Central Barangaroo Concept Plan MOD 9

Air Quality Impact Assessment

31-Oct-2023
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Air Quality Impact Assessment

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Executive Summary

An Air Quality Impact Assessment (AQIA) was prepared by AECOM to assess the potential impact associated with the proposed modification (Mod 9) to the Concept Plan (MP06_0162). Key modifications to the Concept Plan include:

- An increase in total GFA permissible on the Central Barangaroo site;
- Provision of GFA allowable within the total Barangaroo site to reflect spaces which are not currently included in the Barangaroo Concept Plan approval (MOD 11)
- Modification to the approved building envelopes of Block 5, 6 and 7 for additional height, and flexibility in the delineation between the blocks and the distribution of GFA across the blocks;
- A re-adjustment of the Block 5 site and building envelope towards the alignment prior to the MOD 8 approval, whilst providing building setbacks to both Barangaroo South and Hickson Park.
- Modification to the approved building envelopes of Block 5, 6 and 7 for additional height, and flexibility in the delineation between the blocks and the distribution of GFA across the blocks.
- Consequential amendments to the State Significant Precincts SEPP to supports modifications to the Barangaroo Concept Plan (MOD 9) - Central Barangaroo; and
- Revised Statement of Commitments.

Following a review of the proposed modification and current staging plan of the Central Barangaroo development a qualitative impact assessment was undertaken to identify the likely potential impacts to air quality at nearby existing and future sensitive receptors during construction and operation.

For MOD 9 potential dust generating impacts (and associated minor impacts from soil contaminants) during construction; particularly during excavation activities pose the greatest potential air quality impacts from the project to nearby receptors. There is also the potential for minor cumulative impacts associated with construction of Harbour Park and Barangaroo Reserve. As for previous Development Applications for Barangaroo dust generating impacts from individual development applications within the Central Barangaroo site would need to be assessed in accordance with the EP&A Act. The level of assessment would be dependant on the nature of the works involved at the detailed Development Application stage.

Other potential air quality impacts during construction would include combustion from mobile and stationary plant equipment which may be managed appropriately by maintaining equipment and using standard management practices. There is also the potential for minor odour impacts during operation of the water treatment plant.

Potential operational impacts may include minor air quality impacts from commercial properties and vehicle emissions from traffic generating development, particularly along Hickson Road and to a smaller extent Barangaroo Avenue. These may be managed with appropriate planning and design considerations. Current traffic generation estimates predict are slightlylower vehicle numbers for the proposed modification when compared to previous estimates for Mod 10 for two way AM and PM Peak hour traffic forecasts (ARUP 2019 cited in ARUP 2021). The concept plan also allows for the provision of large landscaped areas and green roofs which would have potentially beneficial impact on local air quality by reducing air pollutant concentrations through both direct and indirect pathways.

In conclusion provided that a detailed AQIA for each individual Development Applications specific to the Central Barangaroo is undertaken and appropriate project-specific mitigation strategies are implemented, no adverse effects on local air quality are expected to occur as a result of the proposed modifications to the Concept Plan.

1.0 Introduction

1.1 Background

Barangaroo is a globally recognised 22 hectare urban renewal project located on the western waterfront of Sydney's Central Business District (CBD).

As Australia's first carbon neutral urban precinct, Barangaroo showcases world-class sustainability, whilst delivering extensive new foreshore public spaces on Sydney Harbour, international design excellence, the implementation of leading technologies and public art and cultural programs.

- The *Barangaroo Delivery Authority Act 2009* was established in March 2009 to ensure management and compliance of Barangaroo in achieving the following objectives: Encourage the development of Barangaroo as an active, vibrant and sustainable community and as a location for national and global business;
- Create a high-quality commercial and mixed-use precinct connected to, and supporting, the economic development of Sydney;
- Facilitate the establishment of Barangaroo Reserve and public domain land;
- Promote the orderly and sustainable development of Barangaroo, balancing social, economic and environmental outcomes; and
- Create in Barangaroo an opportunity for design excellence outcomes in architecture and public domain design.

Infrastructure NSW (INSW) was established in July 2011 to assist the NSW Government in identifying and prioritising the delivery of critical public infrastructure for NSW. As of 1 July 2019, INSW is the State Government agency responsible for the development of Barangaroo and management of its public spaces.

1.2 Barangaroo Concept Design

The original environmental assessment requirements for the overall Barangaroo renewal project were issued in June 2006 (MP06_0162) and the original Concept Plan for the redevelopment of Barangaroo was approved in February 2007 by the Minister for Planning.

The Barangaroo Concept Plan creates a development framework of streets and development blocks that can deliver a future mix of commercial, residential, tourist, retail and community uses, whilst dedicating approximately 50% of the 22 hectare site for new public open space or public domain, on or close to the harbour foreshore. The approved Barangaroo Concept Plan has since been modified a number of times and the most recent approved modification is MOD 11 approved on 22 October 2020.

- The Barangaroo Concept Plan defines three distinct precincts referred to as *Barangaroo South, Central Barangaroo and Barangaroo Reserve*. These three precincts together form the overall mixed use development framework as approved under Modification 11 to Barangaroo Concept Plan (MP10_0048 MOD 11) comprise the following: *A mixed use development involving a maximum gross floor area (GFA) of 602,354 sqm, comprised of:*
    - *A maximum 191,031 sq.m of residential GFA of which a maximum of 154,000sqm will be in Barangaroo South.*
    - *A maximum of 76,000sq.m of GFA for tourist uses, of which a maximum of 59,000sqm will be in Barangaroo South.*
    - *A maximum of 34,000sq.m of GFA for retail uses, of which a maximum of 30,000sqm will be in Barangaroo South.*
    - *A maximum of 5,000sq.m of GFA for active uses in the Public Recreation zone, of which 3,500sqm will be in Barangaroo South; and*
    - *A minimum of 12,000sq.m GFA for community uses.*

- *Approximately 11 hectares of new public open space/public domain, with a range of formal and informal open spaces serving separate recreational functions and including an approximate 2.2km public foreshore promenade.*
- *Built form design principles, maximum building heights and GFA for each development block within the mixed-use zone*
- *Public domain landscape concept, including parks, streets and pedestrian connections.*
- *Alteration of the existing seawalls and creation of a partial new shoreline to the harbour.*

Within the Central Barangaroo precinct, Blocks 5, 6 and 7 of the approved Barangaroo Concept Plan provide for future mixed use development, located west of Hickson Road to the east of foreshore land to be dedicated for new public open space and a continuous waterfront promenade.

The Section 75W Modification to the Approved Concept Plan for Barangaroo (Mod 9) was initially commenced in 2014 and recommenced in 2020. The Mod 9 application was submitted in 2021 and proposed a GFA increase of 144,355m^2 for Blocks 5, 6 and 7 (above and below ground). Following the submission of Mod 9 the proposed modification has been modified reducing the GFA by 40,355m^2. A description of the proposed amendments are provided in Section 1.3.

