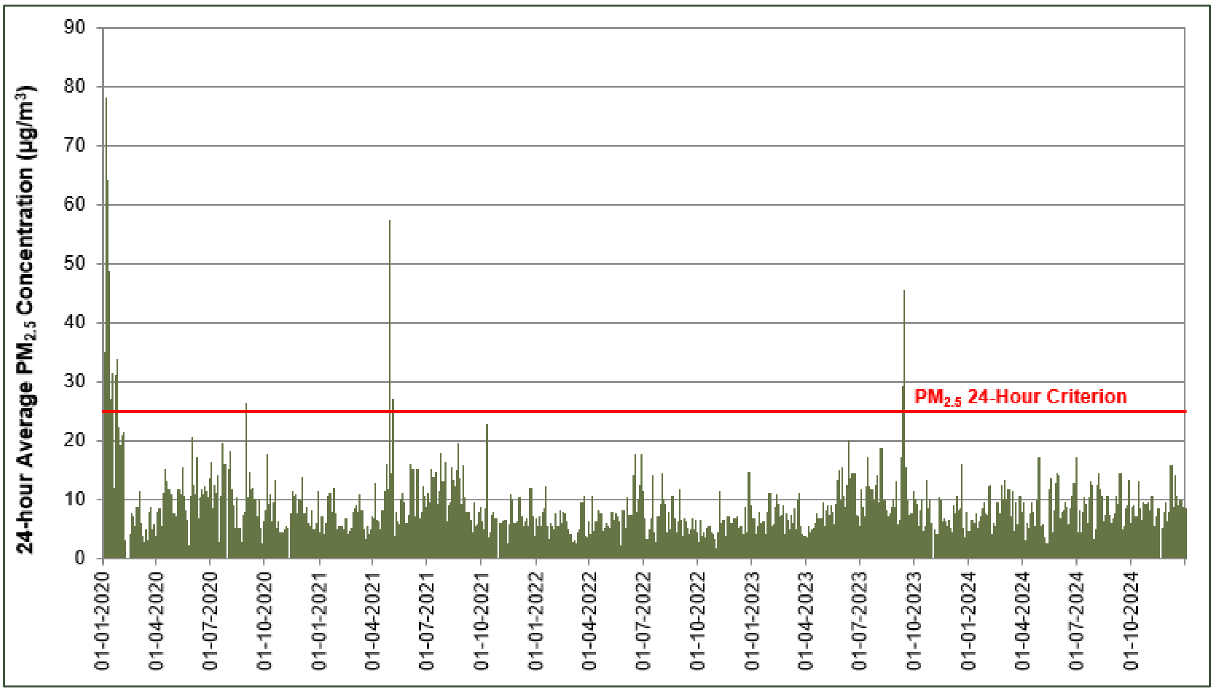


Figure 13 Measured 24-Hour Average $PM_{2.5}$ Concentrations at Bringelly AQMS (2020-2024)



4.0 Assessment Methodology

The assessment of air emissions from the proposed construction Project has been performed quantitatively using dispersion modelling techniques.

The dispersion modelling was performed using the CALPUFF dispersion model (Version 6). The CALPUFF dispersion model is approved by NSW EPA for the modelling of air quality impacts in NSW and it has been used in numerous air quality impact assessments in NSW and across Australia.

CALPUFF is a transport and dispersion model that ejects “puffs” of material emitted from modelled sources, simulating dispersion and transformation processes along the way. In doing so it typically uses the fields generated by a meteorological pre-processor CALMET, Temporal and spatial variations in the meteorological fields selected are explicitly incorporated in the resulting distribution of puffs throughout a simulation period.

The primary output files from CALPUFF contain hourly concentrations or deposition values evaluated at selected receptor locations. The CALPOST post-processor is then used to process these files, producing tabulations that summarise results of the simulation for user-selected averaging periods.

4.1 Meteorological Modelling

Meteorological mechanisms govern the dispersion, transformation and eventual removal of pollutants from the atmosphere. The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth’s boundary layer. Dispersion comprises vertical and horizontal components of motion. The stability of the atmosphere and the depth of the surface-mixing layer define the vertical component. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume ‘stretching’. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. The wind direction, and the variability in wind direction, determines the general path pollutants will follow, and the extent of crosswind spreading.

Pollution concentration levels therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth, and to shifts in the wind field (Oke 1988).

To adequately characterise the dispersion meteorology of the Site, information is needed on the prevailing wind regime, mixing height and atmospheric stability and other parameters such as ambient temperature, rainfall and relative humidity.

In order to determine a representative meteorological year for use in dispersion modelling, five years of meteorological data (2020-2024) from the closest meteorological monitoring station (i.e. Horsley Park Equestrian Centre AWS) were analysed against the five-year average meteorological conditions. Specifically, the following parameters were analysed:

- frequency and distribution of the predominant wind directions
- monthly average wind speeds observed
- monthly average temperatures.

Based on this analysis, it was concluded that the year 2021 was representative of the last five years of meteorological conditions experienced at the Site and hence the 2021 calendar year was adopted for use in this assessment. A summary of the analysis is presented in **Appendix A**.

Details of the meteorological modelling completed are provided below. A summary of the meteorological model domain details is provided in **Table 5.** Evaluation of the processed meteorological data is provided **Appendix B**.

4.1.1 TAPM

In order to calculate all required meteorological parameters required by the dispersion modelling process, meteorological modelling using The Air Pollution Model (TAPM, v 4.0.4) has been performed. TAPM, developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) is a prognostic model which may be used to predict three-dimensional meteorological data and air pollution concentrations.

TAPM model predicts wind speed and direction, temperature, pressure, water vapour, cloud, rainwater and turbulence. The program allows the user to generate synthetic observations by referencing databases (covering terrain, vegetation and soil type, sea surface temperature and synoptic scale meteorological analyses) which are subsequently used in the model input to generate site-specific hourly meteorological observations at user-defined levels within the atmosphere. A full description of TAPM is available in the model user manual (CSIRO, 2008).

TAPM model may assimilate actual local wind observations so that they can optionally be included in a model solution. However, given that TAPM is known to under-predict calm wind conditions, the wind speed and direction observations obtained from the nearest BoM and stations have also been used in the subsequent CALMET component of the modelling as described in Section 4.2.

The dispersion modelling requires twelve months of hourly timestep meteorological data. The Air Pollution Model (TAPM) was used to generate site-representative data for input into CALMET for further processing of the fine scale three-dimensional wind field data required for the CALPUFF dispersion model.

4.1.2 CALMET

In the simplest terms, CALMET is a meteorological model that develops hourly wind and other meteorological fields on a three-dimensional gridded modelling domain that are required as inputs to the CALPUFF dispersion model. Associated two dimensional fields such as mixing height, surface characteristics and dispersion properties are also included in the file produced by CALMET. The interpolated wind field is then modified within the model to account for the influences of topography, sea breeze, as well as differential heating and surface roughness associated with different land uses across the modelling domain. These modifications are applied to the winds at each grid point to develop a final wind field. The final hourly varying wind field thus reflects the influences of local topography and land uses.

A full description of the CALMET/CALPUFF model is available in the CALPUFF manual (SRC 2011).

The CALMET domain was modelled with a resolution of 0.05 km. The TAPM-generated 3-dimensional meteorological data (1 km resolution) was used as the ‘initial guess’ wind field and the local topography and available surface weather observations in the area were used to refine the wind field predetermined by TAPM.

Table 5 TAPM and CALMET Modelling Domain Details

Model and Domain Settings	Details	Model and Domain Settings	Details
TAPM		**CALMET**	
5 nested grids	25 x 25 x 35 grid points	Domain size	7 km x 7 km
Grid point resolutions	30 km, 10 km, 3 km, 1 km, 300 m	Receptor grid	50 m resolution
Domain origin centre point	E: 295,164 N: 6,253,975 Zone: 56H	Domain origin southwest corner	E: 292,500 N: 6,248,500 Zone: 56H
Period	31/01/12 2020 to 01/01/2022	Period	31/01/12 2020 to 01/01/2022
Modelled with wind assimilation data for Badgerys Creek AWS and Horsley Park Equestrian Centre AWS. Further details on model settings can be provided as required.		Initial guess field	3D output from TAPM

4.2 Dispersion Modelling

CALPUFF was used for the dispersion modelling and is widely used in Australia as a suitable model for a range of applications and conditions including odour modelling assessments.

As with any air dispersion model, CALPUFF requires inputs in three major areas:

- emission rates and source details
- meteorology
- terrain and surface details, as well as specification of specific receptor locations.

A summary of the model details is provided in **Table 6**.

Table 6 CALPUFF Domain Details and Model Settings

Item	Details
Domain details	50 m resolution for 7 km by 7 km domain
Receptor details	50 m resolution gridded receptors and 40 discrete receptors
Emissions data	Varys by emission source. Refer to **Section 5.0** for details.
Further details on model settings can be provided as required.	

4.2.1 Model Configuration

Emissions from the activities at the Project were represented by a series of volume sources, while wind erosion from exposed areas was represented by area sources.

The estimated particulate emissions were modelled as:

- Fine Particulates (FP < 2.5 µm);
- Course Matter (2.5 µm<CM<10 µm); and
- the Rest (RE>10 µm).

These parameters were then grouped using CALPOST to predict $PM_{2.5}$, PM_{10} and TSP concentrations at surrounding receptor locations. This approach provides the most realistic treatment of the differing size fractions, with the lighter, finer particulate matter being dispersed further than the heavier size fraction which settles out of the air more rapidly.

Based on the sensitivity of each activity to wind speed, an hourly varying emission file representing hourly FP, CM and RE emissions for each source was generated using the annual average emission rate estimated for each activity. Details of the algorithm used to generate the variable emission files are presented in **Appendix D**.

4.3 Adopted Background for this Assessment

The purpose of assessing background air quality is to determine the concentrations of air pollutants currently experienced at surrounding receptors, with the predicted concentrations from the Project added to these background concentrations to identify the likely future cumulative air quality impacts.

For the purposes of assessing potential cumulative off-site air quality impacts, an estimation of ambient air quality concentrations is required. In accordance with the Approved Methods, the background data used in this AQIA is based on the same year as the meteorological year used in the modelling (ie 2021).

The representative background ambient air quality concentrations adopted for use in this assessment are summarised in **Table 7**.

Table 7 Adopted Background Data

Pollutant	Averaging Period	Regional Background	Notes
TSP	Annual	37.5.0 µg/ m^3	Calculated from PM_{10} concentrations at Bringelly AQMS during 2021 during a PM_{10}/TSP ratio of 0.4
PM_{10}	24-hour	Daily varying	As monitored at Bringelly AQMS during 2021
	Annual	15.0 µg/ m^3	As monitored at Bringelly AQMS during 2021
$PM_{2.5}$	24-hour	Daily varying	As monitored at Bringelly AQMS during 2021
	Annual	7.2 µg/ m^3	As monitored at Bringelly AQMS during 2021
Deposited dust	Annual	2 g/m^2/month	Estimated. Not monitored at Bringelly AQMS

4.4 Accuracy of Modelling

All atmospheric dispersion models, including CALPUFF, represent a simplification of the many complex processes involved in the dispersion of pollutants in the atmosphere. To obtain good quality results it is important that the most appropriate model is used and the quality of the input data (meteorological, terrain, source characteristics) is adequate.

The main sources of uncertainty in dispersion models, and their effects, are discussed below:

- Oversimplification of physics: This can lead to both under-prediction and over-prediction of ground level pollutant concentrations. Uncertainties are greater in Gaussian plume models as they do not include the effects of non-steady-state meteorology (i.e., spatially- and temporally varying meteorology).
- Uncertainties in emission rates: Ground level concentrations are proportional to the pollutant emission rate. In addition, most modelling studies assume constant worst-case emission levels or are based on the results of a small number of stack tests, however operations (and thus emissions) are often quite variable. Accurate measurement of emission rates and source parameters requires continuous monitoring.
- Uncertainties in wind direction and wind speed: Wind direction affects the direction of plume travel, while wind speed affects plume rise and dilution of plume. Uncertainties in these parameters can result in errors in the predicted distance from the source of the plume impact, and magnitude of that impact. In addition, aloft wind directions commonly differ from surface wind directions. The preference to use rugged meteorological instruments to reduce maintenance requirements also means that light winds are often not well characterised.
- Uncertainties in mixing height: If the plume elevation reaches 80% or more of the mixing height, more interaction will occur, and it becomes increasingly important to properly characterise the depth of the mixed layer as well as the strength of the upper air inversion.
- Uncertainties in temperature: Ambient temperature affects plume buoyancy, so inaccuracies in the temperature data can result in potential errors in the predicted distance from the source of the plume impact, and magnitude of that impact.
- Uncertainties in stability estimates: Gaussian plume models use estimates of stability class, and 3D models use explicit vertical profiles of temperature and wind (which are used directly or indirectly to estimate stability class for Gaussian models). In either case, uncertainties in these parameters can cause either under-prediction or over-prediction of ground level concentrations. For example, if an error is made of one stability class, then the computed concentrations can be off by 50% or more.

The US EPA makes the following statement in its Modelling Guideline (US EPA 2005) on the relative accuracy of models:

"Models are more reliable for estimating longer time-averaged concentrations than for estimating short-term concentrations at specific locations; and the models are reasonably reliable in estimating the magnitude of highest concentrations occurring sometime, somewhere within an area. For example, errors in highest estimated concentrations of ±10 to 40% are found to be typical, i.e., certainly well within the often-quoted factor-of-two accuracy that has long been recognised for these models. However, estimates of concentrations that occur at a specific time and site are poorly correlated with actually observed concentrations and are much less reliable."

5.0 Emission Estimation

To effectively estimate the worst-case impacts due to the proposed bulk earthworks for the Project, a maximum day operating scenario was assessed, and assumed to occur every day. This ensures that the worst-case 24-hour impacts are captured.

The maximum cut/fill/transfer activity rates were derived by scaling-up the indicative bulk material volumes over the anticipated 9-month bulk earthworks period (refer to **Table 1**) and assuming all activities occur simultaneously 7-days per week, 365 days per year, between the hours of 7:00 am and 5:00 pm. In reality, bulk earthwork activities will only occur Monday – Friday between the hours of 7:00 am and 5:00 pm and are anticipated to last 9 months.

The equipment inventory is anticipated to include the following:

- 4x 651 Scrapers
- 4 x 627 Scrapers
- 2 x Dozers
- 1 x 70t Extractor
- 5 x 45t dump trucks
- 1 x Grader
- 2 x Water carts

It is important to note that as the emission inventory is based on quantity (and type) of material moved, and/or distance travelled, the precise numbers and types of equipment would not change the extent or shape of the predicted dust dispersion.

In addition, as the precise location of the equipment will vary on a day-to-day basis, the emissions estimation conservatively assumes that multiple equipment will be operating concurrently during the Project. Thus, the predicted contributions are also considered to be conservative, particularly with respect to travel on unsealed roads.

The estimated emissions for each activity are presented in **Table 8**. A detailed breakdown of the emissions factors and assumptions used to determine the Project emissions is provided in **Appendix C.**

The water carts at the Project will be utilised to control the highest dust generating activities by keeping materials and travel routes will be kept moist. To scraper stripping, dozer and grader activities, and wind erosion, a 50% control has been applied. To scraper travel, material transfer (loading/unloading) activities and haulage routes, a 75% control has been applied.

