PROPOSED MIXED USE DEVELOPMENT

7-15 Wren Street, Bowen Hills

Air Quality Assessment

AustralAsian Property Group

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CONTENTS

APPENDICES

FIGURES

TABLES

1. INTRODUCTION

1.1 Overview

Trinity Consultants Australia was commissioned by AustralAsian Property Group to provide air quality consultancy services for the multiple dwelling and health care development proposed at 7-15 Wren Street, Bowen Hills.

Stage 1 of the development has already been constructed and is currently operating for health care uses. Stage 2 includes 240 built-to-rent dwellings and additional health care tenancies.

The assessment has been undertaken to determine the potential air quality impacts of road tunnel traffic emissions from the Clem7 northbound ventilation outlet station onto the development and potential impacts on the existing sensitive uses due to the presence of the new building.

This air quality report is to accompany a Development Application for consideration by Economic Development Queensland (EDQ) for a development permit for a material change of use involving multiple dwelling, health care services, shop, food and drink outlet, bar and parking station.

The assessment has been prepared in response to information request by EDQ issued on 10 May 2024, as copied below:

- *Please submit an air quality report demonstrating the development will minimise impacts from air pollution from vehicle traffic and the ventilation stack on the health and wellbeing of future residents as per section 2.5.9.5 of the development scheme and address the following:*
  - PO1, PO3 and PO4 of the Transport air quality corridor overlay code;
  - PO2 of the Industrial amenity overlay code
- *As a reference, there is a similar development application currently under assessment by Brisbane City Council at 33 Jurgens Street, Woolloongabba (Council ref: A006150645) which is located near a transport air quality corridor and tunnel ventilation stack. It is recommended the applicant review the air quality assessment submitted for this application for an understanding of the requirements and expectations in addressing the Transport air quality corridor overlay code.*
- *It is noted that there may be design changes depending on the recommendations of the Air Quality Report.*

Air dispersion modelling has been undertaken to demonstrate compliance with PO4 of the Brisbane City Council (BCC) Transport air quality corridor overlay code and PO2 of the Industrial amenity overlay code. Addressing these performance outcomes forms the bulk of this assessment report. PO1 and PO3 of the Transport air quality corridor overlay code is addressed through a qualitative review of the built form design, as discussed in **Section 10**.

1.2 Background to Assessment Methodology

Prior to the air dispersion modelling being undertaken, discussions were made between EDQ/SLR and Trinity to confirm the assessment methodology.

A letter report[1] summarising the methodology and model inputs proposed by Trinity was sent to EDQ/SLR for review on 19 July 2024.

[1] Report 247401.0068.R01V01 dated 19 July 2024.

On 23 August 2024, SLR presented their review of the proposed methodology and recommendations during a TEAMS meeting and provided a table summarising all issues to be addressed. In response, Trinity submitted an updated methodology letter[2] on 4 September 2024, addressing all SLR's comments.

On 9 September 2024, SLR confirmed via email their agreement with the proposed changes to the methodology.

Sections 5 to 8 of this report are essentially a copy of the details provided in the updated methodology report. With regards to methodology, this report provides additional information on the following:

- The calculated emission rates for the Clem7 vent and other emissions sources (**Section 5.2** vent, **Section 6.3** road sources and **Section 6.4** ICB portal)
- The final adopted flow field and grid concentration spacing, as recommended by the GRAL user guide for the modelling of high stack sources near large buildings (refer to **Section 8.1**).
- The adoption of hourly NO_2 background concentrations instead of the 70th percentile (refer to **Section 6.6**).
- The use of hourly ozone concentrations from DESI Rocklea station instead of DESI Cannon Hill for estimating NO_x-NO_2 conversion (refer to **Sections 6.6** and **8.2**).

1.3 Scope

This report describes the assessment of the air quality impacts, which is based on the following tasks:

- Review the project and the associated potential air emissions from the Clem7 vent.
- Review existing air quality monitoring data applicable to the project site.
- Model meteorological conditions using GRAMM.
- Model the dispersion of expected air pollutants using GRAL to estimate pollutant concentrations at the proposed development and nearby existing sensitive uses.
- Analyse the results of the dispersion modelling and compare with the relevant air quality criteria.
- Undertake a site visit to make observations of the surrounding built form, to feed into the transport air quality assessment.
- Review the built for with respect to the requirements of the BCC Transport Air Quality Corridor Planning Scheme Policy. Where necessary, make recommendations on changes or alterations to the proposed design to satisfy requirements.

A glossary is included in **Appendix A** to aid in understanding the terms in this report.

[2] Report 247401.0068.R02V01 dated 4 September 2024.

2. PROPOSED DEVELOPMENT

The proposed development is located at 7-15 Wren Street, Bowen Hills. An existing 10-storey building (Stage 1) dedicated to healthcare services and parking currently operates on the site (southern half). The Project involves extending this existing development by adding a new 30-storey building with 240 built-to-rent units (Stage 2). The expanded building podium will also include a bar, healthcare services, a shop, and food and drink outlets. Both Stage 1 and Stage 2 will be interconnected, forming a single cohesive development.

Figure 2.1: 3D Render for Stages 1 and 2

The Clem7 northbound vent is located roughly 70 meters east of the eastern boundary of the property. The Inner City Bypass (ICB) runs between the property and the vent stack outlet. A concrete batching plant is located 263 metres to the north. The presence of these air emissions sources (vent, ICB, concrete batching plant) have triggered the requirement of an assessment according to the BCC City Plan 2014 codes (as requested by EDQ).

The site location is presented in **Figure 2.2**.

Figure 2.2: Site Location

3. STUDY AREA DESCRIPTION

3.1 Zoning of Site and Surrounds

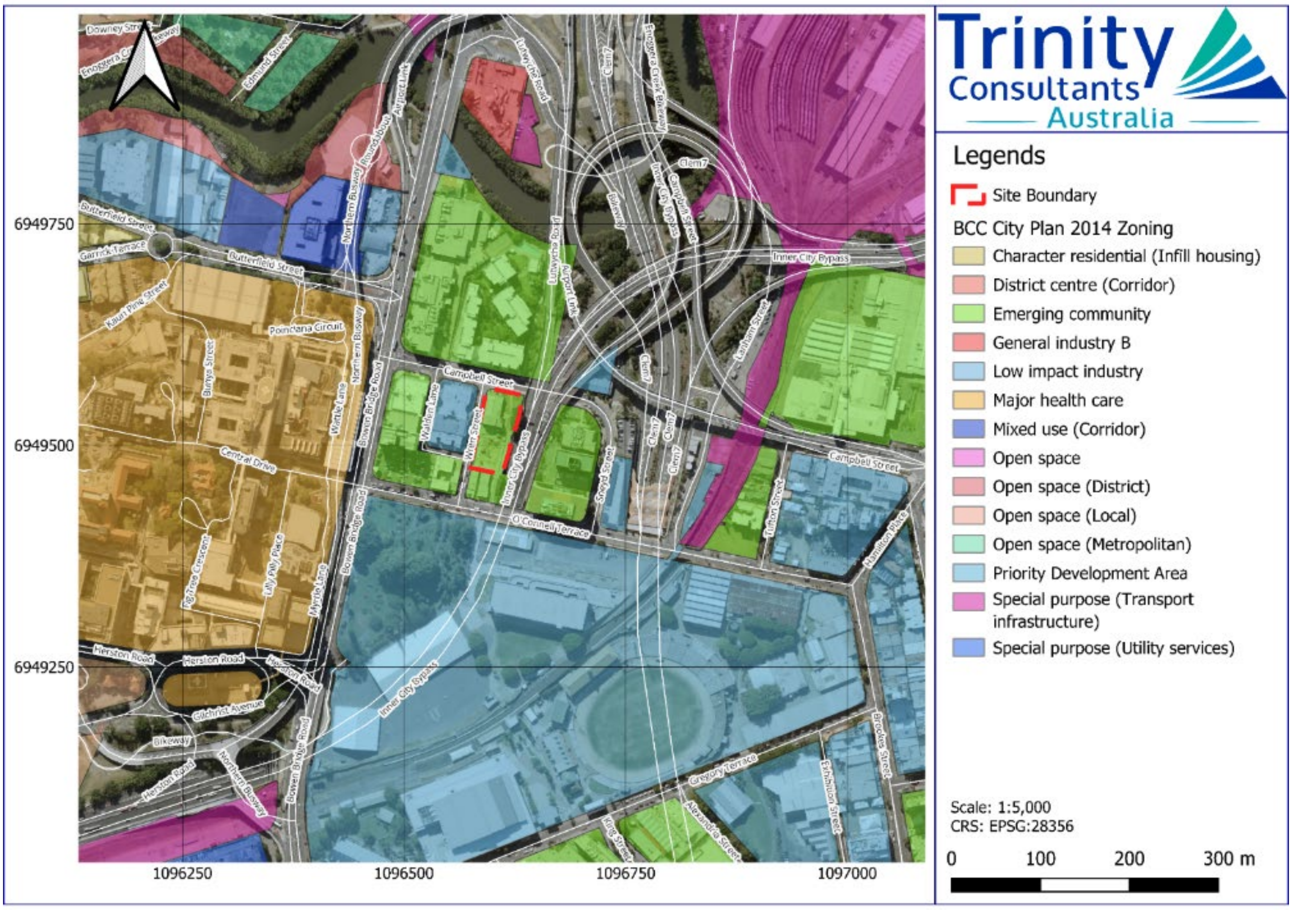
The subject site comprises Lot 23 on RP9941 and Lot 24 on SP276528 and falls within the Bowen Hills Priority Development Area (PDA).

The zoning of the proposed development site and surrounding areas is shown in **Figure 3.1**

The development site is designated as being within an emerging community zone. The nearby land uses follow:

- To the north, mixed use development with residential units and commercial tenancies at ground level, across Campbell Street.
- To the east, the site is bounded by the inner-city bypass.
- To the south, a single storey commercial building and a single storey BCC utilities building.
- To the west, residential and commercial buildings across Wren Street.

Figure 3.1: Zoning Map (Brisbane City Plan)



4. AIR QUALITY VALUES AND CRITERIA

4.1 Overview

As this development falls within the Bowen Hills PDA (Economic Development Queensland, 2022), it will be assessed against the Bowen Hills PDA Development Scheme. The air quality criteria for the PDA reference Brisbane City Council's Transport Air Quality Corridor Overlay and Code. These have been considered in this assessment, which was prepared in accordance with the Brisbane City Plan Air Quality Planning Scheme Policy (Brisbane City Council, 2014).

The following sections detail the air quality requirements of the Bowen Hills PDA Development Scheme and Brisbane City Plan 2014.

4.2 Bowen Hills PDA Development Scheme

Section 2.5.9.5 of the Bowen Hills PDA Development Scheme states the following:

- Development must limit exposure and risk associated with pollutants that could have an adverse effect on human health.
- Development in a transport air quality overlay is designed to:
  1. Minimise the impacts of air pollution from vehicle traffic on the health and wellbeing of uses of a childcare centre, multiple dwelling, residential care facility or retirement facility, and
  2. Maximise wind movement around buildings and the dispersion of traffic air pollutants.
- Development within 100 metres of the Clem Jones Tunnel north ventilation outlet and above RL+45 metres AHD must be designed and oriented to:
  1. Avoid unreasonable impacts on the performance of the ventilation outlet, and
  2. Mitigate potential air quality impacts on occupants resulting from the ventilation outputs.
- Development for a sensitive use within 500 metres of an existing High impact industry identified on Brisbane City Plan Industrial amenity overlay map is designed and constructed to achieve acceptable air quality, odour and health risk standards.

As per the EDQ information request presented in Section 1.1, the above air quality requirements can be met is to be addressed by demonstrating compliance with the following BCC City Plan 2014 codes:

- PO1, PO3 and PO4 of the Transport air quality corridor overlay code;
- PO2 of the Industrial amenity overlay code

These BCC codes are discussed in the following sections.

4.3 BCC City Plan Requirements

4.3.1 BCC Transport Air Quality Overlay Code

The development site is located in the BCC Transport Air Quality Overlay, within sub-categories A, B and C (associated with the operation of the Clem7 northern vent), as shown in **Figure 4.1**.

Regarding sub-category A, the acceptable outcome AO1 describes the minimum set back distances between sensitive uses and the kerb of the road and provides alternatives when these are not met.

Compliance with AO3 for sub-category B is not achieved. Therefore, this report will assess compliance against performance outcome PO3 in accordance with the Transport Air Quality Corridor Planning Scheme Policy.

Finally, sub-category C deals with the Clem7 north vent stack outlet, which is situated 35 meters above ground level, at a similar height to the roof of the existing development. The development is proposed to have a building height of more than 100 metres above ground, which is more than the AO4.1 height of 10 metres lower than the exhaust vent. On this basis, a detailed modelling assessment is required to demonstrate compliance with the air quality criteria. As per PO4, the modelling must demonstrate compliance with proposed on-site and off-site sensitive uses. An assessment of off-site uses is required because the presence of the proposed building can potentially affect the pollutant plume's dispersion and change air quality impacts on the surrounding area.

Details regarding the acceptable and performance outcomes are presented in **Table 4.1**, and the ambient air quality criteria referenced in PO4 can be found in **Table 4.2**.

Figure 4.1: BCC Transport Air Quality Overlay

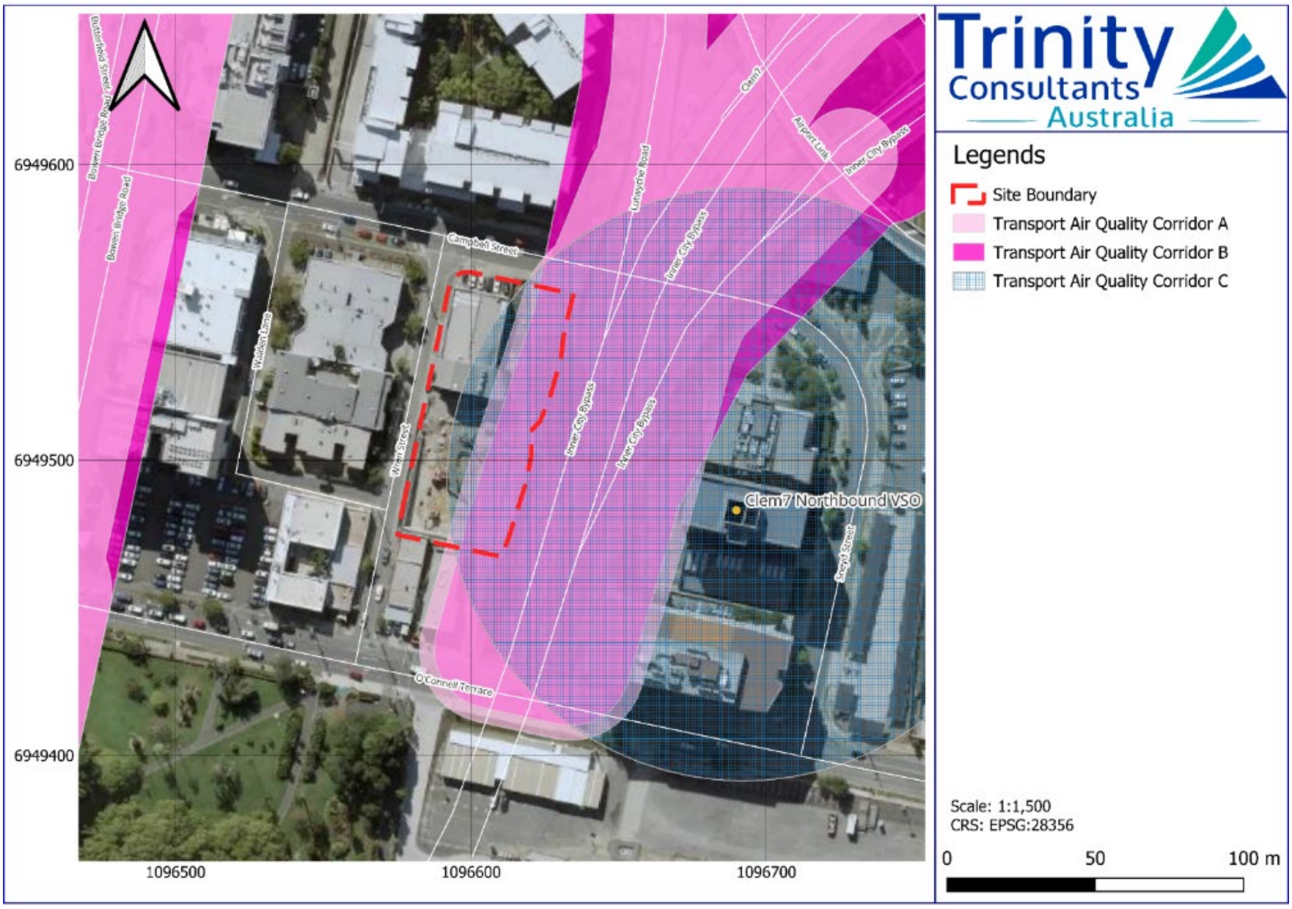


Table 4.1: Transport Air Quality Overlay Code

Performance Outcomes	Acceptable Outcomes
PO1 Development for a multiple dwelling, residential care facility, rooming accommodation where accommodating 6 people or more, or retirement facility minimises exposure of an occupier of the development to road traffic air pollutants through: a. adequate separation from the road; or b. provision of ducted mechanical ventilation with supply of clean outdoor air.	**AO1** Development for a multiple dwelling, residential care facility, rooming accommodation where accommodating 6 people or more, or retirement facility: a. is set back to the greater of the requirements of any use code or the minimum separation distance, measured in the horizontal and vertical planes (refer to Figure a), from the kerb as specified in Table 8.2.23.3.B; or b. is installed with ducted mechanical ventilation for the supply of outdoor air in compliance with AS 1668.2:

Performance Outcomes	Acceptable Outcomes
	The use of ventilation and air conditioning in buildings - Mechanical ventilation in buildings, and: i. locates the mechanical ventilation outdoor air intakes at least the minimum distance, measured in the horizontal and vertical planes (refer to Figure b), from the kerb as specified in Table 8.2.23.3.B; or ii. includes filtration of outdoor air to a minimum performance standard of F6 or minimum efficiency reporting value (MERV) 9. Editor's note—MERV rating system (in accordance with the American Society of Heating, Refrigeration and Air-Conditioning) and the F rating system (in accordance with AS 1324.1 Air filters for use in general ventilation and airconditioning - Application, performance and construction) are measures used to describe the efficiency with which particulate filters remove particles of a specified size from an airstream. The higher the MERV designation, the better the removal efficiency, particularly for smaller particles.
PO3 Development incorporates built form and landscape design elements that maximise wind movement around buildings and the dispersion of road traffic air pollutants, including: a. maintaining gaps between buildings at 7m or higher; b. variation in the building facade, in addition to balconies; c. varying the building shape and form from that of neighbouring buildings; d. significant vegetation between the road and the building. Note—A transport air quality corridor report prepared in accordance with the Transport air quality corridor planning scheme policy can assist in demonstrating achievement of this performance outcome.	**AO3** Development at 7m or higher is set back at least 20m from the kerb.
PO4 Development does not: a. expose the occupants of a sensitive use to an air pollutant that exceeds the air quality planning criteria in Table 8.2.23.3.C, due to the operation of a tunnel ventilation outlet; b. affect the dispersion of air pollutants to the extent that existing sensitive uses will be exposed to air pollutants that exceed the air quality (planning) criteria in Table 8.2.23.3.C. Note—An air quality impact report prepared in accordance with the Air quality planning scheme policy can assist in demonstrating achievement of this performance outcome.	**AO4.1** Development has a building height which is at least 10m lower than the height of the tunnel ventilation outlet. **AO4.2** The development does not include a childcare centre.

Table 4.2: BCC Air Quality Criteria

Compound	Air Quality Criteria (µg/m^3)	Averaging Period	Outcome
Nitrogen dioxide	250	1 hour	Health and Wellbeing
	62	Annual	Health and Wellbeing
Particulate matter (PM) as total suspended particulates (TSP)	90	Annual	Health and wellbeing

Compound	Air Quality Criteria ($\mu g/m^3$)	Averaging Period	Outcome
PM_{10}	50	24 hour	Health and Wellbeing
	25	Annual	Health and Wellbeing
$PM_{2.5}$	25	24 hour	Health and Wellbeing
	8	Annual	Health and Wellbeing
Carbon monoxide	11,000	8 hour	Health and Wellbeing
Deposited dust	4 g/m^2/month	Annual	Protecting aesthetic environment
1,3-butadiene	2.4	Annual	Health and Wellbeing
Benzene	29	1 hour	Health and Wellbeing
	10	Annual	Health and Wellbeing
Benzo(a)pyrene (as marker for PAH)	0.0003	Annual	Health and Wellbeing
Formaldehyde	96	1 hour	Protecting aesthetic environment
	54	24 hours	Health and wellbeing
Toluene	958	1 hour	Odour
	4100	24 hours	Health and wellbeing
	410	Annual	Health and wellbeing
Xylenes	1200	24 hours	Health and wellbeing
	950	Annual	Health and wellbeing

Note:

1. Criteria that are stated in $\mu g/m^3$ are to be referenced to 0°C.
2. Criteria that are stated in ppm are to be expressed as volume/volume.
3. Averaging times of 1 hour or less are to be presented using the 99.9th percentile concentration of the total site impact from dispersion modelling and background concentration for all pollutants in the above table, or the maximum concentration from dispersion modelling if no background concentration is available.
4. Averaging times of greater than 1 hour are to be presented using the maximum concentration of the total site impact from dispersion modelling and background concentration.

In relation to the $PM_{2.5}$ goals, it is expected that in the year 2025, the National Environment Protection Council (NEPC) will reduce the annual goal to 7 $\mu g/m^3$ and 24-hour average goal to 20 $\mu g/m^3$ as part of an updated National Environment Protection (Ambient Air Quality) Measure. The Queensland Environmental Protection (Air) Policy 2019 (EPP Air) and BCC City Plan 2014 codes currently refer to the 8 $\mu g/m^3$ annual and 25 $\mu g/m^3$ 24-hour goals. It is anticipated that regulatory authorities and local councils would ultimately adopt the updated annual goal, but the timing for this change is not known. There are also implications for developments that would need to be explored at a planning level, given that there are areas in Brisbane and other Australian cities where the 7 $\mu g/m^3$ is already exceeded.

NO_2 goals have only been recently updated in the EPP Air (as of 30 August 2024) during the course of responding to EDQ's information request in May 2024 and subsequently undertaking this air quality assessment. The annual and 1-hour goals have been reduced down to 164 $\mu g/m^3$ and 31 $\mu g/m^3$, respectively. The Brisbane City Plan has not been updated yet to reflect these recent changes, noting that the updated goals are 66% and 50% of the previous 1-hour and annual average goals, respectively.

Given the available information and timing of this development application and EDQ information request, it is considered appropriate to continue adopting the current goals. EDQ has specifically requested an assessment against the air quality performance outcomes of the Brisbane City Plan 2014, which specifies the relevant air quality criteria as summarised in **Table 4.2**.

4.3.2 Industrial Amenity Overlay Code

The site also falls within the Industrial Amenity Overlay due to being approximately 270 metres away (as illustrated in **Figure 4.2**) from the Boral Concrete Batching Plant in Windsor, which is classified as a High impact industry. Acceptable outcome AO2 specifies a minimum setback distance of 500 metres from a High impact industry. Since compliance with the acceptable outcome is not possible, air dispersion modelling of the concrete batching plant has been conducted to determine any potential impacts on the future occupants of the development. The predicted results were compared to the criteria presented in **Table 4.2**. Details on the code are presented in **Table 4.3**.

Figure 4.2: Industrial Amenity Overlay

Table 4.3: Industrial Amenity Overlay Code and Table 8.2.13.3.G

Performance Outcomes	Acceptable Outcomes
PO2 Development is located, designed and constructed to achieve the air quality (planning) criteria in Table 8.2.13.3.B, odour criteria in Table 8.2.13.3.C and health risk criteria in Table 8.2.13.3.D. Note—An air quality impact report prepared in accordance with the Air quality planning scheme policy can assist in demonstrating achievement of this performance outcome.	**AO1** Development for a sensitive use is located no closer than the distance stated in Table 8.2.13.3.G.
Established use	**Minimum separation distance (measured to the property boundary of the development)**
High impact industry	500m

5. CLEM7 NORTHERN VENTILATION OUTLET

5.1 Overview

The Clem7 is a 4.8-kilometre twin uni-directional road tunnel running from Bowen Hills to Woolloongabba. The tunnel has two vent outlets, a northern outlet in Bowen Hills (servicing the northbound tunnel) and a southern outlet in Woolloongabba (servicing the southbound tunnel). The subject site is located in close proximity to the northern ventilation outlet.

It is also noted that the Clem7 has tunnel portals located in Bowen Hills, Kangaroo Point and Woolloongabba. Based on the Linkt website (Linkt, 2023), the tunnel ventilation system allows for portal emissions during off peak periods when there is less traffic.

5.2 Emissions Data

The Clem7 Northern VSO emissions were estimated based on:

Item	Description
Northbound traffic along the Clem7 tunnel	Traffic counts have been provided by TTM based on counts conducted from 09/07/24 to 11/07/24.
Traffic volume growth	A traffic volume growth of 1.8% per year to estimate traffic volume on the Project's opening year (2028) and the 10-year horizon (2038). A growth of 1.8% is the same rate adopted in the air quality modelling for Application A006150645, which was relevant to the Clem7 tunnel. The growth rate has been further reviewed for other roads based on advice from TTM, with reference to the BCC Local Government Infrastructure Plan (LGIP). As per Schedule 3 Table SC3.1.7 of the BCC City Plan, the subject site is within service catchment 8. The 10-year growth rate from 2021 to 2031 is noted to also be 1.8%, which has been adopted for estimating future traffic.
Northbound road gradient along the tunnel	Based on the southbound tunnel, as per Application A006150645 (noting that northbound gradients would be the opposite of southbound gradients): ■ Section 1: +4%, 1,520 metres ■ Section 2: -4%, 1,540 metres ■ Section 3: 0%, 920 metres ■ Section 4: ≤-6%, 640 metres Gradient information was sought from BCC, however, this was not ultimately provided. Therefore, information from data used in Application A006150645 was adopted.
Traffic situation	Calculated based on hourly volume-to-capacity ratio. Assumed same capacity as southbound tunnel (3,370 vehicle per hour), as adopted for Application A006150645.
BCC COPERT database	Emission rates calculated considering % road gradient for each section, winter situation (more conservative), 2025 fleet year, 7% proportion of heavy vehicles (as per TTM counts), and traffic situation calculated (freeway or urban).

To evaluate the traffic flow patterns for future years, reference has been made to Section 3.5.2 (Points 5 and 6) of the BCC AQPSP which states:

> *5. Roads should be modelled as Urban traffic situation for most hours of the day, unless the use of the Freeway traffic situation is warranted where the traffic is not congested (see (6) below).*
>
> *6. Emission factors for the Congested traffic situation are to be applied at intersections within the estimated queue length and non-freeway road sections for at least the peak hours throughout the day (6–8 a.m. and 5–7 p.m.). Congestion is to be included for all other hours where the volume-to-capacity ratio exceeds 0.8. The Congested traffic situation is to be used for queuing and moving traffic and not for idling emissions.*

In accordance with 3.2.5(5) and 3.2.5(6) of the AQPSP, the approach to selecting the traffic scenario in COPERT can be summarised as follows:

- As per 3.2.5(5) of the AQPSP, in the first instance, use the Urban setting for all hours of the day.
- As per 3.2.5(5) of the AQPSP, if a freeway or highway is being considered, the Freeway setting can be used if traffic is not congested (i.e. volume-to-lane capacity is equal to or less than 0.8, as per 3.2.5(6) of the AQPSP).
- As per 3.2.5(6) of the AQPSP, for other roads (involving intersections and non-freeway road sections), the Congested setting should be used if the volume-to-lane capacity exceeds 0.8. As a bare minimum, peak hours should utilise congested traffic (6 a.m. to 8 a.m. and 5 p.m. to 7 p.m.).

The Clem7 tunnel is clearly already identified as a motorway in the BCC City Plan 2014 Road Hierarchy Overlay, therefore in accordance with the AQPSP, the Freeway setting can be used if the traffic is not congested. Road capacities have been sourced from ICC Local Government Infrastructure Plan Supporting Document – Transport (Roads) Update 2016 (Ipswich City Council, 2018) and are presented in **Table 5.1.** Based on **Table 5.1**, the estimated capacity of the northbound tunnel is 3,370 vehicles per hour.

Table 5.1: ICC LGIP - Road Network Key Performance Indicators

Link Function	Carriageway Configuration	Operational Environment	Performance Targets					
			Deficiency Capacity	Average Travel Speed (km/h)	Lane Capacity			
					Vehicles / Hour		Vehicles / Day	
					Single	Dual	Single	Dual
Motorway / Highway	Divided	Uninterrupted	LOS D	70	1,560	3,370	15,600	33,700
	Undivided				1,400	3,030	14,000	30,300
Regional Arterial (urban)	Divided	Uninterrupted	LOS D	40	1,320	2,840	13,200	28,400
	Undivided				1,250	2,650	12,500	26,500
Regional Arterial (rural)	Undivided	Uninterrupted	LOS D	60	720	2,710	7,200	27,100
Arterial	Divided	Interrupted	LOS D (90% LOS E)[1]	25	1,080	2,340	10,800	23,400
	Undivided				900	1,980	9,000	19,800
Sub-Arterial	Divided	Interrupted	LOS D (90% LOS E)[1]	20	900	1,980	9,000	19,800
	Undivided				810	1,710	8,100	17,100

1. For roads with uninterrupted flow characteristics (i.e. rural roads), the target deficiency capacity is LOS 'D'. For roads with interrupted flow characteristics (i.e. urban roads), a target deficiency capacity of 90% of LOS 'E' is being used as a proxy for LOS 'D', since it is not possible to determine LOS 'D' capacities for roads exhibiting interrupted flow characteristics.

Table 5.2 presents the volume-to-capacity ratio of the Clem7 northbound tunnel for the years 2028 and 2038.

Table 5.2: Volume-to-Capacity Ratio of Clem7 Northbound

Hour of Day	Vehicles Per Hour		Volume-to-Capacity Ratio	
	2028	2038	2028	2038
1	41	49	1%	1%

Hour of Day	Vehicles Per Hour		Volume-to-Capacity Ratio	
2	24	28	1%	1%
3	35	42	1%	1%
4	49	59	1%	2%
5	159	190	5%	6%
6	549	656	16%	19%
7	1,444	1,726	43%	51%
8	1,906	2,278	57%	68%
9	2,051	2,451	61%	73%
10	1,524	1,822	45%	54%
11	1,007	1,204	30%	36%
12	930	1,111	28%	33%
13	963	1,151	29%	34%
14	1,009	1,206	30%	36%
15	1,300	1,554	39%	46%
16	1,724	2,061	51%	61%
17	1,998	2,389	59%	71%
18	1,958	2,341	58%	69%
19	902	1,079	27%	32%
20	353	422	10%	13%
21	255	305	8%	9%
22	193	231	6%	7%
23	131	157	4%	5%
24	72	86	2%	3%
TOTAL	**20,578**	**24,597**	-	-

As shown in the table above, none of the hours for the years 2028 and 2038 are expected to have a ratio above 80%. Based on this, the Freeway scenario can be applied to all hours. The relatively low ratios are consistent with the fact that the tunnel has always operated well below projected volumes.