1.3 Project Description

This modification application (MOD 9) seeks consent for modifications to the approved Barangaroo Concept Plan MP06_0162 (as modified by MOD 11) in relation to Central Barangaroo, Barangaroo Reserve (Cutaway only) and Barangaroo South (Barton Street and Hickson Park only).

MOD 9 results in modification to approved Concept Plan for Blocks 5, 6 and 7, updates to the Instrument of Approval and Statement of Commitments, and amendments to State Environmental Planning Policy (Precincts – Eastern Harbour City) 2021 (PEHC SEPP) as it applies to Barangaroo.

Following exhibition of the project from 12 July 2022 to 8 August 2022, MOD 9 has been refined by the project team. Extensive engagement has occurred with the Department of Planning and Environment (**DPE**) and Government Architect NSW (**GANSW**) to review key elements of the project including scale of built form compatibility, open space and public amenity.

Overall, it introduces a more simplified building envelope at a reduced and respectful scale to the surrounding heritage context, including additional public domain offering and the deletion of the previously proposed 20 storey tower as a response to submissions.

A summary of the changes is provided in **Table 1**.

Table 1 Comparison of Changes

Component	Approved	Exhibited	Amended	Change**
Overall Development Area				
Project area	22ha	22ha	22ha	None
Maximum Envelope Height				
Block 5	34	RL 44.5	RL 42.45	Reduced by 2.05
Block 6	29	RL 38.7	RL 35	Reduced by 3.7
Block 7	35	RL 73.7	RL 35	Reduced by 38.7
Gross Floor Area				
Residential	191,031m^2	190,031m^2 (1,000m^2 reduction)	237,031m^2 (46,000m^2 increase)	Increased by 47,000m^2
Tourist	76,000m^2	76,000m^2	76,000m^2	None
Retail	34,000m^2	71,800m^2	44,766m^2	Reduced by 27,034m^2

Component	Approved	Exhibited	Amended	Change**
		(37,800m^2 increase)	(10,766m^2 increase)	
Active	5,000m^2	5,000m^2	5,000m^2	None
Community	10,000m^2 2,000m^2 within development Blocks 6 and 7	Up to 19,000 max 2,800m^2 within development Blocks 5, 6 and 7 (800m^2 increase)	Up to 19,000 max 2,800m^2 within development Blocks 5, 6 and 7 (800m^2 increase)	None
GFA distribution	Block 5 - 29,688m^2 Block 6 - 3,000m^2 Block 7 – 15,000m^2	Flexible distribution and allocation permitted for all buildings in Blocks 6, 7 and 8 (below and above ground)	Flexible distribution and allocation permitted for all buildings in Blocks 6, 7 and 8 (below and above ground)	Control retained
Wintergardens	Not applied to Blocks 5, 6 and 7	Wintergardens to be excluded for the maximum residential and commercial GFA for Blocks 5, 6 and 7.	Wintergardens to be excluded for the maximum residential and commercial GFA for Blocks 5, 6 and 7.	Control retained
Building overhangs	None	A building overhang up to 3m wide located above ground level, and/or façade articulation elements up to 650mm wide above ground level	None	Control deleted
*Amendments compared against the current Concept Approval (Approval column) **Changes compared between the exhibited project (Exhibited column) and the amended project (Amended column)				

1.3.1 Modified Concept Plan Development Description

The modifications to the approved Concept Plan require amendments to Schedules of the Instrument of Approval, including the development description and relevant conditions of consent. The Instrument of Approval was last modified as part of MOD 11 on 22 October 2020.

As a result of the amendments previously outlined, the Condition ‘A1 Development Description’ of the approved Concept Plan for Barangaroo (MP06_0162) will be modified by MOD 9, as follows:

*(1) A mixed-use development involving a maximum of ~~602,354~~ **667,686 sqm** gross floor area (GFA), comprised of:*

- *(a) a maximum of ~~191,031~~ **237,031 sqm** of residential GFA of which a maximum of 162,031 sqm will be in Barangaroo South;*
- *(b) a maximum of 76,000sqm of GFA for tourist uses of which a maximum of 59,000 sqm will be in Barangaroo South;*
- *(c) a maximum of ~~34,000~~ **44,766 sqm** of GFA for retail use of which a maximum of 30,000 sqm will be in Barangaroo South;*
- *(d) a maximum of 5,000sqm of GFA for active uses in the Public Recreation zone of which 3,500 will be in Barangaroo South; and*
- *(e) a minimum of ~~12,000~~ **19,000sqm** GFA for community use.*

The exhibited MOD 9 application proposed a GFA of 144,355m^2 for Blocks 5, 6 and 7 (above and below ground). The amended MOD 9 application reduces this by 40,355m^2, resulting in a revised GFA of 104,000m^2 (above and below ground

1.3.2 Modified Concept Plan

The key elements that make up the amended Concept Plan are summarised below in Table 2 and revised building layout and heights are provided in Figure 1 and Figure 2 below.

Table 2 Modified Concept Plan

Element	Description
Land Use	
Uses	Mixed-use development including retail, tourist, community, commercial and shop top housing
GFA	
Above Ground Below Ground Total	Maximum 92,908m^2 Maximum 11,092m^2 Maximum 104,000m^2 (with a maximum 75,000m^2 for residential)
Heights	
Block 5	RL 22, RL 35 and RL 42.45
Block 6	RL 35
Block 7	RL 35