Table 8 Estimated Emissions

Activity		TSP emission (kg/y)	PM_{10} emission (kg/y)	$PM_{2.5}$ emission (kg/y)	Total (kg/y)	Rank
Scraper Strip	Scrapers stripping topsoil	1,811	456	91	2,359	14
Scraper Travel	Scraper travel stripping topsoil	5,041	1,444	144	6,629	10
Scraper Strip	Scraper stripping cut material	16,347	4,115	823	21,284	3
Scraper Travel	Scraper travel moving cut material	65,655	18,803	1,880	86,338	1
Loading/unloading	Excavator removing material at cut area	303	143	22	468	18
Loading/unloading	Loading material to transfer to crusher	213	101	15	329	19
Haulage	Excavated material haulage to crusher	5,933	1,699	170	7,802	9
Loading/unloading	Unloading at stockpiles at crusher	213	101	15	329	20
Loading/unloading	Loading material into crusher	213	101	15	329	21
Crushing	Crushing (uncontrolled)	1,257	559	83	1,899	16
Screening	Screening (uncontrolled)	5,821	2,002	135	7,959	8
Loading/unloading	Loading material to trucks from crushed to fill	213	101	15	329	22
Haulage	Excavated material haulage from crushed to fill	23,731	6,796	680	31,208	2
Loading/unloading	Unloading at fill area (from crushed to fill)	213	101	15	329	23
Loading/unloading	Loading material to trucks in cut area for transfer to fill	90	43	6	139	25
Haulage	Excavated material haulage transfer to fill area	10,036	2,874	287	13,198	6
Loading/unloading	Unloading at fill area (inclusive of all scraped material and all cut material moved by trucks that is not processed)	662	313	47	1,023	17
Haulage	Imported material haulage to fill area	3,272	937	94	4,303	11

Activity		TSP emission (kg/y)	PM_{10} emission (kg/y)	$PM_{2.5}$ emission (kg/y)	Total (kg/y)	Rank
Loading/unloading	Unloading at fill area (from imported material)	125	59	9	193	24
Dozer	Dozer (x2) (assumes for cut and fill)	15,519	3,337	1,629	20,485	4
Grader	Grader	7,849	2,453	243	10,545	7
Wind Erosion	Stage 2 area wind erosion - 1	9,198	4,599	690	14,487	5
	Stage 2 area wind erosion - 2	1,752	876	131	2,759	13
	Stage 2 area wind erosion - 3	1,314	657	99	2,070	15
Combustion	Diesel combustion -Stage 2	936	936	896	2,768	12
Total TSP emissions (kg/yr)		**177,718**	**53,605**	**8,237**	**239,560**	-

6.0 Assessment of Predicted Air Quality Impacts

The sections below present a summary of the air quality impacts predicted by the modelling at the sensitive receptors identified in Section 3.3.

Isopleth plots showing the incremental impact predicted due to the Project emissions (ie excluding background levels) for each pollutant are presented in **Appendix E**. These plots do not represent the dispersion pattern for any individual time period, but rather illustrate the maximum concentration that was predicted to occur at each model calculation point given the range of meteorological conditions occurring over the 2021 modelling period.

6.1 Particles as $PM_{2.5}$

6.1.1 Maximum 24-Hour Average $PM_{2.5}$ Concentrations

Table 9 presents a summary of the predicted maximum incremental and maximum cumulative impacts 24-hour average $PM_{2.5}$ impacts at the sensitive receptors.

Table 9 Summary of 24-Hour $PM_{2.5}$ Cumulative Impact Analysis

Receptor ID	Maximum 24-Hour Average $PM_{2.5}$ Concentrations (µg/m³)		Additional Exceedances
	Incremental Impact	Cumulative Impact	
R1	2.6	58.9	0
R2	1.6	57.6	0
R3	1.3	57.6	0
R4	1.8	57.5	0
R5	7.0	57.6	0
R6	4.3	58.5	0
R7	3.1	58.0	0
R8	3.5	57.7	0
R9	3.1	57.8	0
R10	4.5	57.8	0
R11	4.7	57.7	0
R12	4.2	57.6	0
R13	4.5	57.6	0
R14	7.6	57.6	0
R15	7.6	57.8	0
R16	8.4	57.7	0
R17	9.5	57.8	0
R18	2.0	57.9	0

Receptor ID	Maximum 24-Hour Average $PM_{2.5}$ Concentrations (µg/m³)		Additional Exceedances
	Incremental Impact	Cumulative Impact	
R19	4.2	57.7	0
R20	7.7	58.7	0
R21	2.9	58.9	0
R22	5.3	57.7	0
R23	3.1	58.4	0
R24	5.4	57.7	0
R25	2.2	57.6	0
R26	8.4	57.6	0
R27	6.8	57.7	0
R28	6.0	57.7	0
R29	1.4	57.7	0
R30	1.3	57.6	0
R31	1.1	57.6	0
R32	1.0	57.6	0
R33	1.6	57.6	0
R34	3.0	57.5	0
R35	3.5	57.7	0
R36	3.6	57.6	0
R37	4.4	57.6	0
R38	4.3	57.6	0
Criterion		25	-

Table 9 shows that there are predicted exceedances of the criterion, however impacts are dominated by the background $PM_{2.5}$. There are no additional exceedances due to the Project.

As discussed in **Section 4.3**, daily varying background concentrations were adopted from the Bringelly AQMS for contemporaneous analysis of the cumulative assessment. In accordance with the Approved Methods, a contemporaneous analysis of the maximum predicted concentrations at the worst impacted receptor (R17) was performed and is presented in **Table 10Table 10**. This analysis shows that the contribution of Project Site towards the maximum cumulative $PM_{2.5}$ 24-hour average concentrations does not result in additional exceedances of the criterion.

Table 10 24-hour Average PM_{10} Contemporaneous Analysis Summary (Receptor R17)

Date	$PM_{2.5}$ 24-Hour Average (µg/³)			Date	$PM_{2.5}$ 24-Hour Average (µg/m³)		
	Highest Background	Project Site Increment	Total		Background	Highest Project Site Increment	Total
27-04-2021	57.4	0.5	57.9	04-07-2021	5.8	9.5	15.3
04-05-2021	27.3	5.3	32.6	02-07-2021	9.9	8.7	18.6
03-05-2021	25.7	0.7	26.4	21-06-2021	4.0	8.5	12.5
09-10-2021	22.8	0.8	23.6	11-06-2021	7.1	7.5	14.6
21-08-2021	19.7	1.9	21.6	09-07-2021	13.9	7.5	21.4
23-07-2021	18.0	0.1	18.1	05-06-2021	7.0	7.1	14.1
10-10-2021	17.6	0.3	17.9	19-07-2021	9.4	6.2	15.6
28-04-2021	17.0	0.5	17.5	16-05-2021	2.9	5.7	8.6
29-04-2021	16.6	0.6	17.2	15-07-2021	9.1	5.4	14.5
29-04-2021	16.6	0.6	17.2	04-05-2021	27.3	5.3	32.6

6.1.2 Annual Average $PM_{2.5}$ Concentrations

Table 11 presents the incremental and cumulative annual average $PM_{2.5}$ concentrations predicted at each of the identified receptors.

Table 11 Predicted Incremental and Cumulative Annual Average $PM_{2.5}$ Concentrations

Receptor ID	Annual Average $PM_{2.5}$ Concentrations (µg/m³)		
	Incremental Impact	Cumulative Impact	Additional Exceedance
R1	0.3	7.5	No
R2	0.2	7.4	No
R3	0.1	7.4	No
R4	0.2	7.5	No
R5	1.1	8.4	Yes
R6	0.6	7.8	No
R7	0.3	7.6	No
R8	0.5	7.7	No
R9	0.4	7.7	No
R10	0.5	7.7	No
R11	0.3	7.6	No
R12	0.3	7.5	No
R13	0.4	7.6	No
R14	0.7	8.0	No
R15	0.6	7.9	No

Receptor ID	Annual Average $PM_{2.5}$ Concentrations (µg/m^3)		
	Incremental Impact	Cumulative Impact	Additional Exceedance
R16	0.7	8.0	No
R17	0.9	8.1	Yes
R18	0.3	7.5	No
R19	0.6	7.8	No
R20	1.5	8.8	Yes
R21	0.3	7.6	No
R22	1.0	8.3	Yes
R23	0.4	7.6	No
R24	0.4	7.7	No
R25	0.2	7.5	No
R26	0.6	7.8	No
R27	0.6	7.9	No
R28	0.5	7.8	No
R29	0.1	7.4	No
R30	0.1	7.3	No
R31	0.1	7.3	No
R32	0.1	7.3	No
R33	0.2	7.4	No
R34	0.3	7.5	No
R35	0.2	7.5	No
R36	0.3	7.5	No
R37	0.4	7.6	No
R38	0.3	7.6	No
Criterion			8

Table 11 shows that the cumulative annual average $PM_{2.5}$ concentrations are predicted to exceed the annual average $PM_{2.5}$ criterion of 8 µg/m^3 at seven of the 38 receptors modelled. It is noted that the emission estimation adopted a number of assumptions to ensure short term impacts are not under estimated. For example, while the bulk earth works is expected to be completed in 9 months, all activities have been scaled up by approximately 33% to allow for the assessment of emissions under varying meteorological conditions. These assumptions result in an over estimation of annual predictions by potentially over 30%.

6.2 Particles as PM_{10}

6.2.1 Maximum 24-Hour Average PM_{10} Concentrations

Table 12 presents a summary of the predicted maximum incremental and maximum cumulative impacts 24-hour average PM_{10} impacts at the sensitive receptors.

Table 12 Summary of 24-Hour PM_{10} Cumulative Impact Analysis

Receptor ID	Maximum 24-Hour Average PM_{10} Concentrations (µg/m^3)		Additional Exceedances
	Incremental Impact	Cumulative Impact	
R1	15.9	70.4	0
R2	9.8	70.5	0
R3	7.8	69.9	0
R4	11.5	70.4	0
R5	45.9	75.9	13
R6	27.6	72.9	2
R7	19.9	71.2	0
R8	22.0	71.5	1
R9	19.8	71.2	1
R10	28.7	70.9	1
R11	29.0	70.0	0
R12	24.7	70.3	1
R13	27.4	70.3	1
R14	46.9	71.5	5
R15	46.5	70.9	3
R16	51.6	71.4	6
R17	58.1	72.1	9
R18	12.4	70.7	0
R19	24.8	71.9	1
R20	49.4	78.6	6
R21	18.2	70.9	0
R22	33.5	75.3	1
R23	19.0	70.8	0
R24	33.6	70.4	0
R25	13.7	70.2	0
R26	50.8	71.0	5
R27	41.7	71.1	2
R28	36.7	70.6	1

Receptor ID	Maximum 24-Hour Average PM_{10} Concentrations (µg/m³)		Additional Exceedances
	Incremental Impact	Cumulative Impact	
R29	8.8	70.2	0
R30	8.4	70.2	0
R31	7.3	70.4	0
R32	6.3	70.5	0
R33	9.8	69.8	0
R34	19.2	71.2	0
R35	20.3	70.2	1
R36	21.3	70.1	1
R37	26.3	70.2	1
R38	25.7	70.2	1
Criterion		50	-

Table 12 shows that there are predicted exceedances of the criterion at some receptors.

As discussed in **Section 4.3**, daily varying background concentrations were adopted from the Bringelly AQMS for contemporaneous analysis of the cumulative assessment. In accordance with the Approved Methods, a contemporaneous analysis of the maximum predicted concentrations at the worst impacted receptor (R5) was performed and is presented in **Table 13. Figure 14** shows the daily cumulative impact predicted. It is noted that the highest 24-hour average PM_{10} increment (ie Project only) is predicted at receptor R17, however R5 has the highest number of predicted additional exceedances and is therefore considered the worst impacted receptor for the purpose of contemporaneous analysis.

This analysis shows that the contribution of Project towards the maximum cumulative PM_{10} 24-hour average concentrations results in a number of additional exceedances of the criterion. **Figure 18** provides a plot of the dispersion pattern for the maximum impacts in the project area for the 24-hour averaging period. As illustrated, the incremental impacts associated with the Project are higher in the winter months.

Table 13 24-hour Average PM_{10} Contemporaneous Analysis Summary (Receptor R5)

Date	PM_{10} 24-Hour Average (µg/m³)			Date	PM_{10} 24-Hour Average (µg/m³)		
	Highest Background	Project Increment	Total		Background	Highest Project Increment	Total
27-04-2021	69.0	6.9	75.9	02-07-2021	10.6	45.9	56.5
03-05-2021	39.9	21.6	61.5	03-06-2021	21.3	39.6	60.9
09-10-2021	36.1	13.5	49.6	23-06-2021	17.6	38.7	56.3
23-01-2021	33.5	9.7	43.2	08-07-2021	21.7	38.6	60.3

Date	PM$_{10}$ 24-Hour Average (µg/m³)			Date	PM$_{10}$ 24-Hour Average (µg/m³)		
	Highest Background	Project Increment	Total		Background	Highest Project Increment	Total
21-08-2021	32.2	8.2	40.4	13-07-2021	19.5	37.6	57.1
08-10-2021	31.1	9.5	40.6	02-06-2021	29.7	37.2	66.9
07-10-2021	31.0	5.8	36.8	15-07-2021	16.9	35.6	52.5
04-05-2021	30.5	8.7	39.2	10-06-2021	9.2	33.6	42.8
14-04-2021	30.4	12.6	43.0	12-07-2021	17.4	33.0	50.4
02-06-2021	29.7	37.2	66.9	25-05-2021	11.2	32.8	44.0