On the basis of the above review, **Table 5.3** presents the adopted pollutant emission rates for the Clem7 northbound vent in accordance with the requirements of the AQPSP.

Table 5.3: Clem7 Northbound Emission Rates using COPERT – Year 2028 Traffic

Hour of Day	Traffic (/hour)	Traffic Scenario	NO_x (g/s/m)	PM_{10} (g/s/m)	$PM_{2.5}$ (g/s/m)
1	41	Freeway	0.0159	0.0010	0.0007
2	24	Freeway	0.0091	0.0006	0.0004
3	35	Freeway	0.0137	0.0009	0.0006
4	49	Freeway	0.0190	0.0012	0.0008
5	159	Freeway	0.0611	0.0038	0.0027
6	549	Freeway	0.2117	0.0132	0.0094
7	1,444	Freeway	0.5566	0.0347	0.0248
8	1,906	Freeway	0.7940	0.0613	0.0405
9	2,051	Freeway	0.8544	0.0659	0.0436
10	1,524	Freeway	0.5877	0.0366	0.0262
11	1,007	Freeway	0.3883	0.0242	0.0173
12	930	Freeway	0.3584	0.0223	0.0160
13	963	Freeway	0.3711	0.0231	0.0165
14	1,009	Freeway	0.3891	0.0242	0.0173
15	1,300	Freeway	0.5013	0.0312	0.0223
16	1,724	Freeway	0.6647	0.0414	0.0296
17	1,998	Freeway	0.8326	0.0642	0.0424
18	1,958	Freeway	0.8159	0.0630	0.0416
19	902	Freeway	0.3480	0.0217	0.0155
20	353	Freeway	0.1362	0.0085	0.0061
21	255	Freeway	0.0984	0.0061	0.0044
22	193	Freeway	0.0744	0.0046	0.0033
23	131	Freeway	0.0505	0.0031	0.0023
24	72	Freeway	0.0277	0.0017	0.0012

Hour of Day	Traffic (/hour)	Traffic Scenario	NO_x (g/s/m)	PM_{10} (g/s/m)	$PM_{2.5}$ (g/s/m)
Total	**20,578**	-	-	-	-

Table 5.4: Clem7 Northbound Emission Rates using COPERT – Year 2038 Traffic

Hour of Day	Traffic (/hour)	Traffic Scenario	NO_x (g/s/m)	PM_{10} (g/s/m)	$PM_{2.5}$ (g/s/m)
1	49	Freeway	0.0190	0.0012	0.0008
2	28	Freeway	0.0109	0.0007	0.0005
3	42	Freeway	0.0163	0.0010	0.0007
4	59	Freeway	0.0228	0.0014	0.0010
5	190	Freeway	0.0731	0.0046	0.0033
6	656	Freeway	0.2531	0.0158	0.0113
7	1,726	Freeway	0.6654	0.0415	0.0296
8	2,278	Freeway	0.9490	0.0732	0.0484
9	2,451	Freeway	1.0212	0.0788	0.0521
10	1,822	Freeway	0.7025	0.0438	0.0313
11	1,204	Freeway	0.4641	0.0289	0.0207
12	1,111	Freeway	0.4285	0.0267	0.0191
13	1,151	Freeway	0.4436	0.0276	0.0198
14	1,206	Freeway	0.4651	0.0290	0.0207
15	1,554	Freeway	0.5992	0.0373	0.0267
16	2,061	Freeway	0.7945	0.0495	0.0354
17	2,389	Freeway	0.9952	0.0768	0.0507
18	2,341	Freeway	0.9752	0.0753	0.0497
19	1,079	Freeway	0.4159	0.0259	0.0185
20	422	Freeway	0.1628	0.0101	0.0073
21	305	Freeway	0.1176	0.0073	0.0052
22	231	Freeway	0.0889	0.0055	0.0040
23	157	Freeway	0.0604	0.0038	0.0027
24	86	Freeway	0.0332	0.0021	0.0015
Total	**24,597**	**-**	**-**	**-**	**-**

The year 2038 has been selected as the worst-case emissions scenario for the modelling, as it considers higher traffic volumes than 2028 while still using the conservative 2025 emission factors.

5.3 Flow Rate Data

Flow rate data for the northern vent was sought from BCC, however, this was not ultimately provided. Therefore, reference has been made to the southern vent flow rate data, provided by BCC for the air quality assessment for Application A006150645. Given the different hourly traffic counts for the southbound tunnel, the southern vent flow rate data was adjusted based on the northbound tunnel traffic counts, as described in further detail below.

The vent area was estimated using satellite imagery, while the exit velocity was estimated by conducting a regression analysis between southbound tunnel traffic and Clem7 South VSO hourly flow rates, and then the derived relationship was applied to the existing hourly northbound traffic data.

A quadratic regression analysis was performed between the tunnel's vent flow rate and hourly southbound traffic, as shown in **Figure 5.1**. The strong correlation observed between these parameters enables a reasonable estimation of the north vent's exit velocity. This estimation incorporates both the regression relationship and an estimated vent section area of 49 m^2, derived from Google Earth. The resulting estimated exit velocities for the vent are presented in **Table 5.5**.

Figure 5.1: Clem7 Southbound - Vent Flow Rate vs Hourly Traffic Plot

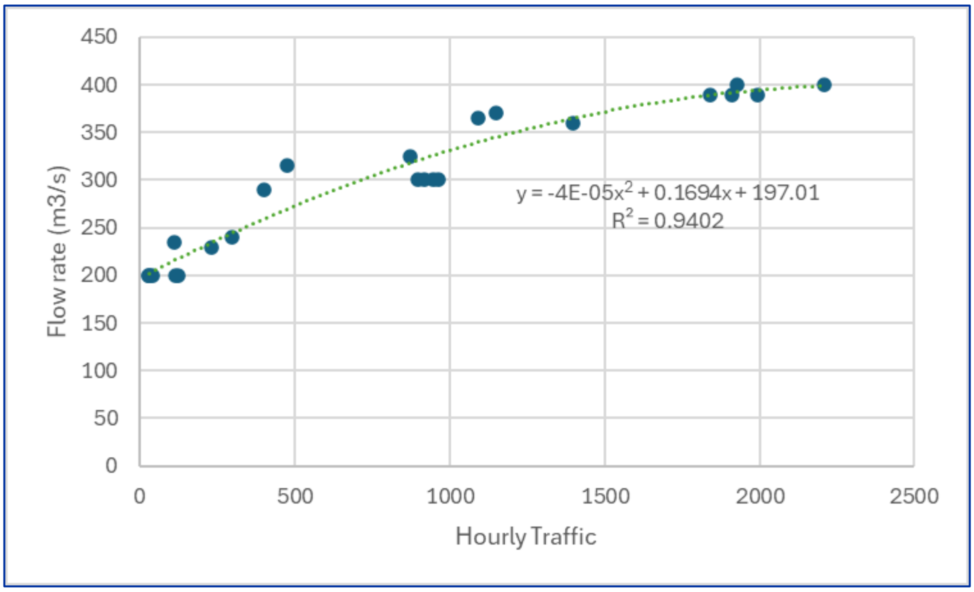


Table 5.5: Clem7 North Vent Estimated Exit Velocity

Hour	2024 Traffic Volume (veh/hour)	Estimated Flow rate (m^3/s)	Estimated Exit Velocity (m/s)
1	38	203	4.2
2	22	202	4.1
3	33	202	4.1
4	46	204	4.2
5	148	215	4.5
6	511	270	5.6
7	1,344	340	7.4
8	1,774	389	7.9
9	1,909	392	8.0
10	1,419	345	7.5
11	938	326	6.6
12	866	321	6.5
13	896	323	6.5
14	940	327	6.6
15	1,211	365	7.2
16	1,605	394	7.7
17	1,861	399	8.0
18	1,823	392	7.9
19	840	318	6.4
20	329	259	5.1
21	238	244	4.8
22	180	235	4.6

Hour	2024 Traffic Volume (veh/hour)	Estimated Flow rate (m^3/s)	Estimated Exit Velocity (m/s)
23	122	217	4.4
24	67	216	4.2

6. BACKGROUND AIR QUALITY

6.1 Relevant Pollutants

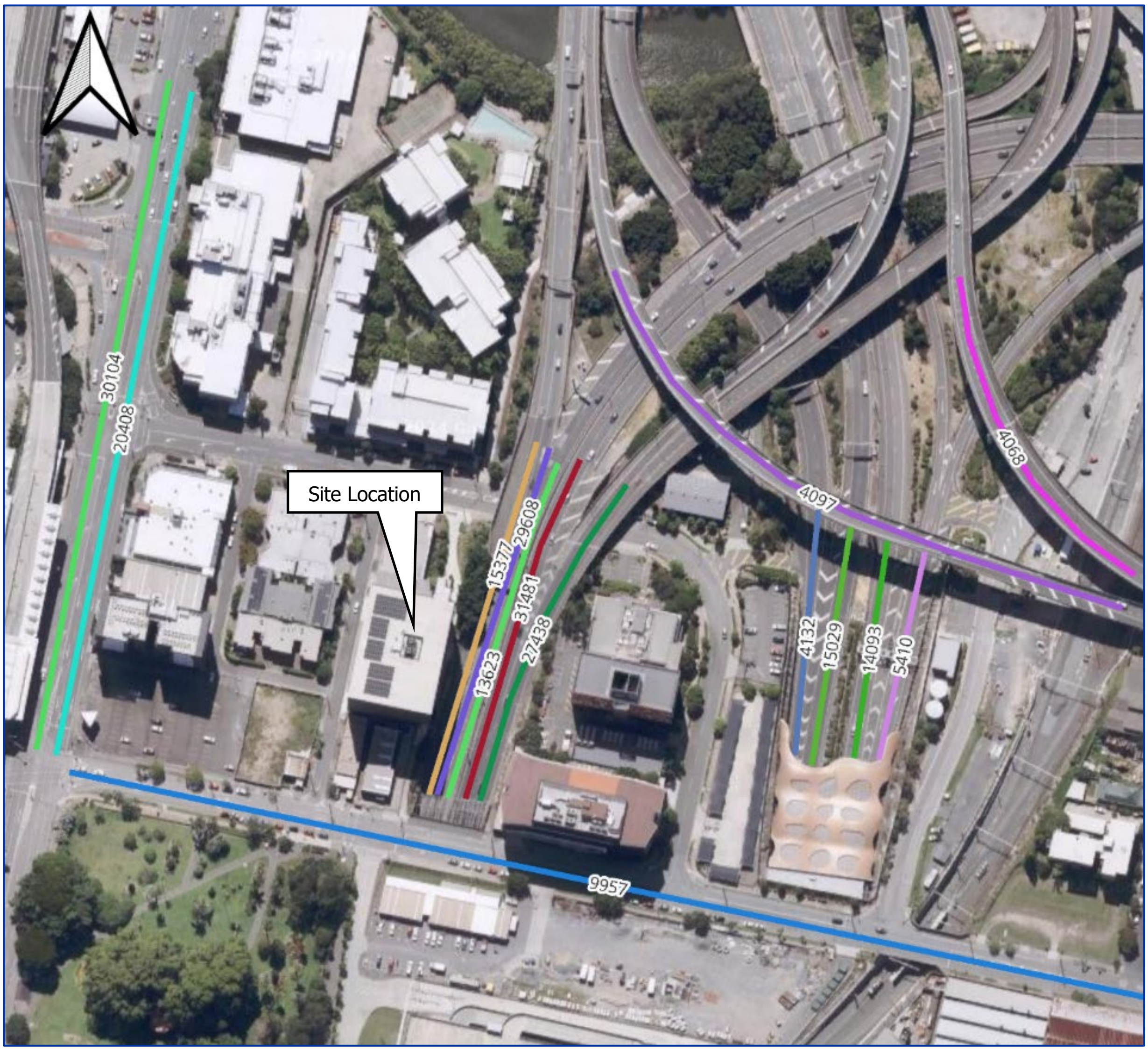
Considering previous experience in road projects such as the Clem7 South VSO air quality assessment, the critical pollutants to be assessed are NO_2, PM_{10}, and $PM_{2.5}$. These three pollutants are most likely to determine compliance at both the subject site and off-site locations.

While CO, benzene, and benzopyrene were also considered in the Clem7 South VSO project, their values were well below the established criteria. Only NO_2, PM_{10}, and $PM_{2.5}$ have been modelled to assess compliance and reduce overall modelling time.

6.2 Local Air Emission Sources

To assess cumulative impacts, associated traffic emissions from the surrounding road network has been modelled, and ambient monitoring data added to the predicted results. Traffic counts was conducted by TTM for the core weekdays (Tuesday to Thursday) from 9 to 11 July 2024. **Figure 6.1** presents the average daily traffic counts for the surrounding road network.

Figure 6.1: Average Daily Traffic Counts (Average of Core Weekdays)

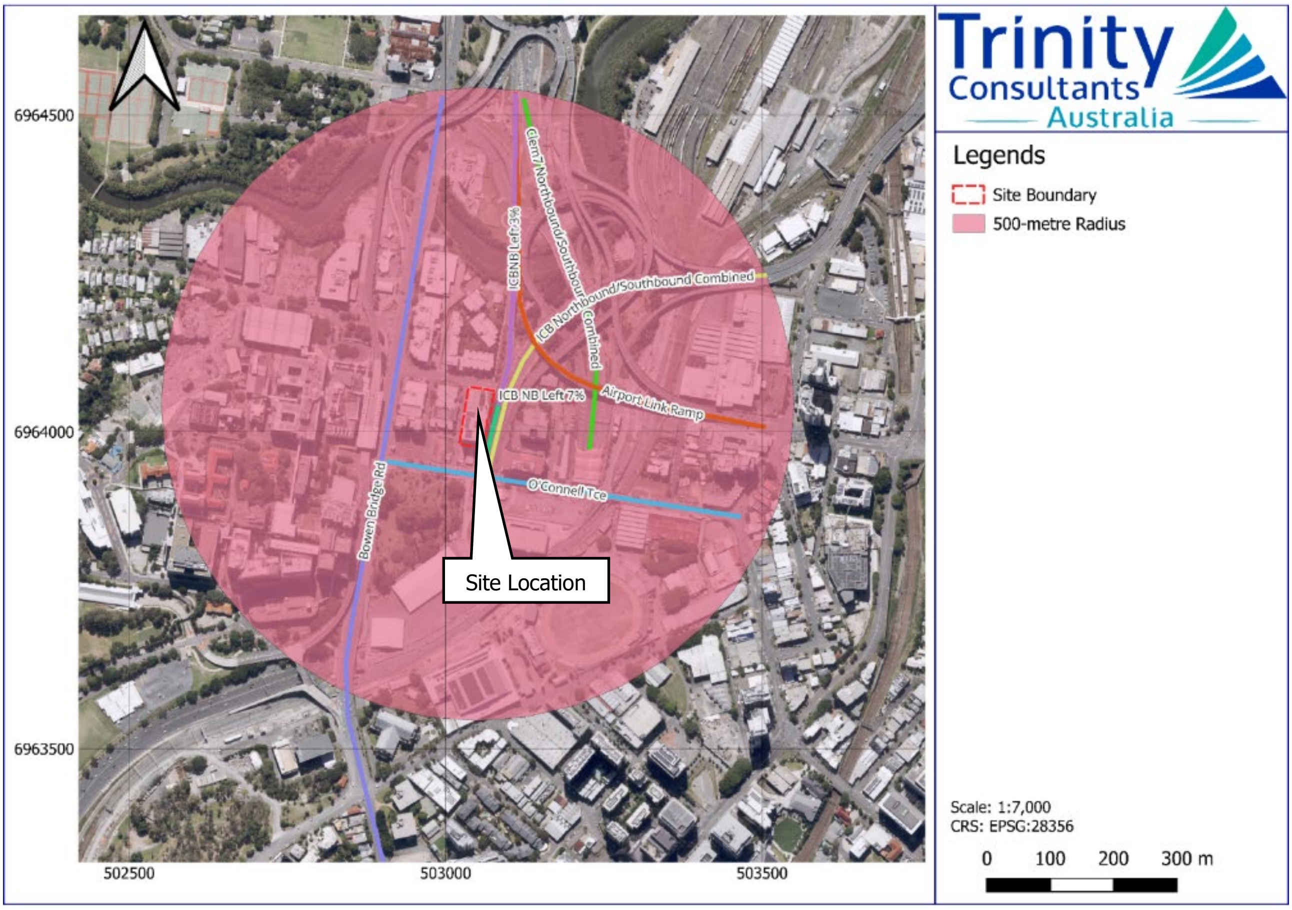


Note: Marked roads do not represent the actual modelled line sources (refer to **Figure 6.2** for this information)

The proposed road sources to be modelled are presented in **Figure 6.2**. These roads were selected to best represent the traffic volume going through the complex traffic network while simplifying the modelling, reducing the number of sources, and consequently running and post-processing times. All major roads within a 500-metre radius of the site have been considered. The simplifications and assumptions are summarised below:

- Bowen Bridge Road modelled as 1 source combining northbound and southbound traffic volume
- The ICB left exit ramp modelled as 2 sources in order to consider the difference in road gradients near the subject site and avoid an overly conservative approach being adopted (e.g. assume worst-case gradient applied to 1 single line source).
- The ICB northbound and southbound traffic volume modelled as 1 source.
- The Clem7 northbound (right turn off lane after tunnel exit) and southbound traffic volume modelled as 1 source.

Figure 6.2: Modelled Road Sources



Note: Each modelled road source is represented by a different colour

Tunnel portal emissions from the ICB were also included in the modelling. No portal emissions were considered for the M7 Clem Jones tunnel. The LinkT website[3] indicates that portal ventilation occurs during off-peak periods when there is less traffic on the road. There are no further details on this ventilation approach from which to base the modelling on (e.g. hours for portal emissions, proportion of portal/vent emissions, which portals). Therefore, for the purpose of the assessment, vent emissions are assumed 100% of the time. This will result in all emissions being emitted closer to the proposed development site.

[3] Linkt. (2023). Linkt. Retrieved from Tunnel air quality: https://www.linkt.com.au/using-toll-roads/about-brisbane-toll-roads/clem7/tunnel-air-quality/brisbane

Additionally, dust emissions from the concrete batching plant have been included in the modelling to account for total cumulative impacts and to address the Industrial Amenity Overlay Code.

6.3 Road Source Emissions

Vehicle emission factors were adopted from COPERT Australia vehicle emission model (Department of Environment, Science, Information, Technology and Innovation, 2016)

The following general inputs were considered:

- Season – as a conservative approach, only winter emissions have been considered.
- Year of traffic fleet – 2025.
- Annual traffic growth of 1.8% and estimated traffic volume for 2038.

Since COPERT only allows for the modelling of gradients less than -6%, -4%, -2%, 0%, 2%, 4%, and greater than 6%, the modelled gradients were selected conservatively.

The same methodology described in **Section 5.2** has been used for selecting the traffic scenario in COPERT.

Specific inputs for each source are presented in **Table 6.1**. It is noted that the gradient may vary over the length of a road. To model varying gradients in detail, each road would need to be split up into multiple line sources, which would result in excessive model run times and post-processing run times. Therefore, a single conservative gradient has been applied to each road/line source as described in the following table.

The estimated emissions are presented in **Table 6.2** to **Table 6.7**.

Table 6.1: BCC COPERT Inputs

Source	Gradient	% Heavy Vehicles	Road Capacity (veh/hour)	Traffic Situation (Freeway/Urban/Congested)
ICB Northbound, Left Exit Ramp	Adopted gradient greater than 6% for the first section after the tunnel exit and 4% for the rest of the road. In reality, the actual gradient levels out to 0% towards the northern end of the road segment.	5.3%	2,840	6 hours exceeded the 0.8 volume-to-lane capacity ratio and were considered congested and urban for the rest of the day.
ICB Combined Northbound (Right Exit Lane)/Southbound	A +2% gradient has been modelled for this road section. The road section near the subject site has a gradient of 7% for northbound traffic and -7% for southbound traffic. It is also noted that most of the traffic (67%) is southbound. Calculations assuming a greater than 6% gradient for northbound traffic and a less than -6% gradient for southbound traffic, compared to assuming a 2% gradient for combined traffic, show that the latter assumption is conservative. This is because it provides PM_{10} and $PM_{2.5}$ emission rates that are 4% to 8% higher and NOx emission rates that are 0% to 44% higher (except for one hour that is 2% lower). This approach is conservative since it predicts higher emissions in this area.	5.4%	2,840 (each double lane)	The volume-to-lane capacity ratio has been checked for each lane. If it exceeds 0.8, the lane has been modelled as congested; otherwise, it is considered urban. Finally, the emissions for individual lanes have been added together.
Clem7 Combined	Adopted gradient greater than 6% northbound and 4% southbound. The worst-case gradient northbound	6.7%	3,370 (each way)	None of the hours exceeded the 0.8 volume-to-lane capacity ratio; therefore, the 4 hours with the

Source	Gradient	% Heavy Vehicles	Road Capacity (veh/hour)	Traffic Situation (Freeway/Urban/Congested)
	is 7% and southbound 3%, but overall, most of the road section is flat.			highest traffic volume were considered urban and freeway for the rest of the day.
Airport Link Ramp	Adopted gradient greater than 6%. The first section of the ramp has a gradient of 7%, then it levels out along the road bend before descending with a -7% gradient to merge with the ICB Northbound left exit ramp.	3.2%	1,320	None of the hours exceeded the 0.8 volume-to-lane capacity ratio; therefore, the 4 hours with the highest traffic volume were considered congested and urban for the rest of the day.
Bowen Bridge Road	Adopted gradient of 4% northbound and greater than 6% southbound. The actual gradient for northbound traffic is 3% in the worst-case section, but for most of the road, the gradient is between -3% and -7%. For southbound traffic, the worst-case gradient is 7%.	2.2%	2,650 (each way)	The volume-to-lane capacity ratio has been checked for each lane. If it exceeds 0.8, the lane has been modelled as congested; otherwise, it is considered urban. Finally, the emissions for individual lanes have been added together.
O'Connell Terrace	The adopted gradient is 4%, while the average slope for this road is 3%. Assuming the road gradient for both-way traffic is higher than the average gradient is a conservative approach.	2.5%	1,710	None of the hours exceeded the 0.8 volume-to-lane capacity ratio; therefore, the 4 hours with the highest traffic volume were considered congested and urban for the rest of the day.

Table 6.2: ICB Northbound, Left Exit Ramp Emission Rates using COPERT – Year 2038 Traffic

			≥ +6% Gradient			+4% Gradient		
Hour of Day	Traffic (/hour)	Traffic Scenario	NO_x (g/s/m)	PM_{10} (g/s/m)	$PM_{2.5}$ (g/s/m)	NO_x (g/s/m)	PM_{10} (g/s/m)	$PM_{2.5}$ (g/s/m)
1	190	Urban	3.10E-05	2.76E-06	1.60E-06	2.71E-05	2.73E-06	1.59E-06
2	128	Urban	2.09E-05	1.85E-06	1.08E-06	1.82E-05	1.84E-06	1.07E-06
3	129	Urban	2.11E-05	1.87E-06	1.09E-06	1.84E-05	1.85E-06	1.08E-06
4	223	Urban	3.64E-05	3.24E-06	1.88E-06	3.18E-05	3.21E-06	1.86E-06
5	699	Urban	1.14E-04	1.02E-05	5.90E-06	9.98E-05	1.01E-05	5.85E-06
6	1,489	Urban	2.43E-04	2.16E-05	1.26E-05	2.12E-04	2.14E-05	1.24E-05
7	2,102	Urban	3.44E-04	3.06E-05	1.77E-05	3.00E-04	3.02E-05	1.76E-05
8	2,421	Congested	6.42E-04	3.72E-05	2.26E-05	5.58E-04	3.66E-05	2.22E-05
9	2,336	Congested	6.19E-04	3.59E-05	2.19E-05	5.39E-04	3.53E-05	2.15E-05
10	2,167	Urban	3.54E-04	3.15E-05	1.83E-05	3.09E-04	3.12E-05	1.81E-05
11	2,069	Urban	3.38E-04	3.01E-05	1.75E-05	2.95E-04	2.98E-05	1.73E-05
12	2,152	Urban	3.52E-04	3.13E-05	1.82E-05	3.07E-04	3.10E-05	1.80E-05
13	2,199	Urban	3.59E-04	3.20E-05	1.86E-05	3.14E-04	3.16E-05	1.84E-05
14	2,259	Urban	3.69E-04	3.28E-05	1.91E-05	3.22E-04	3.25E-05	1.89E-05
15	2,557	Congested	6.78E-04	3.93E-05	2.39E-05	5.89E-04	3.86E-05	2.35E-05
16	2,864	Congested	7.59E-04	4.41E-05	2.68E-05	6.60E-04	4.33E-05	2.63E-05
17	2,925	Congested	7.76E-04	4.50E-05	2.74E-05	6.74E-04	4.42E-05	2.69E-05
18	2,802	Congested	7.43E-04	4.31E-05	2.62E-05	6.46E-04	4.24E-05	2.57E-05
19	2,198	Urban	3.59E-04	3.20E-05	1.86E-05	3.14E-04	3.16E-05	1.84E-05
20	1,369	Urban	2.24E-04	1.99E-05	1.16E-05	1.95E-04	1.97E-05	1.14E-05
21	1,207	Urban	1.97E-04	1.76E-05	1.02E-05	1.72E-04	1.74E-05	1.01E-05
22	1,096	Urban	1.79E-04	1.59E-05	9.25E-06	1.56E-04	1.58E-05	9.16E-06
23	773	Urban	1.26E-04	1.12E-05	6.52E-06	1.10E-04	1.11E-05	6.46E-06
24	392	Urban	6.41E-05	5.70E-06	3.31E-06	5.59E-05	5.64E-06	3.28E-06
Total	**38,744**	-	-	-	-	-	-	-

Table 6.3: ICB Combined Northbound (Right Exit Lane)/Southbound Emission Rates using COPERT – Year 2038 Traffic

	Northbound (Right Exit Lane)		Southbound (Left Lane)		Southbound (Right Lane)		Combined Emissions		
Hour of Day	Traffic (/hour)	Traffic Scenario	Traffic (/hour)	Traffic Scenario	Traffic (/hour)	Traffic Scenario	NO_x (g/s/m)	PM_{10} (g/s/m)	$PM_{2.5}$ (g/s/m)
1	121	Urban	233	Urban	168	Urban	4.45E-05	5.14E-06	2.99E-06
2	74	Urban	135	Urban	102	Urban	2.74E-05	3.17E-06	1.84E-06
3	81	Urban	117	Urban	64	Urban	3.00E-05	3.46E-06	2.01E-06
4	203	Urban	116	Urban	101	Urban	7.50E-05	8.65E-06	5.02E-06
5	823	Urban	387	Urban	388	Urban	3.03E-04	3.50E-05	2.03E-05
6	1,890	Urban	1,306	Urban	1,477	Urban	6.96E-04	8.04E-05	4.67E-05
7	2,523	Congested	2,304	Congested	2,576	Congested	1.53E-03	1.13E-04	6.86E-05
8	2,901	Congested	3,001	Congested	3,178	Congested	1.76E-03	1.30E-04	7.89E-05
9	2,639	Congested	2,920	Congested	2,868	Congested	1.60E-03	1.18E-04	7.18E-05
10	2031	Urban	2,251	Urban	2,295	Congested	9.10E-04	8.79E-05	5.19E-05
11	1832	Urban	2,150	Urban	1,827	Urban	6.75E-04	7.79E-05	4.52E-05
12	1802	Urban	2,065	Urban	1,739	Urban	6.64E-04	7.66E-05	4.45E-05
13	1852	Urban	2,223	Urban	1,862	Urban	6.82E-04	7.87E-05	4.57E-05
14	1933	Urban	2,348	Congested	1,816	Urban	8.66E-04	8.36E-05	4.94E-05
15	2178	Urban	3,019	Congested	2,200	Urban	9.76E-04	9.42E-05	5.56E-05
16	2,688	Congested	3,051	Congested	2,240	Urban	1.42E-03	1.18E-04	7.09E-05
17	2,837	Congested	3,222	Congested	2,397	Congested	1.72E-03	1.27E-04	7.72E-05
18	2,713	Congested	3,032	Congested	2,345	Congested	1.65E-03	1.21E-04	7.38E-05
19	1847	Urban	2,053	Urban	1,624	Urban	6.80E-04	7.85E-05	4.56E-05
20	1093	Urban	1,345	Urban	1,197	Urban	4.03E-04	4.65E-05	2.70E-05
21	910	Urban	1121	Urban	1029	Urban	3.35E-04	3.87E-05	2.25E-05
22	762	Urban	974	Urban	839	Urban	2.81E-04	3.24E-05	1.88E-05
23	493	Urban	636	Urban	527	Urban	1.82E-04	2.10E-05	1.22E-05
24	264	Urban	404	Urban	362	Urban	9.73E-05	1.12E-05	6.53E-06
Total	**36,492**	-	**40,413**	-	**35,222**	-	-	-	-

Table 6.4: Clem7 Combined Emission Rates using COPERT – Year 2038 Traffic

	Northbound		Southbound		Combined Emissions		
Hour of Day	Traffic (/hour)	Traffic Scenario	Traffic (/hour)	Traffic Scenario	NO_x (g/s/m)	PM_{10} (g/s/m)	$PM_{2.5}$ (g/s/m)
1	49	Freeway	74	Freeway	1.70E-05	7.35E-07	5.24E-07
2	28	Freeway	42	Freeway	9.78E-06	4.22E-07	3.01E-07
3	42	Freeway	31	Freeway	1.06E-05	4.44E-07	3.17E-07
4	59	Freeway	45	Freeway	1.48E-05	6.24E-07	4.45E-07
5	190	Freeway	148	Freeway	4.83E-05	2.03E-06	1.45E-06
6	656	Freeway	625	Freeway	1.82E-04	7.70E-06	5.49E-06
7	1,726	Freeway	1,265	Freeway	4.29E-04	1.80E-05	1.29E-05
8	2,278	Urban	2,113	Freeway	6.97E-04	4.68E-05	2.88E-05
9	2,451	Urban	2,234	Urban	8.23E-04	7.03E-05	4.08E-05
10	1,822	Freeway	1,426	Freeway	4.65E-04	1.96E-05	1.40E-05
11	1,204	Freeway	1,112	Freeway	3.29E-04	1.39E-05	9.93E-06
12	1,111	Freeway	1,088	Freeway	3.11E-04	1.32E-05	9.43E-06
13	1,151	Freeway	1,170	Freeway	3.28E-04	1.39E-05	9.95E-06
14	1,206	Freeway	1,217	Freeway	3.42E-04	1.46E-05	1.04E-05
15	1,554	Freeway	1,946	Freeway	4.89E-04	2.10E-05	1.50E-05
16	2,061	Freeway	2,490	Urban	7.23E-04	4.98E-05	3.06E-05
17	2,389	Urban	2,718	Urban	8.89E-04	7.66E-05	4.44E-05
18	2,341	Urban	2,716	Urban	8.80E-04	7.58E-05	4.40E-05
19	1,079	Freeway	1,100	Freeway	3.08E-04	1.31E-05	9.34E-06
20	422	Freeway	484	Freeway	1.27E-04	5.44E-06	3.88E-06
21	305	Freeway	405	Freeway	9.89E-05	4.25E-06	3.03E-06
22	231	Freeway	283	Freeway	7.19E-05	3.08E-06	2.20E-06
23	157	Freeway	186	Freeway	4.80E-05	2.05E-06	1.46E-06
24	86	Freeway	122	Freeway	2.88E-05	1.24E-06	8.86E-07
Total	**24,597**	-	**25,037**	-	-	-	-