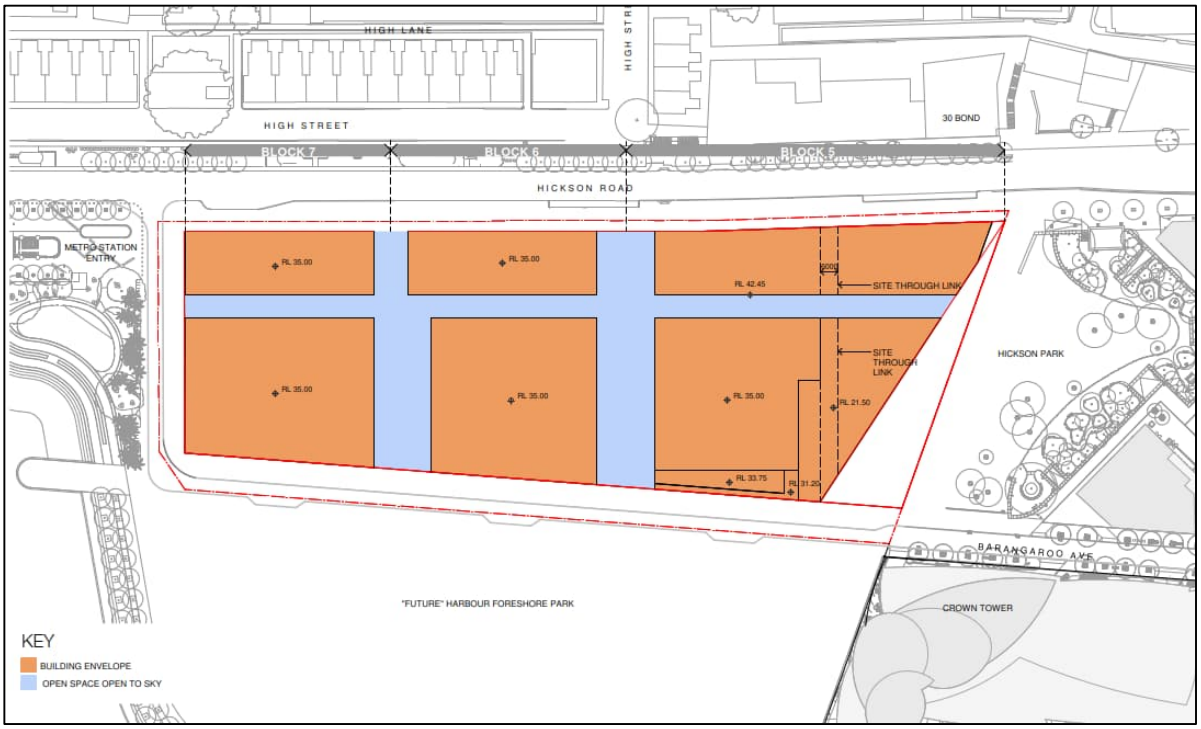

Figure 1 Revised Building Layout

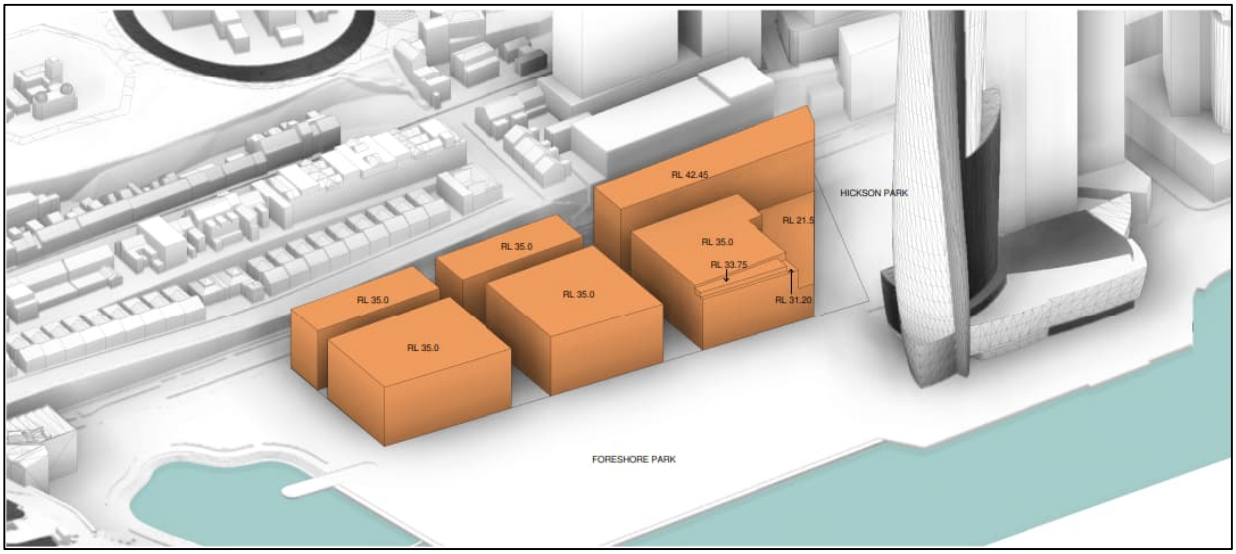

Figure 2 Revised Building Heights

1.3.3 Summary of Concept Plan Refinements Post Exhibition

A summary of the amendments since exhibition is provided below:

GFA Amendments

- Reduced total GFA permissible within Blocks 5, 6 and 7 from 144,355m^2 to 104,000m^2,
- Reduced below ground GFA from 28,166m^2 to 11,092m^2,
- Increased maximum residential component cap from 28,000m^2 to 75,000m^2, and
- No change to the Cutaway GFA uses of up to 24,000m^2.

Building Envelope Amendments

- Removal of the tower element at Block 7 at RL 73.7,
- Reduced building height with the tallest element located on Block 5 at RL 42.45,
- Amendments to the overall dimension and footprint of Blocks 5, 6 and 7 including new pedestrian connections open to the sky,
- Deletion of building cantilever elements into public domain,
- Refinements to the interface of Block 5 and Hickson Park, and
- Simplified building height and massing across the entire site with only three heights proposed to minimise visual impacts from Observatory Hill and Millers Point.

Open Space and Public Domain Amendments

- Increased provision of publicly accessible open space when compared to the approved Concept Plan,
- New north-south pedestrian link with a minimum width of 8m and open to the sky to facilitate visual links from Hickson Park to Nawi Cove,
- Expanded east-west pedestrian connections, known as Plaza North and Plaza South up to 20m wide and open to the sky,
- New east-west arcade between Blocks 5 and 6 with a minimum width of 6m, and
- Additional allowance for deep soil zones across the site.

Traffic and Access Amendments

- Retain Barangaroo Avenue as a one-way shared street, and

- Deletion of Barton Street as a proposed permanent street.

Statutory and Development Control Amendments

- Amendments to the SEPP mapping and provisions to align with amended building envelope GFA, building heights and land uses,
- Removal of proposed SEPP amendment to allow GFA to extend 25m into the RE1 Public Recreation zone below ground level,
- Removal of proposed SEPP amendment to allow building facades to extend by an additional 3m above ground and the 650mm façade articulation zone,
- Amended Design Excellence Strategy to be largely consistent with PEHC SEPP, and
- Amended Urban Design Guidelines to reflect amended building envelope outcomes,

1.3.4 Reference Scheme

The amended project is supported by a revised reference scheme, which demonstrates a proof-of-concept outcome that can be accommodated within the amended building envelopes. This includes consideration of potential basement layouts, access and loading arrangements, land use distribution and mix and typical floorplate layouts.

A summary of the potential land use outcomes and built form of the reference scheme is provided below.