Figure 14 Daily Contemporaneous Analysis

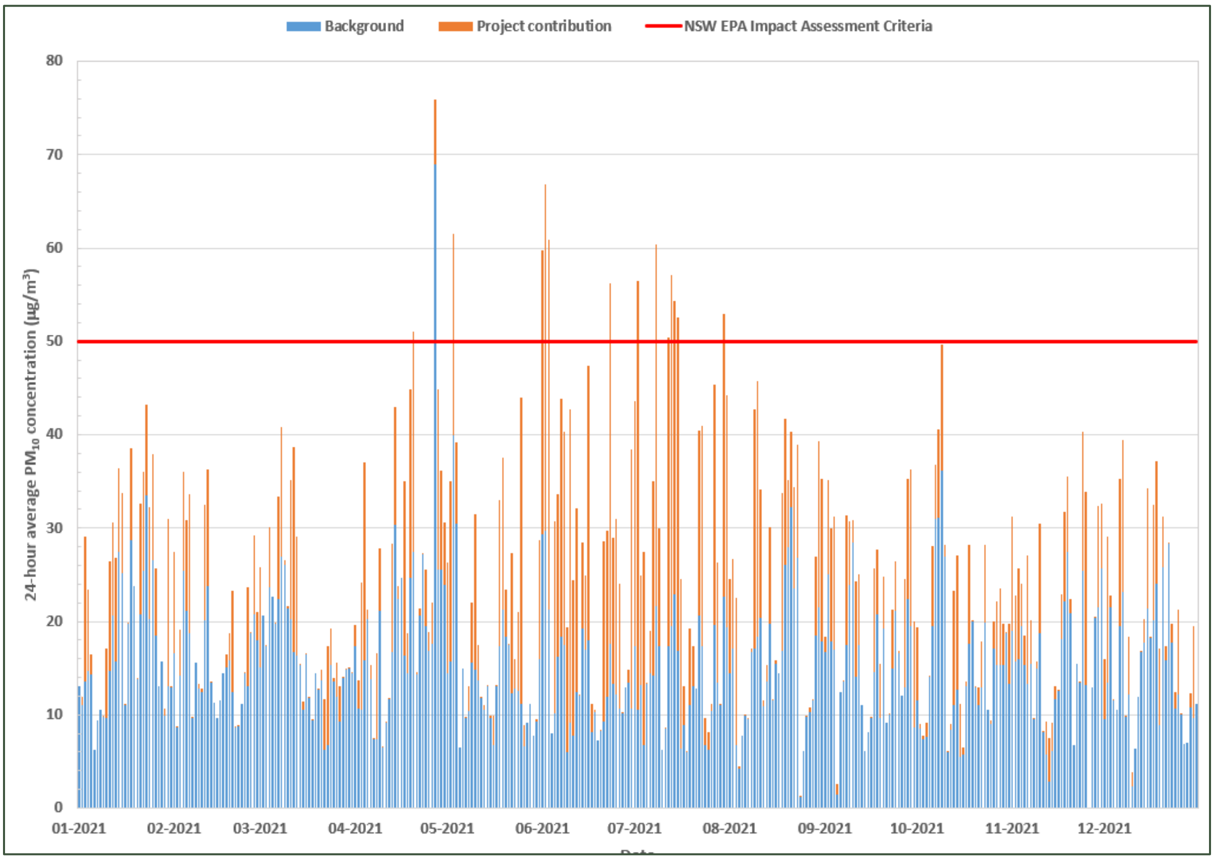
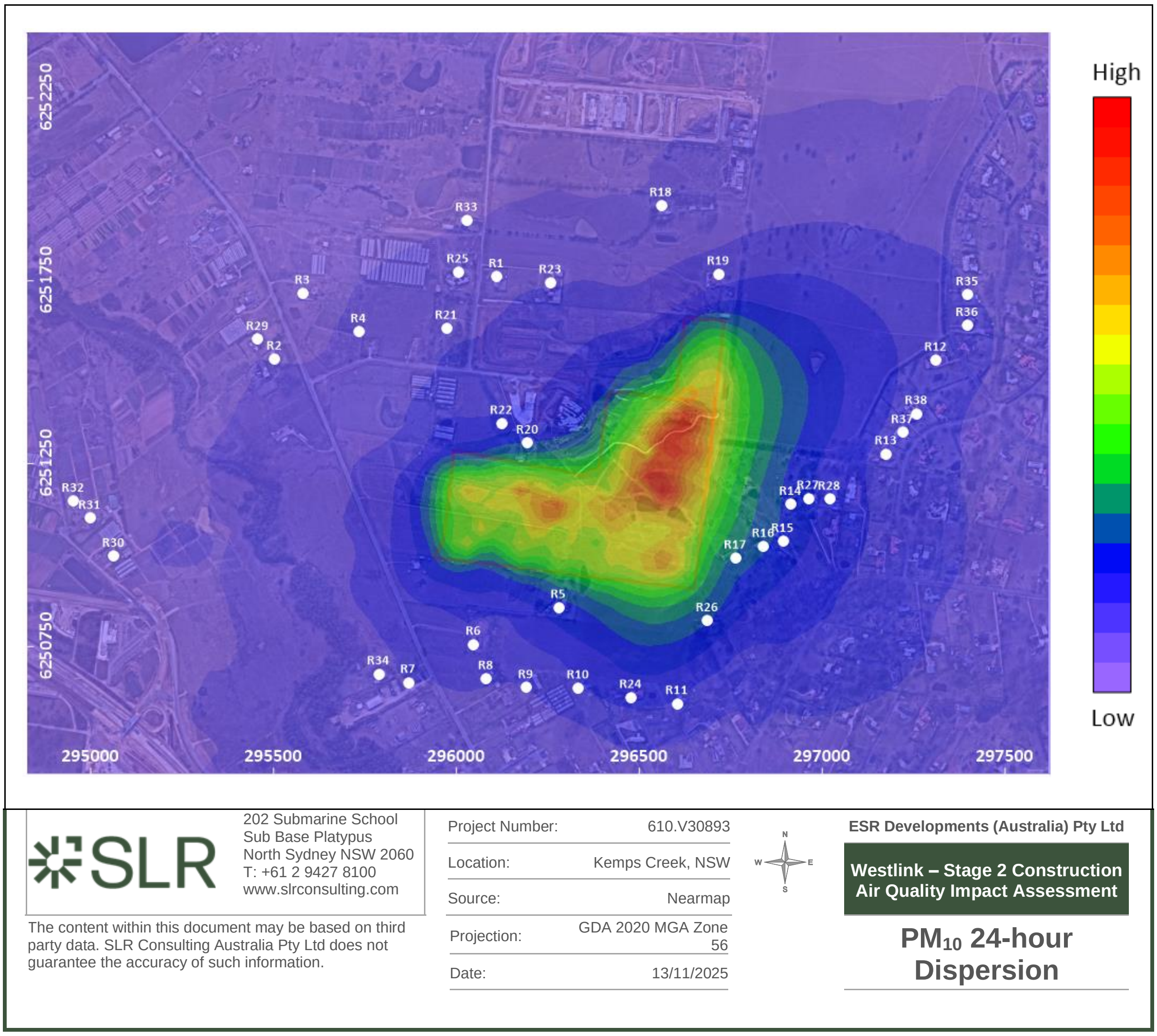


Figure 15 PM_{10} 24-hour Maximum Impact Dispersion Pattern



6.2.2 Meteorological Conditions Contributing to Exceedances

In order to determine the meteorological conditions that result in the highest contribution at the worst impacted receptors, timeseries of predicted 1-hour average PM_{10} contributions were extracted at some of the identified worst case receptors, including the worst impacted receptor (R5), and combined with the contemporaneous windspeed and wind direction data to create the polar plots presented in **Figure 16**.

Polar plots show how the predicted contribution at each receptor varies with both wind speed and direction. All figures are plotted on the same arbitrary scale to allow for direct comparison between them.

A review of the polar plots indicates that the PM_{10} contribution at receptors R17, R5 and R26 is greater at wind speeds under 2 m/s. As there are receptors in all direction from Site, there is not a predominate wind direction causing impacts at receptors.

Figure 17 presents annual and seasonal windroses at the Site based on the meteorological data used in the dispersion modelling for the proposed operating hours (7am to 5pm). A review of these windroses show that low windspeeds occur least frequently in spring, and lest frequently from the northwest and northeast.

Figure 16 Polar Plots of Predicted 1-hour Average PM_{10} Contribution at Selected Worst Impacted Receptors

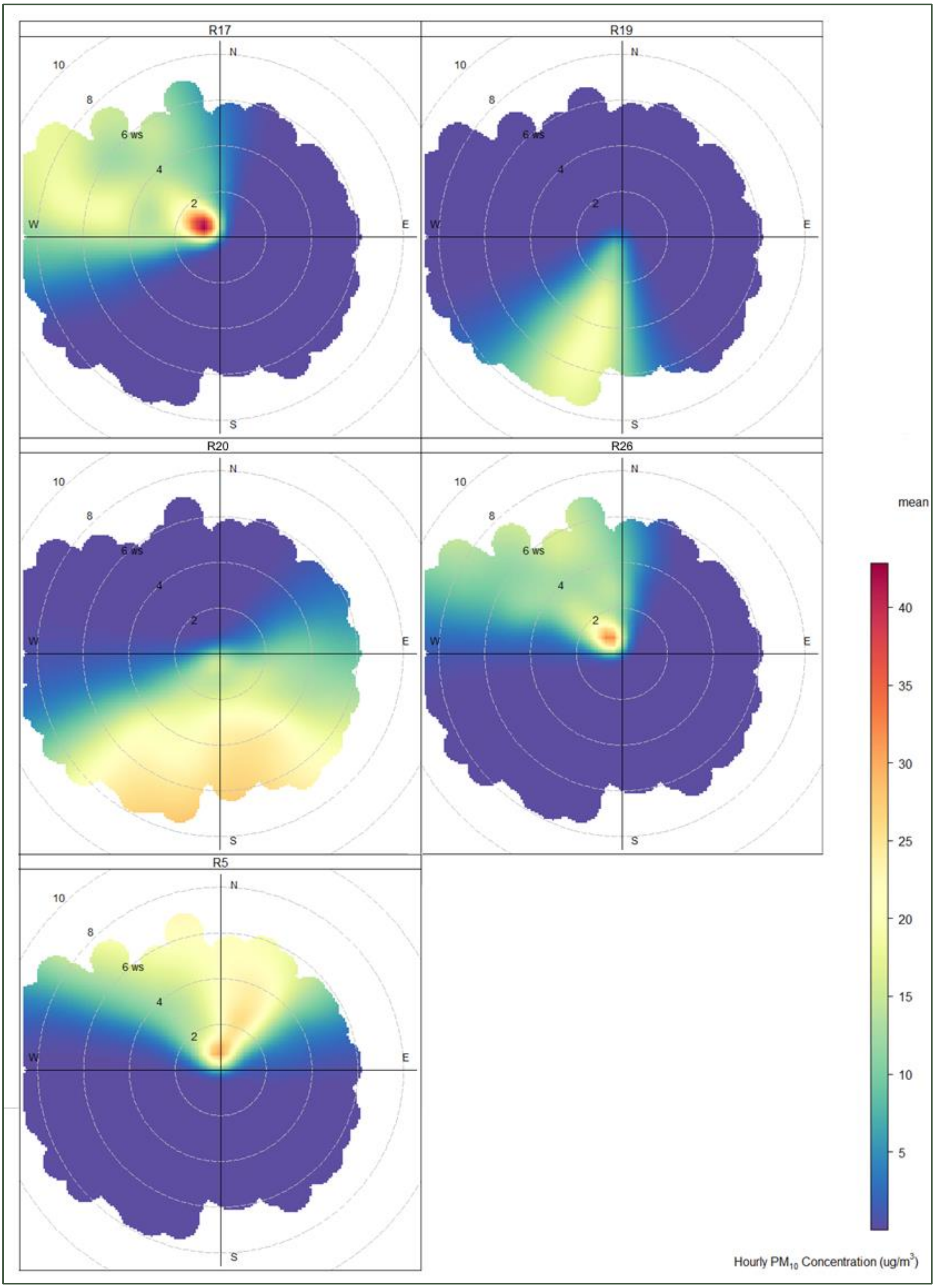
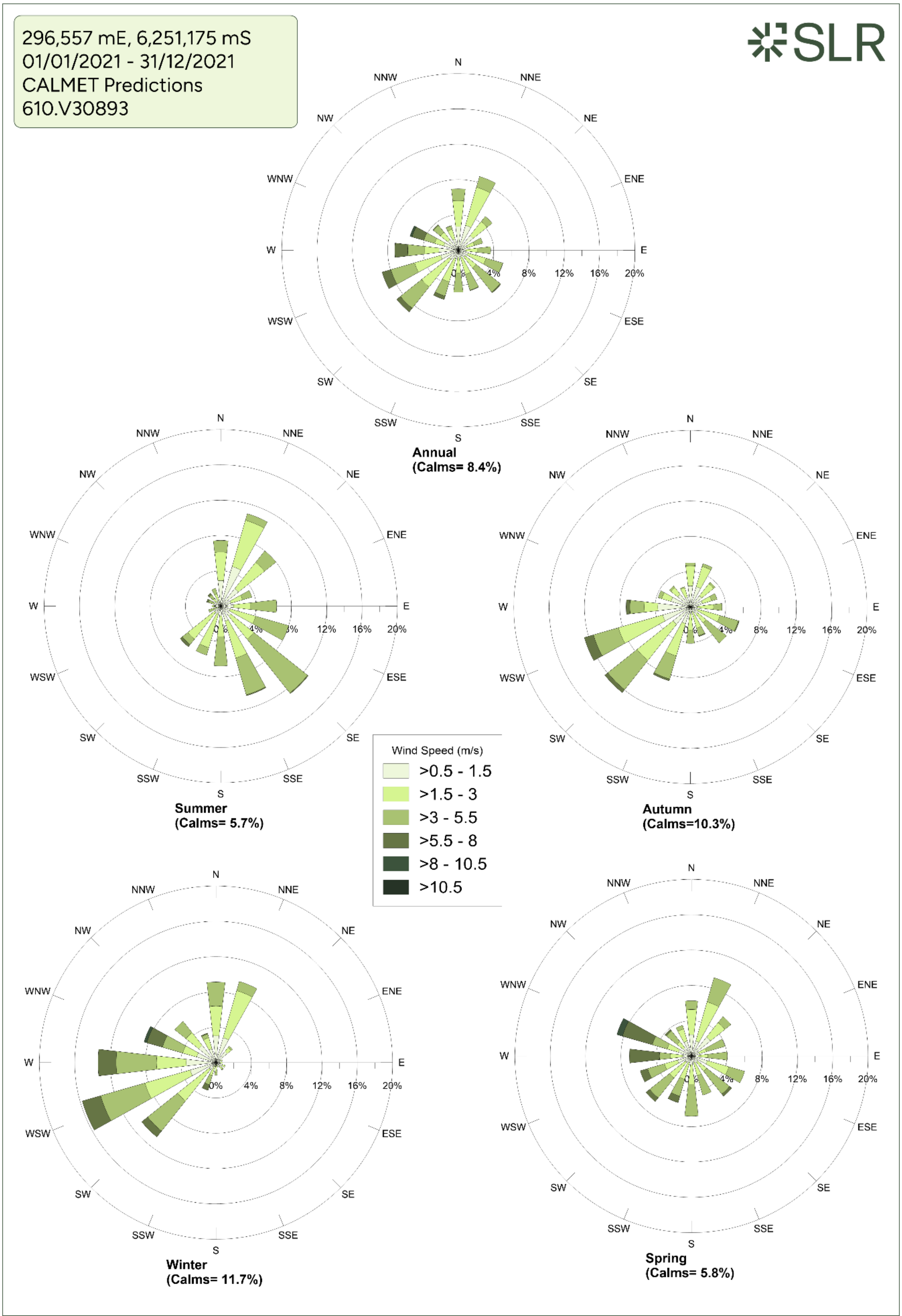


Figure 17 Annual and Seasonal Windroses at the Site: 7am – 5pm



6.2.3 Annual Average PM_{10} Concentrations

Table 14 presents the incremental and cumulative annual average PM_{10} concentrations predicted at each of the identified receptors.

Table 14 Predicted Incremental and Cumulative Annual Average PM_{10} Concentrations

Receptor ID	Annual Average PM_{10} Concentrations (µg/m³)		
	Incremental Impact	Cumulative Impact	Additional Exceedances
R1	1.8	17.1	No
R2	1.0	16.3	No
R3	0.9	16.2	No
R4	1.4	16.7	No
R5	7.3	22.5	No
R6	3.9	19.2	No
R7	2.2	17.5	No
R8	3.0	18.3	No
R9	2.9	18.2	No
R10	3.2	18.5	No
R11	2.0	17.2	No
R12	1.9	17.2	No
R13	2.4	17.7	No
R14	4.4	19.7	No
R15	3.9	19.2	No
R16	4.5	19.8	No
R17	5.5	20.8	No
R18	1.7	17.0	No
R19	3.7	18.9	No
R20	10.1	25.4	Yes
R21	2.1	17.4	No
R22	6.7	22.0	No
R23	2.3	17.6	No
R24	2.6	17.9	No
R25	1.5	16.8	No
R26	3.7	19.0	No
R27	3.8	19.1	No
R28	3.2	18.5	No
R29	0.9	16.1	No
R30	0.5	15.7	No

Receptor ID	Annual Average PM_{10} Concentrations (µg/m^3)		
	Incremental Impact	Cumulative Impact	Additional Exceedances
R31	0.4	15.7	No
R32	0.4	15.7	No
R33	1.2	16.5	No
R34	2.0	17.3	No
R35	1.5	16.8	No
R36	1.6	16.8	No
R37	2.2	17.5	No
R38	2.1	17.3	No
Criterion			25

Table 14 shows that the cumulative annual average PM_{10} concentrations at the receptor are below the annual average PM_{10} criterion of 25 µg/ m^{3}at all receptors except R20. This receptor has a marginal exceedance of 0.4 µg/ m^{3}above the criterion. As noted in Section 6.1.2, the assumptions made for the emission estimation are expected to have resulted in an over estimation of annual predictions by potentially over 30%.

6.3 Particles as TSP

6.3.1 Annual Average TSP Concentrations

Table 15 presents the incremental and cumulative annual average TSP concentrations predicted at each of the identified receptors.