Table 6.5: Airport Link Ramp Emission Rates using COPERT – Year 2038 Traffic

Hour of Day	Traffic (/hour)	Traffic Scenario	NO_x (g/s/m)	PM_{10} (g/s/m)	$PM_{2.5}$ (g/s/m)
1	7	Urban	9.21E-07	9.97E-08	5.80E-08
2	3	Urban	3.25E-07	3.52E-08	2.05E-08
3	5	Urban	6.50E-07	7.04E-08	4.09E-08
4	9	Urban	1.19E-06	1.29E-07	7.50E-08
5	36	Urban	4.55E-06	4.93E-07	2.86E-07
6	79	Urban	1.00E-05	1.08E-06	6.31E-07
7	164	Urban	2.07E-05	2.25E-06	1.31E-06
8	326	Urban	4.13E-05	4.47E-06	2.60E-06
9	318	Urban	4.03E-05	4.36E-06	2.54E-06
10	236	Urban	2.99E-05	3.24E-06	1.88E-06
11	243	Urban	3.08E-05	3.34E-06	1.94E-06
12	263	Urban	3.33E-05	3.61E-06	2.10E-06
13	261	Urban	3.31E-05	3.58E-06	2.08E-06
14	306	Urban	3.87E-05	4.19E-06	2.43E-06
15	448	Congested	8.91E-05	6.48E-06	3.93E-06
16	576	Congested	1.15E-04	8.34E-06	5.06E-06
17	717	Congested	1.43E-04	1.04E-05	6.30E-06
18	692	Congested	1.38E-04	1.00E-05	6.08E-06
19	232	Urban	2.93E-05	3.18E-06	1.85E-06
20	116	Urban	1.47E-05	1.59E-06	9.24E-07
21	76	Urban	9.64E-06	1.04E-06	6.07E-07
22	72	Urban	9.15E-06	9.91E-07	5.76E-07
23	40	Urban	5.09E-06	5.51E-07	3.20E-07
24	33	Urban	4.12E-06	4.46E-07	2.59E-07
Total	**5,259**	-	-	-	-

Table 6.6: Bowen Bridge Road Combined Emission Rates using COPERT – Year 2038 Traffic

	Northbound		Southbound		Combined Emissions		
Hour of Day	Traffic (/hour)	Traffic Scenario	Traffic (/hour)	Traffic Scenario	NO_x (g/s/m)	PM_{10} (g/s/m)	$PM_{2.5}$ (g/s/m)
1	272	Urban	152	Urban	4.44E-05	5.64E-06	3.28E-06
2	197	Urban	111	Urban	3.23E-05	4.10E-06	2.38E-06
3	180	Urban	106	Urban	3.00E-05	3.80E-06	2.21E-06
4	174	Urban	163	Urban	3.57E-05	4.48E-06	2.61E-06
5	240	Urban	368	Urban	6.50E-05	8.09E-06	4.71E-06
6	707	Urban	1,124	Urban	1.96E-04	2.44E-05	1.42E-05
7	1,585	Urban	1,893	Urban	3.71E-04	4.63E-05	2.69E-05
8	1,919	Urban	2,734	Congested	6.62E-04	6.40E-05	3.82E-05
9	1,892	Urban	2,759	Congested	6.63E-04	6.40E-05	3.82E-05
10	1,891	Urban	1,751	Urban	3.86E-04	4.85E-05	2.82E-05
11	1,892	Urban	1,321	Urban	3.39E-04	4.28E-05	2.49E-05
12	2,008	Urban	1,267	Urban	3.44E-04	4.36E-05	2.54E-05
13	2,134	Congested	1,252	Urban	4.71E-04	4.65E-05	2.78E-05
14	2,242	Congested	1,234	Urban	4.86E-04	4.78E-05	2.86E-05
15	2,794	Congested	1,376	Urban	5.87E-04	5.74E-05	3.44E-05
16	3,367	Congested	1,425	Urban	6.82E-04	6.61E-05	3.96E-05
17	3,429	Congested	1,466	Urban	6.96E-04	6.75E-05	4.04E-05
18	3,520	Congested	1,315	Urban	6.94E-04	6.67E-05	4.00E-05
19	2,605	Congested	1,292	Urban	5.49E-04	5.37E-05	3.21E-05
20	1,479	Urban	853	Urban	2.45E-04	3.10E-05	1.81E-05
21	1,253	Urban	769	Urban	2.13E-04	2.69E-05	1.57E-05
22	1,305	Urban	685	Urban	2.08E-04	2.65E-05	1.54E-05
23	1,009	Urban	484	Urban	1.56E-04	1.99E-05	1.16E-05
24	554	Urban	300	Urban	8.95E-05	1.14E-05	6.61E-06
Total	**38,645**	-	**26,199**	-	-	-	-

Table 6.7: O'Connell Terrace Emission Rates using COPERT – Year 2038 Traffic

Hour of Day	Traffic (/hour)	Traffic Scenario	NO_x (g/s/m)	PM_{10} (g/s/m)	$PM_{2.5}$ (g/s/m)
1	109	Urban	1.13E-05	1.45E-06	8.44E-07
2	87	Urban	9.07E-06	1.16E-06	6.75E-07
3	70	Urban	7.28E-06	9.31E-07	5.42E-07
4	71	Urban	7.41E-06	9.49E-07	5.52E-07
5	80	Urban	8.40E-06	1.07E-06	6.25E-07
6	162	Urban	1.69E-05	2.17E-06	1.26E-06
7	438	Urban	4.57E-05	5.85E-06	3.40E-06
8	698	Urban	7.29E-05	9.33E-06	5.43E-06
9	786	Urban	8.20E-05	1.05E-05	6.11E-06
10	632	Urban	6.60E-05	8.45E-06	4.91E-06
11	584	Urban	6.10E-05	7.80E-06	4.54E-06
12	601	Urban	6.27E-05	8.02E-06	4.67E-06
13	662	Urban	6.90E-05	8.83E-06	5.14E-06
14	685	Urban	7.15E-05	9.15E-06	5.32E-06
15	873	Congested	1.40E-04	1.23E-05	7.44E-06
16	1,103	Congested	1.77E-04	1.55E-05	9.39E-06
17	1,171	Congested	1.88E-04	1.65E-05	9.98E-06
18	1,209	Congested	1.94E-04	1.70E-05	1.03E-05
19	802	Urban	8.37E-05	1.07E-05	6.23E-06
20	479	Urban	5.00E-05	6.40E-06	3.72E-06
21	468	Urban	4.88E-05	6.25E-06	3.63E-06
22	470	Urban	4.90E-05	6.27E-06	3.65E-06
23	338	Urban	3.53E-05	4.52E-06	2.63E-06
24	203	Urban	2.12E-05	2.71E-06	1.58E-06
Total	**12,782**	-	-	-	-

6.4 ICB Tunnel Portal

To account for tunnel portal emissions from the northbound traffic travelling through the ICB tunnel, the source has been modelled as follows:

- tunnel portal source type in GRAL;
- ambient exit temperature;
- variable exit velocity and calculated based on **Equation 1** presented below;
- emission rates estimated using COPERT considering, tunnel hourly traffic (traffic counts provided by TTM), a conservative ≥ +6% road gradient, 5.3% percentage of heavy vehicles, traffic situation and tunnel length of 380 metres.

The tunnel exit velocity has been calculated based on the traffic piston equation as presented in Okamoto's study (Okamoto, 1997).

The calculated emissions and exit velocities are presented in **Table 6.8**.

$$\left(1 + \zeta_e + \lambda\frac{L}{D}\right)U_0^2 = \frac{A_m n}{A_r}(V_t - U_0)^2, \quad \text{(Equation 1)}$$

where

ζ_e: tunnel entrance loss coefficient,
λ: tunnel wall friction loss coefficient,
L: tunnel length (m),
D: tunnel diameter (m),
A_r: tunnel cross sectional area (m^2),
V_t: traffic speed in tunnel ($m\ s^{-1}$),
U_0: velocity of jet stream at the portal ($m\ s^{-1}$),
n: number of vehicles in tunnel, and
A_m: equivalent resistance area of the vehicles (m^2).

Table 6.8: ICB Tunnel Portal Emission Rates using COPERT – Year 2038 Traffic

Hour of Day	Traffic (/hour)	Traffic Scenario	NO_x (g/s/m)	PM_{10} (g/s/m)	$PM_{2.5}$ (g/s/m)	Tunnel Exit Velocity (m/s)
1	311	Urban	1.93E-02	1.72E-03	9.97E-04	2.9
2	202	Urban	1.25E-02	1.12E-03	6.48E-04	2.4
3	210	Urban	1.31E-02	1.16E-03	6.74E-04	2.4
4	426	Urban	2.65E-02	2.35E-03	1.37E-03	3.3
5	1,522	Urban	9.46E-02	8.41E-03	4.88E-03	5.4
6	3,379	Urban	2.10E-01	1.87E-02	1.08E-02	7.0
7	4,625	Congested	4.66E-01	2.70E-02	1.64E-02	7.8
8	5,321	Congested	5.36E-01	3.11E-02	1.89E-02	8.1
9	4,975	Congested	5.01E-01	2.91E-02	1.77E-02	7.9
10	4,198	Urban	2.61E-01	2.32E-02	1.35E-02	7.5
11	3,901	Urban	2.42E-01	2.16E-02	1.25E-02	7.4
12	3,954	Urban	2.46E-01	2.18E-02	1.27E-02	7.4
13	4,050	Urban	2.52E-01	2.24E-02	1.30E-02	7.5
14	4,193	Urban	2.61E-01	2.32E-02	1.35E-02	7.5
15	4,735	Congested	4.77E-01	2.77E-02	1.68E-02	7.8
16	5,552	Congested	5.59E-01	3.25E-02	1.97E-02	8.2
17	5,762	Congested	5.81E-01	3.37E-02	2.05E-02	8.3
18	5,515	Congested	5.56E-01	3.22E-02	1.96E-02	8.2
19	4,045	Urban	2.51E-01	2.23E-02	1.30E-02	7.5
20	2,462	Urban	1.53E-01	1.36E-02	7.90E-03	6.4
21	2,117	Urban	1.32E-01	1.17E-02	6.79E-03	6.0
22	1,858	Urban	1.15E-01	1.03E-02	5.96E-03	5.8
23	1,266	Urban	7.86E-02	6.99E-03	4.06E-03	5.0
24	656	Urban	4.08E-02	3.63E-03	2.11E-03	3.9
Total	**75,236**	-	-	-	-	-

6.5 Concrete Batching Plant

Cumulative PM_{10} and $PM_{2.5}$ impacts from the concrete batching plant located approximately 300 metres from the subject site have been considered.

In order to estimate the emission rates, a review of available published literature relating to concrete recycling and batching activities has been completed. The following documents have been utilised to estimate emissions:

1. AP 42 (5th Edition), Compilation of Air Pollutant Emission Factors, Vol. 1 Stationary Point and Area Sources, Chapter 13.2.4, Aggregate Handling and Storage Piles, 2006.

2. Emission Estimation Technical Manual for Concrete Batching and Concrete Product Manufacturing, National Pollution Inventory, 1999.
3. AP 42 (5th Edition), Compilation of Air Pollutant Emission Factors, Vol. 1 Stationary Point and Area Sources, Chapter 11.12, Concrete Batching, 2006.
4. AP 42 (5th Edition), Compilation of Air Pollutant Emission Factors, Vol. 1 Stationary Point and Area Sources, Chapter 13.2.1, Paved Roads, 2011.

Table 6.9: Concrete Batching Plant Emission Factors

Activity	Units	PM_{10}	$PM_{2.5}$	Reference
Unloading aggregates to ground bins	kg/m^3	0.00184	0.00028	3 - Table 11.12-6
Cement unloading – pneumatic	kg/m^3	0.00006	0.00001	3 - Table 11.12-6
Sand and aggregate transfer to storage	kg/m^3	0.00184	0.00028	3 - Table 11.12-6
Transport along conveyor	kg/m^3	0.00184	0.00028	3 - Table 11.12-6
Weigh hopper loading	kg/m^3	0.00225	0.00034	3 - Table 11.12-6
Mixer loading (central mix)	kg/tonne	0.00280	0.00042	3 - Table 11.12-1
Wind erosion	kg/m^2/day	0.00039	0.00006	2 – Table 6
Paved roads	g/VKT	56.7	13.7	4 – Equation 1

To derive the emission rates using the above emission factors, the following assumptions have been made:

- a daily throughput of 600 tonnes per day based on previous experience with concrete batching plants of similar size;
- concrete density of 2.4 tonne/m^3;
- operation hours 05:00 am to 5:00 pm;
- truck capacity of 7 m^3/truck;
- 3 vehicles per hour (derived from assumed throughput, operating hours and truck capacity);
- road surface silt loading: 12 g/m^2 (Ref 4, Table 13.2.1-3, concrete batching plant);
- vehicle gross mass of 28 tonnes (typical size of haul truck);
- 12 hours of operation per day;
- controlled emissions for cement unloading and mixer loading;
- 95% reduction to emissions for water sprays and three-sided enclosures for the sand and aggregate transfers, transport along conveyor;
- 99% reduction to emissions around the weigh hopper loading and truck loading area (filter system);
- haul road (paved) length of 150 metres;
- stockpiles area of 200 m^2 (wind erosion).

A summary of the emission data for particulates is presented in **Table 6.10**.

Table 6.10: Concrete Batching Plant Emission Rates

Activity	Units	PM_{10}	$PM_{2.5}$
Unloading aggregates to ground bins	kg/h	0.038309	0.005746
Cement unloading – pneumatic	kg/h	0.001236	0.000185
Sand and aggregate transfer to storage	kg/h	0.000096	0.000014
Transport along conveyor	kg/h	0.000096	0.000014
Weigh hopper loading	kg/h	0.000005	0.000001
Mixer loading (central mix)	kg/h	0.140000	0.021000
Wind erosion	kg/h	0.0032500	0.0004875
Paved roads	kg/h	0.0253	0.0061
Combined emission rate	**kg/h**	**0.2082**	**0.0336**

6.6 Monitoring Stations

Since the main road emission sources near the subject site will be included in the air dispersion model, background air quality data has been used from a station not immediately exposed to traffic emissions. Department of Environment and Science and Innovation (DESI) operates air monitoring stations in Queensland. Historical reports of DESI data do not provide the 70th percentile, so it is necessary to analyse raw data from DESI to obtain that. Data has become freely available on the Queensland Government data website (<https://data.qld.gov.au>). Due to data limitations, the assessment considers information from 2017 to 2021. Data for 2023 was unavailable, and 2022 data has significant missing values (30%).

Background air monitoring data from the Rocklea station has been adopted for NO_2, PM_{10} and $PM_{2.5}$. Being collected at a monitoring station, this data has been used to account for background concentrations associated with regional sources and no major road traffic impacts. For the case of ozone, the year 2021 has been adopted (same year as the meteorological year, as detailed in **Section 7**).

Notably, 397 hours of nitrogen dioxide (NO_2) data and 393 hours of ozone data are missing for 2021. To ensure a complete dataset for the assessment, missing data was addressed using linear interpolation for single-hour gaps. For longer gaps, data from the Cannon Hill station was used to fill in the missing information.

For NO_2, the 70th percentile was not used to address cumulative impacts; instead, the hourly concentrations for 2021 were applied.

Table 6.11 presents the ambient air quality data used in the dispersion modelling.

Table 6.11: Ambient Pollutant Concentrations

Pollutant	Ambient Pollutant Concentration[a]	Averaging Period	Monitoring Station
NO_2	16.4[b]	70th percentile, 1-hour (2019)	Rocklea
	14.4	Max Annual (2018)	
PM_{10}	19.8	70th percentile, 24-hour (2019)	
	19.4	Max Annual	

Pollutant	Ambient Pollutant Concentration[a]	Averaging Period	Monitoring Station
		(2019)	
$PM_{2.5}$	8.7	70th percentile, 24-hour (2019)	
	6.6	Average 2017-2021	
Ozone	49.2[b]	70th percentile, 1-hour (2021)	

[a] The highest concentration across the 5 years of data (2017-2021) for the relevant statistical parameter has been adopted. For $PM_{2.5}$, the average across 5 years has also been adopted as per the BCC AQPSP.

[b] Hourly data has been adopted when applying the Ozone Limiting Method (OLM)

7. METEOROLOGICAL MODELLING

7.1 Overview

Atmospheric dispersion modelling involves the mathematical simulation of the dispersion of air contaminants in the environment. The modelling utilises a range of information to estimate the dispersion of pollutants released from a source, including:

- Meteorological data for surface and upper air winds, temperature and pressure profiles, as well as humidity, rainfall, cloud cover and ceiling height information;
- Emissions parameters, including source location and height, source dimensions and physical parameters (e.g. effective height and length of side) along with pollutant mass emission rates;
- Terrain elevations and land-use both at the source and throughout the surrounding region;
- The location, height, and width of any obstructions (such as buildings or other structures) that could significantly impact on the dispersion of the plume; and
- Sensitive receptor locations and heights.

For the purpose of the assessment, meteorological modelling has been undertaken using GRAMM to predict localised meteorological conditions. In addition to the topography and land use data, GRAMM requires hourly meteorological surface data for parameters such as wind speed, wind direction and stability class. Since stability classes are not readily available from any weather monitoring stations, they have been derived from CALMET using observational surface data and TAPM prognostic data. The meteorological data derived from these models have been used as an input for the GRAL dispersion modelling. The following sections present the details of the meteorological modelling. **Sections 8** and **9** present the inputs and results of the air dispersion modelling.

7.2 Model Year

The nearest available weather station, Brisbane BOM station, is approximately 3.8 kilometres south of the subject site.

Data for the years 2018 – 2022 were available for analysis, model year selection, and assimilation into the model run. **Table 8.1** summarises the relevant wind conditions from 2018 to 2022 at the Brisbane BOM weather station. **Figure 8.1** presents windroses for each year and the 2018 – 2022 average.

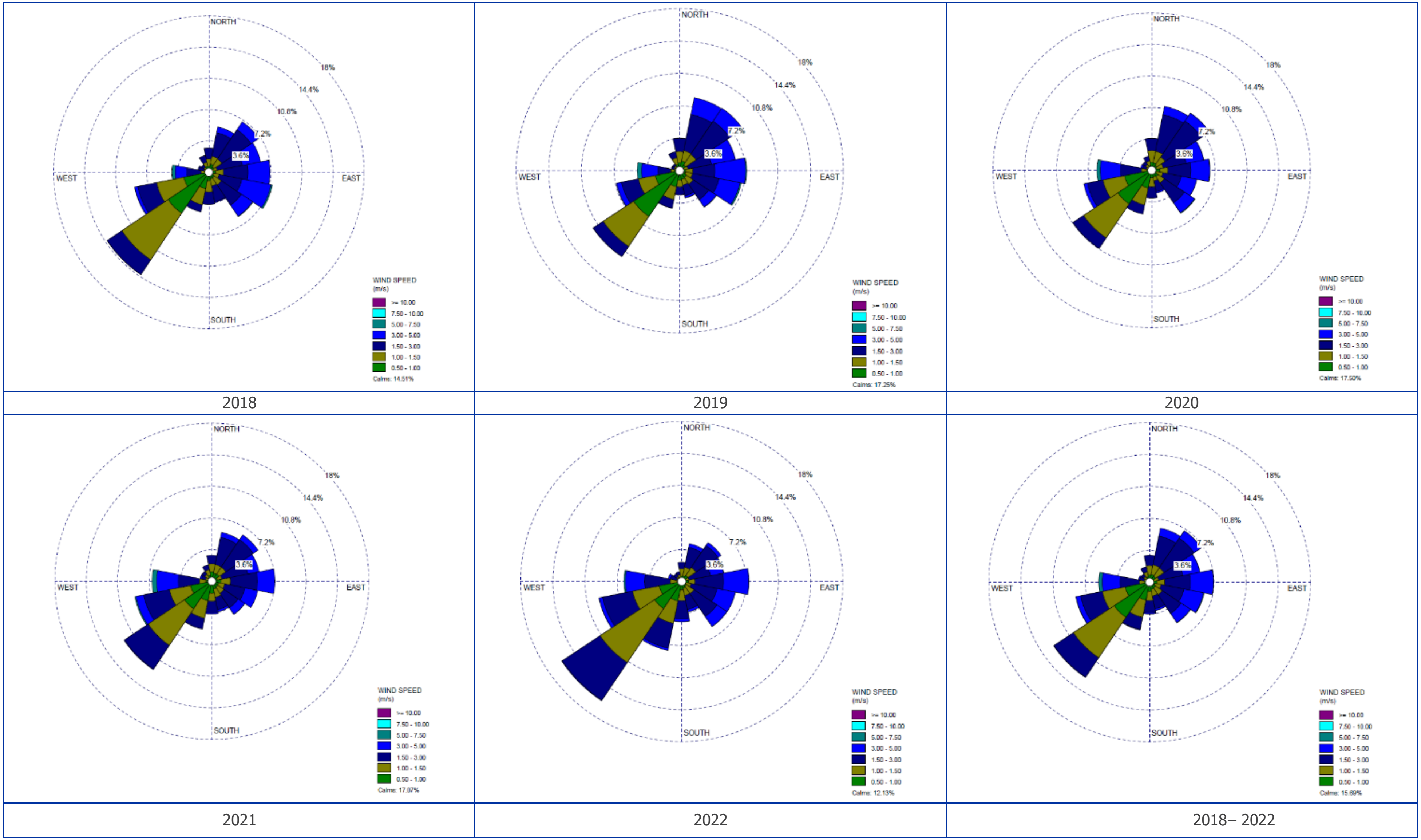
The average wind speed presents minimal variability at the BOM station (1.5 – 1.6 m/s). Low wind speed conditions ranged from 37.2% to 40.2% of the year, and calm conditions from 12.1% to 17.5%. The data shows that wind speed conditions for 2021 are conservative due to the lower average wind speed, above than average proportion of calms, representative of the long-term average frequency of light winds and lower than average proportion of high-speed winds.

In light of the above analysis, the year 2021 has been adopted for the purpose of the assessment.

Table 7.1: Summary of Wind Conditions at the Brisbane BOM Station (2018-2022)

Year	AVG WS (m/s)	Calms (%)	0.5 - 1.5 m/s (%)	1.5 – 3.0 m/s (%)	> 3.0 m/s (%)
2018	1.6	14.5	40.2	31.2	14.1
2019	1.6	17.3	37.2	28.9	16.7
2020	1.5	17.5	38.1	31.3	13.1
2021	**1.5**	**17.1**	**38.8**	**32.5**	**11.6**
2022	1.6	12.1	38.3	37.0	12.6
Average	**1.6**	**15.7**	**38.5**	**32.2**	**13.6**

Figure 7.1: Annual Windroses at the Brisbane BOM Station



7.3 GRAMM Setup

7.3.1 Overview

GRAMM has been modelled for the year 2021 to predict site-specific meteorological conditions. GRAMM is a prognostic non-hydrostatic mesoscale model which predicts flow fields. The GRAMM modelling system interprets land use and terrain data to predict 3D flow fields.

It is noted that there are different approaches to deriving meteorology using GRAMM. One approach is to use a synthetic meteorological file covering a range of meteorological conditions. GRAMM is run in the first instance to fit these conditions to the modelled terrain. Then the match-to-observations function is utilised with local observational data to match the modelled conditions to the measured data. Meteorological data from the South Brisbane station operated by the DESI has been subsequently incorporated into the GRAMM modelling. More specifically, after initialising GRAMM with an all situations meteorological file, the wind fields were then matched to the observed data from the South Brisbane DESI station. Hourly stability classes were calculated based on measured data using the Sigma Theta method. This method is one of the accepted methods included in the BCC City Plan 2014 Air Quality Planning Scheme Policy.

The South Brisbane DESI dataset exhibits 99% completeness. The periods of 1 hour of missing data were addressed using linear interpolation, while for the remaining periods, Brisbane CBD DESI data was used as a substitute. Brisbane CBD station is 900 meters north of South Brisbane and shows comparable wind patterns, while exhibiting a higher frequency of lower wind speeds. This adds to the overall conservatism adopted in the assessment. A total of 8 periods of missing data have been replaced with Brisbane CBD data, with duration spanning from 2 to 55 consecutive missing hours.

Finally, the GRAMM predictions were validated against measured data from the Brisbane BOM station. Initially, the match-to-observations function was used with the Brisbane BOM dataset, but the attempts to validate the predictions at the South Brisbane DESI station were unsatisfactory. This led to a change in methodology compared to the previous version of the methodology document (Trinity Report 247401.0068.R01V01, 19 July 2024) and the adoption of the South Brisbane DESI dataset in the GRAMM modelling (details presented in the updated methodology report 247401.0068.R02V01, 4 September 2024).

Several weighting factors were considered when incorporating the measured data through the match-to-observations function. A higher weighting factor lowers the influence of the stability class and increases the weighting of the wind speed and direction. Therefore, a high weight resulted in wind speeds and direction being very similar to the measured data. However, the stability class was poorly reflected in the initial predicted data with noticeably lower stable conditions (F and G) and higher unstable conditions. A weighting factor of 0.7 was considered based on an iterative process to ensure that predicted wind conditions and stability classes were reasonably accurate.

Table 7.2 presents the GRAMM input parameters adopted in the modelling.

Table 7.2: Adopted GRAMM Parameters

GRAMM Parameter	Adopted Value
GRAMM Domain (SW Corner)	500500 m, 6959800 m
GRAMM Domain (NE Corner)	506400 m, 6965600 m
Horizontal grid resolution	100 m
Vertical thickness of first layer	10 m
Number of vertical layers	15
Vertical stretching factor	1.10 m
Height of top layer	328 m

GRAMM Parameter	Adopted Value
Max time step	5 sec
Modelling time	3600 sec
Relaxation velocity	0.10
Relaxation scalars	0.10
Match-to-observations factors	Weighting factor = 0.7 Direction factor = 6

7.3.2 Terrain and Land Use Data

Terrain data for the area surrounding the development site was obtained from the LiDAR Derived 5-metre Digital Elevation Model (DEM), which represents a national 5-metre (bare earth) DEM derived from some 236 individual LiDAR surveys between 2001 and 2015. Data for a 6 kilometre x 6.7 kilometre area surrounding the site has been extracted in an ASCII raster format for use in the modelling.

Land use data was also created based on the 2019 Queensland Government Queensland Land Use Mapping Program dataset (QLUMP). The land use data within a 500-metre radius of the site has been reviewed and updated to reflect the current land cover more accurately. Land use data for a 6 kilometre x 6.7 kilometre area surrounding the site was converted from a vector shapefile to an ASCII raster file using the CORINE land use categories for inclusion in the modelling.

Figure 7.2 and **Figure 7.3** present the modelled terrain and land use included in the GRAMM modelling.