Element	Description		
Land Use/GFA	**Above Ground**	**Below Ground**	**Subtotal**
Residential	67,219m^2	2,581m^2	69,800m^2
Retail	10,420m^2	4,346m^2	14,766m^2
Hotel	14,841m^2	1,057m^2	15,898m^2
Community	428m^2	2,372m^2	2,800m^2
Commercial	736m^2		736m^2
Total	**92,908m^2**	**11,092m^2**	**104,000m^2**
Building Program			
Block 5	Three buildings ranging from 4, 8 and 10 storeys including food and beverage, hotel and residential uses		
Block 6	Two buildings at 8 storeys including ground level community, retail and upper level residential uses		
Block 7	Two buildings at 8 storeys including ground level retail and upper level residential uses		
Basement	Vehicular entry via Hickson Road to three levels of basement containing community, recreation and retail uses and back of house. Integration with Barangaroo Metro Station Concourse via Metro Escalators into Block 7 (exact location to be confirmed in detailed applications)		
Open Space and Public Domain (within site boundary)			
Hickson Park Promenade	1,434m^2		
12 x 20m plazas (Plaza North and Plaza South)	3,231m^2		
8m north-south link (open to the sky)	1,785m^2		

Element	Description
6m east-west lane (partial open to the sky)	489m^2
Total	**6,939m^2**

The reference scheme is not subject to approval in MOD 9. The ultimate detailed design and mix will be the subject of future State Significant Development Applications (**SSDAs**) across the site. **Figure 3** provides the indicative project layout.

Figure 3 Indicative Project Layout

1.4 Project Objectives and Scope

AECOM Pty Ltd (AECOM) were commissioned to provide a qualitative air quality impact assessment (AQIA) to address the air quality and odour requirements of the Director General Requirement 14 (DGRs) issued for Mod 9 to the Barangaroo Concept Plan (MP06_0162) in 2021. Following the amendments to MOD 9 the air quality assessment has been revised to account for changes to the proposed modification.

The air quality assessment has been undertaken in accordance with the following documents:

- *Protection of the Environment Operations (Clean Air) Regulation 2010* (NSW);
- *The Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (EPA 2017) (The Approved Methods);
- *Assessment and Management of Odour from stationary sources in NSW, Technical framework (and notes)* (DEC 2006); and

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- *Institute of Air Quality Management: Guidance on the assessment of dust from demolition and construction* (IAQM 2014)

The project scope includes:

- Description of the proposed modification
- Identification of ambient air quality and odour criteria as listed under the Approved Methods (EPA 2017)
- Description of the existing environment including:
  - Local meteorology and climate;
  - Existing air quality
  - Terrain and land use including identification of future and existing nearby sensitive receptors.
- A qualitative assessment of the potential air quality impacts from construction including:
  - Potential dust impacts during construction using the UK IAQM 2014 guidance document;
  - Potential air quality impacts from combustion;
  - Potential air quality impacts from airborne contaminants in the soil from dust generating activities; and
  - Potential odour impacts from treatment of groundwater.
- A qualitative assessment of potential operational impacts including:
  - Potential impacts from traffic generating development and commercial industries;
  - Beneficial impacts from inclusion of green roofs.
- Discussion and recommendations of potential air quality impacts including:
  - Any safeguard measures to manage or mitigate potential air emissions from proposed works; and
  - Any additional assessment requirements that may be required for further development application within Central Barangaroo including identification of relevant legislation and guidance documents as listed under DGR 14.

1.5 Acknowledgment of Country

We would like to acknowledge the Gadigal people who are the Traditional Custodians of this land. We would also like to pay respect to the Elders both past and present of the Eora Nation and extend that respect to all Aboriginal people.

2.0 Site Background and Air Emission Sources

2.1 Barangaroo Site History and Contamination

2.1.1 Site History

Between 1820 and 1930 Barangaroo was used for wharf and port related uses. Coupled with operation of the previous Millers Gas Works and uncontrolled filling have resulted in contamination of local soil and ground water.

The EPA Declaration Area refers to a portion of land underneath Hickson Road between addresses 30-34 and 38 Hickson Road the northern area of Barangaroo South and the areas known as Block 4 and Block 5. In May 2009, the EPA determined that this portion of land was contaminated in such a way as to present a significant risk of harm to human health and the environment. As a consequence, the EPA declared the area to be a remediation site (Declaration Number 21122; Area Number 3221) under the *Contaminated Land Management Act 1997*. Formerly the site to which this declaration relates is part of the former Millers Point gasworks and is described as:

- Part Lot 5 and Part Lot 3 in Deposited Plan (DP) 876514, Hickson Rd, Millers Point
- The part of Hickson Road adjacent to:
    - 30 – 34 Hickson Road being Lot 11 DP1065410,
    - 36 Hickson Road being Lot 5 DP873158 and Lot 12 DP1065410; and
    - 38 Hickson Road being SP72797, Millers Point

On 18 December 2015 the Department of Planning and Environment approved a Development Application (SDD 14_6533) lodged by Lend Lease to remediate the portion of the Declaration Area known as Block 5 and adjacent areas which forms part of Central Barangaroo. Block 5 remediation work was completed in February 2020 and NSW EPA determined that the site had been successfully remediated, formally ending the declaration in June 2020. This includes the southern end of the basement on Block 5 that extends into a portion of the former Declaration Area that has been remediated and validated to a depth of 10m below existing ground levels.

2.1.2 Contamination post completion of declaration area

Following completion of the remediation of the Former Declaration area it was identified that by EDP Consultants Pty Ltd (EDP) in October 2020 that under the MOD 9 concept plan further excavation of the Block 5 site may encounter some minor localised tar deposits still present in deep fill, marine sediment or fractured bedrock below a depth of 10m (EDP 2020).

A waste classification assessment at the proposed Central Barangaroo site (EDP 2023) of the in-situ material for the proposed basement footprint within Block 5, 6 and 7 would require bulk excavation. The in-situ assessment targeted a proposed excavation depth of 15.5m below ground level with borehole samples collected to a depth approximately 1m below the proposed final depth, or into sandstone.

A total of 104 borehole samples were taken between July and November 2022. Representative soil samples along the soil profile were collected from each borehole and submitted to a National Association of Testing Authorities (NATA) accredited labourites for analysis of potential contaminants of concern. Field observations noted fill material was observed across the entirety of the site with no discernible soil horizons or homogenous regions. Generally, there was no visible evidence of soil staining, discolouration or oily patched but hydrocarbon odour was noted from slight to high intensity across the site.

The potential contaminants of concern identified for the assessment of the proposed Central Barangaroo site included:

- Total petroleum hydrocarbons (TPH),
- Benzene, toluene, ethylbenzene, xylenes and Naphthalene (BTEXN),
- Polycyclic aromatic hydrocarbons (PAH),

- Heavy metals (arsenic, cadmium, chromium, copper, mercury, lead, nickel and zinc)
- Asbestos

A summary of the results and distribution of contaminants from the waste classification assessment (EDP 2023) are provided in Table 4.