Table 15 Predicted Incremental and Cumulative Annual Average TSP Concentrations

Receptor ID	Annual Average TSP Concentrations (µg/m^3)		
	Regional Background	Incremental Impact	Cumulative Impact
R1	37.5	4.7	42.2
R2	37.5	2.5	40.0
R3	37.5	2.4	39.9
R4	37.5	3.6	41.1
R5	37.5	20.6	58.1
R6	37.5	10.7	48.2
R7	37.5	6.1	43.6
R8	37.5	8.2	45.7
R9	37.5	7.8	45.3
R10	37.5	8.5	46.0
R11	37.5	5.1	42.6
R12	37.5	4.5	42.0
R13	37.5	5.9	43.4

Receptor ID	Annual Average TSP Concentrations (µg/m³)		
	Regional Background	Incremental Impact	Cumulative Impact
R14	37.5	11.7	49.2
R15	37.5	10.2	47.7
R16	37.5	12.0	49.5
R17	37.5	15.1	52.6
R18	37.5	4.4	41.9
R19	37.5	9.8	47.3
R20	37.5	28.5	66.0
R21	37.5	5.5	43.0
R22	37.5	18.6	56.1
R23	37.5	6.0	43.5
R24	37.5	6.9	44.4
R25	37.5	4.0	41.5
R26	37.5	9.9	47.4
R27	37.5	10.0	47.5
R28	37.5	8.2	45.7
R29	37.5	2.2	39.7
R30	37.5	1.1	38.6
R31	37.5	1.0	38.5
R32	37.5	0.9	38.4
R33	37.5	3.0	40.5
R34	37.5	5.4	42.9
R35	37.5	3.6	41.1
R36	37.5	3.7	41.2
R37	37.5	5.4	42.9
R38	37.5	5.0	42.5
Criterion			90

Table 15 indicate that the predicted cumulative concentrations at both receptors are below the annual average TSP criterion of 90 µg/ m³. As noted in Section 6.1.2, the assumptions made for the emission estimation are expected to have resulted in an over estimation of annual predictions by potentially over 30%.

6.4 Dust Deposition

Table 16 shows the annual average dust deposition rates predicted at each of the identified receptors.

Table 16 Predicted Annual Average Dust Deposition Rates

Receptor ID	Annual Average Dust Deposition Rate (g/m^2/month)		
	Regional Background	Incremental Impact	Cumulative Impact
R1	2.0	0.2	2.2
R2	2.0	0.1	2.1
R3	2.0	0.1	2.1
R4	2.0	0.2	2.2
R5	2.0	0.9	2.9
R6	2.0	0.4	2.4
R7	2.0	0.2	2.2
R8	2.0	0.3	2.3
R9	2.0	0.3	2.3
R10	2.0	0.4	2.4
R11	2.0	0.2	2.2
R12	2.0	0.2	2.2
R13	2.0	0.3	2.3
R14	2.0	0.5	2.5
R15	2.0	0.4	2.4
R16	2.0	0.5	2.5
R17	2.0	0.7	2.7
R18	2.0	0.2	2.2
R19	2.0	0.4	2.4
R20	2.0	1.7	3.7
R21	2.0	0.3	2.3
R22	2.0	1.0	3.0
R23	2.0	0.3	2.3
R24	2.0	0.3	2.3
R25	2.0	0.2	2.2
R26	2.0	0.4	2.4
R27	2.0	0.4	2.4
R28	2.0	0.4	2.4
R29	2.0	0.1	2.1
R30	2.0	0.0	2.0
R31	2.0	0.0	2.0
R32	2.0	0.0	2.0
R33	2.0	0.1	2.1

Receptor ID	Annual Average Dust Deposition Rate (g/m^2/month)		
	Regional Background	Incremental Impact	Cumulative Impact
R34	2.0	0.2	2.2
R35	2.0	0.2	2.2
R36	2.0	0.2	2.2
R37	2.0	0.2	2.2
R38	2.0	0.2	2.2
Criterion			4

Table 16 indicates that the predicted incremental and cumulative annual average dust deposition rates at both receptors are below the criterion of 2 g/m^2/month (incremental increase in dust deposition) and below 4 g/m^2/month (cumulative dust deposition). At all receptors modelled with the exception of R5, R17, R20 and R22, the incremental impacts predicted due to the estimated emissions from the Project are very low (<0.5 g/m^2/month) and represent a negligible contribution to the total cumulative concentrations. As noted in Section 6.1.2, the assumptions made for the emission estimation are expected to have resulted in an over estimation of annual predictions by potentially over 30%.

6.5 Cumulative Impacts

Cumulative impacts presented above have been calculated by adding the predicted incremental impacts from the Project to the background air quality data recorded by the Bringelly AQMS.

Consideration has been given to surrounding sources with the potential to cause similar impacts. However, SLR understands that all significant dust generating construction works for Westlink Stage 1 will be completed before Project construction begins and that there are no other construction activities within 500 metres with significant potential to lead to cumulative impacts.

7.0 Dust Mitigation Measures

The results of the dispersion modelling indicate potential exceedances of both short-term (24-hour) and long term (annual average) particulate averages criteria for PM_{10} and exceedances of the long-term particulate averages criterion for $PM_{2.5}$. It is noted that conservative assumptions made to ensure short term impacts are not underpredicted are expected to have resulted in potentially significant over estimation of long-term impacts. Therefore, if appropriate measures are put in place to ensure compliance with the relevant short-term criteria, exceedances of long-term criteria are unlikely.

Control measures already quantified for the purpose of this AQIA and proposed to be adopted for the Project are listed in **Appendix C** .

Dust mitigation and management measures recommended by the Original AQIA are listed in **Table 17** to **Table 20**. It is noted that benefits gained from all mitigation measures recommended by the Original AQIA could not be quantified.

These mitigation measures may be adopted in a site-specific Air Quality Management Plan (AQMP). AQMPs cover all sources of emissions, such as those identified in Section 4.3 of this AQIA, including wind erosion, wheel generated dust, extraction, material handling and processing of extracted material.

In addition, it is recommended that the Project utilises a Trigger Action Response Plan (TARP) supported by PM_{10} real-time air quality monitors to manage impacts at receptors.

Table 17 Recommended Dust Mitigation Measures for the Project

	Activity
1	Display the name and contact details of person(s) account-able for air quality and dust issues on the site boundary. This may be the environment manager/engineer or the site manager.
2	Display the head or regional office contact information.
3	Develop and implement a Dust Management Plan (DMP), which may include measures to control other emissions, approved by the Local Authority. The level of detail will depend on the risk and should include as a minimum the highly recommended measures in this document. The desirable measures should be included as appropriate for the site.
Site Management	
4	Record all dust and air quality complaints, identify cause(s), take appropriate measures to reduce emissions in a timely manner, and record the measures taken.
5	Make the complaints log available to the local authority when asked.
6	Record any exceptional incidents that cause dust and/or air emissions, either on- or off-site, and the action taken to resolve the situation in the logbook.
Monitoring	
7	Undertake daily on-site and off-site inspection, where receptors (including roads) are nearby, to monitor dust, record inspection results, and make the log available to the local authority when asked. This should include regular dust soiling checks of surfaces such as street furniture, cars and window sills within 100 m of site boundary, with cleaning to be provided if necessary.

	Activity
8	Carry out regular site inspections to monitor compliance with the DMP, record inspection results, and make an inspection log available to the local authority when asked.
9	Increase the frequency of site inspections by the person accountable for air quality and dust issues on site when activities with a high potential to produce dust are being carried out and during prolonged dry or windy conditions.
Preparing and Maintaining the Site	
10	Plan site layout so that machinery and dust causing activities are located away from receptors, as far as is possible.
11	Erect solid screens or barriers around dusty activities or the site boundary that are at least as high as any stockpiles on site.
12	Fully enclose site or specific operations where there is a high potential for dust production and the site is actives for an extensive period
13	Avoid site runoff of water or mud.
14	Keep site fencing, barriers and scaffolding clean using wet methods.
15	Remove materials that have a potential to produce dust from site as soon as possible, unless being re-used on site. If they are being re-used on-site cover as described below.
16	Cover, seed, or fence stockpiles to prevent wind whipping.
Operating Vehicle/Machinery and Sustainable Travel	
17	Ensure all vehicles switch off engines when stationary - no idling vehicles.
18	Avoid the use of diesel- or petrol-powered generators and use mains electricity or battery powered equipment where practicable.
19	Impose and signpost a maximum-speed-limit of 15 mph on surfaced and 10 mph on un-surfaced haul roads and work areas (if long haul routes are required these speeds may be increased with suitable additional control measures provided, subject to the approval of the nominated undertaker and with the agreement of the local authority, where appropriate).
Operations	
20	Only use cutting, grinding or sawing equipment fitted or in conjunction with suitable dust suppression techniques such as water sprays or local extraction, e.g. suitable local exhaust ventilation systems.
21	Ensure an adequate water supply on the site for effective dust/particulate matter suppression/mitigation, using non-potable water where possible and appropriate.
22	Use enclosed chutes and conveyors and covered skips.
23	Minimise drop heights from conveyors, loading shovels, hoppers and other loading or handling equipment and use fine water sprays on such equipment wherever appropriate.

	Activity
24	Ensure equipment is readily available on site to clean any dry spillages and clean up spillages as soon as reasonably practicable after the event using wet cleaning methods.
Waste Management	
25	Avoid bonfires and burning of waste materials.

Table 18 Mitigation Measures Specific to Earthworks

Activity
Re-vegetate earthworks and exposed areas/soil stockpiles to stabilise surfaces as soon as practicable.
Use Hessian, mulches or trackifiers where it is not possible to re-vegetate or cover with topsoil, as soon as practicable.
Only remove the cover in small areas during work and not all at once.

Table 19 Mitigation Measures Specific to Construction

Activity
Avoid scabbling (roughening of concrete surfaces) if possible.
Ensure sand and other aggregates are stored in bunded areas and are not allowed to dry out, unless this is required for a particular process, in which case ensure that appropriate additional control measures are in place.
Ensure bulk cement and other fine powder materials are delivered in enclosed tankers and stored in silos with suitable emission control systems to prevent escape of material and overfilling during delivery.
For smaller supplies of fine power materials ensure bags are sealed after use and stored appropriately to prevent dust.

Table 20 Mitigation Measures Specific to Trackout

Activity
Use water-assisted dust sweeper(s) on the access and local roads, to remove, as necessary, any material tracked out of the site. This may require the sweeper being continuously in use.
Avoid dry sweeping of large areas.
Ensure vehicles entering and leaving sites are covered to prevent escape of materials during transport.
Inspect on-site haul routes for integrity and instigate necessary repairs to the surface as soon as reasonably practicable.
Record all inspections of haul routes and any subsequent action in a site log book.
Install hard surfaced haul routes, which are regularly damped down with fixed or mobile sprinkler systems, or mobile water bowsers and regularly cleaned.

Activity
Implement a wheel washing system (with rumble grids to dislodge accumulated dust and mud prior to leaving the site where reasonably practicable).
Ensure there is an adequate area of hard surfaced road between the wheel wash facility and the site exit, wherever site size and layout permit.
Access gates to be located at least 10 m from receptors where possible.

7.1 Ambient Air Quality Monitoring Locations

Indicative locations for the real-time ambient air quality monitors are located as shown in **Figure 18**. The type of monitor and locations will be finalised for inclusion in the Construction Air Quality Management Plan.

As discussed in **Section 6.2.2**, as there are receptors in all direction from Site, there is not a predominate wind direction causing impacts at receptors, therefore it is recommended that monitors are located in each direction near the most impacted receptors.

The location of these will allow for effective Project management and assist in minimising the potential for adverse air quality impacts at the sensitive receptors.

It is recommended that these locations are reviewed periodically to ensure representative of current construction activities and the seasonal variation in wind directions presented in **Figure 17**.

Figure 18 Recommended Locations of Ambient Air Quality Monitors

7.2 Trigger Action Response Plan

Trigger action response plans (TARPs) define the minimum set of actions required by workers in response to a deviation from normal working conditions.

A 1-hour average time period has been selected as a practical time-step for identifying sustained elevated dust concentrations that could potentially result in an exceedance of the NSW EPA 24-hour average PM_{10} criterion, while providing sufficient time for additional mitigation measures to be implemented at the Project to reduce dust emissions before such an exceedance occurs.

Table 21 presents recommended 1-hour average PM_{10} concentrations and actions. In the absence of local guidance, these values are adapted from the recommendation in the UK Institute of Air Quality Management (IAQM) Guidance on Monitoring in the Vicinity of Demolition and Construction Sites (IAQM 2018) that was developed based on extensive monitoring in the vicinity of construction sites and recommended a 1-hour average PM_{10}

concentration of 190 mg/m^3 as the trigger upon which action must immediately be taken to minimise dust emissions. The upper trigger has been conservatively lowered to 150 mg/ m^3.

Table 21 TARP PM_{10} Trigger Levels and Responses

Level	1-hour Average PM_{10} Trigger Level	Action
Alert	≥100 mg/ m3 but < 125 mg/ m^3 Or Wind speed < 2m/s Or Visible dust leaving the Site	• Review operations via a visual inspection of dust emissions from current activities to ensure all standard dust mitigation measures are being appropriately implemented. Where appropriate, implement additional remedial measures, such as: • Deployment of additional water sprays, water trucks etc • Determine if background concentrations may be the key contributor to high concentrations being recorded (e.g., based on wind direction, information on regional events such as bush fires or dust storms, etc). • Continue to closely monitor PM_{10} concentrations being recorded.
Action I	≥125 mg/ m^3 but < 150 mg/ m^3 AND Wind speed < 2m/s Or Visible dust leaving the Site	• Increase watering rates on haul roads where appropriate. • Reduce speed of equipment / vehicles. • Continue to closely monitor PM_{10} concentrations being recorded. • Undertake an investigation of the dust generating activities, and if necessary, temporarily halt the dust generating activities
Action II	≥ 150 mg/ m^3 AND Wind speed < 2m/s AND Or Visible dust leaving the Site	• Review planned operations considering exposed areas. • Cease any non-critical dust-producing activities or relocate relevant activities where possible away from sensitive receptors, or to less exposed locations. • Continue to closely monitor PM_{10} concentrations being recorded.

8.0 Summary

This report has predicted the dispersion of TSP, PM_{10} and $PM_{2.5}$ emissions from bulk earthworks proposed for the Project construction at the Site.

The emission estimation was based on a conservative scenario assuming all activities occur concurrently. The dispersion modelling has shown that exceedances of short term and long term PM_{10} criteria are predicted to occur.

Considering the following factors, overestimation of predicted concentrations by the model is likely:

- Inability to quantify benefits gained from some of the proposed mitigation measures (e.g. speed reduction, reducing the intensity of dust generating activities on days with elevated background pollutant concentrations or weather conditions conducive to dust impacts, etc.)
- Overestimation of annual impacts by scaling up activities from 9 to 12 months.
- Assessment of all activities operating simultaneously for at all times.
- Limitation of the CALPUFF model in predicting nearfield pollutant concentrations.
- Limitation of dispersion modelling to representatively predict reduced pollutant dispersion due to rainfall.

Regardless, it is recommended that:

- Real-time monitoring of ambient air quality be performed throughout the construction period to allow for effective site management and assist in minimising the potential for adverse air quality impacts at the sensitive receptors.
- A TARP based on 1-hour average PM_{10} concentrations and wind directions with a range of actions to minimise the potential for adverse effects at the sensitive receptors be adopted.

It is concluded that with an appropriate ambient air quality monitoring plan and TARP in place, the proposed construction activities can be completed without any significant impact on the surrounding receptors.

9.0 References

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Appendix A Selection of Representative Meteorological Data

Westlink – Stage 2 Construction

Air Quality Impact Assessment

ESR Developments (Australia Pty) Ltd

SLR Project No.: 610.V30893.00506

26 February 2025

Meteorological Year Selection

Once emitted to atmosphere, the emissions will:

- Rise according to the momentum and buoyancy of the emission at the discharge point relative to the prevailing atmospheric conditions.
- Be advected from the source according to the strength and direction of the wind at the height which the plume has risen in the atmosphere.
- Be diluted due to mixing with the ambient air, according to the intensity of turbulence.
- (Potentially) be chemically transformed and/or depleted by deposition processes.

Dispersion is the combined effect of these processes. Dispersion modelling is used as a tool to simulate the air quality effects of specific emission sources, given the meteorology typical for a local area together with the expected emissions. Selection of a year when the meteorological data is atypical means that the resultant predictions may not appropriately represent the most likely air quality impacts. Therefore, in dispersion modelling, one of the key considerations is the representative nature of the meteorological data used.

The year of meteorological data used for the dispersion modelling was selected by reviewing the most recent five years of historical surface observations at (2019 to 2023 inclusive) to determine the year that is most representative of average conditions. Wind direction and wind speed were compared to averages for the region to determine the most representative year.

It is noted that comparison of meteorological data was conducted prior to January 2025, therefore 2024 has not been included in the comparison.