Figure 7.2: Modelled Terrain

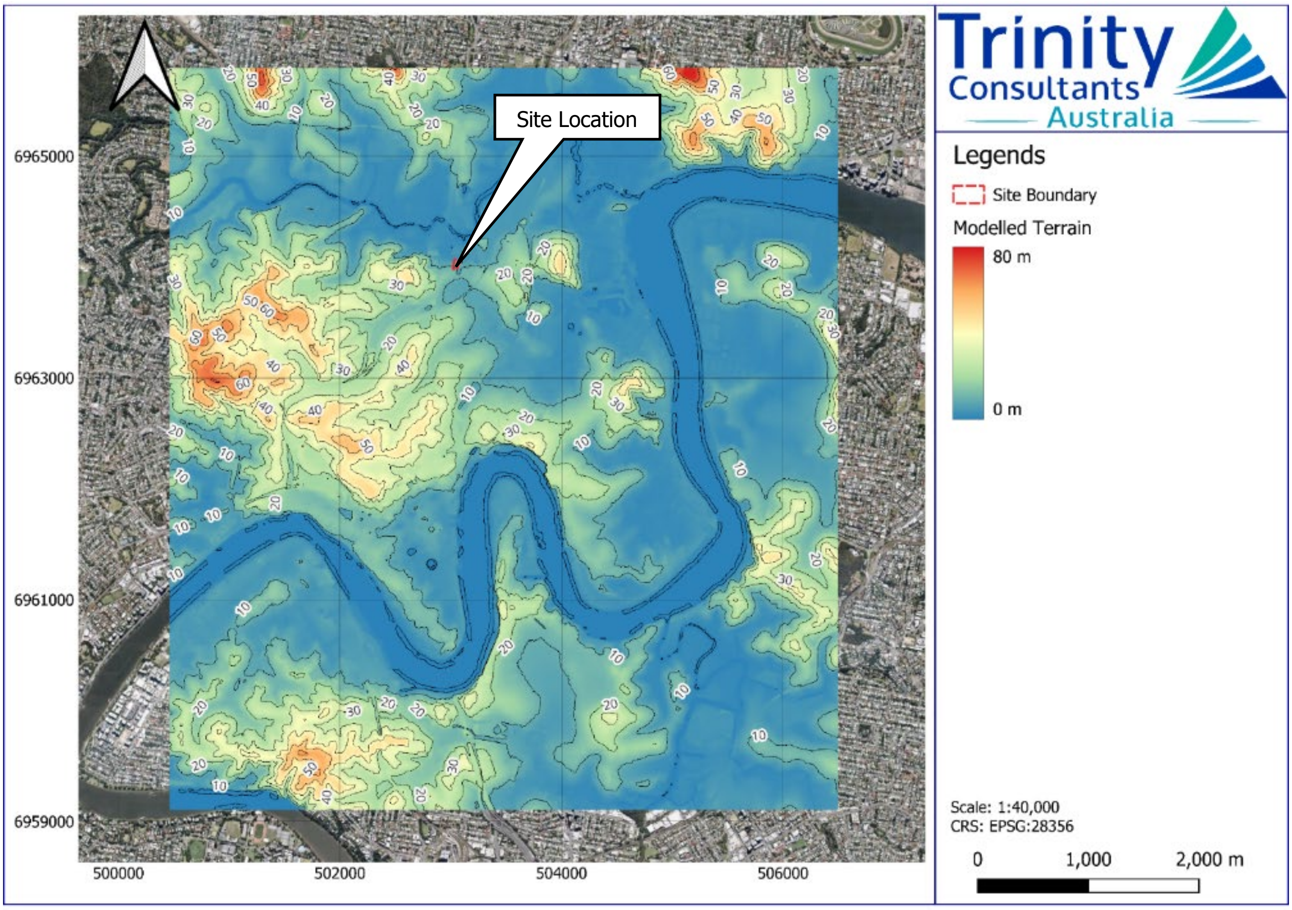
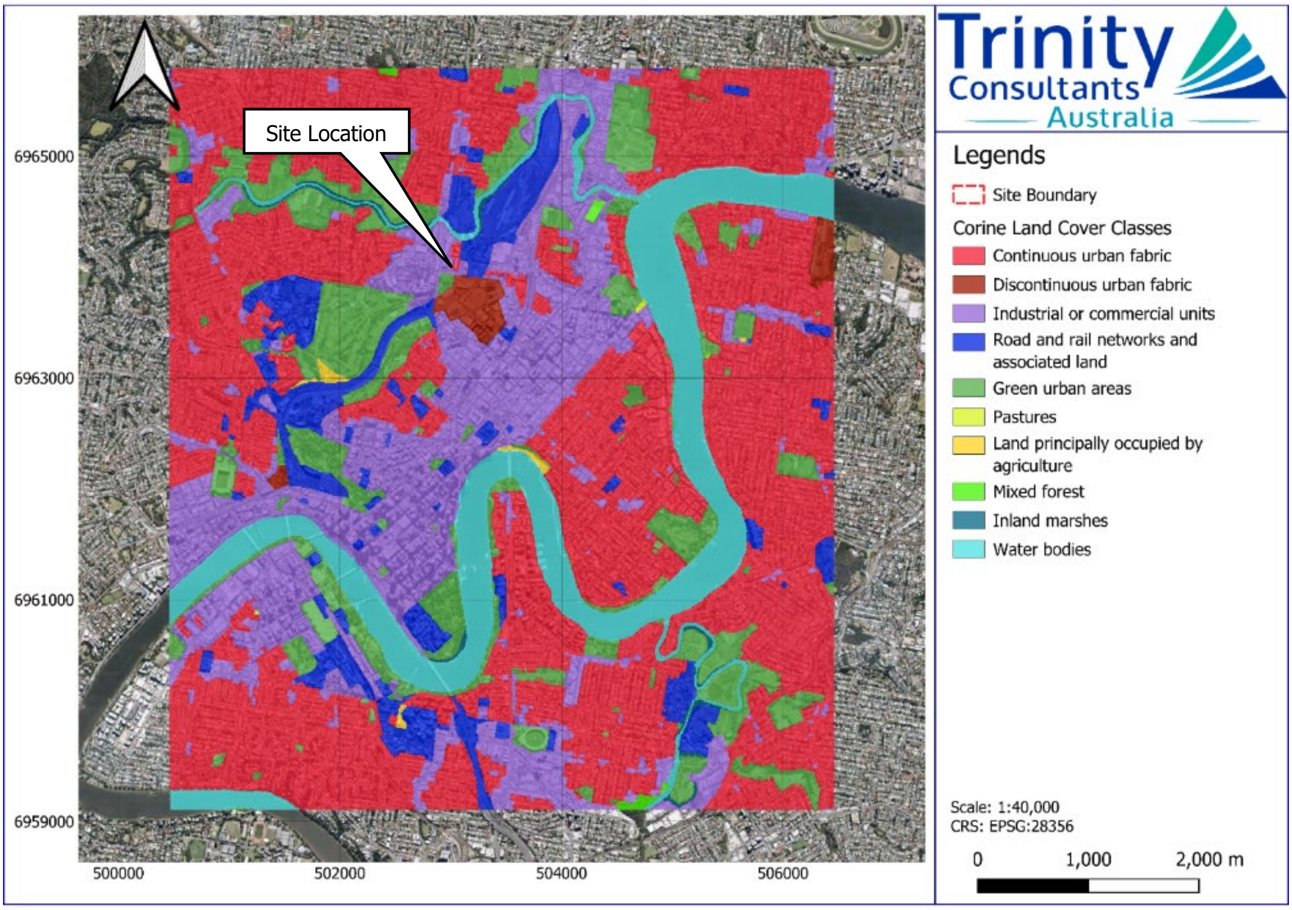


Figure 7.3: Modelled Land Use



7.3.3 Observational Data

Meteorological data from the Department of Environment, Science and Innovation (DESI) South Brisbane station, located approximately 4 kilometres south of the site, was included in the GRAMM run.

7.4 Meteorological Predictions

7.4.1 Wind Predictions

The observed and GRAMM predicted 2021 South Brisbane DESI station, Brisbane BOM station, and subject site location wind conditions are presented in **Figure 7.4**. The predicted wind rose at the DESI station is comparable to the observational data, with respect to south-westerly wind components (191 – 259 degrees clockwise) occurring around 35 - 38% of the time, northeasterly around 12 - 20% of the time, southeasterly around 17 - 18%, and minimal occurrence of north-westerly winds.

The proportion of calms and lower wind speed conditions are overpredicted. Calms were measured 6.1% of the time versus 7.3% predicted, and low wind speed conditions (wind speeds 0.5 - 1.5 m/s) were measured at approximately 42% versus 51% predicted.

Regarding the validation at the Brisbane BOM station, GRAMM is able to capture the prevailing wind component from the southwest although it overestimates the occurrence of these winds. It also captures the occurrence of northeasterly winds (18% measured vs 16% predicted) and southeasterly winds (13% measured vs 12% predicted). Regarding calms, GRAMM underpredicts the number of calm hours during the year (17.1% measured vs 12.5% predicted), although the Brisbane BOM station does capture a higher proportion of calms compared to the South Brisbane station. Finally, low wind speed conditions were significantly overpredicted (measured at approximately 31% measured versus 62% predicted).

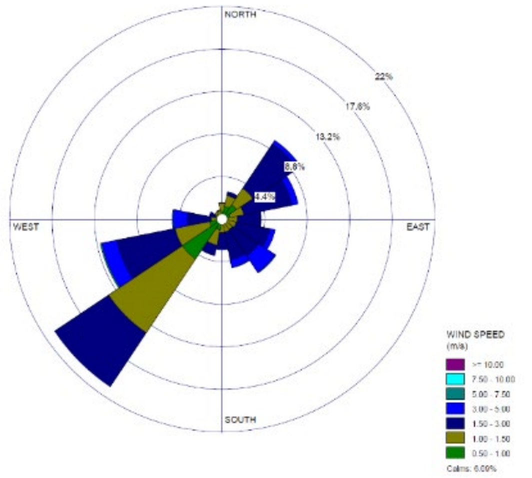
Regarding the subject site predictions, the fraction of wind speeds lower than 1.5 m/s is 62%, and the proportion of calms predicted on-site is 8.9%. These values are higher (and potentially conservative) when compared to those measured at the DESI and BOM stations which restrict dispersion and lead to higher pollutant concentrations.

Another conservative element noted is the predicted higher occurrence of east-southeasterly winds, i.e. a higher occurrence of source-to-receiver downwind conditions at the site compared to the measured DESI data.

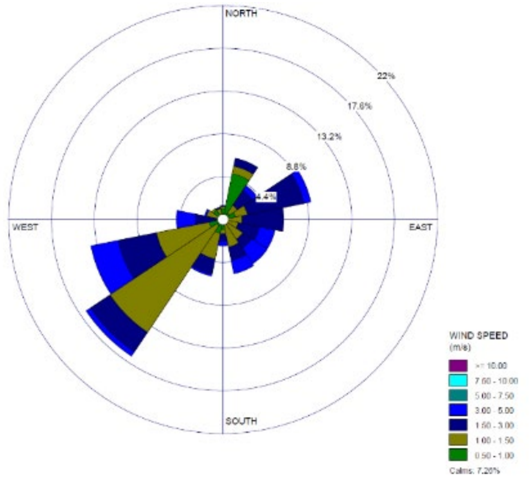
In terms of wind direction, some differences are expected at the subject site due to its location, approximately 4 kilometres from the DESI station. Nevertheless, there are some similarities, such as a dominant south-westerly component and a similar occurrence of southeasterly winds (17% measured at DESI vs 20% predicted on-site), which are critical for this assessment. The main differences include a lower occurrence of northeasterly and easterly winds on-site and a shift of some of the south-westerly winds to westerly.

The results are consistent with observations and considered to lean towards the conservative side. Multiple iterations of the meteorological modelling have been undertaken, with respect to changing the weighting factors and using different observation stations. The final selected parameters and input data has provided the most representative data for use in the assessment.

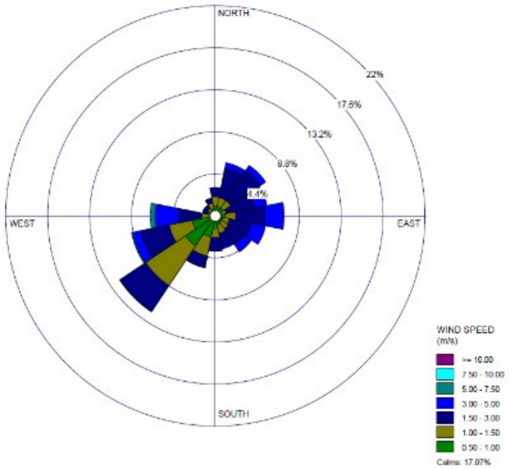
Figure 7.4: GRAMM Predicted Wind Roses (2021)



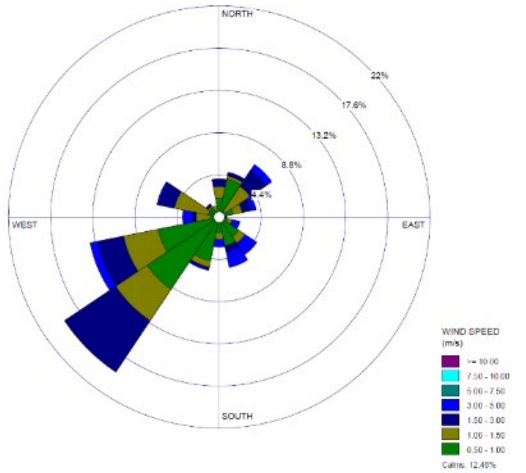
DESI South Brisbane observations



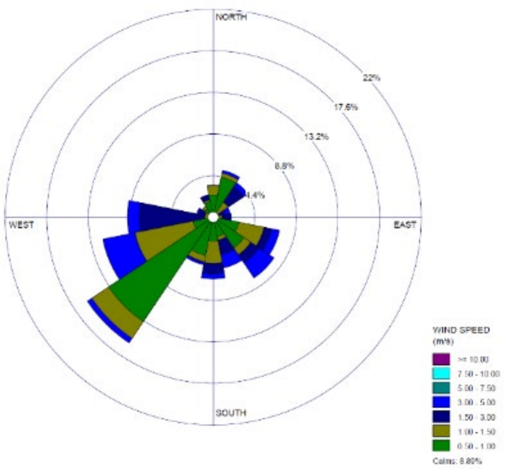
DESI South Brisbane GRAMM predicted



BOM Brisbane GRAMM observations



BOM Brisbane GRAMM predicted



Site GRAMM predicted

7.4.2 Predicted Atmospheric Stability

The amount of turbulence in the ambient air has a major effect upon the rise and dispersion of emissions. The amount of turbulence in the atmosphere is often described using series of seven Pasquill stability classes A, B, C, D, E, F and G. Of these, Class A denotes the most unstable or most turbulent conditions and Class G denotes the most stable or least turbulent conditions. The larger proportion of stable conditions is likely to result in poorer dispersion conditions and higher pollutant concentrations in the air dispersion modelling.

Measured data from the South Brisbane DESI station has been used to calculate hourly stability classes using the Sigma Theta method. This method is an accepted method in the BCC City Plan 2014 Air Quality Planning Scheme Policy. The calculated stability classes are shown in **Figure 7.5.**

Predicted stability classes at the South Brisbane DESI station and the subject site are presented in **Figure 7.6** and **Figure 7.7**.

While the measured data shows a higher proportion of stable when considering slightly stable, stable, and very stable conditions combined, the predicted GRAMM dataset shows a higher proportion of very stable conditions of 33% and 8.5% stable. In contrast, the measured dataset shows no very stable conditions during the year, with mostly stable conditions and a small fraction of slightly stable conditions. Regarding unstable conditions, both datasets show a proportion of unstable conditions occurring approximately 49% of the time. However, the GRAMM site predictions are more conservative due to the lower proportion of very unstable conditions compared to the measured data.

At the subject site, the predicted stability classes are comparable to those predicted at the DESI station, with the difference presenting a higher proportion of slightly unstable conditions and a higher proportion of very unstable while still being lower than the measured data.

Based on this, the stability classes predicted at the DESI station and subject site are considered conservative. Additionally, the stability class conditions are representative of a typical urban area and are considered suitable for modelling. As noted previously, multiple iterations of the meteorological modelling have been undertaken, with respect to changing the weighting factors and using different observation stations. The final selected parameters and input data has provided the most representative data for use in the assessment.

Figure 7.5: Summary of Calculated Stability Classes at the DESI South Brisbane Station (based on Measured Data)

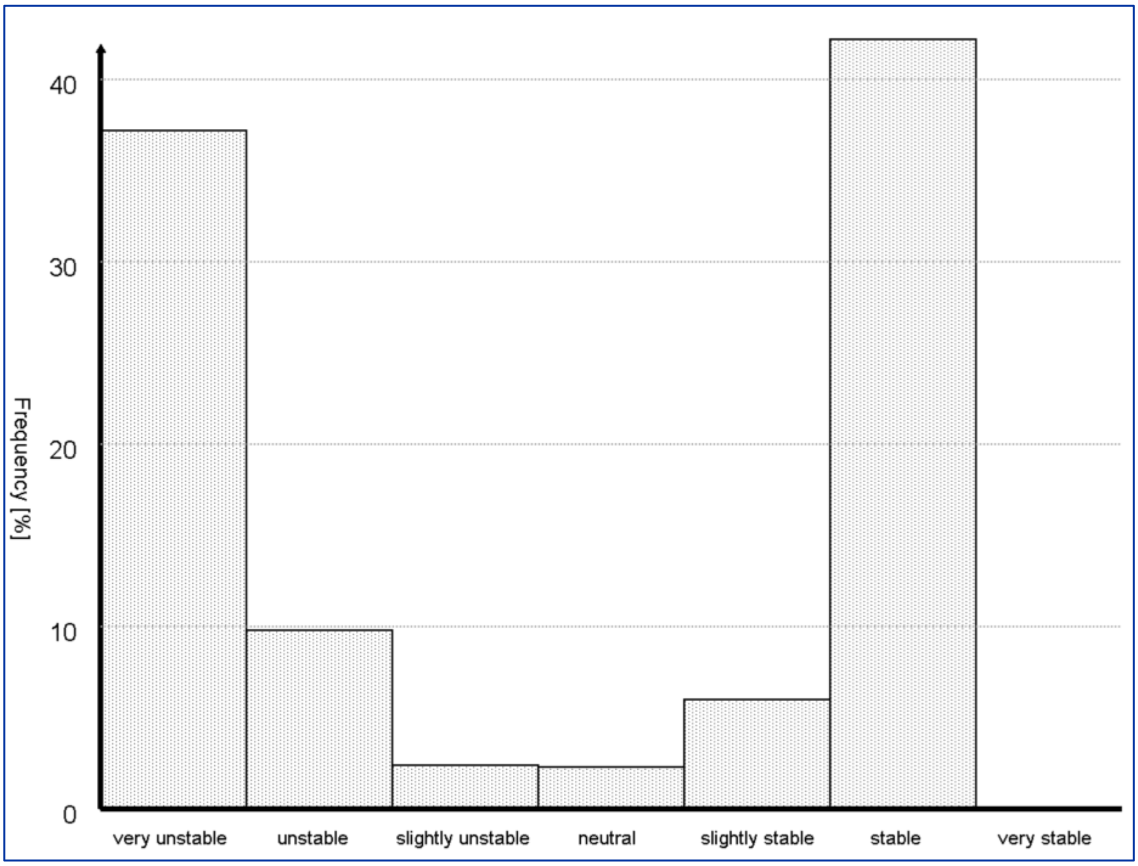


Figure 7.6: Summary of GRAMM Predicted Stability Classes at the DESI South Brisbane Station

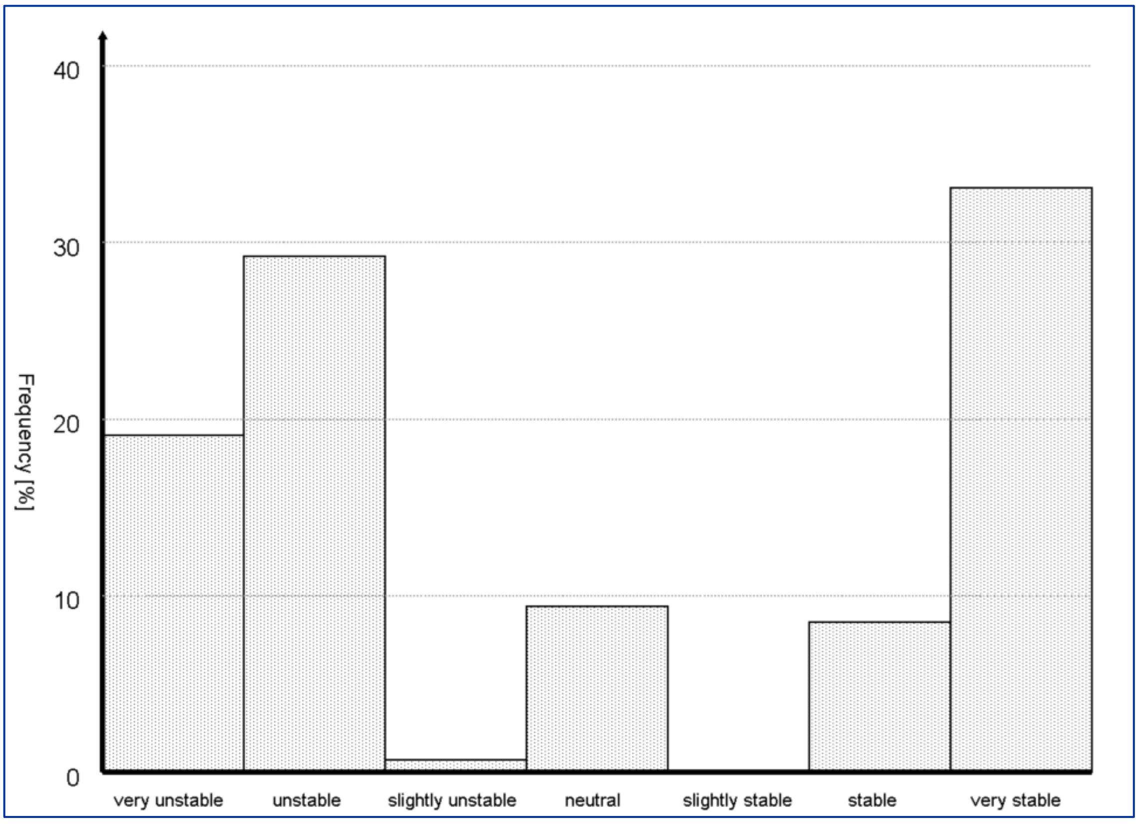
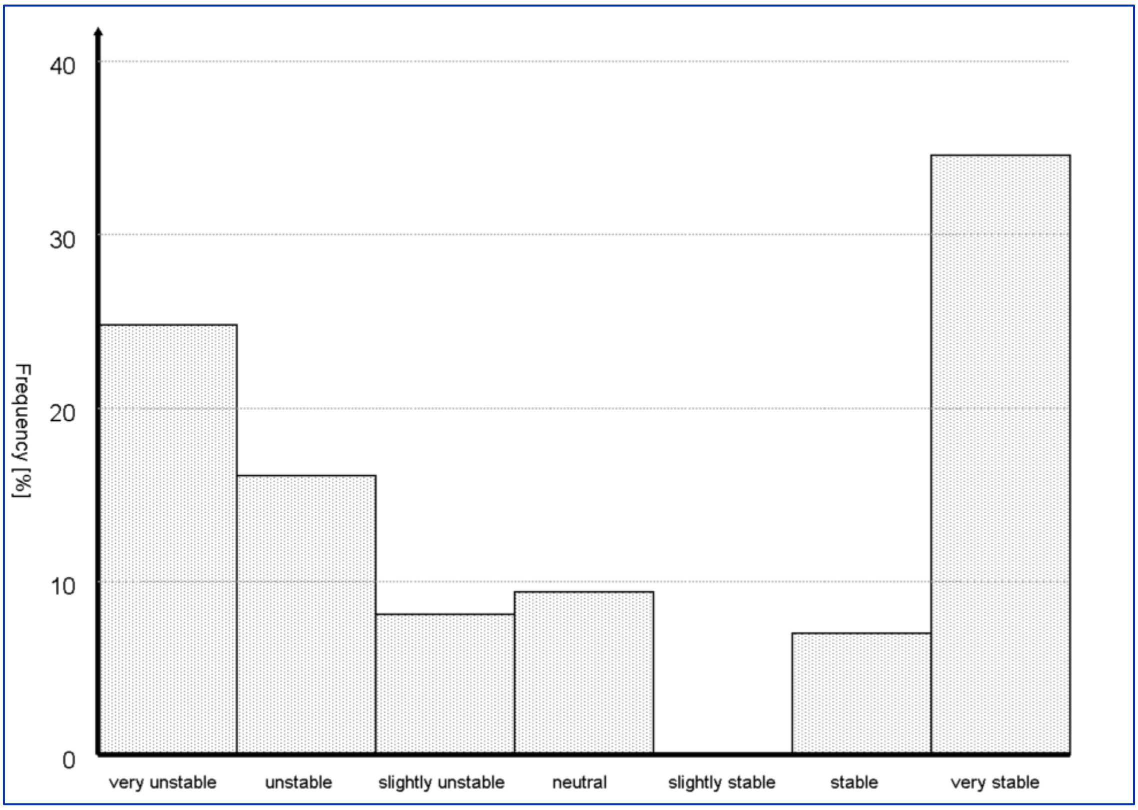


Figure 7.7: Summary of Predicted Stability Classes at Subject Site



8. AIR DISPERSION MODELLING

8.1 GRAL

GRAL was run in transient and prognostic mode to allow for the modelling of a full year of meteorology and to consider the on-site and off-site buildings structures affecting air flow and pollutant dispersion across the site. In order to reduce run times, GRAL was run without discrete receptors to compute the gridded concentrations for each modelled height above ground. Finally, the concentration time series for each discrete receptor was extracted using the GRAL GUI post-processing tool.

Compliance with the air quality criteria will be assessed for both the on-site and off-site receptors. Moreover, a scenario without the proposed building has been modelled to compare with the predicted results of the with-Project scenario and assess the predicted incremental changes in air quality for the area considering varying levels at existing buildings, as well as future potential sensitive receptor areas.

Table 8.1 summarises the GRAL parameters.

Table 8.1: Adopted GRAL Parameters

GRAL Parameter	Adopted Value
General	
Dispersion time	3600 seconds
Particles per second	500
Surface roughness	Local land use file included
Latitude	-27.45 degrees
Buildings	Prognostic GRAL
Topography	Original GRAL topography option adopted to allow modelling of buildings with absolute heights for the subject site. The rest of the buildings were modelled with relative heights.
Concentration Grid	
Horizontal grid resolution	4.0 metres [4]
Vertical dimension of concentration layers	1.0 metres
Number of horizontal slices	32 (Divided into 4 separate runs) GRAL only allows up to 9 horizontal slices per run. All levels have been modelled.
Internal Flow Field Grid	
Horizontal grid resolution	2.0 metres [2]
Vertical thickness of first layer	2.0 metres
Vertical stretching factor	Flexible: 1.00 (height < 20 metres) 1.02 (20 < height < 50 metres) 1.05 (50 < height < 150 metres) 1.10 (150 < height < 250 metres) 1.20 (height > 250 metres)

[4] In the air quality modelling for Application A006150645, a grid resolution of 2 metres was used for both the concentration and internal flow field grids. However, based on our experience and the recommendations provided in the GRAL Graphical User Interface 24.04 (Öttl, 2024), for high stack emissions influenced by large buildings or obstacles, the flow field grid should be finer, while the concentration grid should be coarser to reduce statistical errors.

GRAL Parameter	Adopted Value
Number of prognostic cells in z-direction	40
Minimum iterations	100
Maximum iterations	500

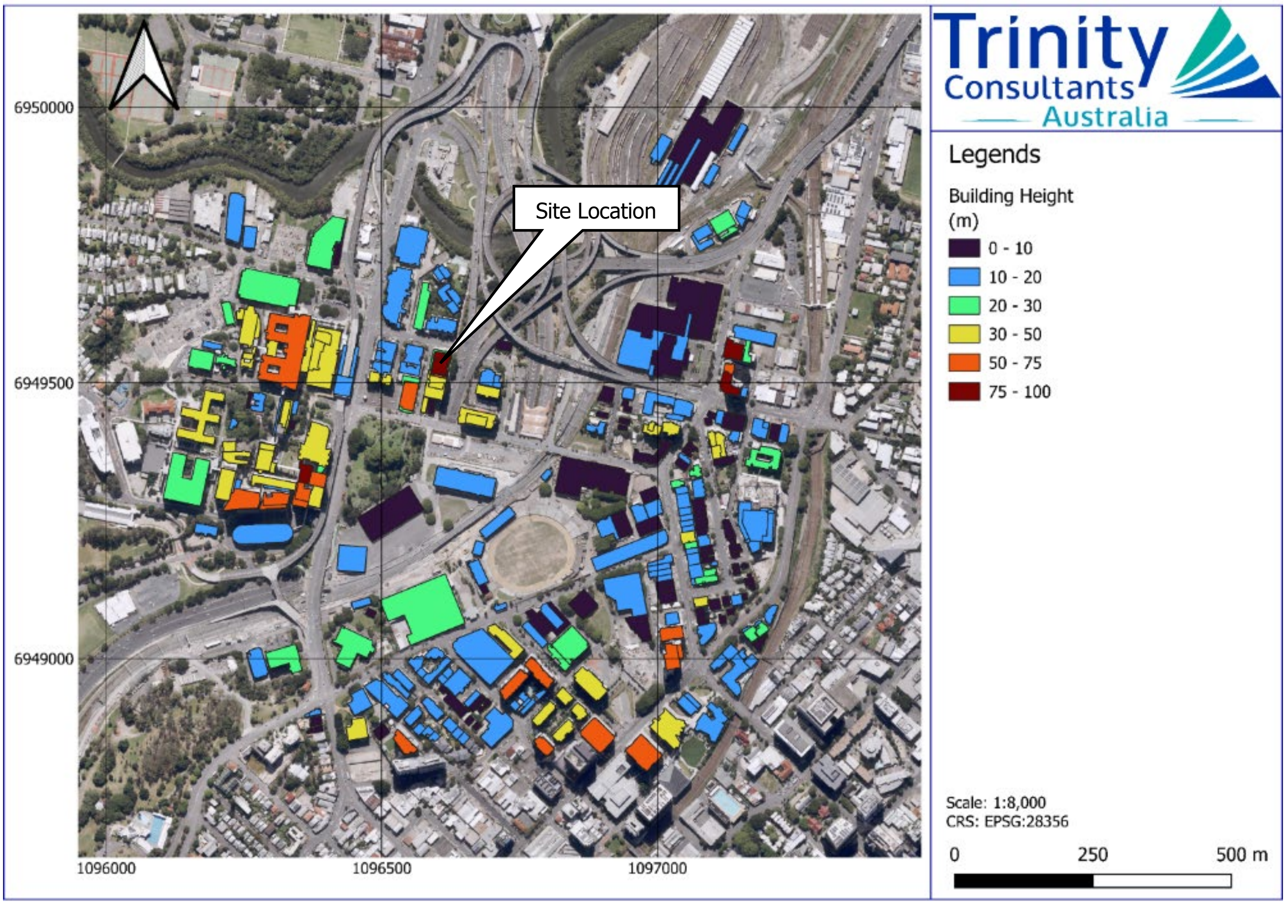
Building footprint and height data have been sourced from Geoscape[5].

A review of DA applications in the area has been conducted, and the following approved developments have been included in the model:

- 65 & 67 O'Connell Terrace (development permit for material change of use for food and drink outlet, health care service, hospital, office and shop)
- 63 O'Connell Terrace (development permit for material change of use for visitor accommodation, food premises and office)

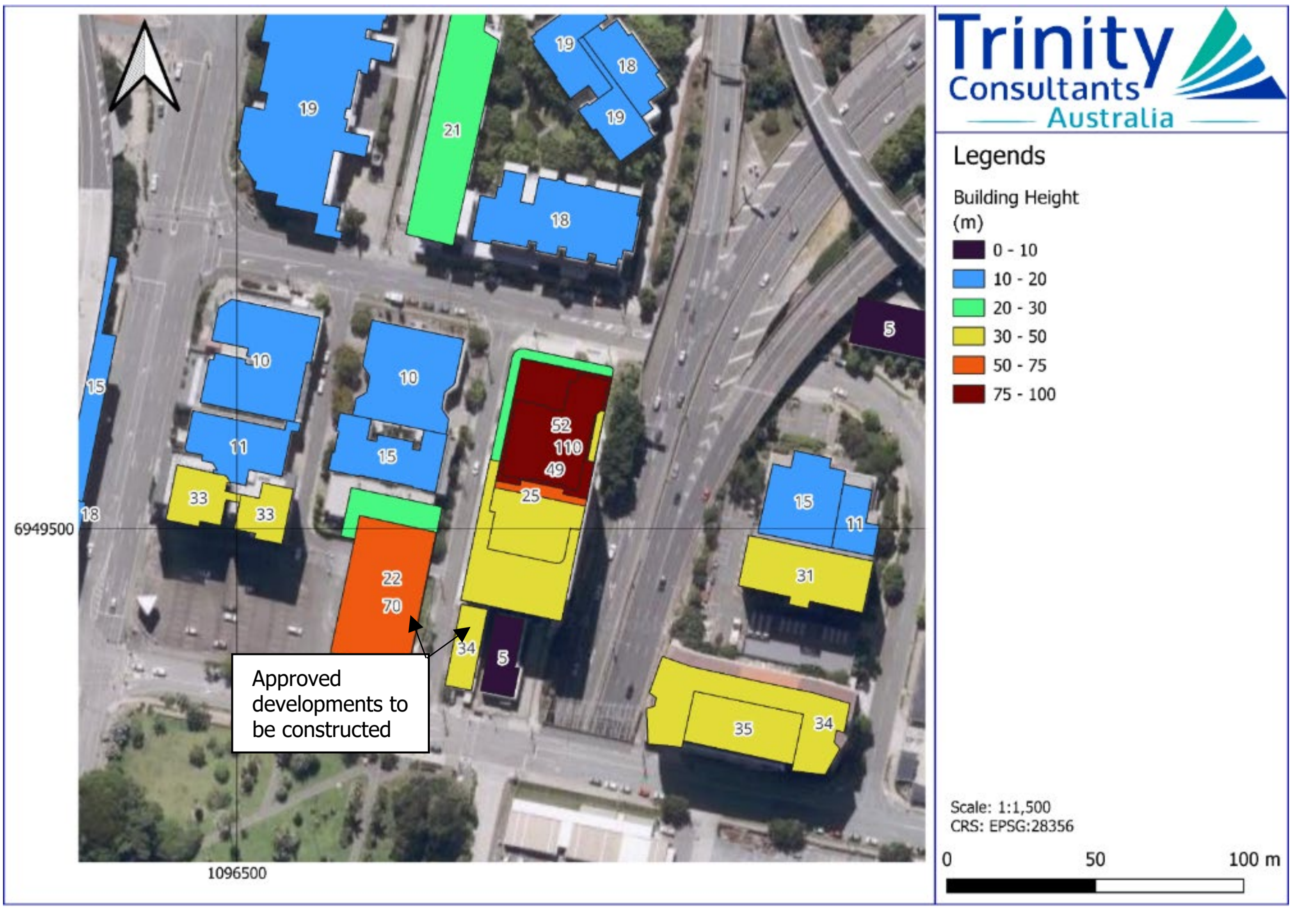
Figure 8.1 and **Figure 8.2** present the modelled building locations and heights considered in the prognostic mode.