Table 3 Results and Distribution of Contaminants of Concern (EDP 2023)

Pollutant	Discussion
TPH	• Six of 1,285 samples (<1%) returned values exceeding relevant soil concentration criteria of 10,000 mg/kg. • Exceedances were found at a depth of 7-13m below ground level; located at the southern end of the site where tar was visually observed.
BTEXN	• Seven of 1,285 samples (<1%) returned values exceeding relevant soil concentration criteria of 18 mg/kg. • Exceedances were located at the southern end of the site where tar was visually observed.
PAH (as BaP)	• Of 1,285 samples, 25 of samples (approximately 2%) returned values exceeding relevant soil concentration criteria of 10 mg/kg. • Exceedances were spread across the site and into the natural soil profile at depths ranging from 0.5-16.5m below ground level with no clear pattern of distribution, with exception to the southern basement area where tar impact was observed.
Heavy metals	• No exceedances of soil criteria were observed for arsenic, cadmium, chromium and mercury. No criteria were set for copper and zinc. • Six of 1,285 samples (<1%) returned values exceeding relevant soil concentration criteria for lead of 1,500 mg/kg. Elevated concentrations for nickel were also observed in 73 of of 1,285 samples (approximately 5%). • Lead and nickel exceedances were observed generally throughout the fill with no clear pattern of distribution.
Asbestos	• Amosite, chrysotile and crocidolite asbestos was detected in 30 of the 1,232 samples collected throughout the fill layer with no clear pattern of distribution.

2.2 Excavation Activities and Waste Volumes

As part of the Waste Classification Report (EDP 2023) spoil material to be removed as part of the proposed basement excavation works was classified in accordance with the NSW EPA (2014) Waste Classification Guidelines and estimate spoil volumes based on the current basement design plans.

Section 2.2.1 and **Section 2.2.2** provide a description of the proposed excavation activities and estimated waste volumes as described in the Insitu Waste Classification Report (EDP 2023).

2.2.1 Excavation Activities.

Several areas would require excavation within the Central Barangaroo precinct to accommodate the north and south basement spanning Block 5, Block 6 and Block 7 as shown in **Figure 4**. The basement would be designed to a nominal depth of 15m below ground level (EPD 2023).

The total basement excavation footprint would be approximately 26,100m^2; with an expected volume of 387,000m^3 requiring offsite disposal (EDP 2023).

2.2.2 Waste Volumes

Waste estimates provided in the EDP 2023 report was based on total site area and volumes provided by Aqualand and classified using 2022 field observations and borehole analysis data. The in-situ fill and natural materials were classified as Special Waste (asbestos) conservative considered to be friable in nature. Waste was further classified based on their chemical nature into General Solid Waste (GSW), Restricted Solid Waste (RSW), Hazardous Waste (HW) and Special Waste (SW) in accordance with the NSW EPA (2014) Waste Classification Guidelines. A summary of estimated waste volumes by waste classification for each block is provided in **Table 4**.

Fill profiles were also anticipated to contain acid sulphate soils (ASS) and would require treatment with agricultural lime and neutralisation prior to off-site disposal.

Table 4 Waste Volume Estimates and Waste Classification (EDP 2023)

Waste Classification	Approximate Volume (m^3)	Hotspot Locations
Special Waste (asbestos) as General Solid Waste	373,800	Sitewide.
Special Waste (asbestos) as Restricted Solid Waste	8,400	Isolated hotspot areas both in the northern and southern basement areas.
Special Waste (asbestos) as Hazardous Solid Waste	4,800	Generally located within a small area at the southern end of the site immediately west of the former tar impacted area.

2.3 Project Staging and Construction

Key construction milestones for Central Barangaroo are provided in **Figure 4** with the proposed construction program expected to be completed by 2028. Key construction activities Construction stages identified worst case air quality impacts are likely to be experienced would be Stage 1 Basement North which is expected to be completed in 2028 and Stage 6 Basement South which is expected to be completed in 2029. Additional dust generation activities expected to occur would be during land scaping works associated with public domain works and from removal of Barton Street.

Other projects surrounding Central Barangaroo that have the potential to result in cumulative impacts are also shown in **Figure 4** and include Harbour Park, Barangaroo Metro Station and Barangaroo Reserve are discussed in detail in **Section 6.1** and **Section 6.3**.