Data collected from 2019 to 2023 is summarised in **Figure A-1** to **Figure A-2**. Examination of the data indicates the following:

Figure A-1 indicates relatively similar wind roses for all years analysed.

Figure A-2 indicates that 2021 exhibit wind speeds that are lower than the 5-year average which will result in a conservative assessment due to reduced dispersion.

Given the above, the year 2021 was selected as the representative year of meteorology.

Figure A-1 Frequency of Winds at Horsley Park Equestrian Centre AWS for 2019 – 2023

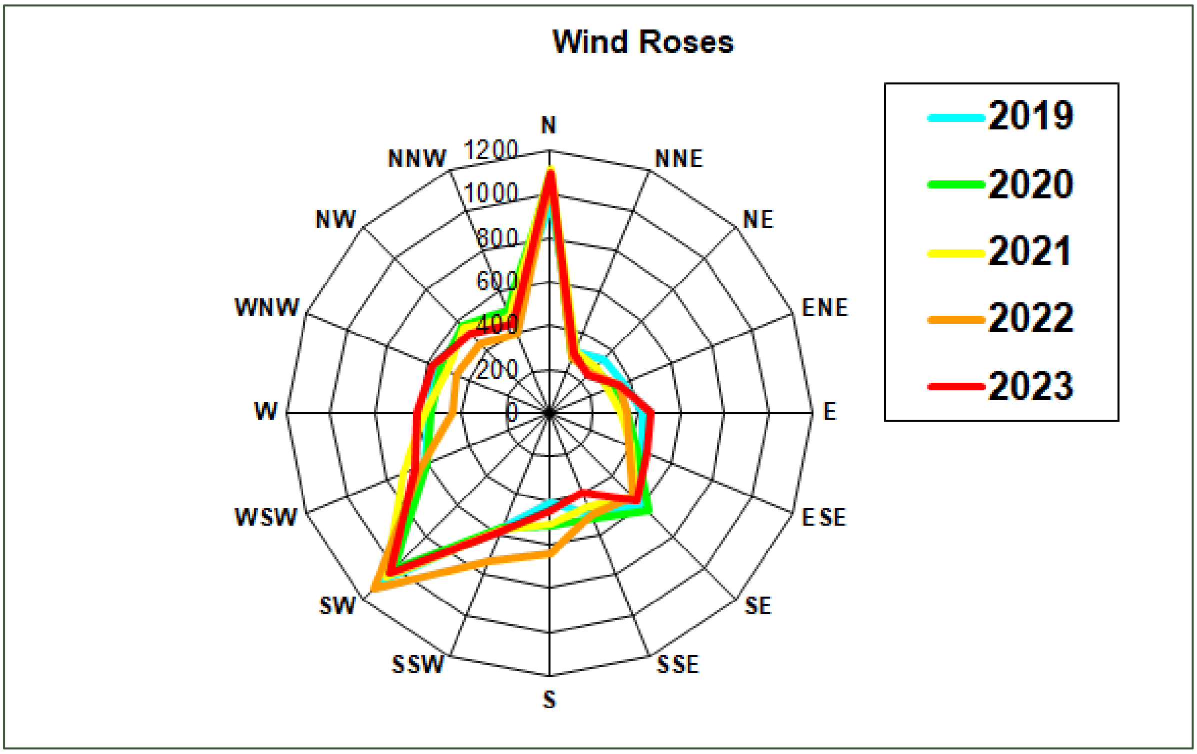
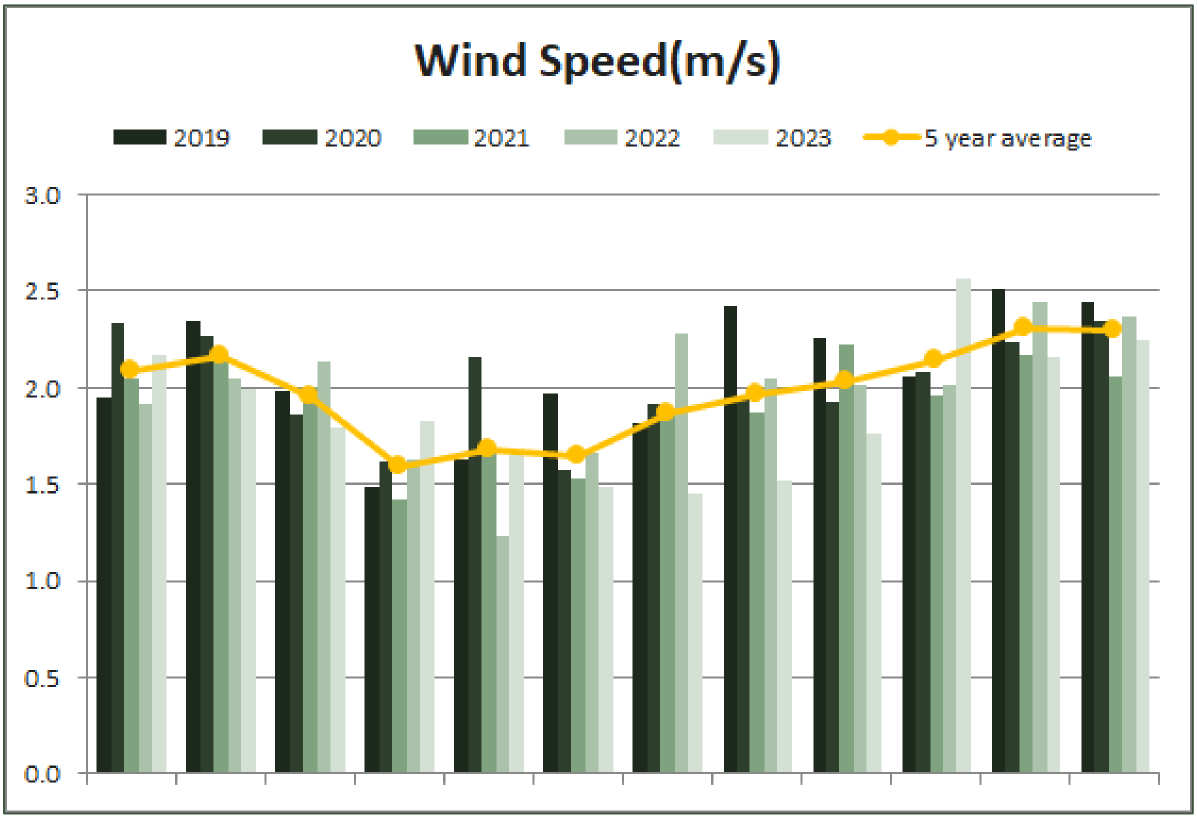


Figure A-2 Monthly Average Wind Speed at Horsley Park Equestrian Centre AWS for 2018 – 2023



Appendix B Evaluation of Meteorological Data

Westlink – Stage 2 Construction

Air Quality Impact Assessment

ESR Developments (Australia Pty) Ltd

SLR Project No.: 610.V30893.00506

26 February 2025

The primary meteorological data parameters relevant for dispersion modelling are typically:

- wind (wind speed and direction)
- turbulence (atmospheric stability)
- mixing height (depth of turbulent layer)

A review of the meteorological data used in the dispersion modelling for the above parameters is provided below.

Wind Speed and Wind Direction

A summary of the annual wind behaviour predicted by CALMET for 2021 (extracted at the Site) is presented as wind roses in **Figure B-1** and as a wind speed distribution plot in **Figure B-2**. These plots show that winds in the study area were predicted to be predominantly light to moderate during 2021. Calm wind conditions were predicted to occur approximately 17% of the time throughout the modelling period. Generally, higher wind speeds winds and low percentage of calm wind conditions will assist pollutant dispersion, resulting in lower pollution concentrations at the surrounding receptors.

The seasonal wind roses indicate that typically:

- In summer, winds blow from all directions except the northwestern quadrant, where winds occur infrequently. Calms were recorded approximately 15% of the time during the summer months.
- In autumn, winds predominantly blow from the southwestern quadrant, with the least frequent winds originating from the northeastern quadrant. Calms were recorded approximately 19% of the time during the autumn months.
- In winter, winds predominantly blow from the southwestern and northwestern quadrant, with the least frequent winds originating from the northeastern and southeastern quadrants. Calms were recorded 20% of the time.
- In spring, winds blow almost evenly from all directions. Calms were recorded approximately 14% of the time during spring.

A comparison of the wind roses presented in **Figure B-1** with the Horsley Park Equestrian Centre AWS wind roses presented in **Figure 10** shows that the frequency distribution of wind speed and direction for both is very similar throughout the year, with the CALMET predictions having slightly lower calms frequency. Based on the wind roses, the receptors with the greatest potential for air quality impacts are located to the the northeast, as southwesterly winds are predominate, primarily in Winter and Autumn.

Figure B-1 CALMET-Predicted Seasonal Wind Roses for the Site – 2021

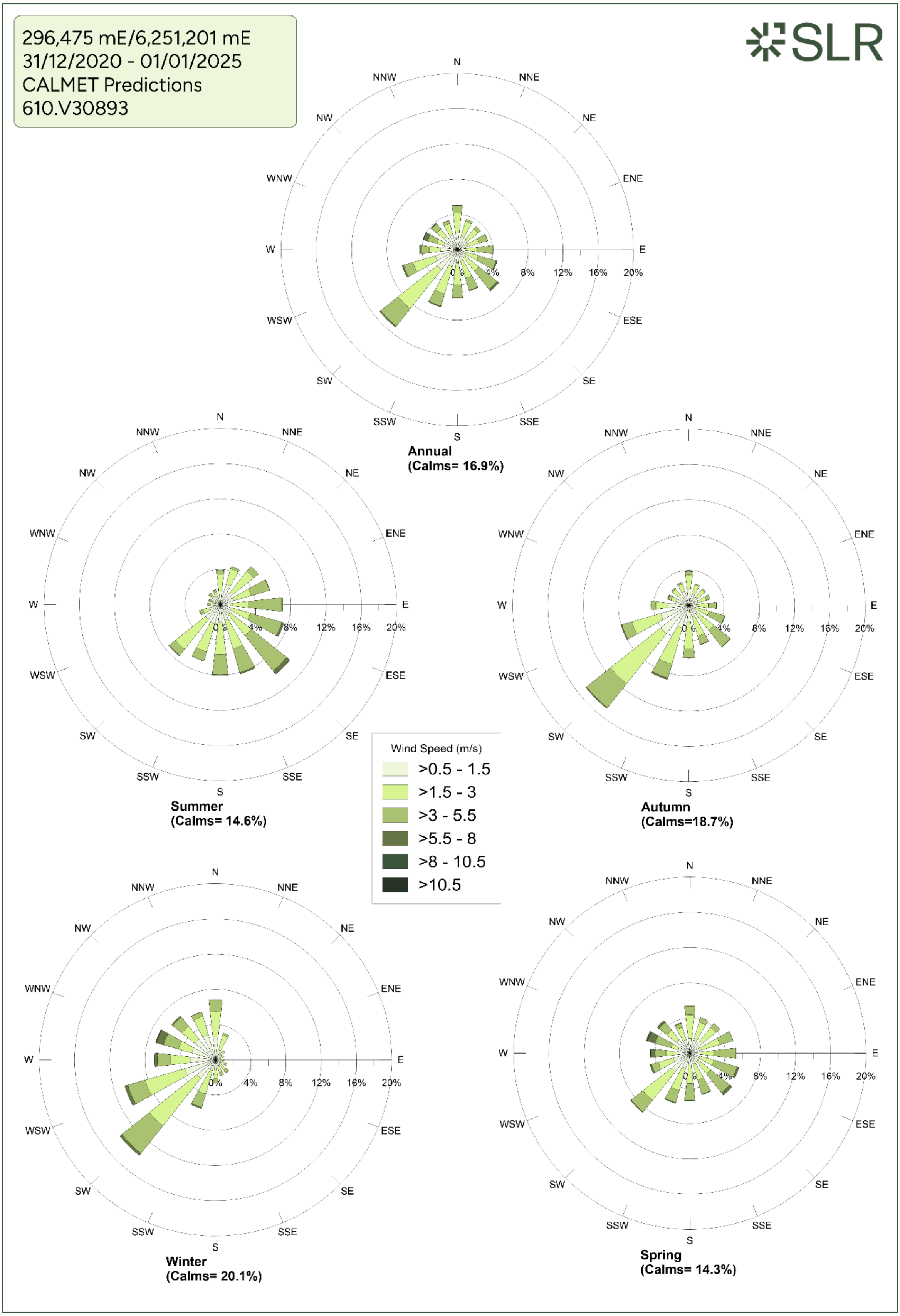
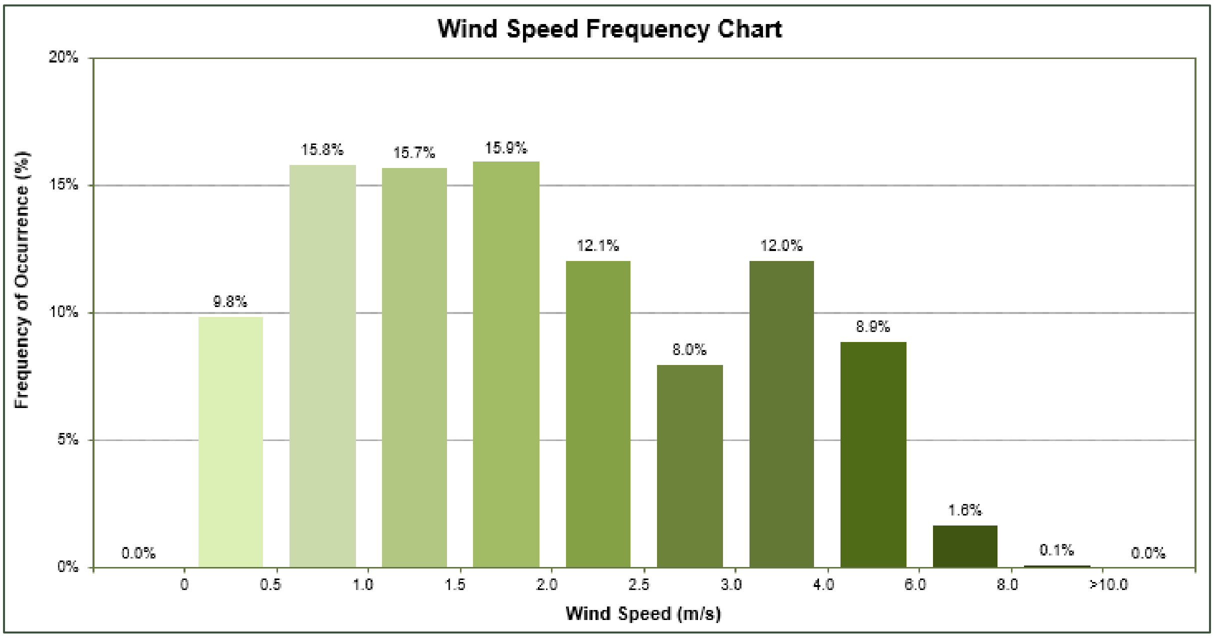


Figure B-2 Annual Wind Speed Frequencies at the Site (CALMET Predictions, 2021)



Atmospheric Stability

Atmospheric stability refers to atmospheric turbulence and the tendency of the atmosphere to resist or enhance vertical motion. Depending on conditions the atmospheric stability can either inhibit or promote pollutant dispersion. The Pasquill-Gifford scheme provides six stability classes, A to F, to categorise the degree of atmospheric stability as follows:

- A = Extremely unstable conditions
- B = Moderately unstable conditions
- C = Slightly unstable conditions
- D = Neutral conditions
- E = Slightly stable conditions
- F = Moderately stable conditions

The meteorological conditions defining each PGT stability class are shown in **Table B-1**.

Unstable conditions are favourable for dispersion, while stable conditions are unfavourable for dispersion.

The dispersion modelling in CALPUFF used a more advanced atmospheric stability scheme (based on micro meteorology). Stability class data was extracted from the meteorological dispersion modelling data set for the meteorological data evaluation.