Figure 8.1: Overview of Modelled Buildings



[5] https://geoscape.com.au/

Figure 8.2: Modelled Buildings - Subject Site and Approved DA Applications



8.1.1 Source Parameters

The following sections describe the model inputs for all the assessed point, line, tunnel portal and area sources. A summary of the sources is presented in **Figure 8.3** to **Figure 8.5**.

Figure 8.3: Modelled Point and Tunnel Portal Sources

Figure 8.4: Overview of Modelled Road Sources

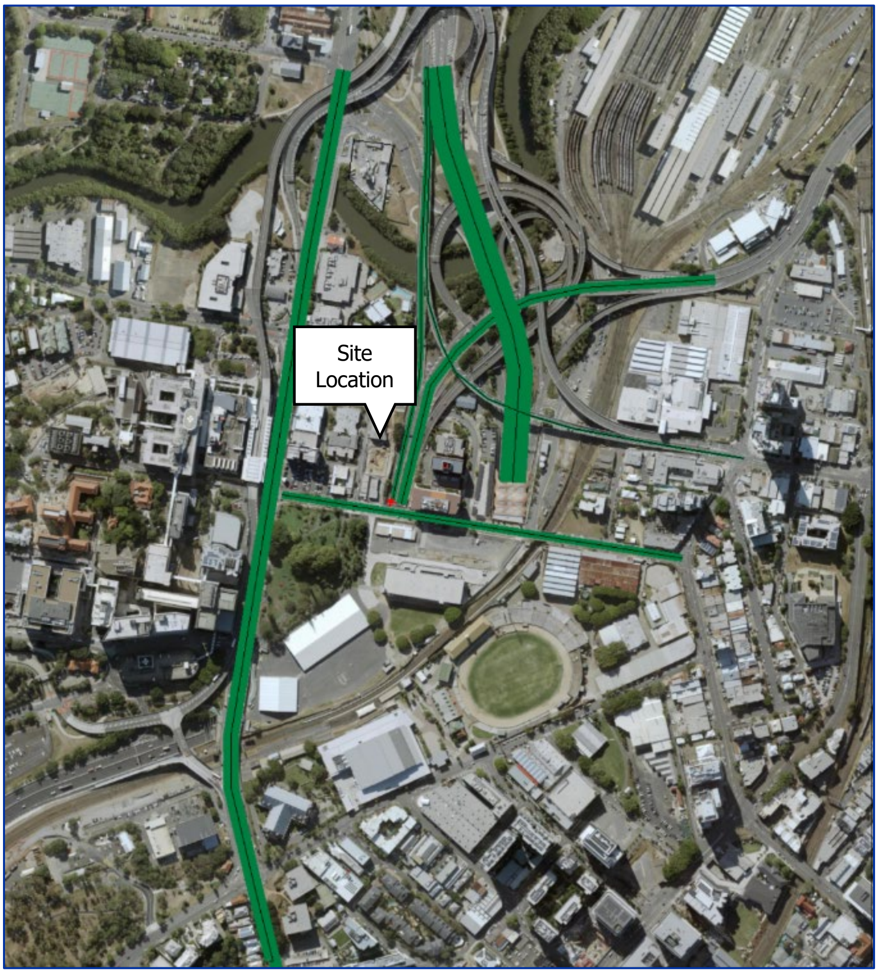


Figure 8.5: Modelled Area Source

8.1.1.1 Clem7 Vent

The Clem7 vent has been modelled as a point source. **Table 8.2** presents the source parameters for the Clem7 northern ventilation outlet.

Table 8.2: Clem7 Modelled Source Parameters – Point Source

Source	Centre Co-ordinates (UTM Zone 56)	Stack Height (m)	Diameter (m)	Exit Velocity (m/s)	Exit Temperature (K)
Clem7 vent	503134.2 6963994.3	35	7.9[a]	As per **Table 5.5**	Ambient

[a] Estimated using Google Earth based on estimated vent dimensions of 6.5 x 7.5 metres.

8.1.1.2 Road Sources

Table 8.3 presents the source parameters for the modelled road sources.

Table 8.3: Modelled Source Parameters – Line Sources

Source	Type	Height (m)	Vert. Ext [6] (m)	Width (m)	Length (m)
ICB Left Exit Ramp (A)	Line	Variable 3D Line to account for bridge geometry	1.4	7.0	85
ICB Left Exit Ramp (B)		Variable 3D Line to account for bridge geometry	1.4	7.0	511
ICB Combined Northbound/Southbound		Variable 3D Line to account for bridge geometry	1.4	14.0	603
Clem7 Combined		0.8	1.3	36.0	583
Airport Link Ramp		Variable 3D Line to account for bridge geometry	1.3	3.5	842
Bowen Bridge Road		0.8	1.3	21.0	1,239
O'Connell Terrace		0.8	1.3	10.5	553

8.1.1.3 Tunnel Portal

Table 8.4 presents the source parameters for the modelled tunnel portal source.

[6] Calculated based Haul Road Workgroup Final Report (USEPA, 2012), which determines the Sigma Z based on a weighted average of the vehicle height (mix of cars and HV).

Table 8.4: Modelled Source Parameters – Tunnel Portal Source

Source	Type	Height (m)	Base Height (m)	Exit Velocity (m)	Exit Temperature (K)	Width (m)
ICB Tunnel Portal	Tunnel portal	4.6	0	Hourly exit velocity as per **Table 6.8**	Ambient	14

8.1.1.4 Area Source

Table 8.5 presents the source parameters for the modelled area source. It is assumed all emissions from the batching plant are emitted from a single area source to minimise run times (otherwise, the batching plant would require up to 8 sources, which would significantly increase model run and post-processing times). Furthermore, as the batching plan at a large distance from the site, source detail is not considered critical to the modelling outcome.

Table 8.5: Modelled Source Parameters – Area Source

Source	Type	Mean Height (m)	Vert. Ext (m)	Area (m^2)
Concrete Batching Plant	Area	1.0	1.0	3,872

8.1.2 Discrete Receptors

Pollutant concentrations for discrete receptor were extracted using the 'Generate time series for several evaluation points' tool in the GRAL GUI. This approach interpolates concentrations for the selected receptor locations for each horizontal slice modelled. The approach also allows for faster run times (compared to modelling individual discrete receptors within GRAL).

Discrete receptor locations have been selected to present the nearest off-site existing sensitive receptors and various levels of the proposed development. **Figure 8.6** presents the locations of the adopted off-site sensitive receptors. Receptors have also been selected for the proposed façades of the approved developments nearby.

Figure 8.6: Modelled Off-site Receptors

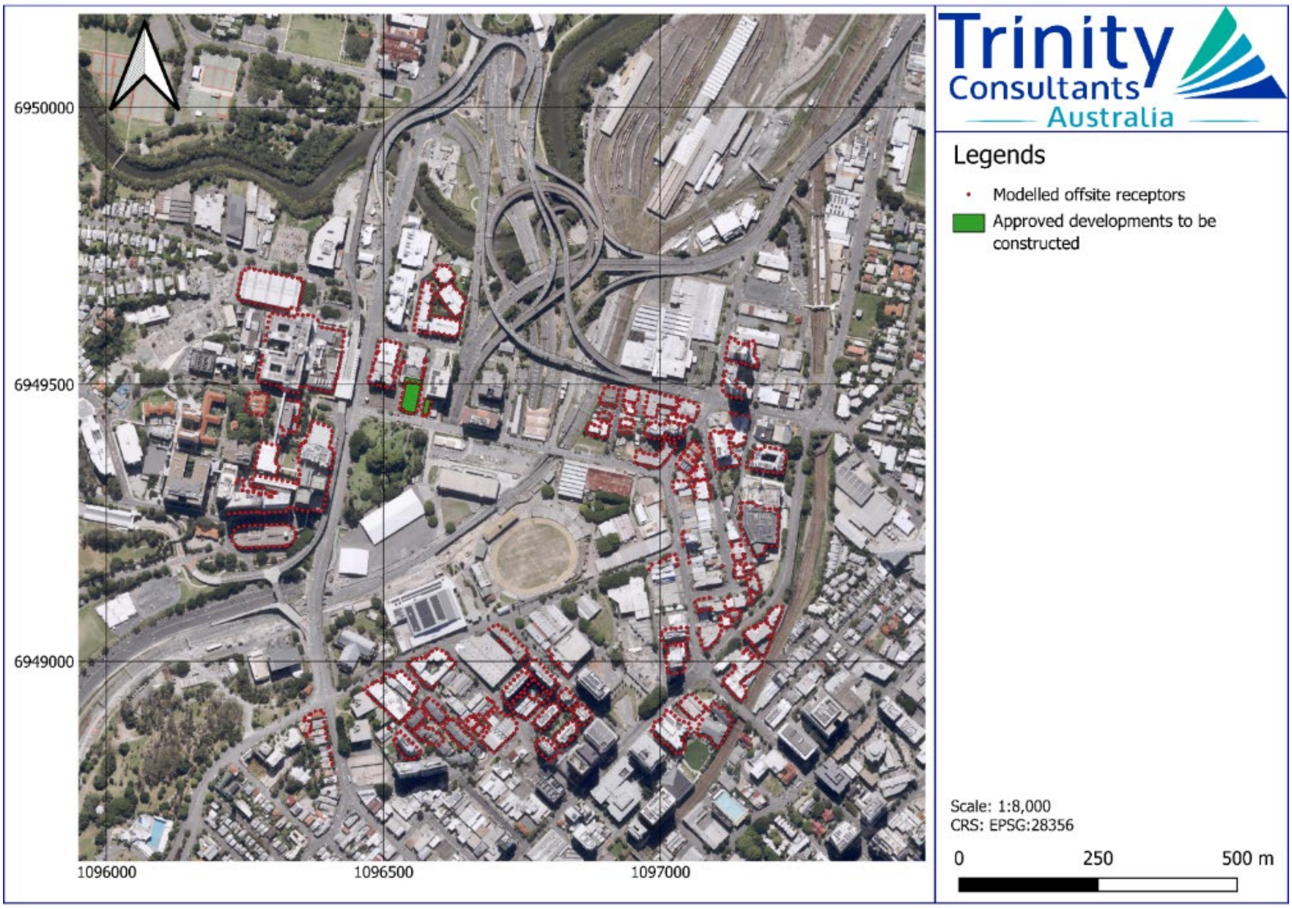


Figure 8.7 provides examples of how receptors were modelled across floor levels of the proposed development (not every level is shown).

Figure 8.7: Modelled Receptors Locations On-site

8.2 NO_X – NO_2 Conversion

For conversion of NO_x to NO_2, the US EPA Ozone Limiting Method (OLM) has been adopted. This method assumes all ozone in the atmosphere reacts with NO_x to form NO_2 (regardless of distance and atmospheric conditions).

Hourly NO_2 predictions has been converted to NO_2 concentrations using the OLM method based on hourly ambient ozone concentrations at the Rocklea station for 2021.

A 0.22 initial NO_2/NO_x ratio was assumed for the calculations based on the typical initial ratio for roads using the COPERT Australia vehicle emission model.

8.3 Modelling Conservatism

It is acknowledged that there are a number of conservative aspects in the modelling methodology. These are summarised in the following table followed by further comments.

Table 8.6: Modelling Conservatism

Modelling Input	Conservative Aspect
Meteorology	The proportion of low wind speed conditions at the subject site is higher than those measured at the South Brisbane DESI and Brisbane BOM stations. Additionally, source-to-receiver wind conditions are slightly higher at the subject site. See **Section 7.4** for discussion.
Surface road emission factors	Use of COPERT (year 2025) is expected to result in high emission rates for NO_x when modelling the 2038 traffic scenario (when newer emission technologies and EV vehicles will reduce NO_x emissions). This approach has been adopted as previously required by BCC for Application A006150645 and specified in Section 3.5.2 of the AQPSP.
Road gradients	Simplifications in road gradients have been adopted to reduce the number of line sources in GRAL (as discussed in **Section 6.3**).
NO_x-NO_2 conversion	The OLM method has been adopted following the methodology adopted for Application A006150645. The approach is considered conservative since it assumes all the ozone will react with NO_x to produce NO_2.

9. DISPERSION MODELLING RESULTS

9.1 On-site Receptors

Table 9.1 presents the maximum predicted pollutant concentrations for each level of the proposed development.

The modelling results demonstrate compliance with air quality criteria for NO_2, PM_{10}, and $PM_{2.5}$ at all on-site receptor locations across all averaging periods. The worst-case short-term pollutant is NO_2, 1-hour 99.9th percentile, and the highest predicted cumulative concentration is 228.2 µg/m^3 at level 22, corresponding to 91% of the criterion. For the case of long-term pollutants, $PM_{2.5}$ annual average is the worst-case pollutant, with the highest predicted concentration being at level 11 (7.7 µg/m^3, 96% of the criterion).

Consequently, the development complies with the requirements outlined in performance outcome PO4(a) of the Transport Air Quality Corridor Overlay code and PO2 of the Industrial Amenity Overlay code.

The concentration plots for NO_2, 1-hour 99.9th percentile at level 22 and $PM_{2.5}$ annual average at level 11 are shown in **Figure 9.1** and **Figure 9.2**.

Table 9.1: Predicted Results - On-site Receptors

Level	NO_2 (µg/m^3)		PM_{10} (µg/m^3)		$PM_{2.5}$ (µg/m^3)	
Averaging Time	**1-hr, 99th percentile**	**Annual Avg.**	**Max. 24-hr**	**Annual Avg.**	**Max. 24-hr**	**Annual Avg.**
Maximum	**228.2**	**27.1**	**35.5**	**21.1**	**19.1**	**7.7**
Criteria	**250**	**62**	**50**	**25**	**25**	**8**
L8	146.5	27.1	30.5	21.1	13.5	7.6
L9	155.9	25.9	25.9	21.0	12.6	7.6
L10	151.8	24.1	27.7	20.7	13.9	7.4
L11	182.0	26.7	28.4	21.1	14.3	7.7
L12	175.2	25.1	30.0	20.9	15.4	7.5
L13	198.2	24.8	29.9	20.9	15.3	7.5
L14	172.9	23.9	30.8	20.8	15.9	7.5
L15	182.4	23.1	26.3	20.7	13.0	7.4
L16	204.6	22.6	31.9	20.7	16.7	7.4
L17	197.3	21.8	29.6	20.6	15.1	7.3
L18	206.8	21.7	29.1	20.6	14.8	7.4
L19	206.5	21.3	30.0	20.6	15.4	7.3
L20	218.2	20.6	29.3	20.5	14.9	7.3
L21	223.2	20.3	26.8	20.5	13.3	7.3
L22	228.2	20.0	27.4	20.4	13.7	7.3
L23	201.4	19.5	27.0	20.4	13.5	7.2
L24	210.2	19.2	35.5	20.3	19.1	7.2
L25	213.5	18.7	27.4	20.3	13.7	7.1
L26	206.8	18.3	28.8	20.2	14.6	7.1
L27	218.0	17.9	28.1	20.1	14.1	7.1
L28	205.3	17.9	27.7	20.2	14.0	7.1
L29	202.8	17.7	28.4	20.2	14.4	7.1
L30	186.4	17.4	28.9	20.1	14.7	7.0

Figure 9.1: Predicted Cumulative NO_2 1-Hour 99.9th Percentile – Level 22

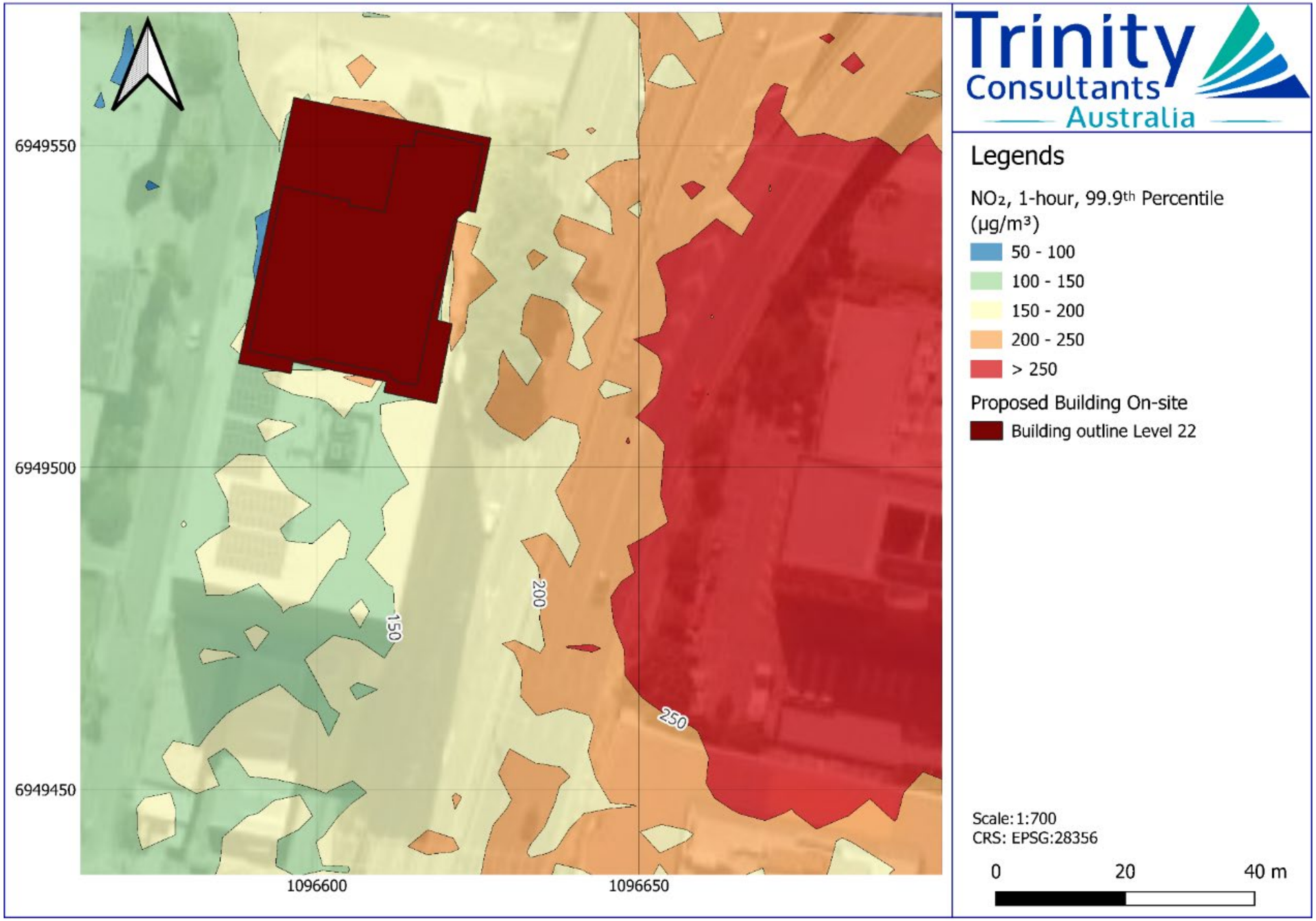
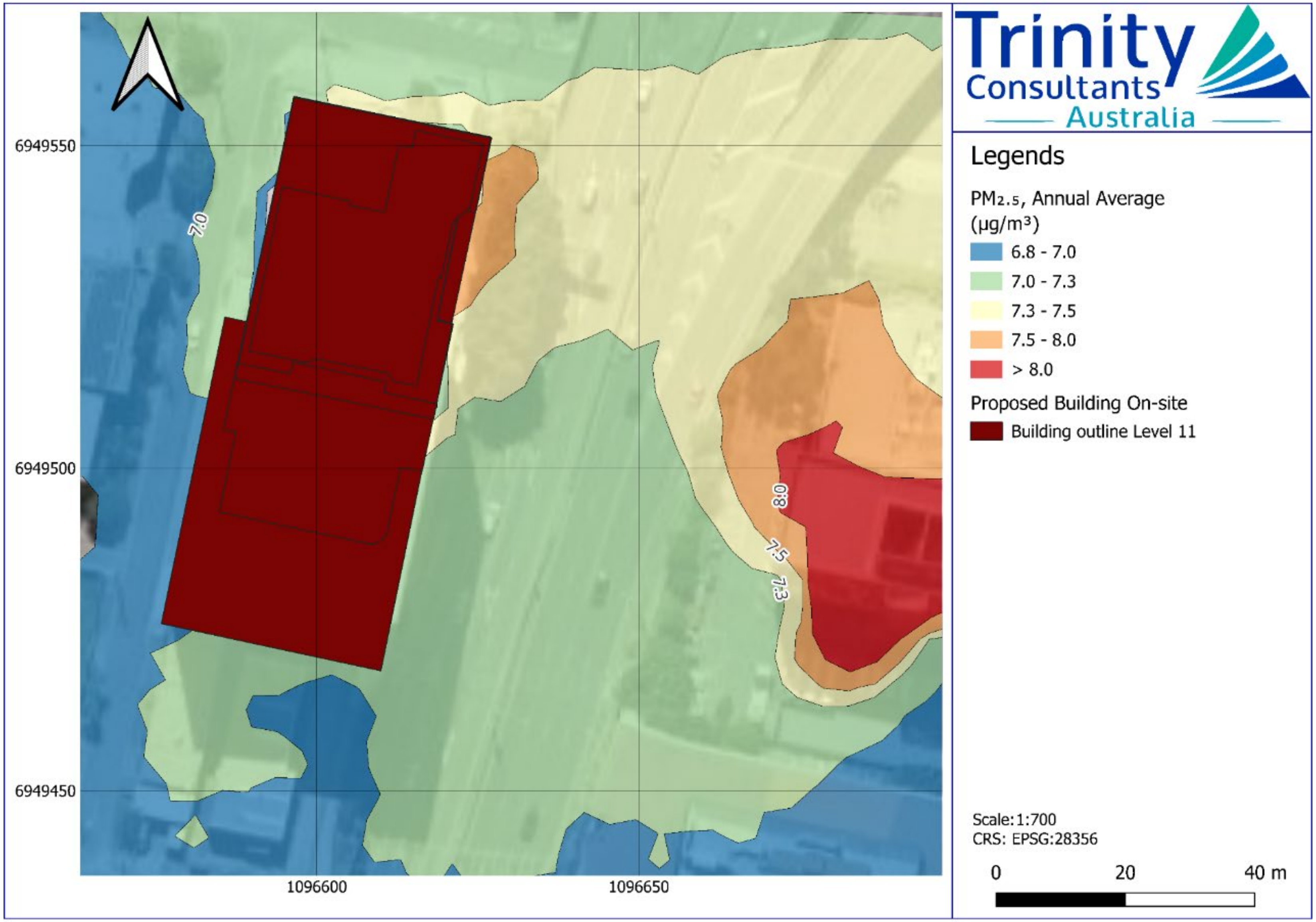


Figure 9.2: Predicted Cumulative $PM_{2.5}$ Annual Average – Level 11



9.2 Off-site Receptors

9.2.1 Introduction

The purpose of the air quality assessment is to address PO4 of the Transport Air Quality Corridor Overlay Code:

> *Development does not:*
>
> *a. expose the occupants of a sensitive use to an air pollutant that exceeds the air quality planning criteria in Table 8.2.23.3.C, due to the operation of a tunnel ventilation outlet;*
>
> *b. affect the dispersion of air pollutants to the extent that existing sensitive uses will be exposed to air pollutants that exceed the air quality (planning) criteria in Table 8.2.23.3.C.*
>
> *Note—An air quality impact report prepared in accordance with the Air quality planning scheme policy can assist in demonstrating achievement of this performance outcome.*

PO4(b) addresses potential impacts onto off-site sensitive receptors. Under PO4(b), a development must not affect the dispersion of air pollutants to the extent that existing sensitive uses will be exposed to air pollutants that exceed the air quality goals. An initial assessment against PO4(b) is to simply identify if there are any new exceedances at sensitive receptors as a result of a development. However, for the existing receptors of interest, background air quality is already close to or above the $PM_{2.5}$ and PM_{10} annual average air quality goals. Therefore, any change in pollutant dispersion (irrespective of how minor) could result in an exceedance or an increase in the extent of an already existing exceedance.

In this context, in addition to identifying new exceedances, compliance with PO4(b) should be further reviewed by identifying whether the concentration increases at off-site receptors (as a result of the development influencing vent plume dispersion) are reasonable. This analysis should focus only on receptors where concentrations exceed the criteria. For receptors where compliance with the fixed air quality is predicted with the Project, any increase in concentration is deemed acceptable.

9.2.2 Predicted Off-Site Results

Table 9.2 presents a summary of the modelling results for the With and Without Project scenarios. The table includes only the results for those receptors where an exceedance of the air quality criteria is predicted in the With Project scenario and where an increase in concentrations is observed compared to the Without Project scenario.

Compliance with the air quality criteria is achieved at all off-site receptor locations for the following pollutants/averaging periods:

- NO_2 1-h 99.9th percentile
- NO_2 annual average
- PM_{10} 24-h max average
- $PM_{2.5}$ 24-h max average

Exceedances of the PM_{10} and $PM_{2.5}$ annual average are only predicted for a limited number of receptors at the Oaks Brisbane Mews Suites development, located to the north of the development across Campbell Street in close proximity to the ICB and receptors located to the west of the development near Bowen Bridge Road. **Figure 9.3** presents the location of the exceeding off-site receptors.

Table 9.2 also presents a detailed analysis of the incremental increase in concentrations (With Project minus Without Project concentrations) and Clem7 vent-only contribution to total concentrations at receptors where exceedances are predicted (with the Project).

Concentration plots for the ground level PM_{10} and $PM_{2.5}$ annual averages for the with and without Project scenarios are presented in **Figure 9.4** to **Figure 9.7**.

Figure 9.3: Exceeding Off-site Receptors

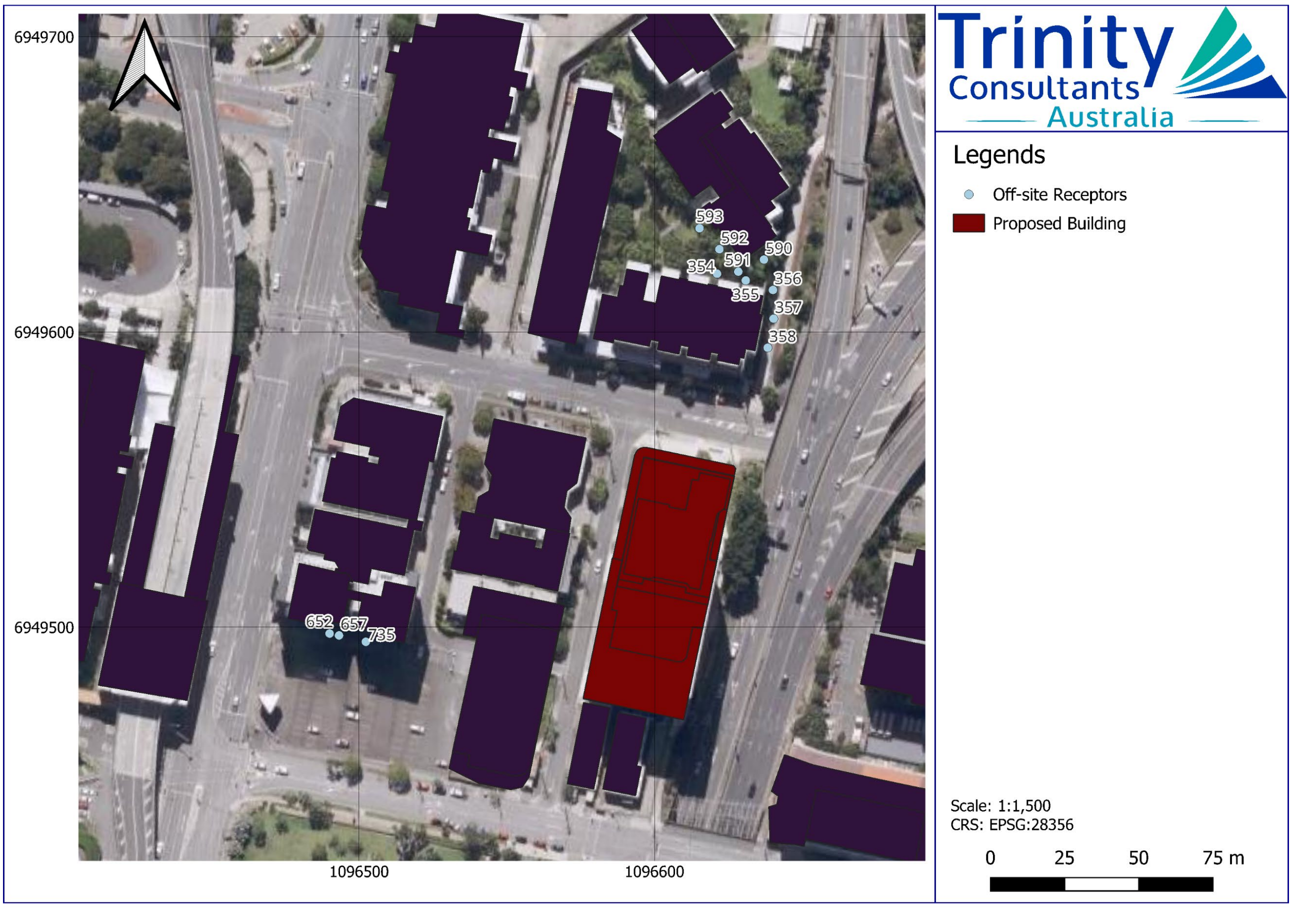


Table 9.2: Predicted Results - Off-site Receptors

ID	Height (m)	Without Project		With Project		Incremental Change		Contribution from Clem7 Vent Only (Without Project)		Contribution from Clem7 Vent Only (With Project)	
		PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)
Averaging Time		**Annual Avg.**	**Annual Avg.**	**Annual Avg.**	**Annual Avg.**	**Annual Avg.**	**Annual Avg.**	**Annual Avg.**	**Annual Avg.**	**Annual Avg.**	**Annual Avg.**
Maximum		**25.4**	**10.2**	**25.6**	**10.2**	**0.27**	**0.21**	**0.12**	**0.10**	**0.09**	**0.07**
Criteria		**25**	**8**	**25**	**8**	**-**	**-**	**-**	**-**	**-**	**-**
354	2	22.3	8.3	22.6	8.4	-	0.15	-	0.08	-	0.06
354	4.4	22.2	8.2	22.4	8.4	-	0.13	-	0.05	-	0.04
354	7.8	22.1	8.2	22.3	8.3	-	0.10	-	0.08	-	0.06
354	11.2	21.9	8.0	22.0	8.1	-	0.06	-	0.06	-	0.04
355	2	22.7	8.5	23.0	8.7	-	0.14	-	0.05	-	0.03
355	4.4	22.7	8.5	22.9	8.7	-	0.15	-	0.06	-	0.04
355	7.8	22.5	8.4	22.8	8.6	-	0.12	-	0.05	-	0.03
355	11.2	22.2	8.3	22.4	8.4	-	0.09	-	0.07	-	0.05
355	14.6	21.9	8.1	22.0	8.1	-	0.05	-	0.07	-	0.05
356	4.4	24.2	9.4	24.4	9.6	-	0.15	-	0.06	-	0.04
357	4.4	25.1	10.0	25.3	10.1	0.18	0.11	0.06	0.08	0.08	0.06
357	7.8	25.2	10.0	25.4	10.1	0.20	0.12	0.05	0.06	0.06	0.04
358	4.4	25.4	10.2	25.6	10.2	0.15	0.09	0.07	0.08	0.08	0.06
358	7.8	25.2	10.0	25.5	10.2	0.27	0.15	0.12	0.09	0.09	0.06
358	11.2	24.5	9.6	24.8	9.8	-	0.14	-	0.07	-	0.05
358	14.6	23.6	9.1	23.7	9.2	-	0.07	-	0.10	-	0.07
590	2	24.3	9.5	24.5	9.6	-	0.15	-	0.07	-	0.05
590	4.4	24.2	9.4	24.4	9.5	-	0.12	-	0.07	-	0.05
590	7.8	23.9	9.3	24.1	9.4	-	0.12	-	0.07	-	0.05
591	2	22.3	8.3	22.6	8.5	-	0.16	-	0.06	-	0.04
591	4.4	22.2	8.3	22.5	8.4	-	0.16	-	0.05	-	0.04