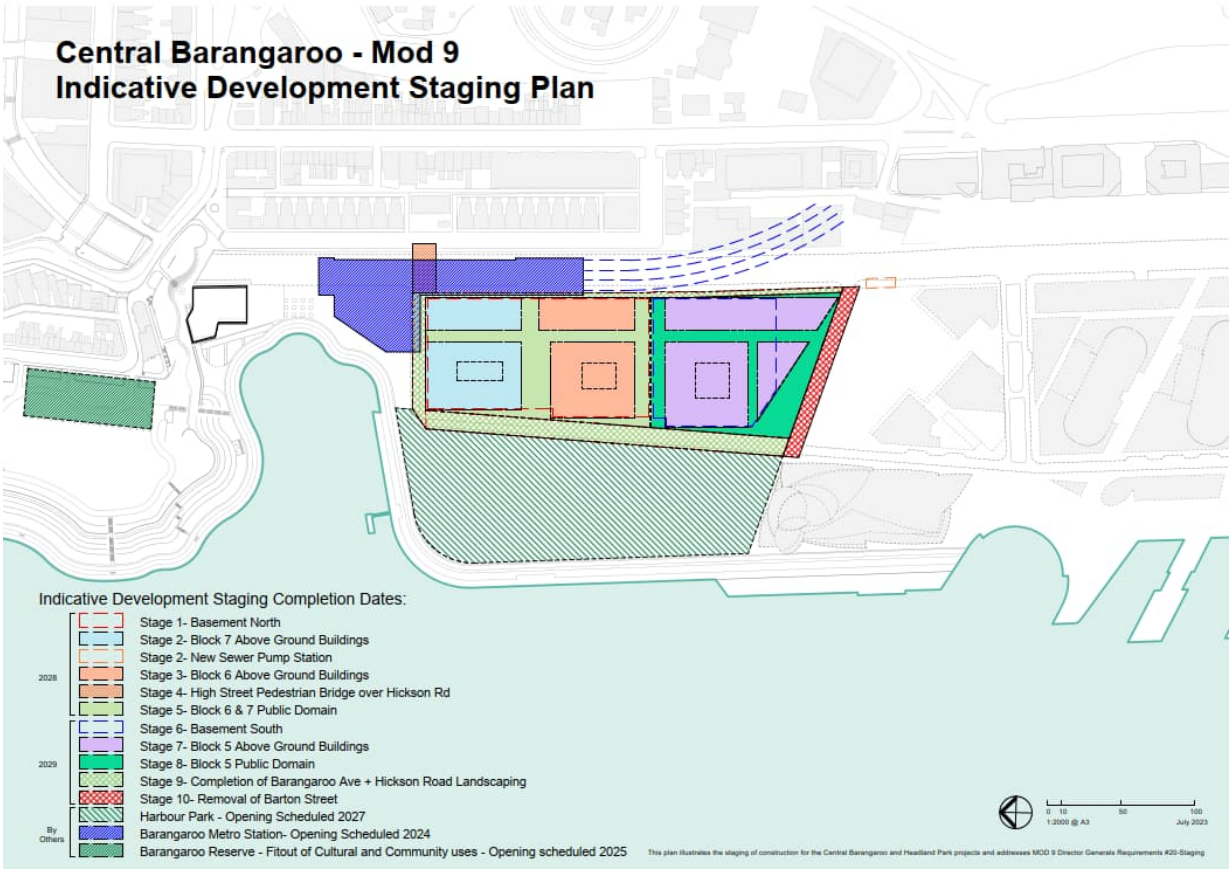

Figure 4 Central Barangaroo Mod 9 Indicative Development Staging Plan

2.4 Potential Air Emission Sources

The proposed work has the potential to generate air quality impacts from a number activities including:

- Potential construction impacts such as:
  - Dust emissions from excavation, materials handling and land forming activities,
  - Heavy metals detected within the soil may be released to the air attached to the dust,
  - Dust emissions and other airborne contaminants associated with onsite remediation works of contaminated spoil (if required),
  - Combustion emissions from mobile and plant equipment during construction; and
  - Odour impacts from exposure of soil contaminants during excavation activities and treatment of contaminated ground water during excavation
- Potential operational impacts including:
  - Increased vehicle emission from traffic generating development
  - Minor emissions associated with commercial activities; and
  - Beneficial air quality effects from implementation of green roofs.

For consistency; with previous air quality impact assessments conducted within Barangaroo South (e.g. AECOM 2013, AECOM 2014) the following pollutants are considered to be of interest for the assessment of the Central Barangaroo site[1] (although it is noted that many of these pollutants will not be present due to the expected completion of the remediation of the Barangaroo South area):

- Total suspended particulates (TSP),
- Particulate matter equal to or less than 10 microns in diameter (PM_{10}),
- Particulate matter equal to or less than 2.5 microns in diameter ($PM_{2.5}$),
- Oxides of Nitrogen (NO_x),
- Benzene, toluene, ethylbenzene, xylenes and Naphthalene (collectively as BTEXN),
- Phenol,
- Heavy metals (cadmium, chromium VI, copper, lead, mercury, nickel, zinc) attached to TSP,
- Benzo(a)pyrene; and
- Odour.

Potential air emissions for construction and operation from the development of Central Barangaroo have been assessed in **Section 6.1** and **Section 6.2** of this report respectively. Predicted impacts in **Section 6.0** based on the existing Concept Plan provide a holistic overview of potential air quality impacts for Central Barangaroo with the intent of identifying potential air quality impacts requiring further impact assessment at the Development Application (DA) Stage(s) (see **Section 7.4**). Where proposed individual Development Applications would occur simultaneously or coincide with nearby development these would also need to be taken into consideration.

[1] Asbestos was not assessed in this AQIA. Management of asbestos encountered on the site would be in accordance with the site Asbestos Management Plan to be prepared for the works, which may include monitoring of site works

3.0 Assessment Criteria

3.1 Ambient Air Quality Criteria

As discussed in **Section 2.4** major contributing air pollutants from the existing and proposed operations would include combustion products, dust and soil contaminants. **Table 5** summarises the NSW EPA's impact assessment criteria as detailed in the *NSW Approved Methods for Modelling and Assessment of Air Pollutants in New South Wales* (EPA 2022) for the pollutants included in the assessment. In general, these criteria relate to the total burden of air pollutants in the air and not just the air pollutants from project-specific sources. Therefore, some consideration of background levels needs to be made when using these criteria to assess impacts. A discussion of background levels in the study area is provided in **Section 5.3**.

Table 5 EPA Impact Assessment Criteria – Combustion Products, Dust and Soil Contaminants

Pollutant	Averaging Period	Criteria (µg/m^3)
Combustion Products and Dust		
Nitrogen dioxide (NO_2)	1 hour	164
	Annual	31
Total suspended particulates (TSP)	Annual	90
Particulate matter (PM_{10})	24 hours	50
	Annual	25
Fine Particulate Matter ($PM_{2.5}$)	24 hours	25
	Annual	8
Soil Contaminants		
Arsenic	1 hour	0.09
Benzene	1 hour	29
Beryllium	1 hour	0.004
Cadmium	1 hour	0. 018
Chromium VI	1 hour	0.009
Copper (dust and mist)	1 hour	0.018
Cyanide	1 hour	90
Ethylbenzene	1 hour	8,000
Lead	Annual	0.5
Manganese	1 hour	18
Mercury (organic)	1 hour	0.18
Naphthalene	1 hour	440*
Nickel	1 hour	0.18
Phenol	1 hour	20
Polycyclic aromatic compounds (PAHs) (as benzo[α]pyrene)	1 hour	4
Toluene	1 hour	360
Xylenes	1 hour	190
Zinc (as zinc chloride fumes)	1 hour	18

Pollutant	Averaging Period	Criteria (µg/m^3)
*As adopted for previous Barangaroo assessments undertaken by AECOM (e.g. AECOM 2013, AECOM, 2014, AECOM 2014a, AECOM 2014b). Criterion is equivalent to the odour threshold for naphthalene.		

3.2 Odour Criteria

The perception of odour is based on an individual's response to chemical exposure. The odour threshold is the theoretical minimum concentration of a chemical that produces an olfactory response, which, in practice, is used to indicate whether an odour is detectable; the odour threshold defines 1 odour unit (1 OU) for each chemical. The threshold relates to odour detection and does not consider the recognition of an odours character.

The EPA's odour assessment criteria for complex mixtures of odorous air pollutants (EPA 2022) are shown in **Table 6**. These criteria take into account individual sensitivity to odour in the community and use a statistical approach for determining the appropriate criterion for a particular site based on the size of the surrounding population. As population size increases, the likelihood of sensitive individuals being within that population also increases; as such, areas with larger populations require more stringent criteria.

Table 6 EPA Impact Assessment Criteria – Complex Odours

Population	Criteria (OU)*
Urban (≥ ~2000) and/or schools and hospitals	2
~ 500	3
~ 125	4
~ 30	5
~ 10	6
Single residence (≤ ~2)	7
*99th percentile nose response time	

Central Barangaroo is located within the urban environment on the western edge of Sydney's CBD. Based on the proximity and density of existing sensitive receptors on Hickson Road and Barangaroo South and future receptors within Barangaroo an odour assessment criterion of 2 OU would be applicable for this assessment. This is consistent with the criterion adopted for all Barangaroo South AQIAs.