Table B-1 Meteorological Conditions Defining PGT Stability Classes

Surface Wind Speed (m/s)	Daytime Insolation			Night-Time Conditions	
	Strong	Moderate	Slight	Thin overcast or > 4/8 low cloud	<= 4/8 cloudiness
< 2	A	A - B	B	E	F
2 - 3	A - B	B	C	E	F
3 - 5	B	B - C	C	D	E
5 - 6	C	C - D	D	D	D
> 6	C	D	D	D	D

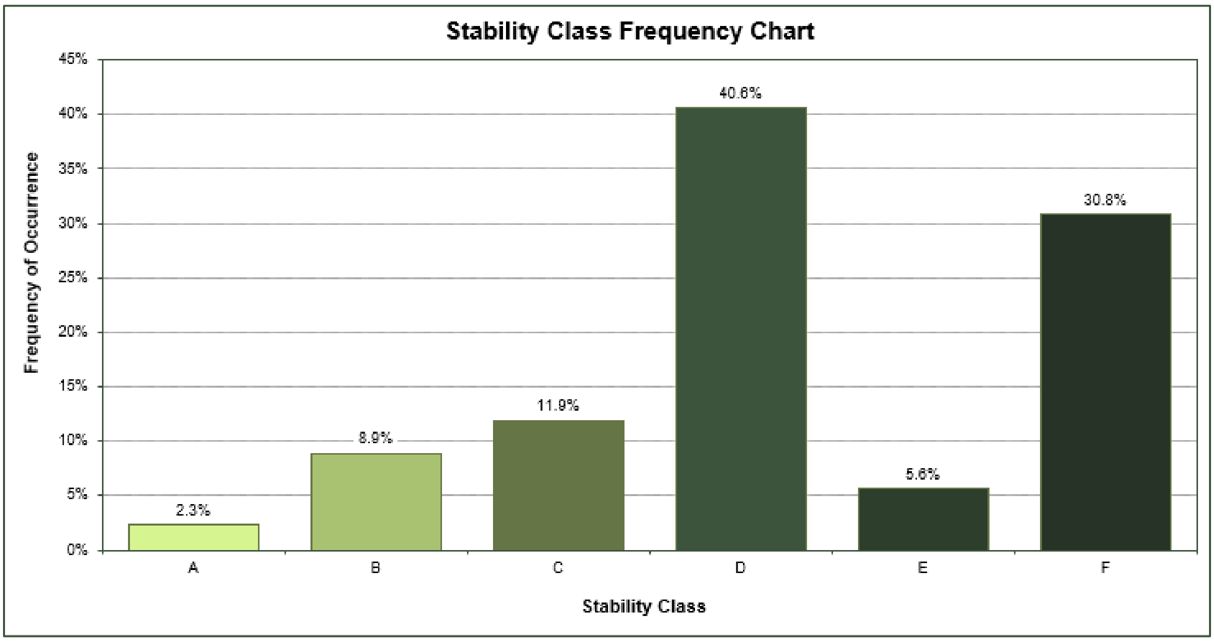
Source: (NOAA 2018)

Notes:

1. Strong insolation corresponds to sunny midday in midsummer in England, slight insolation to similar conditions in midwinter.
2. Night refers to the period from 1 hour before sunset to 1 hour after sunrise.
3. The neutral category D should also be used, regardless of wind speed, for overcast conditions during day or night and for any sky conditions during the hour preceding or following night as defined above.

The frequency of each stability class predicted by CALMET at the Site during the modelling period is presented in **Figure B-3**. The results indicate a high frequency of conditions typical to Stability Class D and F. Stability Class D is indicative of neutral conditions, conducive to a moderate level of pollutant dispersion due to mechanical mixing. Stability Class F is indicative of calm conditions, that typically indicates poorer dispersion of pollutants.

Figure B-3 Predicted Stability Class Frequencies at the Site (CALMET predictions, 2021)



Mixing Heights

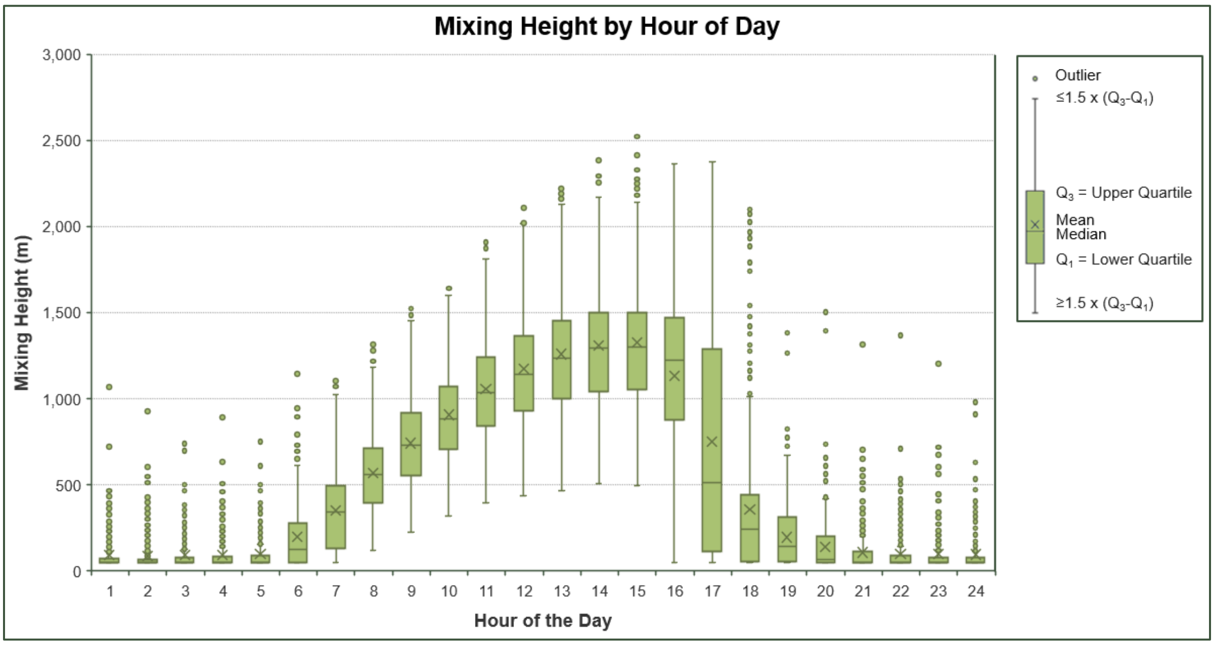
The mixing height is the depth of the atmospheric mixing layer between ground level and an elevated temperature inversion. Depending on conditions, vertical dispersion is typically limited by the mixing height. This is an important parameter in dispersion modelling since the mixing height largely sets the vertical profile the dispersion can take place in.

Mixing heights have a diurnal variation in response to mixing from convection due to insolation and grow from sunrise to around midday. Followed by a decline until sunset when there typically is a rapid decline. If a plume penetrates through, or is released above, the mixing height the pollutants will be trapped aloft with no mixing to ground level (unless in specific conditions such as fumigation). Similarly, if a plume is trapped below a low mixing height (inversion layer) the vertical dispersion will be limited, and higher ground-level concentrations are likely to occur.

Diurnal variations in maximum and average mixing heights predicted by CALMET at the Site during the 2021 modelling period are illustrated in **Figure B-4**.

As would be expected, an increase in mixing depth during the morning is apparent, arising due to the onset of vertical mixing following sunrise. Maximum mixing heights occur in the mid to late afternoon, due to the dissipation of ground-based temperature inversions and growth of the convective mixing layer.

Figure B-4 Predicted Mixing Heights at the Site (CALMET predictions, 2021)



Appendix C Emission Factors and Assumptions for Emissions Estimation

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Particulate matter emissions from the Project have been estimated using published emission factors for the relevant emission sources. Emission factors were sourced from the following documents:

- National Pollutant Inventory Emissions Estimation Technique Manual (NPI EETM) for Mining Version 3.1 (DSEWPC 2012)
- US EPA AP42 Section 11.9 Western Surface Coal Mining (US EPA 1998)
- US EPA AP42 Section 11.19.2 Crushed Stone Processing and Pulverized Mineral Processing (US EPA 2004)
- US EPA AP42 Section 13.2.2 Unpaved Roads (US EPA 2006a)
- US EPA AP42 Section 13.2.4 Aggregate Handling and Storage Piles (US EPA 2006b)
- US EPA AP42 Section 13.2.5 Industrial Wind Erosion (US EPA 2006)
- Proposed Revisions to Fine Fraction Ratios Used for AP-42 Fugitive Dust Emission Factors (Cowherd, Donaldson and Hegarty 2010)
- National Pollutant Inventory Emissions Estimation Technique Manual (NPI EETM) for Combustion engines Version 3.0 June 2008 (DEWHA 2008)

A summary of the emission factor equations used to estimate emissions from each activity at the Site are presented in **Table C-1**.

The assumptions applied to the relevant equations are provided as follows:

- Material properties refer to **Table C-2.**
- Vehicle properties and exposed areas refer to **Table C-3**.

Dust control measures are presented in **Table C-5**.

Estimated emission rates are presented in **Table C-6**.

Table C-1 Summary of Emission Factor/ Equations Used to Estimate Emissions

Activity	Emission Factor			Units	Source	Notes
	TSP	PM_{10}	$PM_{2.5}$			
Scraper stripping topsoil and cut material	EFTSP = 0.029	$EFPM_{10}$ = 0.0073	$EFPM_{2.5}$ = 0.0015	kg/t	EFTSP: (US EPA 1998) $EFPM_{10}$: (DSEWPC 2012) $EFPM_{2.5}$: (Cowherd, Donaldson and Hegarty 2010)	As detailed in Section 1.1.13 of the NPI EETM for Mining (DSEWPC 2012), the PM_{10} emission factor was derived from the application of PM_{10}/TSP ratio for the scraper in travel mode (i.e. 25%).
Unloading and unloading (material transfer)	$EF_{TSP} = \frac{0.74 \times 0.0016 \times \frac{U}{2.2}^{1.3}}{\frac{M}{2}^{1.4}}$	$EF_{PM10} = \frac{0.35 \times 0.0016 \times \frac{U}{2.2}^{1.3}}{\frac{M}{2}^{1.4}}$	$EF_{PM2.5} = \frac{0.053 \times 0.0016 \times \frac{U}{2.2}^{1.3}}{\frac{M}{2}^{1.4}}$	kg/t	EFTSP & $EFPM_{10}$: (DSEWPC 2012) $EFPM_{2.5}$: (US EPA 2006b)	U1.3/2.2 = wind speed factor = 1.0 Refer to **Table C-2** for moisture (M) assumptions

Activity	Emission Factor			Units	Source	Notes
	TSP	PM_{10}	$PM_{2.5}$			
Dozer	$EF_{TSP} = 2.6 \times \frac{s^{1.2}}{M^{1.3}}$	$EF_{PM10} = 0.34 \times \frac{s^{1.5}}{M^{1.4}}$	$EFPM_{2.5} = 0.105 \times EFPM_{10}$	kg/h	EFTSP & $EFPM_{10}$: (DSEWPC 2012) $EFPM_{2.5}$: (Cowherd, Donaldson and Hegarty 2010)	Refer to **Table C-2** for silt (s) and moisture (M) assumptions
Crushing	EFTSP = 0.0027	$EFPM_{10} = 0.0012$	$EFPM_{2.5} = 0.148 \times TSP$	kg/t	(US EPA 2004)	The $PM_{2.5}$ emission factor was derived from the application of $PM_{2.5}/PM_{10}$ ratio of tertiary crushing (controlled) emission factors
Screening	EFTSP = 0.029	$EFPM_{10} = 0.0043$	$EFPM_{2.5} = 0.068 \times EFPM_{10}$	kg/t	(US EPA 2004)	The $PM_{2.5}$ emission factor was derived from the application of $PM_{2.5}/PM_{10}$ ratio of tertiary screening (controlled) emission factors

Activity	Emission Factor			Units	Source	Notes
	TSP	PM_{10}	$PM_{2.5}$			
Grader	$EF_{TSP} = 0.0034 \times S^{2.5}$	$EF_{PM10} = 0.3375 \times \frac{S^{1.5}}{M^{1.4}}$	$EFPM_{2.5} = 0.148 \times EFPM_{10}$	kg/vkt	(US EPA 1998)	As detailed in Table 11.9-2 of AP42 Section 11.9, the $PM_{2.5}$ emission factor was derived from the scaling factor for $PM_{2.5}$/TSP
Vehicle Movements on Unpaved Roads	$EF_{TSP} = \left(\frac{0.4536}{1.6093}\right) \times 4.9 \times \left(\frac{s}{12}\right)^{0.7} \times \left(\frac{W \times 1.1023}{3}\right)^{0.45}$	$EF_{PM10} = \left(\frac{0.4536}{1.6093}\right) \times 1.5 \times \left(\frac{s}{12}\right)^{0.9} \times \left(\frac{W \times 1.1023}{3}\right)^{0.45}$	$EF_{PM2.5} = \left(\frac{0.4536}{1.6093}\right) \times 0.15 \times \left(\frac{s}{12}\right)^{0.9} \times \left(\frac{W \times 1.1023}{3}\right)^{0.45}$	kg/VKT	(US EPA 2006a)	Refer to **Table C-2** for surface silt (s) and vehicle weight (W) assumptions
Diesel Combustion	EFTSP = 1.17	$EFPM_{10}$ = 1.17	$EFPM_{2.5}$ = 1.12	kg/ m^3	(DEWHA 2008)	All TSP is assumed to be PM_{10}
Wind Erosion of Exposed Areas	EFTSP = 0.4	$EFPM_{10}$ = 0.5 × EFTSP	$EFPM_{2.5}$ = 0.075 × EFTSP	kg/ha/hr	EFTSP & $EFPM_{10}$: (DSEWPC 2012) $EFPM_{2.5}$: (US EPA 2006)	Refer to **Table C-4** for assumptions.