ID	Height (m)	Without Project		With Project		Incremental Change		Contribution from Clem7 Vent Only (Without Project)		Contribution from Clem7 Vent Only (With Project)	
		PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)
591	7.8	22.1	8.2	22.4	8.3	-	0.14	-	0.06	-	0.04
591	11.2	21.9	8.0	22.1	8.2	-	0.11	-	0.07	-	0.05
592	2	22.2	8.3	22.5	8.4	-	0.15	-	0.06	-	0.04
592	4.4	22.0	8.1	22.3	8.3	-	0.16	-	0.07	-	0.05
592	7.8	21.8	8.0	22.0	8.1	-	0.14	-	0.08	-	0.06
593	2	21.9	8.0	22.2	8.2	-	0.21	-	0.10	-	0.07
593	4.4	21.6	7.9	21.9	8.1	-	0.17	-	0.08	-	0.06
652	4.4	22.0	8.1	22.1	8.2	-	0.05	-	0.03	-	0.02
657	4.4	22.0	8.1	22.1	8.2	-	0.05	-	0.03	-	0.02
735	4.4	21.9	8.1	22.0	8.1	-	0.06	-	0.04	-	0.03

Figure 9.4: Concentration Plot - PM_{10} Annual Average (Without Project)

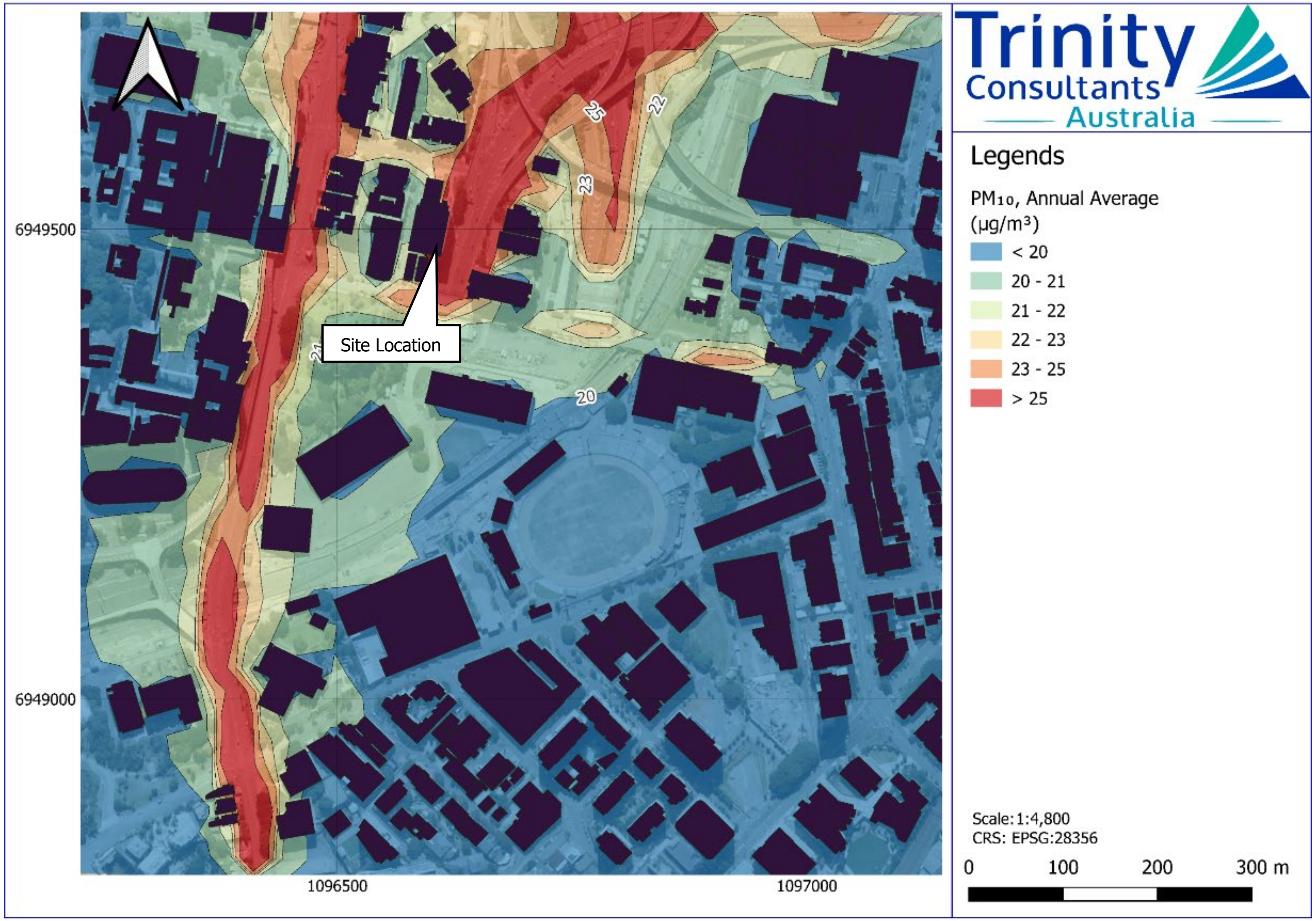


Figure 9.5: Concentration Plot - PM_{10} Annual Average (With Project)

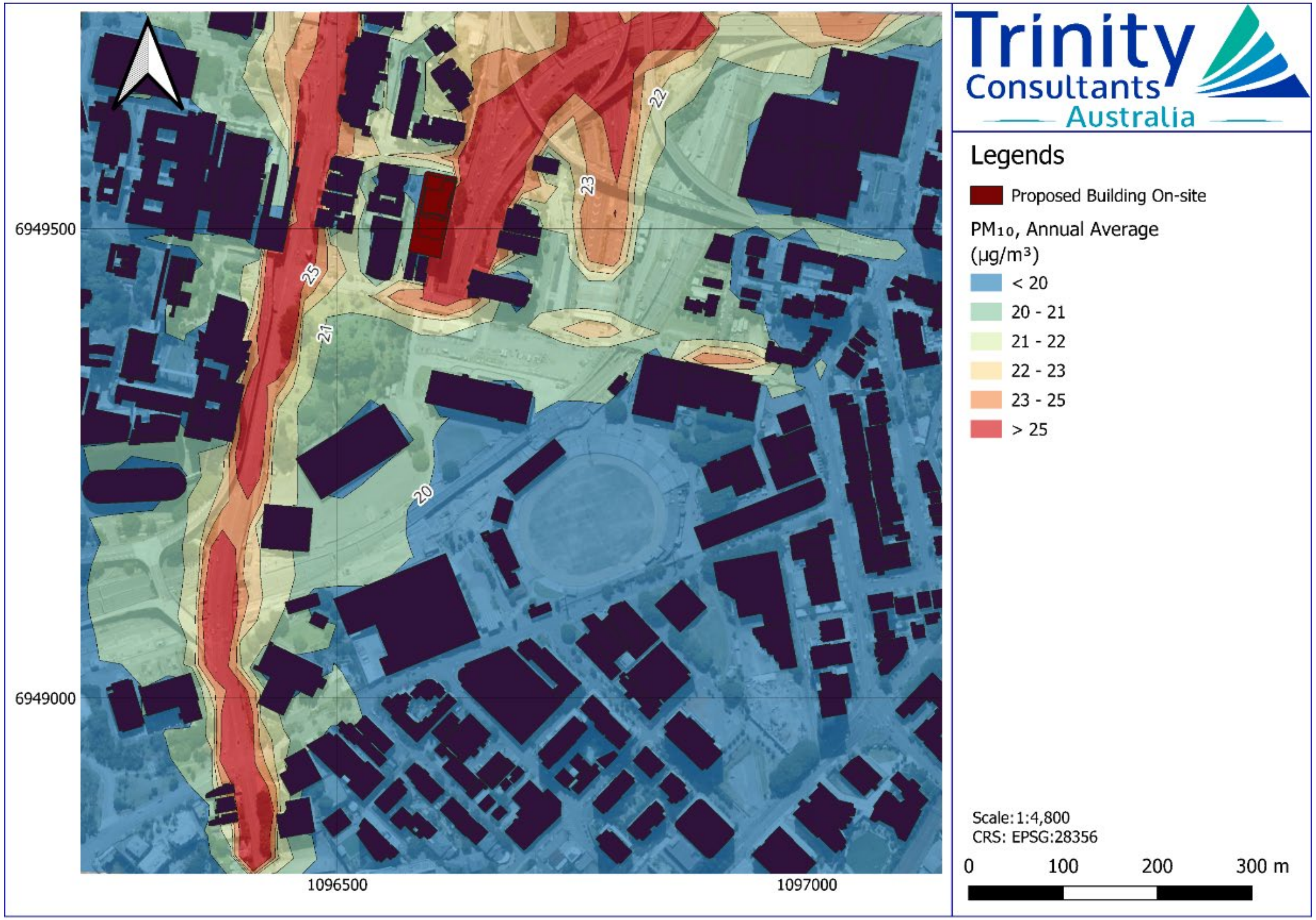


Figure 9.6: Concentration Plot - $PM_{2.5}$ Annual Average (Without Project)

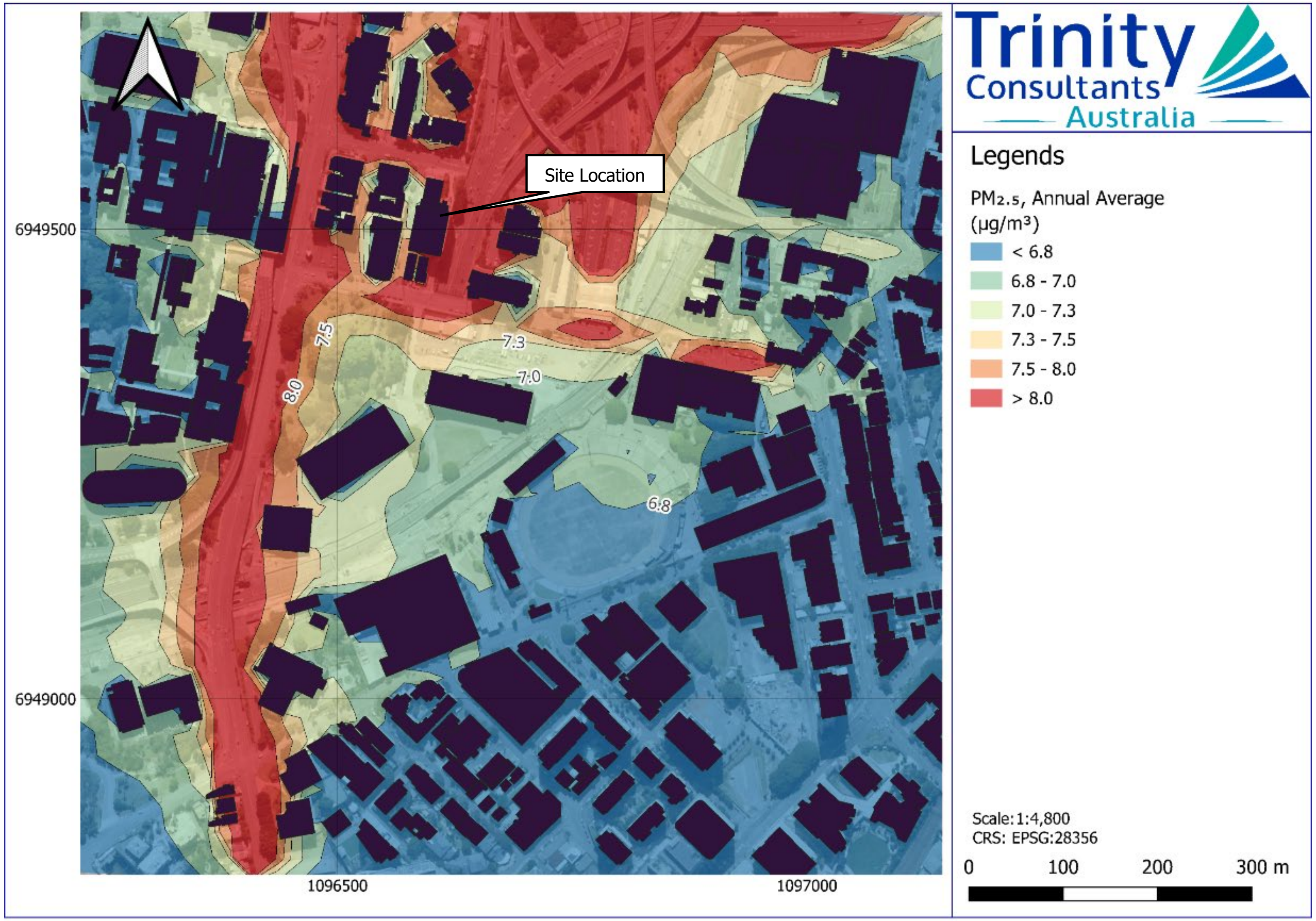
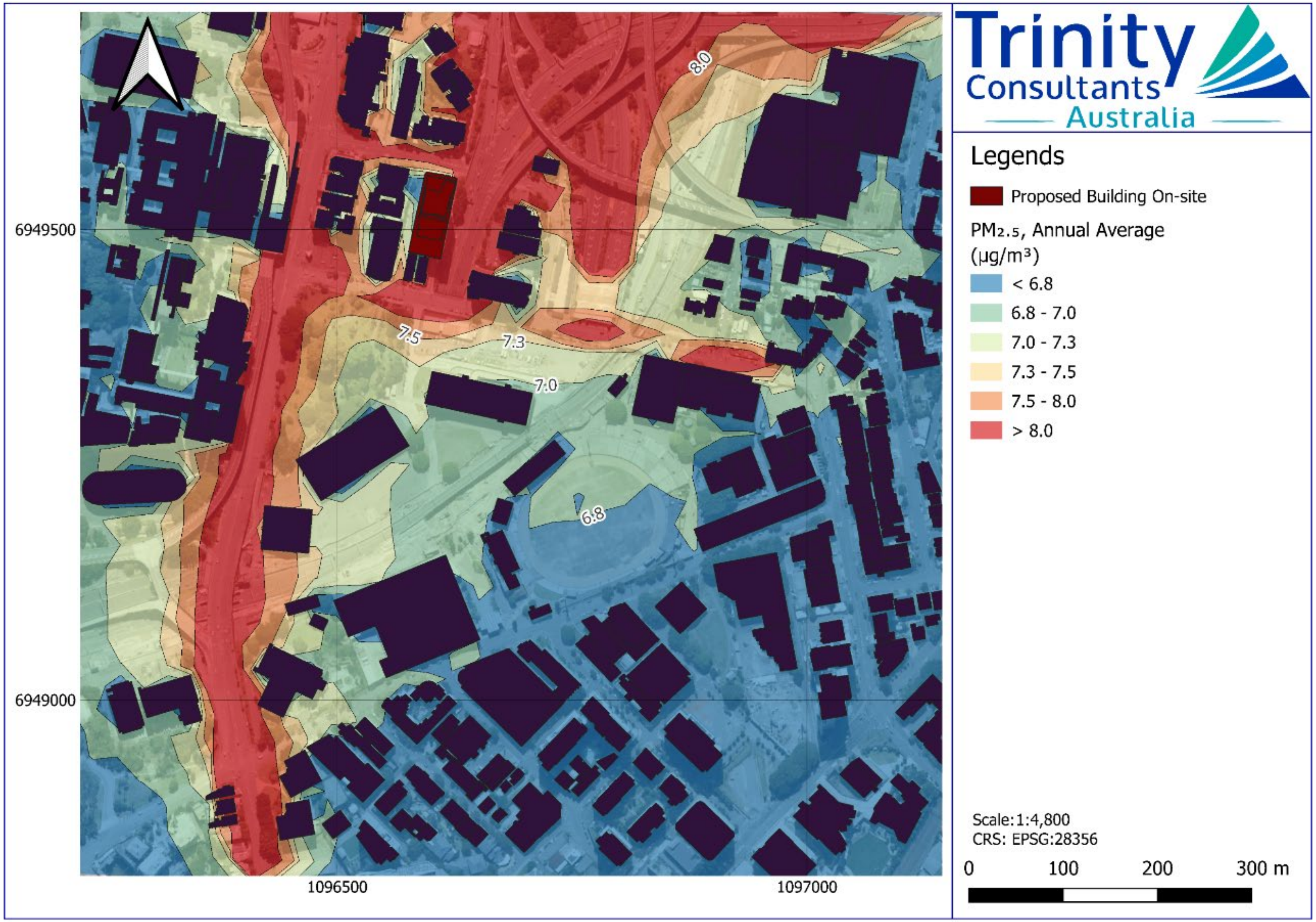


Figure 9.7: Concentration Plot - $PM_{2.5}$ Annual Average (With Project)



9.2.3 Number of Exceedances

A review of the $PM_{2.5}$ and PM_{10} results shows that the annual average concentrations are already similar to or, in most cases, higher than the 8 µg/m^3 and 25 µg/m^3 ambient air quality goals, respectively, for the Without Project scenario.

The results show that there is a small change in the number of receptors exceeding the air quality goals. 29 receptors exceed the annual $PM_{2.5}$ goal without the Project. With the Project, 2 additional receptors exceed the goal (resulting in a total of 31 dwellings exceeding the air quality goal). For the case of PM_{10} annual average, no additional exceedances are predicted, with 4 receptors predicted to exceed the goal without and with the Project. While there is an additional 2 exceedances, these are due to already elevated background levels and it is important to understand the incremental increase in concentrations to provide a final assessment of impacts (see **Section 9.2.4**).

It is further noted that the vent contribution to the total predicted concentrations is very low. There is a 0.9% or less contribution from the vent to the total predicted concentrations (where exceedances are predicted) for $PM_{2.5}$ and 0.4% for PM_{10}. This highlights that background air emission sources (local traffic and regional sources) are the primary sources in the area and dominate the exceedances in the Project area.

Therefore, in terms of the changes to the air quality goal compliance status of individual receptors, the results show that the overall impact of the development on the surrounding area is negligible.

9.2.4 Incremental Change in Concentration

As discussed previously, to assess compliance against PO4(b) in an area where background concentrations are elevated, a review of incremental changes in pollutant concentrations is considered necessary.

There is no specific guidance within the BCC City Plan 2014 on how to address situations of elevated background concentrations similar to or above the ambient air quality goal. In order to address the incremental change in concentration, reference has been made to the study conducted by Adam Capon and Jackie Wright and published in the Public Health Research and Practice journal, "*An Australian incremental guideline for particulate matter ($PM_{2.5}$) to assist in development and planning decisions*"[7]. The study seeks to identify risk acceptability categories based on incremental changes to $PM_{2.5}$ concentrations and associated increases to mortality. This study was also referred to in the air quality assessment of Application A006150645. **Table 9.3** presents a summary of the suggested incremental assessment criteria for annual $PM_{2.5}$ exposure.

Table 9.3: Incremental Assessment Criterion for Annual $PM_{2.5}$ Exposure

Incremental annual average $PM_{2.5}$ concentration (µg/m^3)	Increased risk of mortality	Risk acceptability and suggested interpretation
0 – 0.02	< 1 in 1,000,000	**Negligible**
0.02 – 0.17	1 in 1,000,000 – 1 in 100,000	**Acceptable** Development needs to show use of best practice with consideration of reasonable and feasible measures to reduce pollutant load
0.17 – 1.7	1 in 100,000 in 1 in 10,000	**Tolerable** Only if best practice is proven and reasonable, and feasible measures have been demonstrated. At this level, costly interventions are now considered reasonable and feasible, that would not have been in the acceptable range.
> 1.7	> 1 in 10,000	**Unacceptable**

[7] Capon A, Wright J. An Australian incremental guideline for particulate matter ($PM_{2.5}$) to assist in development and planning decisions. Public Health Res Pract. 2019; 29(4):e2941928. https://doi.org/10.17061/phrp2941928

The above table presents the predicted change in $PM_{2.5}$ annual average concentrations for the vent predictions only and associated risk rating. Only $PM_{2.5}$ concentrations are addressed in the study. It is noted that there are 4 modelled receptors (357 and 358, 4.4 and 7.8 m above ground, refer to **Table 9.2**) where there is an exceedance and increase in both $PM_{2.5}$ and PM_{10} annual concentrations. In the absence of studies focusing on PM_{10} increases it is assumed that assessing the risk associated with an increase in $PM_{2.5}$ is sufficient for addressing PM_{10} also. With this in mind, the following results and discussions focus on PM_{10}.

Table 9.4 presents the change in vent contribution and total (vent plus roads) $PM_{2.5}$ concentrations.

Table 9.4: Predicted Change in $PM_{2.5}$ Annual Concentration

Receptor ID	Height (m)	Without Project (µg/m³)	With Project (µg/m³)	Incremental Change (Vent Only) (µg/m³)	Risk Rating (Vent Only Change)	Incremental Change (Total) (µg/m³)	Risk Rating (Total Change)
354	2	8.3	8.4	0.01	Negligible	0.15	Acceptable
354	4.4	8.2	8.4	-0.01	Improvement	0.13	Acceptable
354	7.8	8.2	8.3	-0.02	Improvement	0.10	Acceptable
354	11.2	8.0	8.1	-0.02	Improvement	0.06	Acceptable
355	2	8.5	8.7	-0.03	Improvement	0.14	Acceptable
355	4.4	8.5	8.7	0.00	No Change	0.15	Acceptable
355	7.8	8.4	8.6	-0.01	Improvement	0.12	Acceptable
355	11.2	8.3	8.4	0.00	No Change	0.09	Acceptable
355	14.6	8.1	8.1	0.00	No Change	0.05	Acceptable
356	4.4	9.4	9.6	-0.01	Improvement	0.15	Acceptable
357	4.4	10.0	10.1	0.01	Negligible	0.11	Acceptable
357	7.8	10.0	10.1	0.01	Negligible	0.12	Acceptable
358	4.4	10.2	10.2	0.01	Negligible	0.09	Acceptable
358	7.8	10.0	10.2	-0.02	Improvement	0.15	Acceptable
358	11.2	9.6	9.8	-0.01	Improvement	0.14	Acceptable
358	14.6	9.1	9.2	0.02	Acceptable	0.07	Acceptable
590	2	9.5	9.6	-0.02	Improvement	0.15	Acceptable
590	4.4	9.4	9.5	0.00	No Change	0.12	Acceptable
590	7.8	9.3	9.4	0.01	Negligible	0.12	Acceptable
591	2	8.3	8.5	0.01	Negligible	0.16	Acceptable
591	4.4	8.3	8.4	0.00	No Change	0.16	Acceptable
591	7.8	8.2	8.3	0.01	Negligible	0.14	Acceptable
591	11.2	8.0	8.2	0.01	Negligible	0.11	Acceptable
592	2	8.3	8.4	-0.01	Improvement	0.15	Acceptable
592	4.4	8.1	8.3	0.00	No Change	0.16	Acceptable
592	7.8	8.0	8.1	0.02	Acceptable	0.14	Acceptable
593	2	8.0	8.2	0.00	No Change	0.21	Tolerable
593	4.4	7.9	8.1	0.00	No Change	0.17	Tolerable
652	4.4	8.1	8.2	0.01	Negligible	0.05	Acceptable
657	4.4	8.1	8.2	0.01	Negligible	0.05	Acceptable

Receptor ID	Height (m)	Without Project (µg/m³)	With Project (µg/m³)	Incremental Change (Vent Only) (µg/m³)	Risk Rating (Vent Only Change)	Incremental Change (Total) (µg/m³)	Risk Rating (Total Change)
735	4.4	8.1	8.1	0.01	Negligible	0.06	Acceptable
No. of Receptors with a Decrease/Improvement in Concentrations					10		0
No. of Receptors with No Change					8		0
No. of Receptors with Negligible Change					11		0
No. of Receptors with Acceptable Change					2		29
No. of Receptors with Tolerable Change					0		2
No. of Receptors with Unacceptable Change					0		0

9.2.5 Change in Vent Contribution

The incremental vent-only change in concentration at receptors that exceed the $PM_{2.5}$ annual goal is less than 0.02 µg/m³ for all receptors. The vent only changes fall into the Negligible and Acceptable risk categories.

The overall outcome of the Transport Air Quality Corridor Overlay associated with P04(b) is to minimise air quality impacts from the vent onto off-site receptors. On the basis of the Negligible/Acceptable risk ratings of Capon and Wright (2019) for concentration changes and the minimal impacts to exceedances discussed in the previous section, it is concluded that compliance with PO4(b) and the relevant overall outcome is achieved by the development.

9.2.6 Total Concentration Change

Table 9.2 also presents the predicted change in total (vent + other sources/background) PM_{10} and $PM_{2.5}$ annual concentrations at each receptor, where an exceedance of the air quality goal was predicted. This information is not specifically required to address PO4(b) which focuses on the vent contribution, however, it is nonetheless provided to review air quality impacts as a whole for the proposed development.

The change in total $PM_{2.5}$ annual concentrations (vent plus other sources/background) at the majority of sensitive uses (where exceedances are predicted) are in the Acceptable category. The only exception is the receptor 593 at 2.0 and 4.4 metres above ground, where the change in concentration is marginally inside the Tolerable range (0.21 and 0.17 µg/m³ increase, Tolerable rating range is 0.17-1.7 µg/m³). For these two receptors, there is no change in vent contribution, therefore, the small increase is due to surface road traffic concentrations increasing (as a result of the Project). Other receptors in the vicinity of Receptor 593 (i.e. 591, 592, 354, 354), have very similar incremental increases (up to 0.16 µg/m³), which are marginally within the Acceptable category.

Capon and Wright (2019) suggest that reasonable and feasible measures be implemented when the incremental change lies within the Acceptable range. As per the built form assessment in **Section 10**, the proposed development is reasonably designed and located to prevent build-up of pollutants in the road corridor. Ultimately, the increase is marginally in the Tolerable range and is limited to 2 modelled receptor locations.

As a further note, according to Section 13.8 of EPA Victoria Publication 1961: *Guideline for assessing and minimising air pollution in Victoria*, an incremental contribution of less than 4% of the criterion is not considered to be significant. This corresponds to an incremental concentration of 1 µg/m³ for PM_{10} and 0.32 µg/m³ for $PM_{2.5}$. None of the increments due to the Project, as predicted by the model, are greater than 4% for either pollutant. For PM_{10}, the highest increment is 0.8% of the criteria (0.20 µg/m³), while for $PM_{2.5}$, it is 2.6% (0.21 µg/m³), which are well within the 4% guideline.

In view of the data presented in this section, the influence of the Project on off-site air quality outcomes is considered to be minor and acceptable.

10. TRANSPORT AIR QUALITY CORRIDOR ASSESSMENT

10.1 Overview

The subject site falls within the Transport Air Quality Corridor Overlay for sub-categories A, B, and C. Sub-category C has been addressed in previous sections, with the final outcomes presented in **Section 8**. The following sections address the outcomes for sub-categories A and B. The acceptable outcomes and minimum separation distances have been presented in **Section 4.3.1**.

10.2 Transport Air Quality Corridor A Sub-category

Figure 10.1 presents the affected areas due to the Transport Air Quality Corridor A Sub-category. Most of the eastern half of the site falls under the overlay due to its proximity to the Inner City Bypass (ICB), which is classified as a route type Category 4. The minimum separation distances for a Category 4 route are 25 metres from the kerb and 10 metres vertically from the ground.