4.0 Existing Environment

The existing environment has the potential to influence the level of air pollutants adjacent to a particular site. Aspects of the ambient environment relevant to this assessment include:

- Existing air quality due to regional and local sources of air pollution (natural and anthropogenic) that emit similar air pollutants as those being assessed; and
- Meteorological conditions and terrain features.

The following sections provide a description of the existing air quality and general meteorology of the study area.

5.0 Local Meteorology

Meteorology in the area surrounding the resource recovery centre is affected by several factors such as terrain and land use. Wind speed and direction are largely affected by topography at the small scale, while factors such as synoptic scale winds affect wind speed and direction on the larger scale. Wind speed and direction are important variables in assessing potential air quality impacts, as they dictate the direction and distance air pollutant plumes travel.

5.1.1 Observation Data

The Bureau of Meteorology (BoM) operates a network of meteorological monitoring stations around the country. The closest station to the site is located at Observatory Hill approximately 0.7km east of Central Barangaroo. Observatory Hill monitoring station also has long term wind speed and wind direction data collected between 1955 and 1992. Wind speed and wind direction are no longer recorded at this station due to removal of the site's anemometer in April 1992. The next closest monitoring station operated by BoM is at Fort Denison, located approximately 2.2km to the north east of Central Barangaroo.

Closer than the BoM Fort Denison station is the DPIE operated Cook and Phillip Sydney CBD air quality monitoring station commissioned on the 6th September 2019. The station is located at the north-western corner of Cook and Philip park approximately 1.5km southeast of the site. The station was installed as temporary measure to measure air quality within the CBD while NSW Public Works overseas the construction of a permeant station nearby. The station also measures wind speed, wind direction, temperature and humidity. A review of 12 months of data between December 2019 and November 2020 resulted in an annual average wind speed of 0.6 m/s and a maximum wind speed of 3.5 m/s. This is likely attributed to the sheltered location of the monitoring station and is therefore likely to underpredict local wind speeds as such data for this assessment has been sourced from the BoM monitoring station at Fort Denison, located approximately 2.2km to the north east of Central Barangaroo.

Given the proximity of the BoM Fort Denison station to the Barangaroo development it is considered representative of local meteorological conditions at Barangaroo at the macro scale. Due to the high-density urbanised environment micro-meteorological conditions are likely to be highly influenced by surrounding development. The large proportion of nearby high-rise buildings and associated high aspect ratios of nearby roads are likely to have a significant influence on local wind fields at a micro-level. This is further discussed in **Section 6.1.1.4** in relation to urban canyons.

Annual and seasonal wind roses for the Fort Denison monitoring station showing wind speed and wind direction data recorded between 2012 and 2021 are presented in **Figure 5** to **Figure 6**. It can be seen from **Figure 5** on an annual basis, west to west north westerly winds occur most frequently. The annual average wind speed is moderate at 4.3 metres per second (m/s) and calm conditions (wind speeds of less than 0.5m/s) occur less than one percent of the time. The high occurrence of westerly winds indicates that sensitive receptors along Hickson Road are more likely to be susceptible to air quality impacts during construction works (refer to **Section 6.1**).

During autumn through to spring the dominant wind direction is from the west to west northwest, with a high frequency of northeast to easterly winds also occurring during spring. During the winter months the predominant wind direction is from the northwest (refer to **Figure 6)**. Similar to the annual trend seasonal average wind speeds are also moderate with only small changes observed seasonally. Seasonal average wind speeds were found to be 4.4m/s with exception to autumn which was slightly

lower at 4.1m/s. Calm conditions seasonally were generally below one percent but were slightly higher in spring at 1.9%.

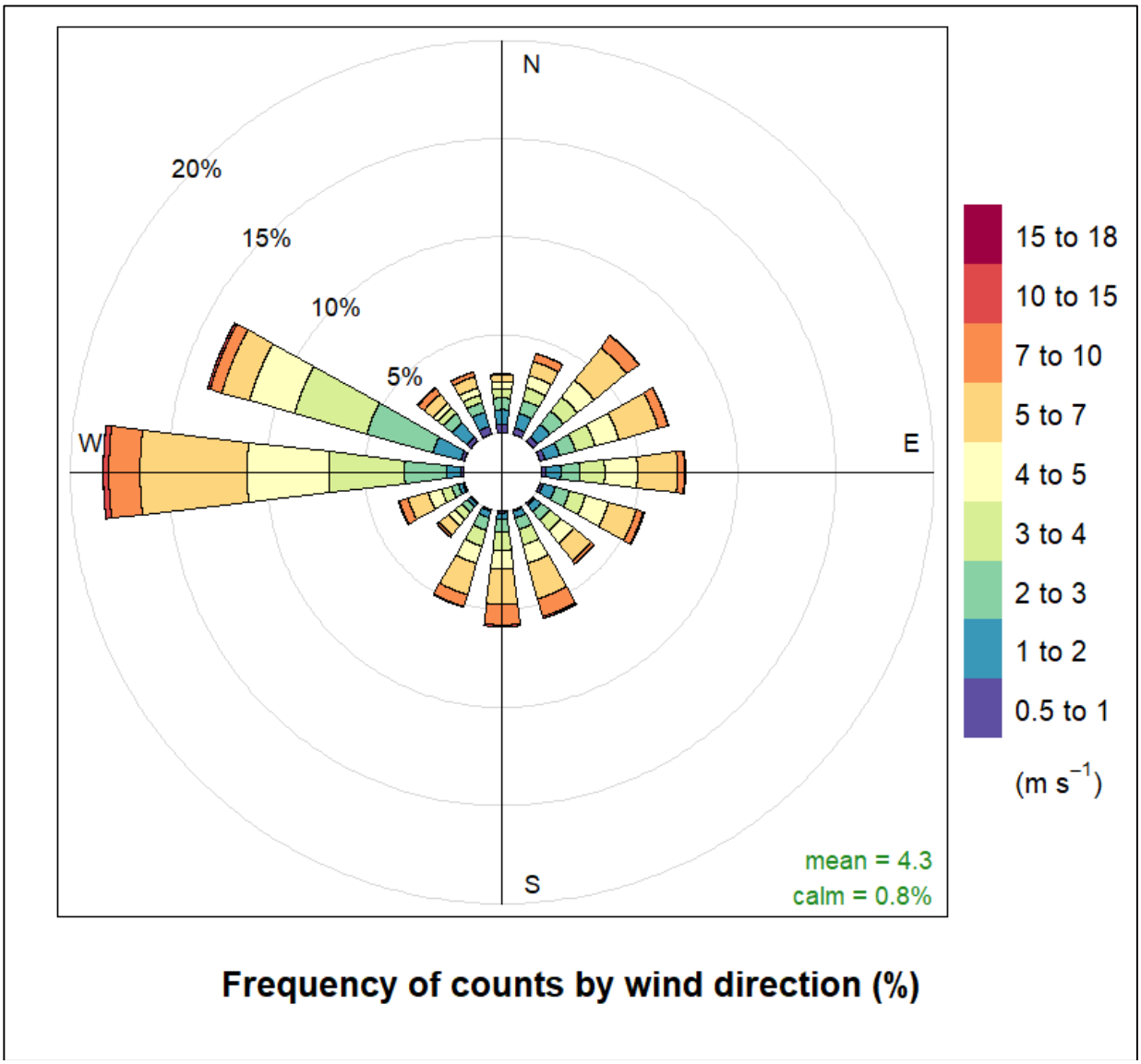

Figure 5 BoM Annual Wind Roses for Fort Denison (2012 to 2021)