Activity	Emission Factor			Units	Source	Notes
	TSP	PM_{10}	$PM_{2.5}$			
Where:						
M = material moisture content (%)						
s = material silt content (or surface silt content in unpaved roads) (%)						
U = wind speed (m/s)						
W = mean vehicle weight (tonnes)						
S = mean vehicle speed (km/h)						

Table C-2 Emission Factor Assumptions - Material Properties

Parameter	Value	Units	
Silt content	8.6	%	Double the average silt content value in AP42 Section 11.9 Table 11.9-3 (Overburden mean) (US EPA 1998)
Moisture content	4	%	Conservatively half of the average moisture content value in AP42 Section 11.9 Table 11.9-3 (Overburden mean) (US EPA 1998)
Haul road moisture content	2.4	%	AP42 Section 11.9 Table 11.9-3 (haul truck mean) (US EPA 1998)
Topsoil density	1.60	t/m^3	Densities used by SLR for projects in Mamre Road Precinct
Clay density	1.64	t/m^3	
Shale density	2.37	t/m^3	
Hard rock density	3.0	t/m^3	

Table C-3 Emission Factor Assumptions – Vehicles

Variable	Value	Units	Source
Scrapers -Topsoil			
Empty weight	41.0	tonnes	https://www.cat.com/en_AU/products/new/equipment/wheel-tractor-scrapers/open-bowl-scrapers/121340.html
Capacity	26.0	tonnes per load	
Gross weight	67.0	tonnes	
Average empty/gross weight	54.0	tonnes	

Variable	Value	Units	Source
Scrapers – Cut			
Empty weight	75.0	tonnes	https://www.cat.com/en_US/products/new/equipment/wheel-tractor-scrapers/open-bowl-scrapers/111020.html
Capacity	47.0	tonnes per load	
Gross weight	122.0	tonnes	
Average empty/gross weight	97.5	tonnes	
Dozers - Hard Rock - Extraction(a)(b)			
Number of units	2	-	Client information
Utilisation	75	%	
Operating hours	3,420	Hours per year	Client information
Haul Trucks – Removal			
Empty weight	33.0	tonnes	Client information
Capacity	41.0	tonnes per load	
Gross weight	74	tonnes	
Average empty/gross weight	53.5	tonnes	
Import/Export Trucks			
Empty weight	28.0	tonnes	Client information
Capacity	42.0	tonnes per load	
Gross weight	70.0	tonnes	
Average empty/gross weight	49.0	tonnes	

Table C-4 Material Movements and Travel Distances

Parameter	Annual/Max Unit	Unit
Earthworks quantities		
Topsoil total	58,560	m^3/9 months
	93,696	tonnes/9 months
	124,928	tonnes/year
	78,080	m^3/year
Cut material total	582,110	m^3/9 months
Cut/fill composition - Clay	30	%
Cut/fill composition - Brown shales	45	%
Cut/fill composition - Hard rock	25	%
Cut - clay	286,398	tonnes/9 months
	381,864	tonnes/year
	232,844	m^3/year
Cut - brown shales	619,511	tonnes/9 months
	826,014	tonnes/year
	349,266	m^3/year
Cut - hard rock	436,583	tonnes/9 months
	582,110	tonnes/year
	194,036	m^3/year
Cut (excluding topsoil)	1,342,491	tonnes/9 months
	1,789,988	tonnes/year
	776,146	m^3/year
Import	89,020	m^3/9 months

Parameter	Annual/Max Unit	Unit
	205,302	tonnes/9 months
	273,737	tonnes/year
Fill	671,130	m^3/9 months
	1,547,794	tonnes/9 months
	2,063,725	tonnes/year
Wind Erosion		
Exposed Area (Estimated maximum working area)	7	Ha
Scrapers		
Topsoil removal	1	% of topsoil material moved using scraper
Topsoil removal	78,080	m^3
Clay removal	0.9	% of all material moved using scraper
Clay removal	217,321	m^3
Shale removal	0.9	% of all material moved using scraper
Shale removal	325,982	m^3
All material removal	0.7	% of all material moved using scraper
All material removal	543,303	m^3
Topsoil		
Topsoil removal oil	124,928	tonnes/year
Scraper trips	4,805	trips/year
Scraper travel	4,805	VKT/year
Cut material		
Scrapers removal - clay	356,407	tonnes/year
Scrapers removal - brown shale	770,947	tonnes/year

Parameter	Annual/Max Unit	Unit
Scrapers removal - hard rock	0	tonnes/year
Scrapers removal - total	1,127,353	tonnes/year
Scraper travel distance	2	km/trip
Scraper trips	23,986	trips/year
Scraper - travel	47,973	VKT/year
Excavator / FEL		
Road length to crusher	0.5	km/return trip
Quantity of material moved - clay	25,458	tonnes/year
Quantity of material moved - brown shale	55,068	tonnes/year
Quantity of material moved - hard rock	582,110	tonnes/year
Quantity of material moved - total	662,635	tonnes/year
Grader		
Speed of Grader	10	km/hr
Grader Vehicle km travelled	14,600	km/year
Crushing and Screening		
Crushing	465,688	tonnes/year
Screening	465,688	tonnes/year
Onsite material transfer		
Truck removal % clay	0.1	%
Truck removal clay (m3)	15,523	m^3/annum
Truck removal % shale	0.1	%
Truck removal shale (m3)	23,284	m^3/annum
Truck removal % hard rock	1	%

Parameter	Annual/Max Unit	Unit
Truck removal hard rock (m3)	194,037	m^3/annum
Percentage of total cut material moved by dump truck	0.3	%
Cut material moved by dump truck (m3)	232,844	m^3/annum
Cut material moved by dump truck	662,635	Tonnes/annum
Truck removal - clay	25,458	tonnes/year
Truck removal - brown shale	55,068	tonnes/year
Truck removal - hard rock	582,110	tonnes/year
Truck removal - total	662,635	tonnes/year
Number of return trips	5,679	trips/annum
Haul road silt content	8.6	%
Haul road length	2	km/return trip
Truck unloading at fill area	662,635	tonnes/annum
Number of return trips across pit	6,518	trips/annum
Haul road silt content	8.6	%
Haul road length	0.5	km/return trip
Truck unloading at fill area	273,737	tonnes/year

Table C-5 Control Measures

Control Measure	Control Efficiency
Water carts used while scrapers stripping	50%
Water carts used while scraper travels	75%
Water carts used during material transfer activities	75%
Water carts used on haulage routes (Level 2 watering (>2 L/m^2/h)	75%
Water carts used with dozer activities*	50%
Water carts used with grader activities	50%
Water carts used on exposed area	50%
Source: (DSEWPC 2012) *Assumed to be similar to scrapers stripping.	

Haul Road Watering to Supress Wheel Generated Dust

The NPI EETM for Mining indicates emission control of wheel generated dust as follows:

- Level 1 watering (2 L/m^2/h): 50% control
- Level 2 watering (>2 L/m^2/h): 75% control

Site specific watering emission control C expressed as a percentage can be estimated from typical evaporation rates for the area and haul road traffic rate using the following equation (Air & Waste Management Association 2000):

$$C = 100 - \frac{0.8pdt}{i}$$

where p is the average hourly daytime evaporation rate, d is the average hourly daytime traffic rate, t is the time (hours) between water application and i is the application intensity (L/m2).

BoM[2] publish total evaporation maps for Australia showing the amount of water which evaporates from an open pan. Annual average and seasonal average evaporation rates for the area in which the Project is situated are calculated from these maps which indicate the following:

- approximate total annual average evaporation rate: 1600 mm, or 0.18 mm/h
- approximate total summer average evaporation rate: 600 mm, or 0.28 mm/h

Using water carts and water sprays to supress dust emissions will achieve less control in areas with greater evaporation than areas with less evaporation. Greater rates of watering are likely to be required in summer when evaporation rates are increased to achieve adequate dust control.

From the evaporation rates above, if a conservative traffic rate of 40 movements per hour and 1 hour between water applications, a control of greater than 90% is calculated for the Site haul roads (including for the summer months) with a watering rate of less than 1 L/m^2/h.

[2] Australian Climate Averages - Evaporation (Climatology 1975-2005), , http://www.bom.gov.au/jsp/ncc/climate_averages/evaporation/index.jsp?period=sum#maps, accessed February 2025

This control rate would increase with more frequent water application, likely lower traffic rates, and the anticipated watering rate of less than 2 L/m^2/h. However, for modelling purposes, a 75% control factor was conservatively applied to the unpaved haul road wheel generated dust estimates.

Table C-6 Emission Factors

Activity		TSP Emission Factor	PM_{10} Emission Factor	PM2.5 Emission Factor	Units
Scraper Strip	Scrapers stripping topsoil	0.03	0.007	0.001	kg/t
Scraper Travel	Scraper travel stripping topsoil	0.2	0.05	0.005	kg/t
Scraper Strip	Scrapers stripping cut material	0.03	0.01	0.001	kg/t
Scraper Travel	Scraper travel moving cut material	0.2	0.1	0.01	kg/t
Loading/unloading	Excavator removing material at cut area	0.0005	0.0002	0.00003	kg/t
Loading/unloading	Loading material to transfer to crusher	0.0005	0.0002	0.00003	kg/t
Haulage	Excavated material haulage to crusher	0.1	0.01	0.001	kg/t
Loading/unloading	Unloading at stockpiles at crusher	0.0005	0.0002	0.00003	kg/t
Loading/unloading	Loading material into crusher	0.0005	0.0002	0.00003	kg/t
Crushing	Crushing (uncontrolled)	0.003	0.001	0.0002	kg/t
Screening	Screening (uncontrolled)	0.01	0.004	0.0003	kg/t
Loading/unloading	Loading material to trucks from crushed to fill	0.0005	0.0002	0.00003	kg/t
Haulage	Excavated material haulage from crushed to fill	0.2	0.1	0.01	kg/t
Loading/unloading	Unloading at fill area (from crushed to fill)	0.0005	0.0002	0.00003	kg/t
Loading/unloading	Loading material to trucks in cut area for transfer to fill	0.0005	0.0002	0.00003	kg/t
Haulage	Excavated material haulage transfer to fill area	0.2	0.1	0.01	kg/t
Loading/unloading	Unloading at fill area (inclusive of all scraped material and all cut material moved by trucks that is not processed)	0.0005	0.0002	0.00003	kg/t
Haulage	Imported material haulage to fill area	0.05	0.01	0.001	kg/t
Loading/unloading	Unloading at fill area (from imported material)	0.0005	0.0002	0.00003	kg/t

Activity		TSP Emission Factor	PM_{10} Emission Factor	PM2.5 Emission Factor	Units
Dozer	Dozer (x2) (assumes for cut and fill)	5.7	1.2	0.6	kg/h
Grader	Grader	1.1	0.3	0.03	kg/vkt
Wind Erosion	Stage 2 area wind erosion - 1	0.4	0.2	0.03	kg/ha/hour
	Stage 2 area wind erosion - 2	0.4	0.2	0.03	kg/ha/hour
	Stage 2 area wind erosion - 3	0.4	0.2	0.03	kg/ha/hour
Combustion	Diesel combustion -Stage 2	1.2	1.2	1.1	kg/ m^3

Appendix D Variable Emission file

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Variable Emission File – Calculation Steps

A brief summary of the steps used in calculating the hourly varying emission rates for each source are presented below.

Step 1: Calculate annual average emission rate (kg/year) for FP, CM and RE

FPannual = $PM_{2.5}$, annual	(FP) Fine Particulate – particulate of size less than 2.5 µm
CMannual = PM_{10}, annual – $PM_{2.5}$, annual	(CM) Coarse Particulate – particulate of size between 10 µm and 2.5 µm
REannual = TSPannual - PM10, annual	(RE) Rest Particulate – particulate of size greater than 10 µm

Step 2: Identify the operating hours for each activity

Step 3: Classify the sensitivity of each type of activity to wind speed

Wind insensitive: activities with emission factor that is independent of wind speed (e.g. blasting)

Wind sensitive: activities with emission factor that is a function of (wind speed/2.2)1.3 (e.g. loading)

Wind erosion: emission from exposed areas/stockpiles

Step 4: Identify the number of sources associated with each activity

Note that each wind erosion source is modelled as an independent source.

Step 5: Calculate the hourly average emission rate for each activity per source

$$FP_{AC,i,h} = \frac{FP_{annual,i} \times 1000}{N_{days} \times OH_i \times 3600 \times N_{s,i} \times WSFactor_{i,h}}$$ $$CM_{AC,i,h} = \frac{CM_{annual,i} \times 1000}{N_{days} \times OH_i \times 3600 \times N_{s,i} \times WSFactor_{i,h}}$$ $$RE_{AC,i,h} = \frac{RE_{annual,i} \times 1000}{N_{days} \times OH_i \times 3600 \times N_{s,i}} \times WSFactor_{i,h}$$ **FOR WIND INSENSITIVE ACTIVITIES** $$WSFactor_{i,h} = 1$$ **FOR WIND SENSITIVE ACTIVITIES** $$WSFactor_{i,h} = \frac{\left(\frac{WS_h}{2.2}\right)^{1.3}}{\frac{\sum_{j=1}^{n}\left(\frac{WS_j}{2.2}\right)^{1.3}}{n}}$$ **FOR WIND EROSION ACTIVITIES** $$WSFactor_{i,h} = \frac{(WS_h)^3}{\frac{\sum_{j=1}^{n}(WS_j)^3}{n}}$$	WHERE: FPAC,I,H- FINE PARTICULATES EMISSION RATE FOR ACTIVITY I (G/S) AT HOUR H CMAC,I,H- FINE PARTICULATES EMISSION RATE FOR ACTIVITY I (G/S) AT HOUR H CMAC,I,H- FINE PARTICULATES EMISSION RATE FOR ACTIVITY I (G/S) AT HOUR H OHI-DAILY OPERATING HOURS (1- 24) FOR ACTIVITY I NDAYS -NUMBER OF DAYS IN THE METEOROLOGICAL DATA FILE NS,I -NUMBER OF SOURCES ASSOCIATED WITH ACTIVITY I WSH-WIND SPEED AT THE HOUR N -NUMBER OF HOURS IN THE METEOROLOGICAL DATA FILE

Note: If the activity was modelled as area source, the equation on the left column of the table needs to be divided by the area of that activity.

Step 6: Calculate hourly average emission rate for each source

To calculate the emission rate for a particular source for a particular hour, add up the calculated emission rate for each activity associated with source.

For example, if Source 1 is associated with Activity 1, Activity 2 and Activity 3, then:

ERS1,h,FP = FPAC,1,h+ FPAC,2,h+ FPAC,3,h

ERS1,h,CM = CMAC,1,h+ CMAC,2,h+ CMAC,3,h

ERS1,h,RE = REAC,1,h+ REAC,2,h+ REAC,3,h

Appendix E Isopleths

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26 February 2025

Figure E-1 24-hour Average Incremental Impacts of $PM_{2.5}$

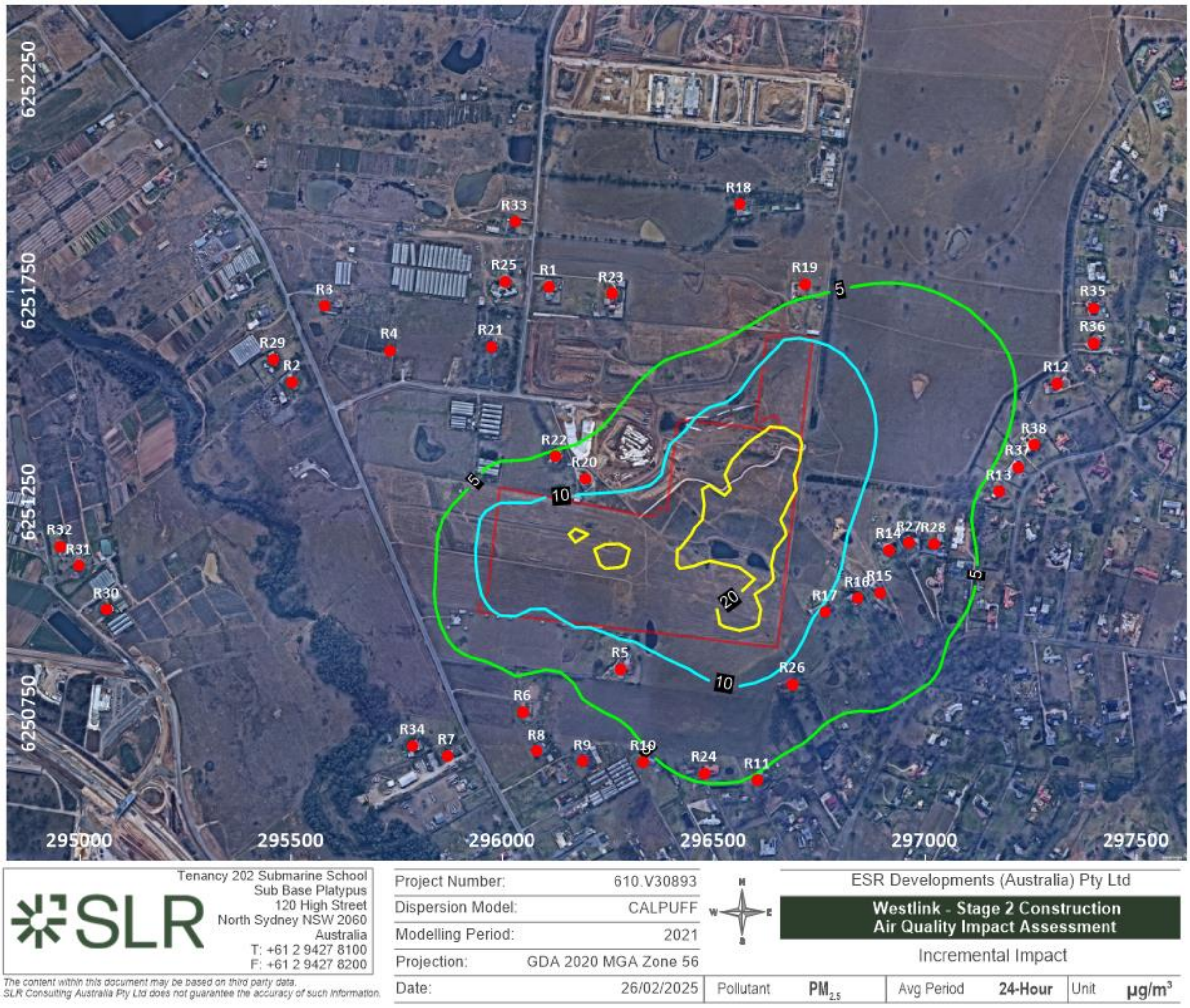


Figure E-2 Annual Average Incremental Impacts of $PM_{2.5}$

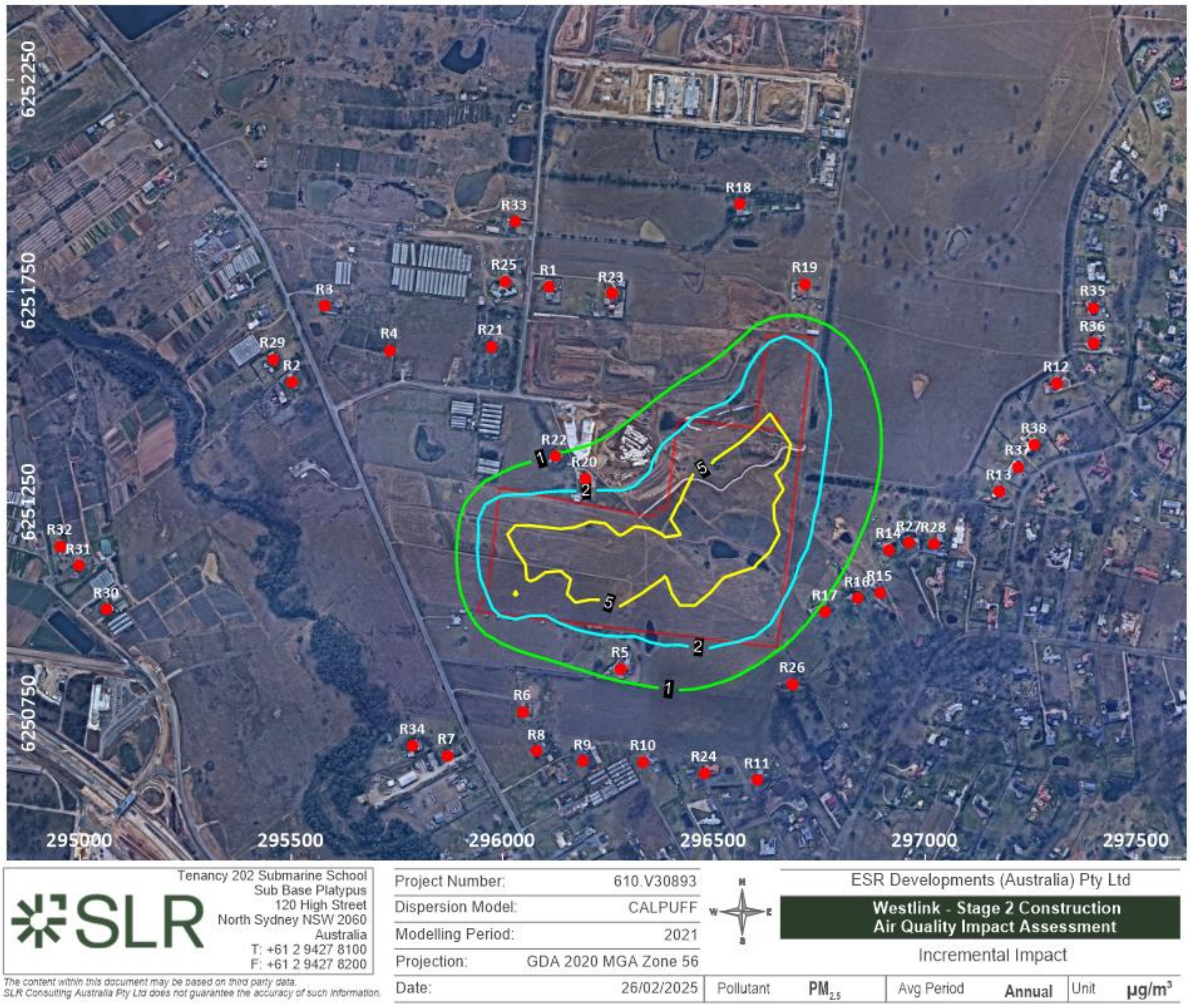
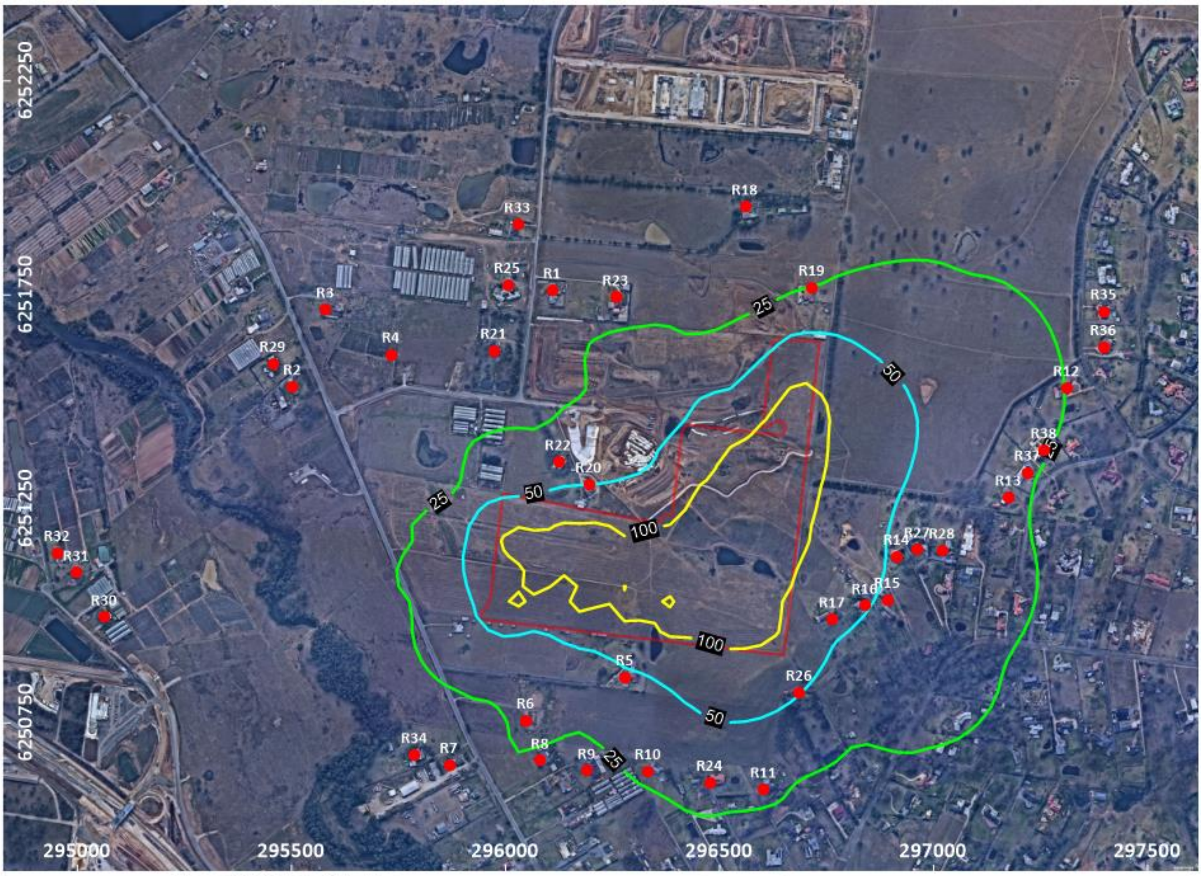


Figure E-3 24-hour Average Incremental Impacts of PM_{10}



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SLR Consulting Australia Pty Ltd does not guarantee the accuracy of such information.

Project Number:	610.V30893
Dispersion Model:	CALPUFF
Modelling Period:	2021
Projection:	GDA 2020 MGA Zone 56
Date:	26/02/2025

ESR Developments (Australia) Pty Ltd
Westlink - Stage 2 Construction
Air Quality Impact Assessment
Incremental Impact

Pollutant	PM_{10}	Avg Period	24-Hour	Unit	$\mu g/m^3$

Figure E-4 Annual Average Incremental Impacts of PM_{10}

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	Dispersion Model:	CALPUFF	Westlink - Stage 2 Construction Air Quality Impact Assessment
	Modelling Period:	2021	
	Projection:	GDA 2020 MGA Zone 56	Incremental Impact
	Date:	26/02/2025	Pollutant PM_{10} Avg Period Annual Unit µg/m³

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Figure E-5 Annual Average Incremental Impacts of TSP

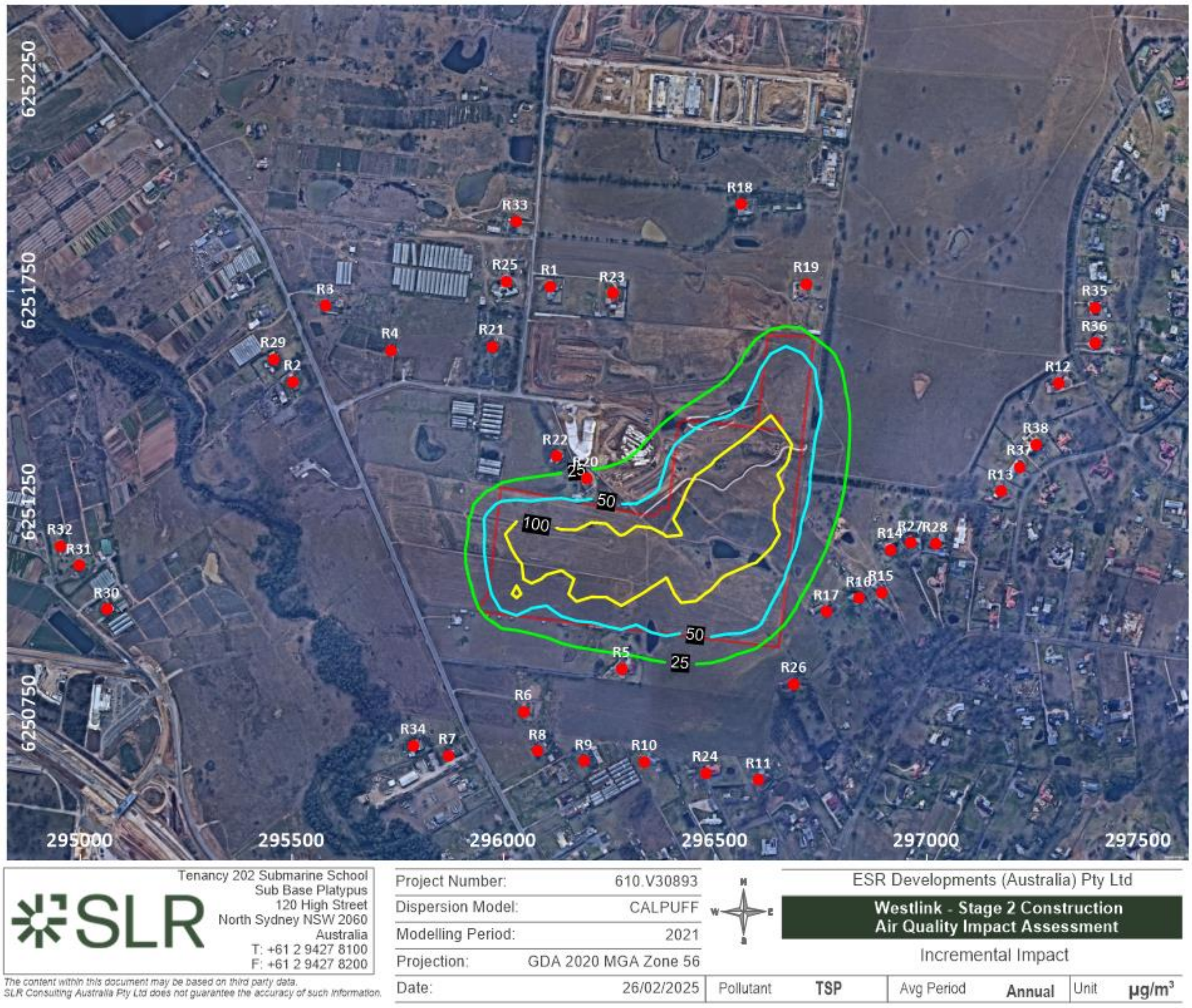
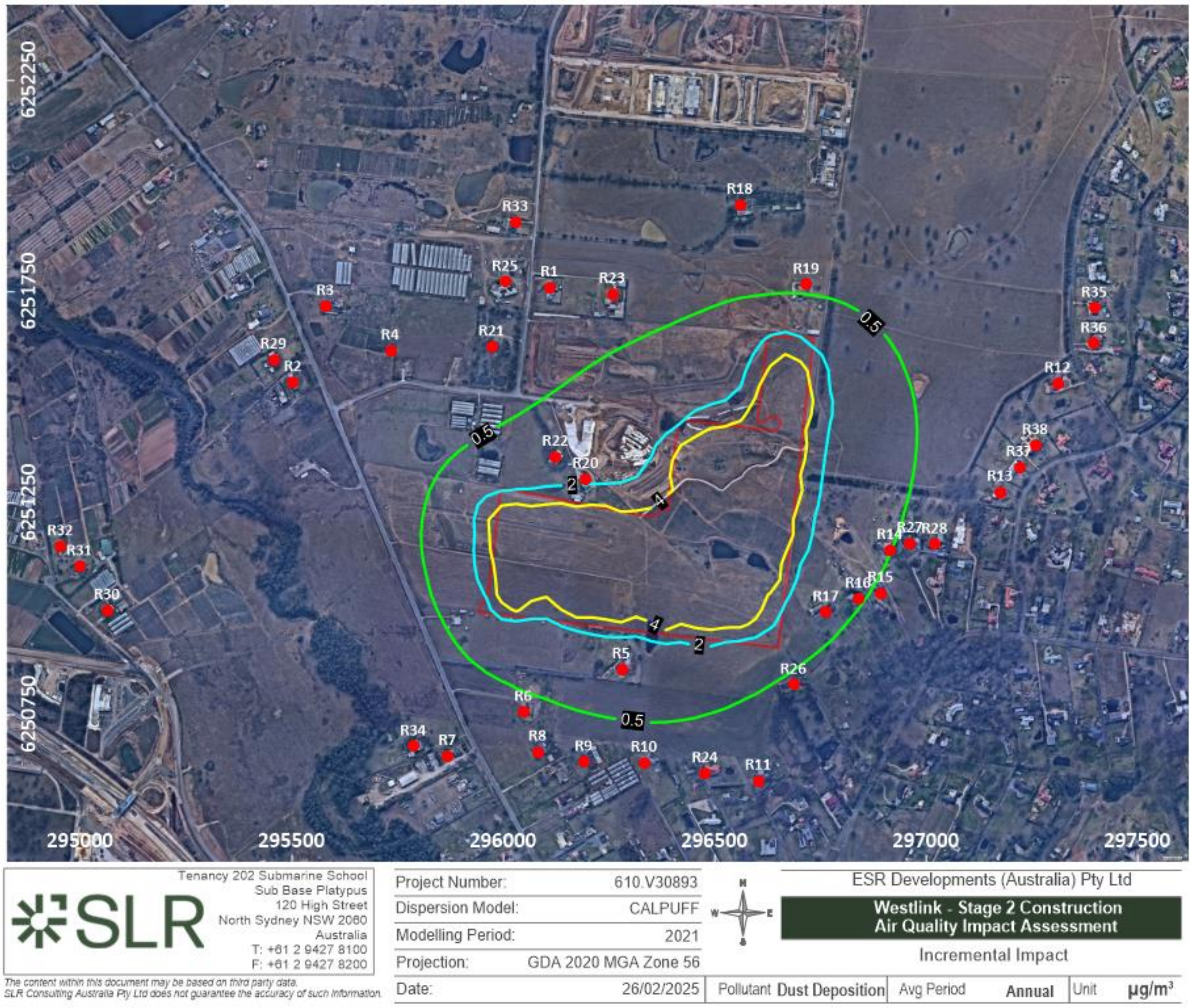


Figure E-5 Annual Average Incremental Impacts of Dust Deposition



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