Figure 10.1: Transport Air Quality Corridor A Sub-category

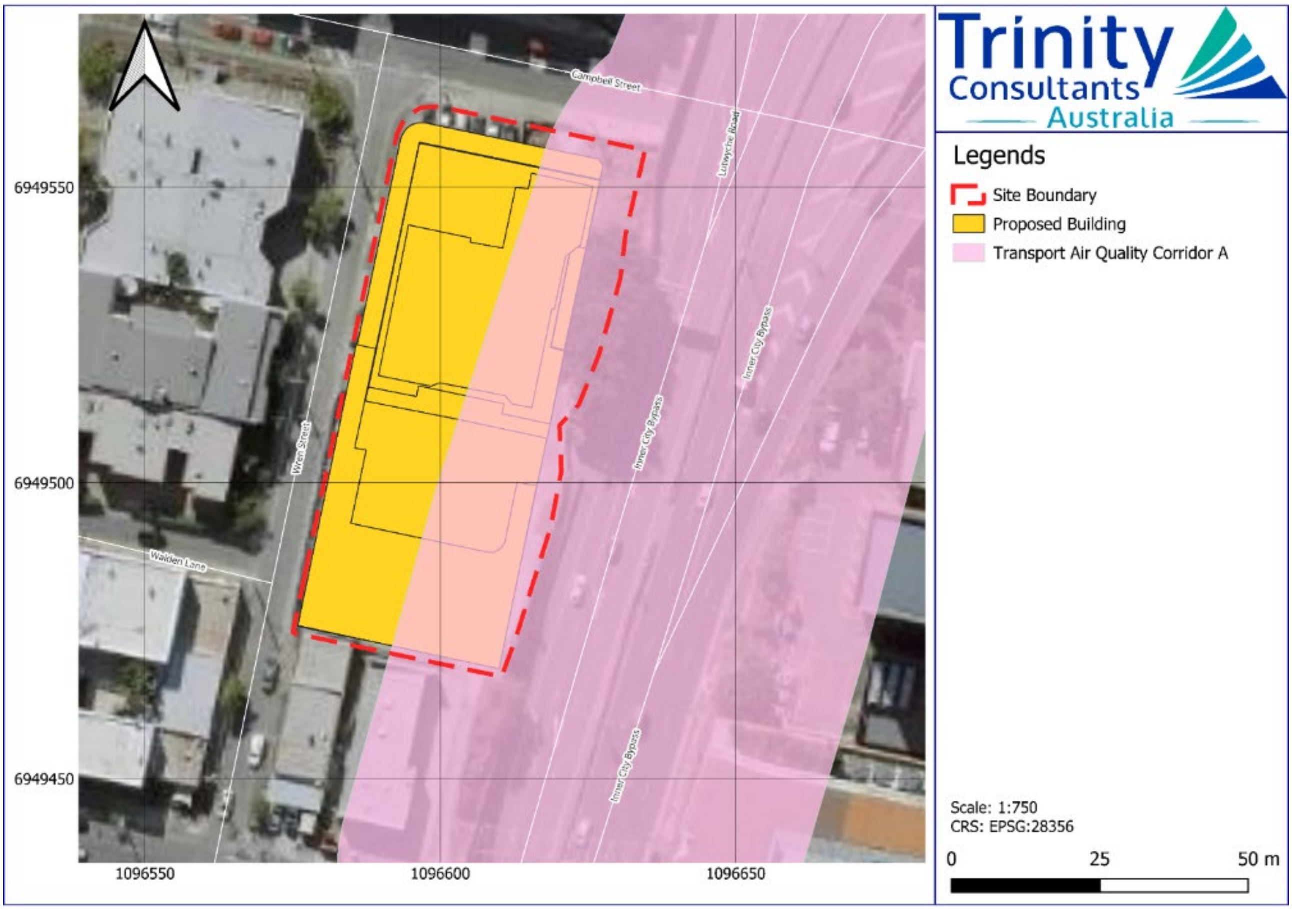


Figure 10.2 to **Figure 10.5** illustrate the development areas impacted by Transport Air Quality Corridor A that fall within the minimum horizontal and vertical separation distances. These impacted areas include the Ground Level, Service Mezzanine, and Levels 1 and 2. The development's east elevation is presented in **Figure 10.6**.

Despite the impact of Transport Air Quality Corridor A on sections of various tenancies across all development levels, the project complies with AO1 of the Transport Air Quality Corridor Overlay Code due to achieving the minimum setback distances outlined in the code for sensitive receptors, consequently also complying with PO1. The nearest sensitive receptors within the minimum horizontal setback distance (residential units) are located on Level 11, significantly exceeding the minimum vertical separation distance.

It is noted that no operable windows or openings are planned for the proposed tenancies within the affected areas. The code prescribes the minimum requirements for multiple dwelling, residential care facility, rooming accommodation or retirement facility uses, but does not include health care.

Nevertheless, as a good air quality management practice, the ventilation requirements of A01 are still recommended for potential healthcare services. Specifically, the installation of ducted mechanical ventilation systems with the following specifications is recommended:

- Supply outdoor air in accordance with AS 1668.2: The use of ventilation and air conditioning in buildings - Mechanical ventilation in buildings; AND
- Intake requirements:
    - Locate the mechanical ventilation outdoor air intakes at least the minimum distance from the kerb in both horizontal and vertical planes (refer to **Figure 10.2** to **Figure 10.5**, intakes to be located outside pink area for affected floor levels); OR
    - Alternatively, if within the minimum separation distance, employ filtration of outdoor air to a minimum performance standard of F6 or minimum efficiency reporting value (MERV) 9.

Figure 10.2: Affected Area - Ground Level

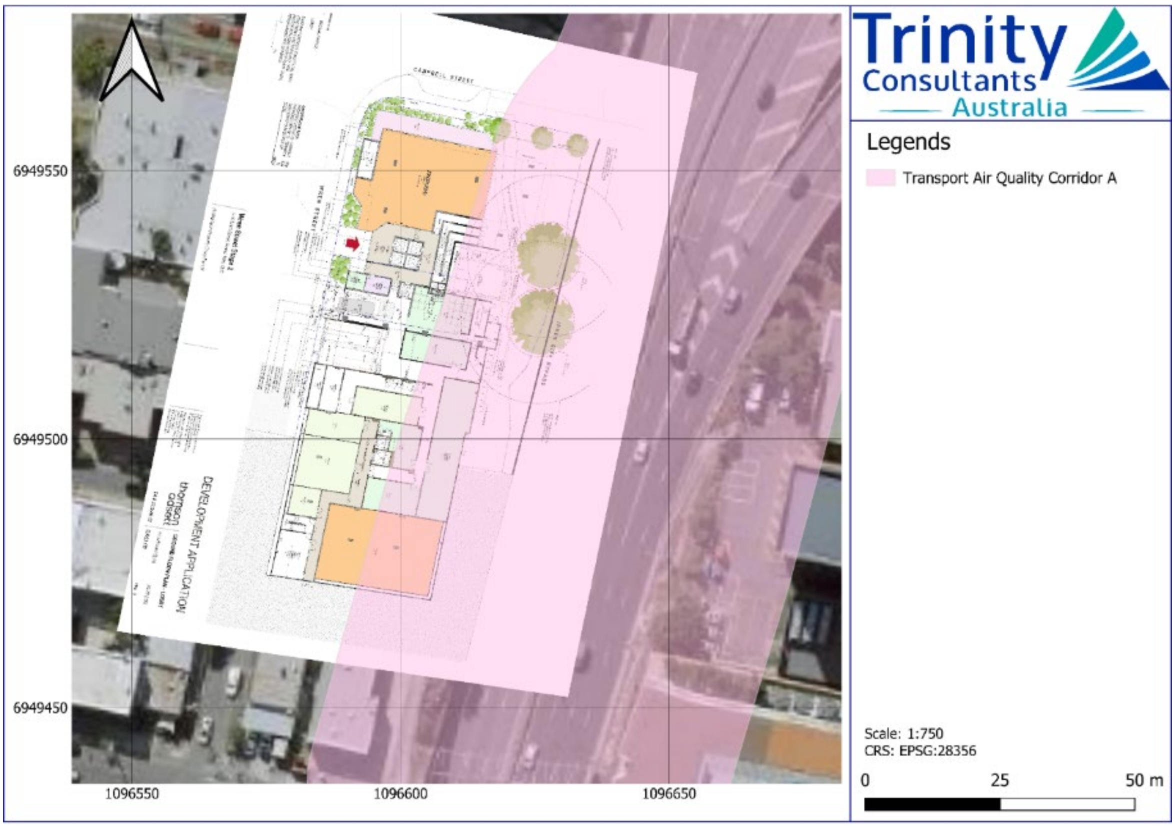


Figure 10.3: Affected Area - Mezzanine Level

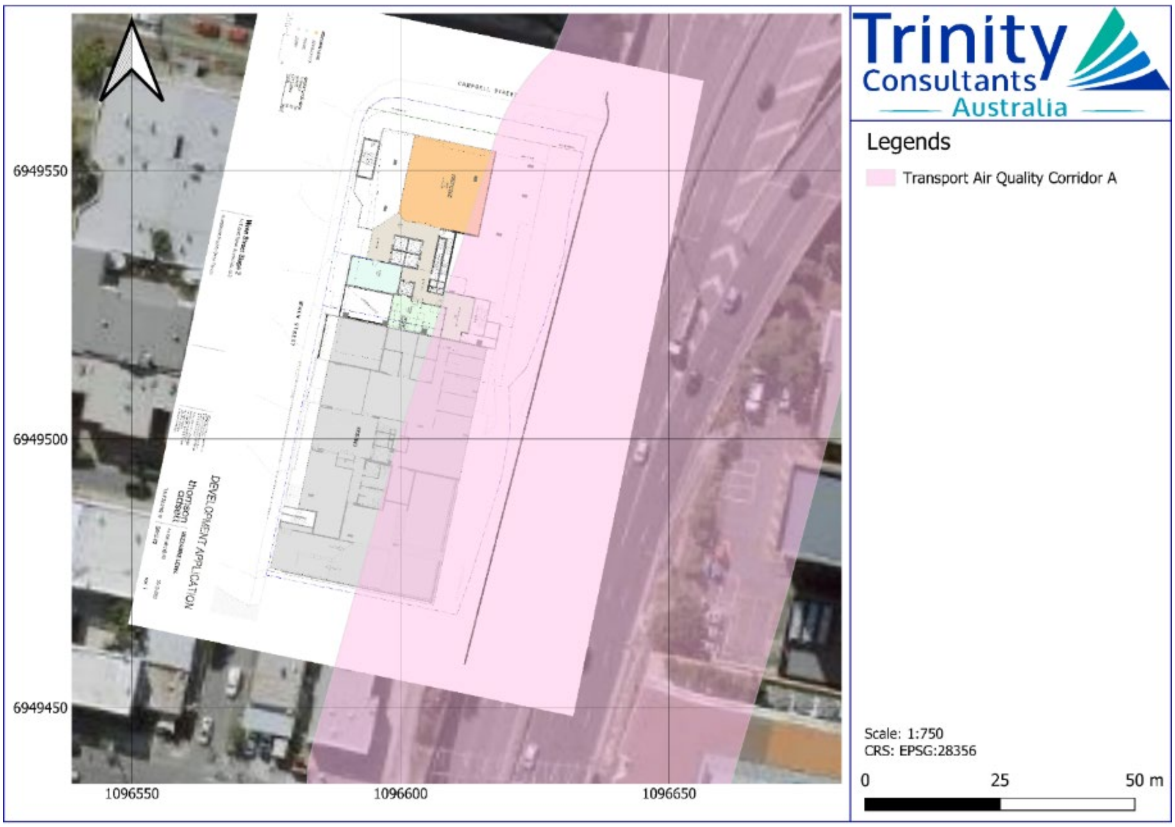


Figure 10.4: Affected Area - Level 1

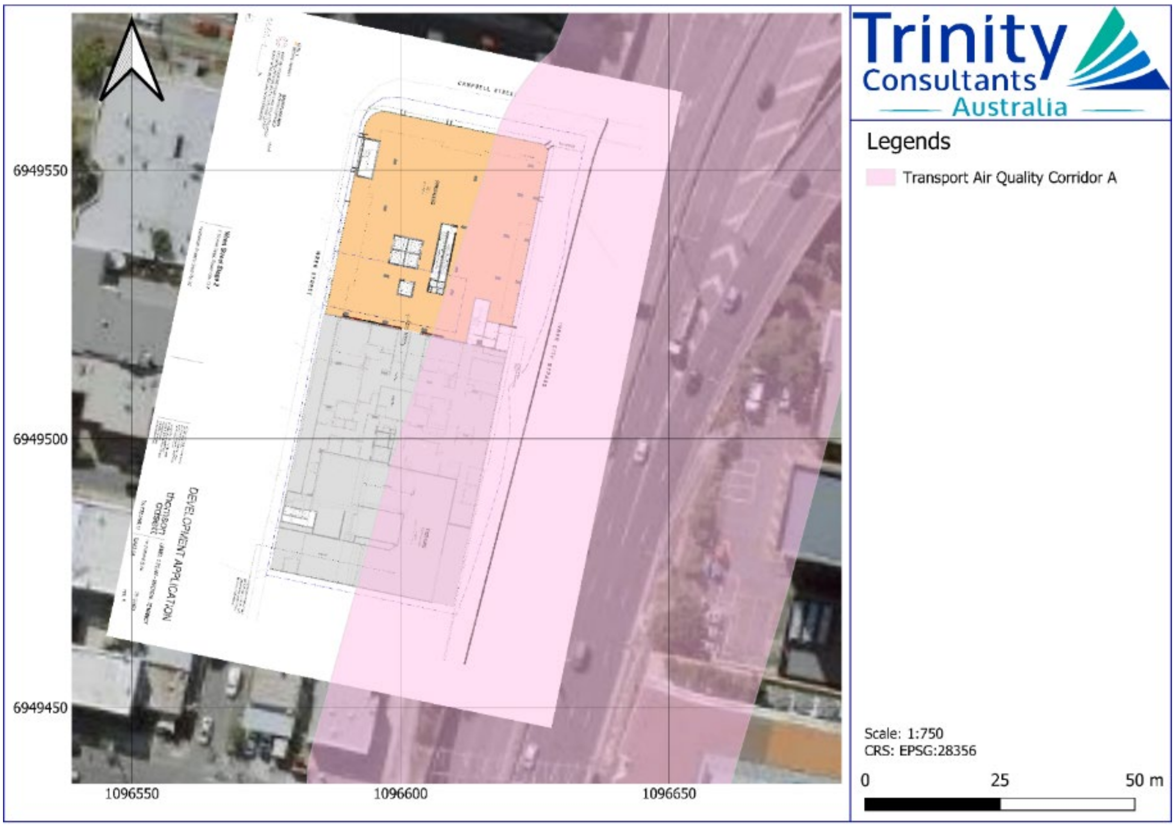


Figure 10.5: Affected Area - Level 2

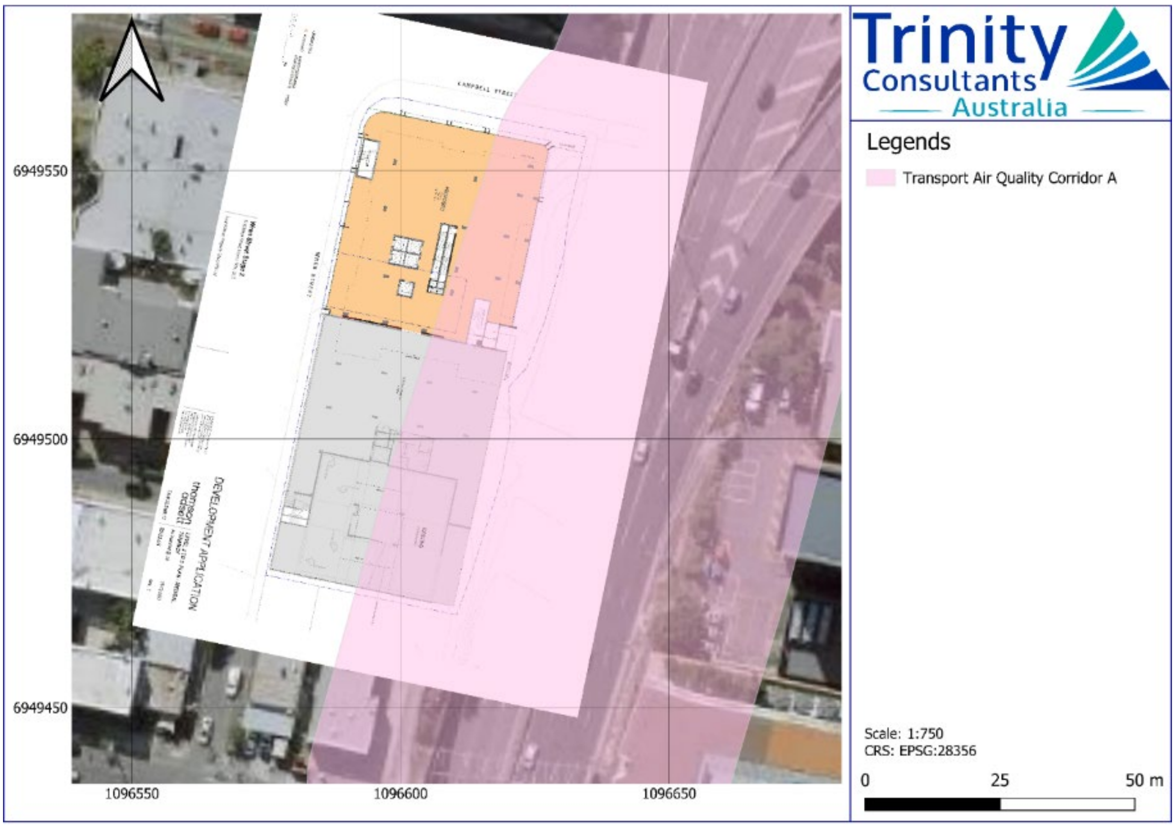
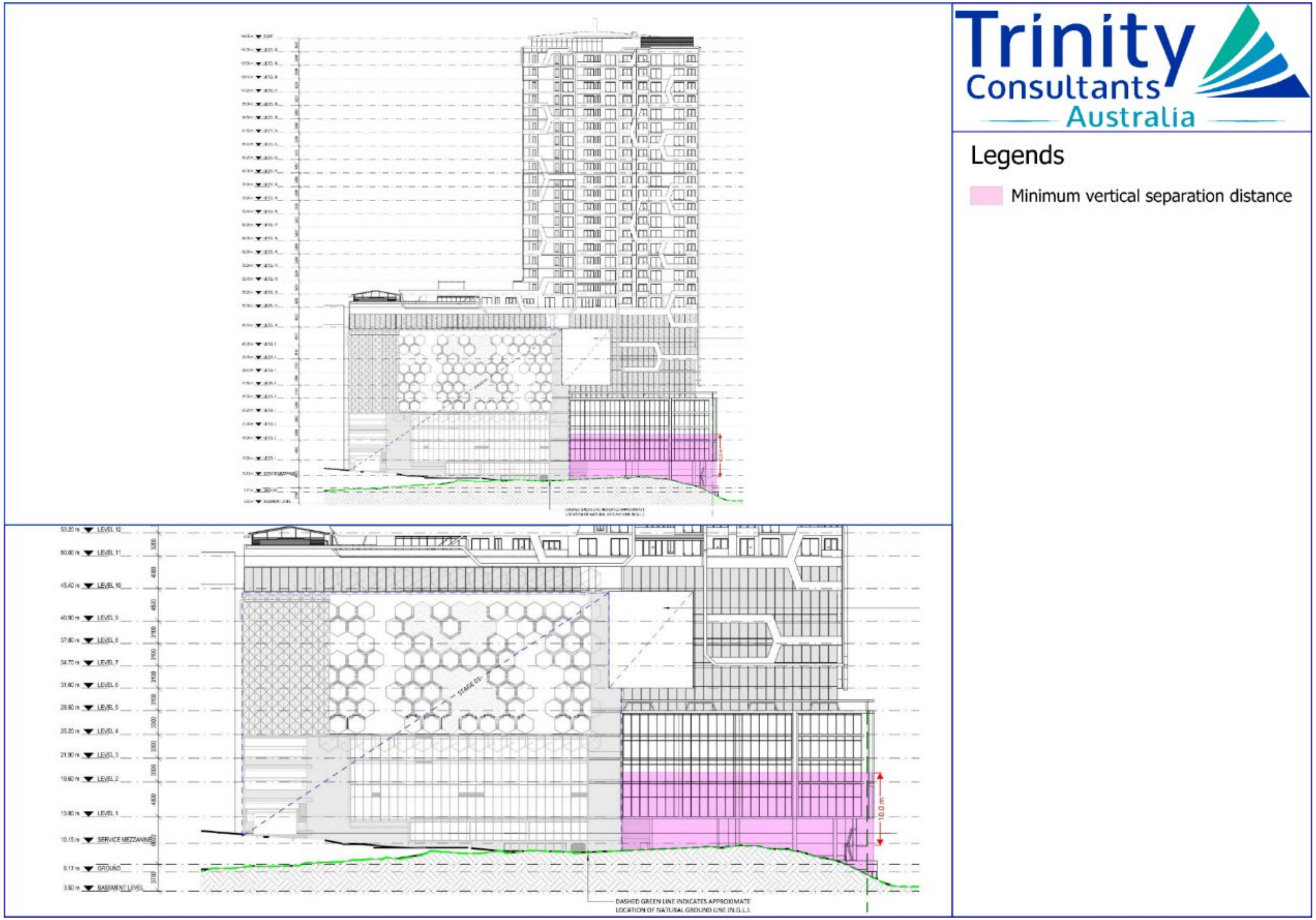


Figure 10.6: East Elevation - Minimum Vertical Separation Distance



10.3 Transport Air Quality Corridor B Sub-category

10.4 Element 1 – Avoiding Street Canyon Effect

The street canyon effect occurs in deep narrow spaces in streets with tall buildings on either side with minimal airflow, thus trapping road traffic pollutants in the street canyon. The following sections assess the potential for street canyoning effects at the proposed development site and design features which act to minimise and mitigate the impacts.

10.4.1 Street Canyon Dimensions

The proposed heigh for the building is 110 metres and is to be located less than 15 metres from the kerb of the Inner City Bypass (ICB).

The Transport Air Quality Corridor Planning Scheme Policy requires the assessment of building heights for a distance of five times the height of the proposed development, in both directions from the development. However, the ICB becomes a tunnel to the south of O'Connell Terrace, thus not requiring the assessment of street canyon effects. On the other hand, to the north of Campbell Street, there are no buildings to the east of the ICB due to the presence of the complex road network that links the ICB (M3) and the Airport Link (M7). Consequently, only the ICB section between O'Connell Terrace and Campbell Street has been considered in this assessment.

The height of the neighbouring buildings has been determined based on a desktop review on 17th June 2024 and site visit (13th June 2024) and is presented in **Figure 10.7,** and the 3D view modelled in **Figure 10.8** to **Figure 10.10**. The subject building is presented in yellow in the 3D views. The average height of the existing buildings along the road for the study area is 24 metres.

Figure 10.7: Neighbouring Buildings Heights

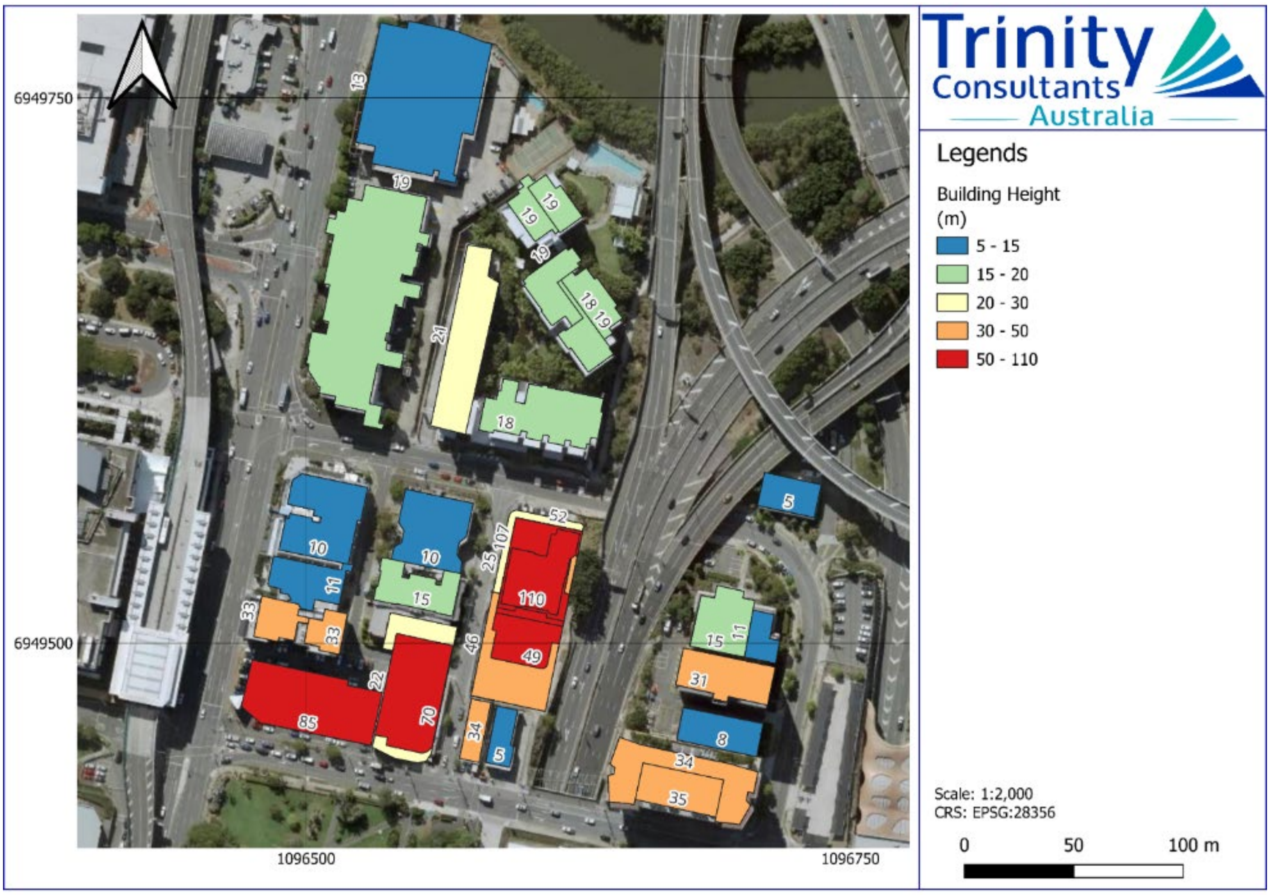


Figure 10.8: South 3D View

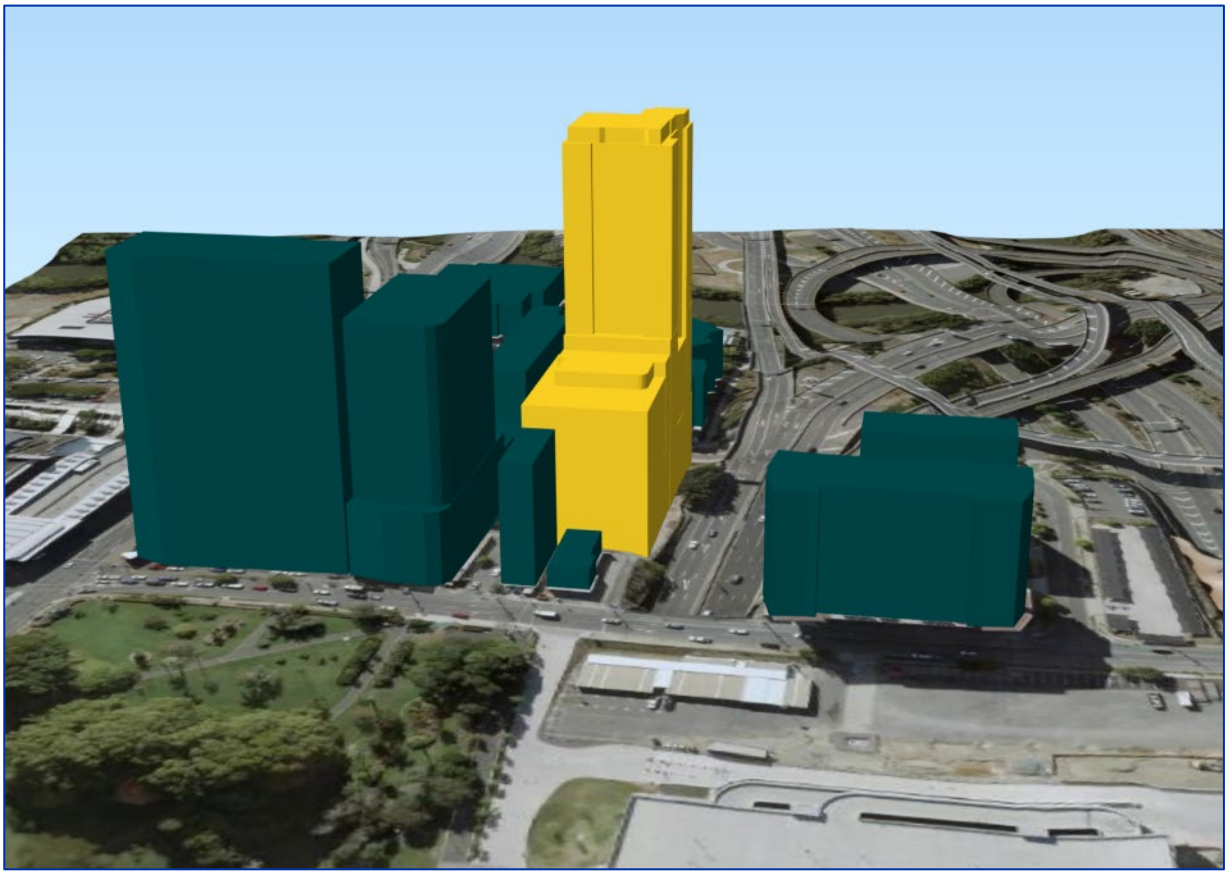


Figure 10.9: East 3D View

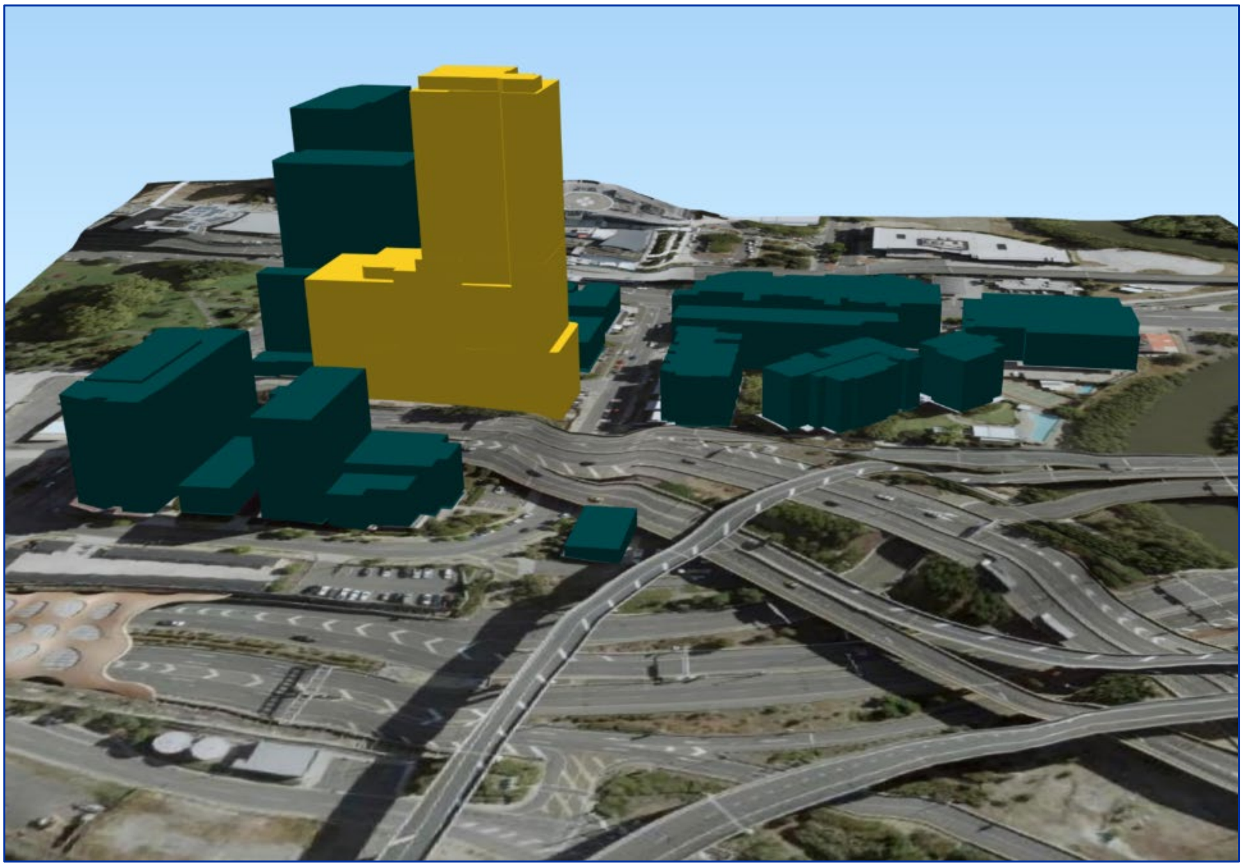
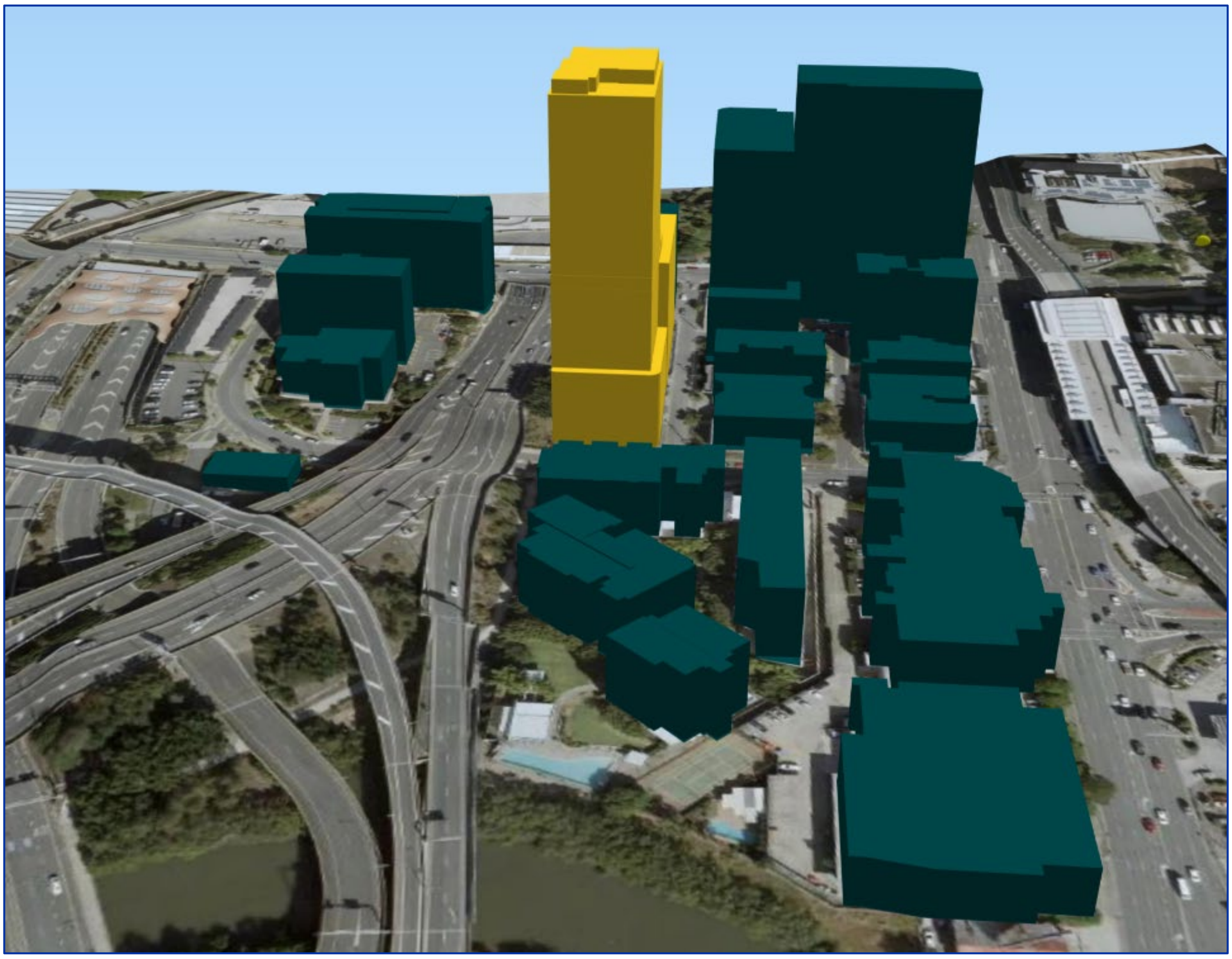


Figure 10.10: North 3D View



The separation distances analysis for each building section is presented in **Table 10.1**. The different levels have been grouped based on similar built forms and building outlines.

Table 10.1: Minimum Separation Distances per Building Section.

Reference to the Separation Distance	Distance
Height of the building	110 m
Ground Level and Mezzanine (Figure 10.11)	
Width of the building	84.3 m
Building to the kerb of the road	11.2 m
Building to the north boundary	6.2 m
Building to the east boundary	4.7 m
Building to the south boundary	1.2 m
Building to the west boundary	0 m
Level 1 to Level 4 (Figure 10.12)	
Width of the building	87.4 m
Building to the kerb of the road	7.0 m
Building to the north boundary	3.0 m
Building to the east boundary	0 m
Building to the south boundary	1.2 m

Reference to the Separation Distance	Distance
Building to the west boundary	0 m
Level 5 to Level 10 (Figure 10.13)	
Width of the building	83.3 m
Building to the kerb of the road	7.0 m
Building to the north boundary	3.5 m
Building to the east boundary	0 m
Building to the south boundary	1.2 m
Building to the west boundary	0.5 m
Level 11 (Figure 10.14)	
Width of the building	65.3 m
Building to the kerb of the road	11.1 m
Building to the north boundary	6.5 m
Building to the east boundary	1.6 m
Building to the south boundary	20.0 m
Building to the west boundary	4.0 m
Level 12 (Figure 10.15)	
Width of the building	44.5 m
Building to the kerb of the road	10.8 m
Building to the north boundary	6.5 m
Building to the east boundary	1.6 m
Building to the south boundary	39.4 m
Building to the west boundary	4.0 m
Level 13 to Level 29 (Figure 10.16)	
Width of the building	42.0 m
Building to the kerb of the road	11.0 m
Building to the north boundary	6.5 m
Building to the east boundary	1.6 m
Building to the south boundary	43.4 m
Building to the west boundary	4.0 m
Rooftop (Figure 10.17)	
Width of the building	38.6 m
Building to the kerb of the road	15.0 m
Building to the north boundary	7.7 m
Building to the east boundary	5.5 m
Building to the south boundary	45.3 m
Building to the west boundary	5.2 m

Figure 10.11: Separation Distances at Ground Level and Mezzanine

Figure 10.12: Separation Distances at Level 1 to Level 4

Figure 10.13: Separation Distances at Level 5 to Level 10

Figure 10.14: Separation Distances at Level 11

Figure 10.15: Separation Distances at Level 12

Figure 10.16: Separation Distances at Level 13 to Level 29

Figure 10.17: Separation Distances at Rooftop Level

The canyon width-to-height ratio is low at 0.2 (calculated by dividing the 26.1-metre road width (measured kerb to kerb) by the 110-metre building height). This falls short of the recommended ratio of 0.7 in the Transport Air Quality Corridor Planning Scheme. Despite this low ratio, several factors may mitigate the canyon effect:

- The proposed building is taller than surrounding buildings on the same side of the road. Additionally, the surrounding area has buildings of varying heights and distances from the road kerb, creating an asymmetrical local building topography. The proposed building height is 3 times higher than the tallest building along the road, above the preferable 1.5 times described in the policy.
- Street corridor and surrounding buildings could be described as asymmetric (i.e. buildings vary in height opposite one another).
- The area south of O'Connell Terrace is primarily open space including the RNA and Bowen Park, and the area north of Campbell Street has buildings only on the western side of the road. These factors limit the formation of a true street canyon.

10.4.2 Gaps in Airflow

Gaps in the streetscape can improve the dispersion of road traffic pollutants. South of the Stage 1 building, there is a minimal gap of 1.2 metres between it and the lot boundaries. However, on the opposite side, a larger gap of approximately 6.5 metres exists on the lot where the Clem7 Northbound tunnel vent is located.

Moreover, a carpark to the north of the Transurban building further expands the existing air gap created by the Campbell Street corridor. It is important to take into consideration that the Stage 1 building is already present and the Stage 2 tower will face the above-mentioned carpark and the relatively short Transurban building right next to the street corridor.

As discussed previously, there is also the O'Connell Terrace street corridor to the south providing a permanent gap for air flow.

Given the above information, there is a variation in building heights along the transport air quality corridor, and gaps for airflow as show in **Figure 10.18**. On this basis, the proposed building is unlikely to contribute to street canyon effects.

Figure 10.18: Gaps in Airflow

10.5 Element 2 – Encouraging Turbulence

Air dispersion from road traffic is improved with the introduction of turbulence to the road corridor. Turbulence can be introduced to the road corridor through increasing building roughness, providing gaps between building and vegetation.

10.5.1 Building Roughness

The proposed building is not block like and incorporates various textures and roughness features. Particularly, the new Stage 2 tower includes a 5-storey podium (Ground to Level 4), followed by an increased setback from the road for Levels 5 to 10, and finally a tower from Levels 11 to 30. Several design features are incorporated into the façade in order to increase the building roughness and they are shown in **Figure 10.19**.

Figure 10.19: Proposed Building Render Facing East

10.5.2 Variation in Streetscape

The surrounding buildings exhibit a variation in height. To the north, across Campbell Street, sits the Oaks Brisbane Mews Suites hotel. Buildings in this area are significantly shorter than the proposed Stage 2 tower. Similarly, the neighbouring lots to the south currently feature one-story buildings. The lot adjacent to the ICB includes a Brisbane City Council (BCC) utility building with unlikely development prospects. The lot bordering Wren Street, however, has a development approval for a nine-story hotel, similar in height to the existing Stage 1 building. Nevertheless, the presence of the BCC building between the ICB and the approved hotel including a larger setback from the road, adds to the variation in streetscape and building roughness.

On the eastern side of the ICB, while the commercial building along O'Connell Terrace share similar height with the Clem7 Vent building, a two-storey warehouse within the vent's lot disrupts the visual continuity, creating a more varied streetscape on this side.

Figure 10.20 to **Figure 10.23**, illustrate the streetscape variation mentioned above.

Figure 10.20: Existing Building to the North Across Campbell Street

Figure 10.21: Existing Buildings to the South

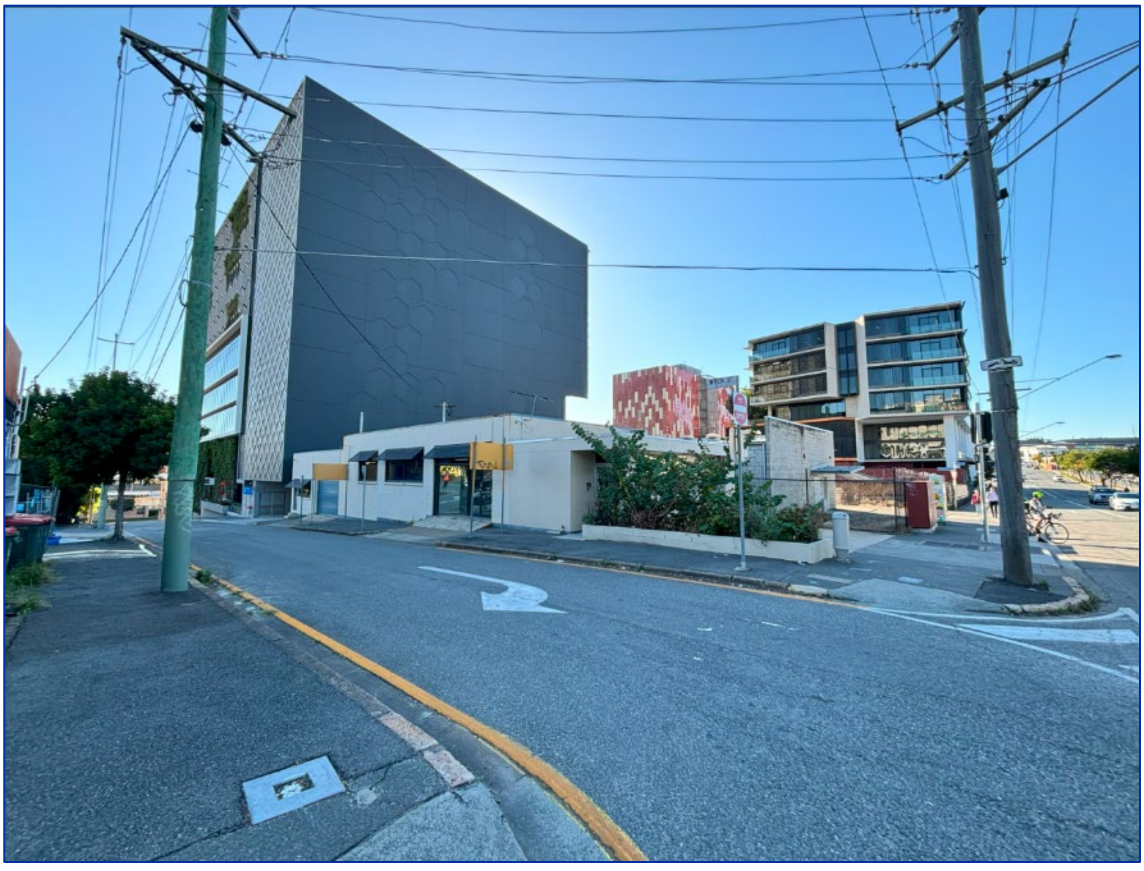
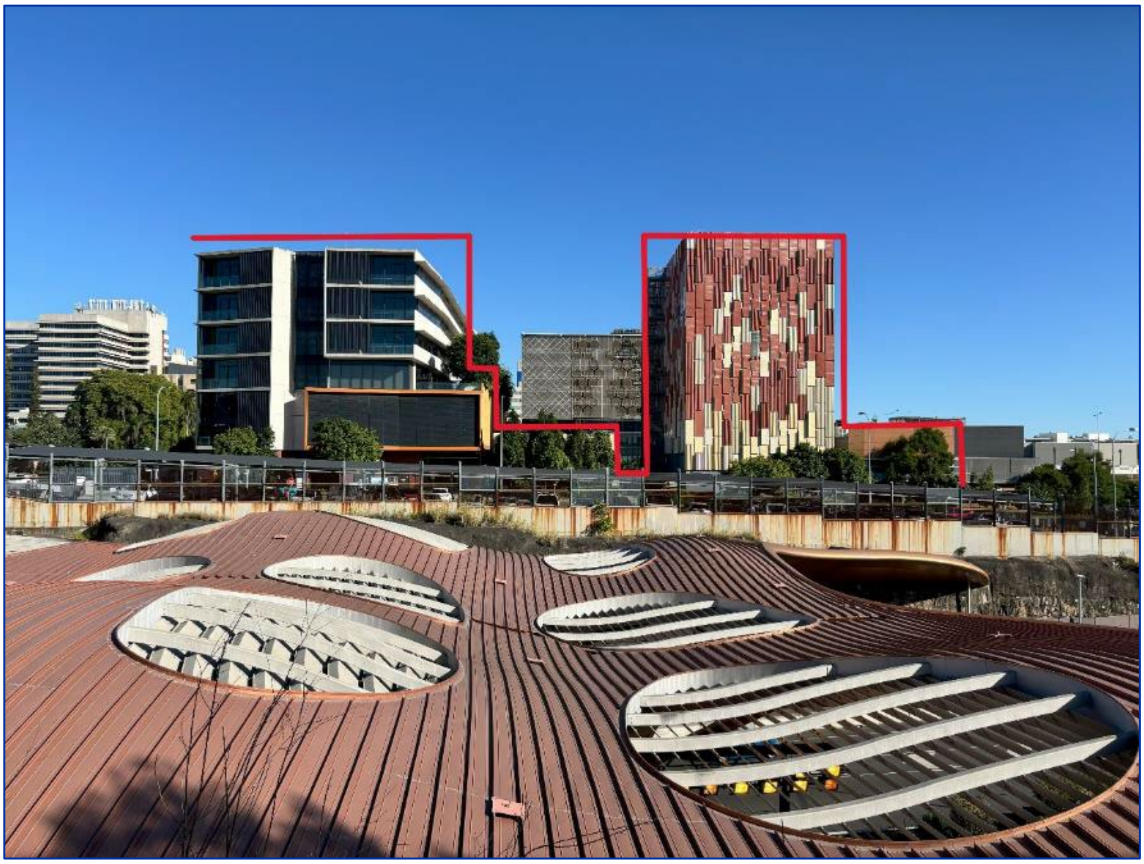


Figure 10.22: Existing Buildings to the East Across the ICB

Figure 10.23: Existing Buildings East of the ICB (Clem7 Tunnel View)



10.5.3 Vegetation

The presence of an existing bike path limits the available space for significant vegetation between the road and the building. Consequently, to avoid any potential interference with the bike path, no new plantings are proposed on the ICB side. However, the existing vegetation will be maintained. **Figure 10.24** and **Figure** 10.25 show the existing vegetation and bike path location. **Figure 10.26** shows the lack of space between the ICB and the development to include additional vegetation.

The existing vegetation is substantial enough to cover a significant portion of the Stage 2 podium, enhancing turbulence and pollutant dispersion in the area.

Figure 10.24: Existing Vegetation Plan

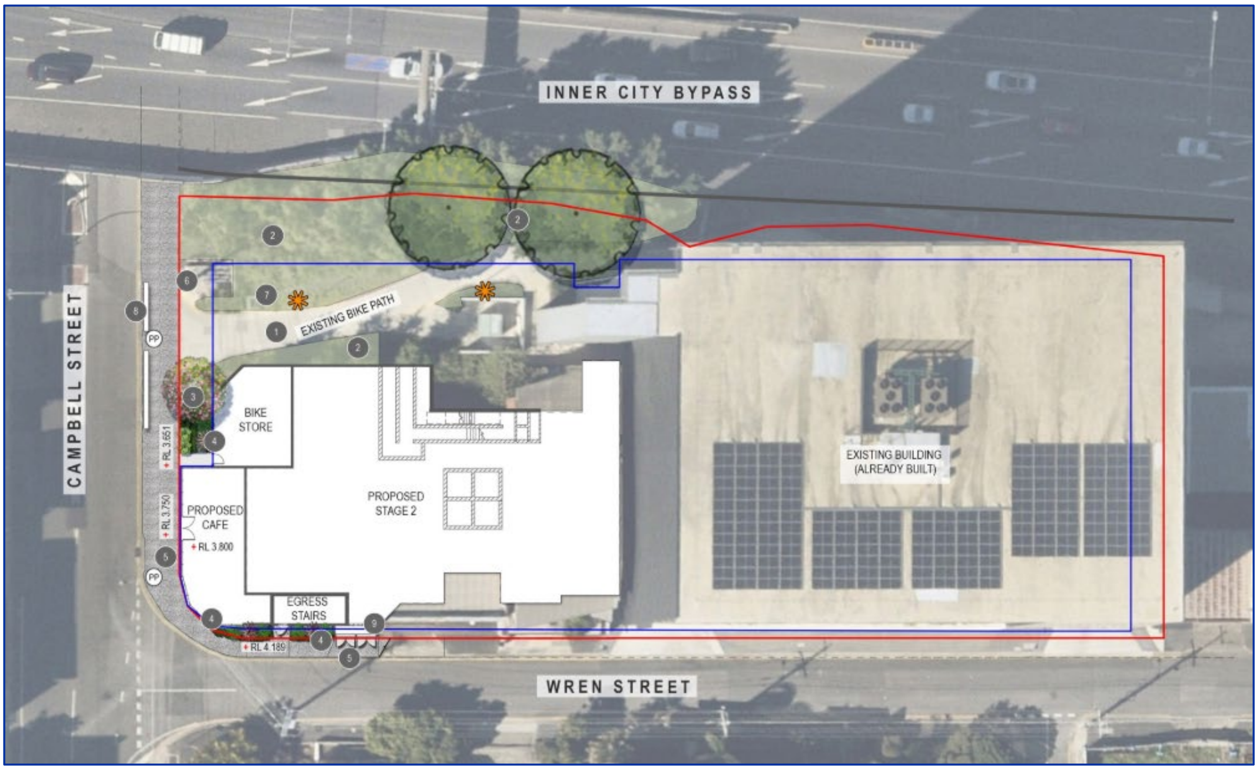


Figure 10.25: Existing Vegetation

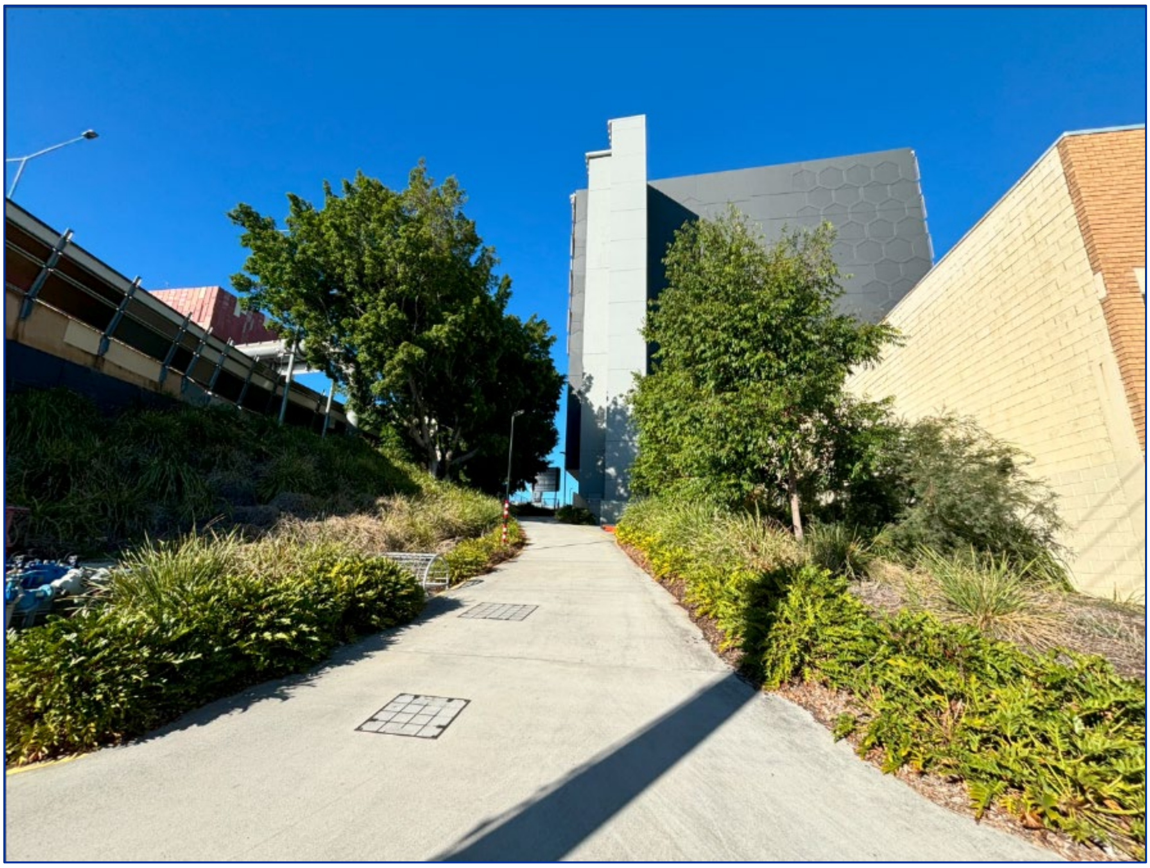
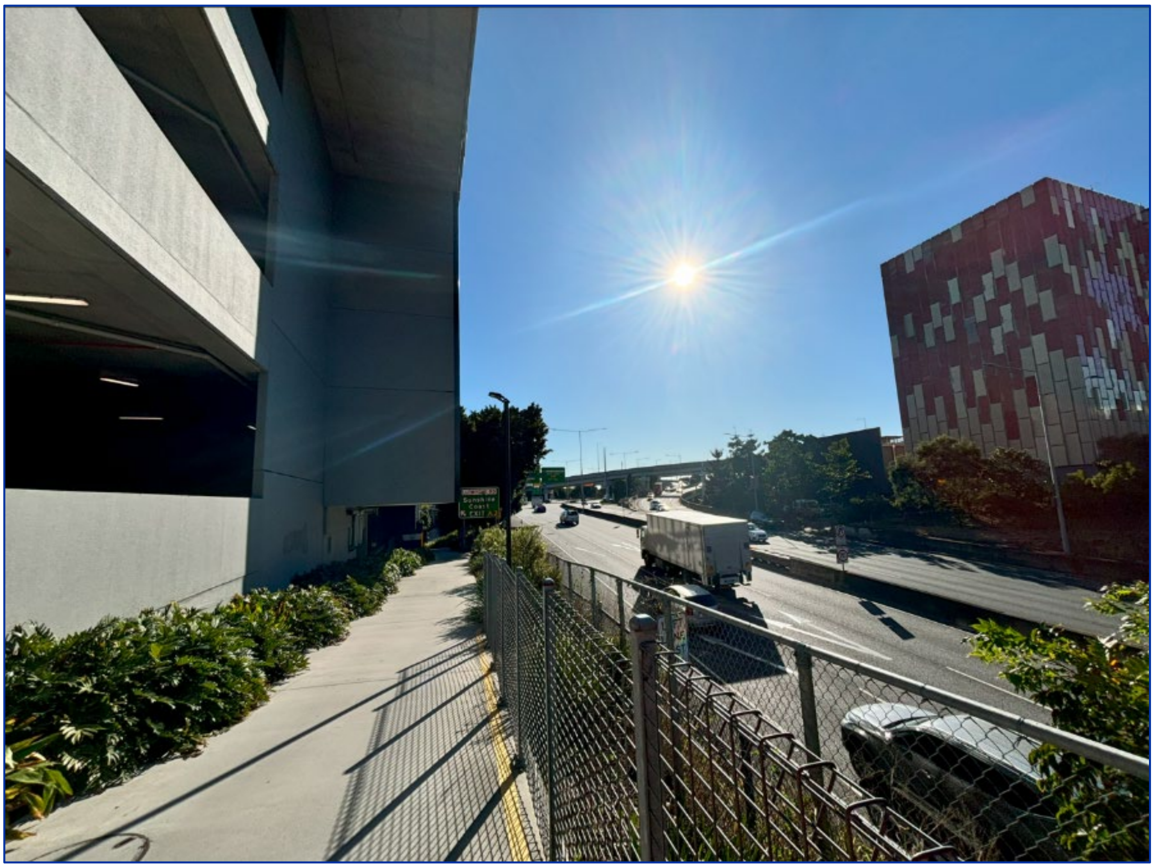


Figure 10.26: View from the Bike Path Between the ICB and Proposed Development



11. RECOMMENDATIONS AND CONCLUSIONS

An air quality assessment has been conducted for the proposed multiple dwelling development to be located at 7-15 Wren Street, Bowen Hills. As required by EDQ, the assessment addresses the PO1, PO3 and PO4 in the Transport Air Quality Corridor Overlay Code and PO2 of the Industrial Amenity Overlay Code.

The findings of the assessment are as follows:

- PO1 of Transport Air Quality Corridor A:
  - The nearest residential unit on Level 11, complies with AO1 and PO1. These units are located well above the minimum separation distance of 10 metres from the road. Therefore, there are no requirements for mechanical ventilation or filtration.
  - **Recommendation 1:** Although not mandatory according to the BCC City Plan 2014, installing mechanical ventilation systems in accordance with AS 1668.2, with outdoor air intakes at least 25 and 10 metres away (horizontally and vertically) from the kerb OR filtration systems with a minimum performance standard of F6 or minimum efficiency reporting value (MERV) 9 to ensure good indoor air quality. Refer to **Section 10.2** for further details.
- PO3 of Transport Air Quality Corridor B – built form requirements:
  - The building height and setback triggered the need for a detailed assessment against PO3.
  - Street canyon effects are unlikely to occur due to the varying heights of surrounding buildings and gaps in the streetscape.
  - The overall building design has sufficient roughness elements on the outside to promote turbulence and mixing of air.
  - Other buildings along the ICB are either low or well separated.
  - While additional vegetation between the proposed building and the ICB is not feasible due to space limitations, the existing vegetation is substantial enough to cover a significant portion of the Stage 2 podium, enhancing turbulence and pollutant dispersion in the area.
- PO4 of Transport Air Quality Corridor C:
  - GRAL air dispersion modelling has been completed to predict pollutant concentrations at the on-site and off-site sensitive receptors.
  - P04(a) – on-site impacts:
    - The modelling predicts compliance with the air quality criteria for all pollutants and averaging periods assessed at all on-site receptor locations.
  - P04(b) – off-site impacts:
    - For the off-site receptors, compliance with the air quality goals for NO_2, PM_{10} (24-hour), $PM_{2.5}$ (24-hour) is predicted at all off-site receptors.
    - A number of off-site receptors exceed the PM_{10} and $PM_{2.5}$ annual average concentrations with and without the Project. However, the results demonstrate a negligible change in the number of receptors exceeding the air quality goals with and without Project.
    - At receptors where exceedances are predicted, the increase in PM_{10} and $PM_{2.5}$ annual average concentrations associated with vent emissions and due to the Project are very low (typically less than 0.07 µg/m^3 for PM_{10} and 0.02 µg/m^3 for $PM_{2.5}$). The majority of increases in vent concentrations at these off-site receptors can be categorised as improvement, no change or negligible.
- PO2 of Industrial Amenity Overlay code:
  - The development complies with the air quality criteria outlined in the Industrial Amenity Overlay code, thereby meeting the requirements of PO2 of the code.

Based on the assessment, the proposed development site represents a suitable location for the proposed development, and achieves the requirements of the Transport Air Quality Corridor Overlay Code.

12. REFERENCES

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APPENDIX A GLOSSARY

Parameter or Term	Description
Conversion of ppm to mg/m^3	Where R is the ideal gas constant; T, the temperature in Kelvin (273.16 + T°C); and P, the pressure in mm Hg, the conversion is as follows: mg/m^{-3} = (P/RT) x Molecular weight x (concentration in ppm) $= \frac{P \times \text{Molecular weight} \times (\text{concentration in ppm})}{62.4 \times (273.2 + T°C)}$
g/s	Grams per second
mg/m^3	Milligrams per cubic metre
$\mu g/m^3$	Micrograms per cubic metre
Ppb	Parts per billion
Ppm	Parts per million
PM_{10}, $PM_{2.5}$, PM_1	Fine particulate matter with an equivalent aerodynamic diameter of less than 10, 2.5 or 1 micrometres respectively. Fine particulates are predominantly sourced from combustion processes. Vehicle emissions are a key source in urban environments.
99.5th Percentile	The value exceeded 99.5% of the time
CO	Carbon monoxide.
NO_x	Oxides of nitrogen – a suite of gaseous contaminants that are emitted from road vehicles and other sources. Some of the compounds can react in the atmosphere and, in the presence of other contaminants, convert to different compounds (eg, NO to NO_2).
NO_2	Nitrogen dioxide.
VOC	Volatile Organic Compound/s. These compounds can be both toxic and odorous.
Odour Unit	One odour unit (ou) is the number of dilutions required for a sample of odour to reach the odour intensity at which a panel of qualified people can just detect it. Refer to AS 4323.1:2001.

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