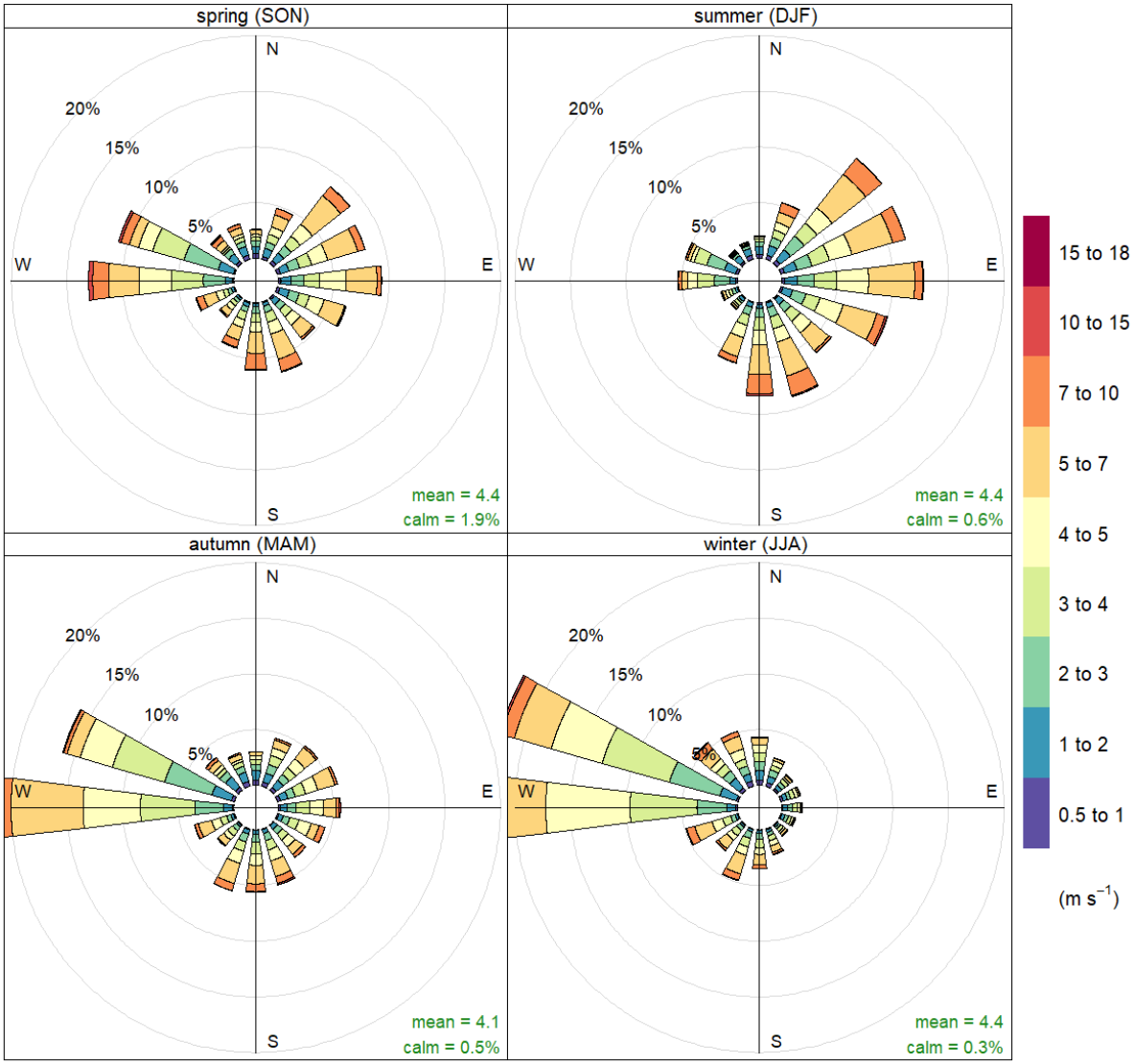

Figure 6 BoM Seasonal Wind Roses for Fort Denison (2012 to 2021)

5.1.2 Meteorological Modelling Data

In the absence of site-specific data, the meteorological model GRAMM was used to provide 2022 prognostic data for the Central Barangaroo site. Meteorological modelling data for the assessment was based on observational data from several Bureau of Meteorology (BOM) monitoring stations in the eastern Sydney region for 2022. Monitoring stations included:

- Fort Denison
- Canterbury Racecourse
- Mascot
- Sydney Olympic Park
- North Head

In accordance with GRAMM assessment methodology approved by the NSW Chief Scientist, the GRAMM Match to Observation (MTO) function was used along with observed and synthetic meteorological data set to predict the meteorological conditions in the Sydney Region. Meteorological modelling inputs presented in **Appendix A** and also includes a comparison with Sydney Airport BoM data, which was examined in the Pedestrian Wind Assessment for the proposal (RWDI 2023)

Annual and seasonal wind roses for Central Barangaroo wind speed and wind direction meteorological modelling data from GRAMM for 2022 are presented in **Figure** 7 and Figure 8. **Figure** 7 shows that on an annual basis, westerly winds occur most frequently which is similar to data recorded for Fort Denison as discussed in **Section 5.1.1**. The predicted annual average wind speed at Central Barangaroo was found to be a light to moderate 3.0 m/s with calm conditions were found to occur 7.1% of the time. The high occurrence of westerly winds indicates that sensitive receptors to the east of Hickson Road are more likely to be susceptible to air quality impacts during construction works (refer to **Section 6.1**).

Seasonal meteorology showed that during autumn and winter, the dominant wind direction is from the west. During spring and summer, north north-easterly winds are more common, with southerly winds also occurring frequently during summer. Seasonal average wind speeds were light to moderate, which was similar to the annual trend for wind speed. Seasonal average wind speeds were found to range from 2.5 m/s in autumn and 3.3 m/s in summer. Calm conditions seasonally were generally higher in autumn at 10.5%.

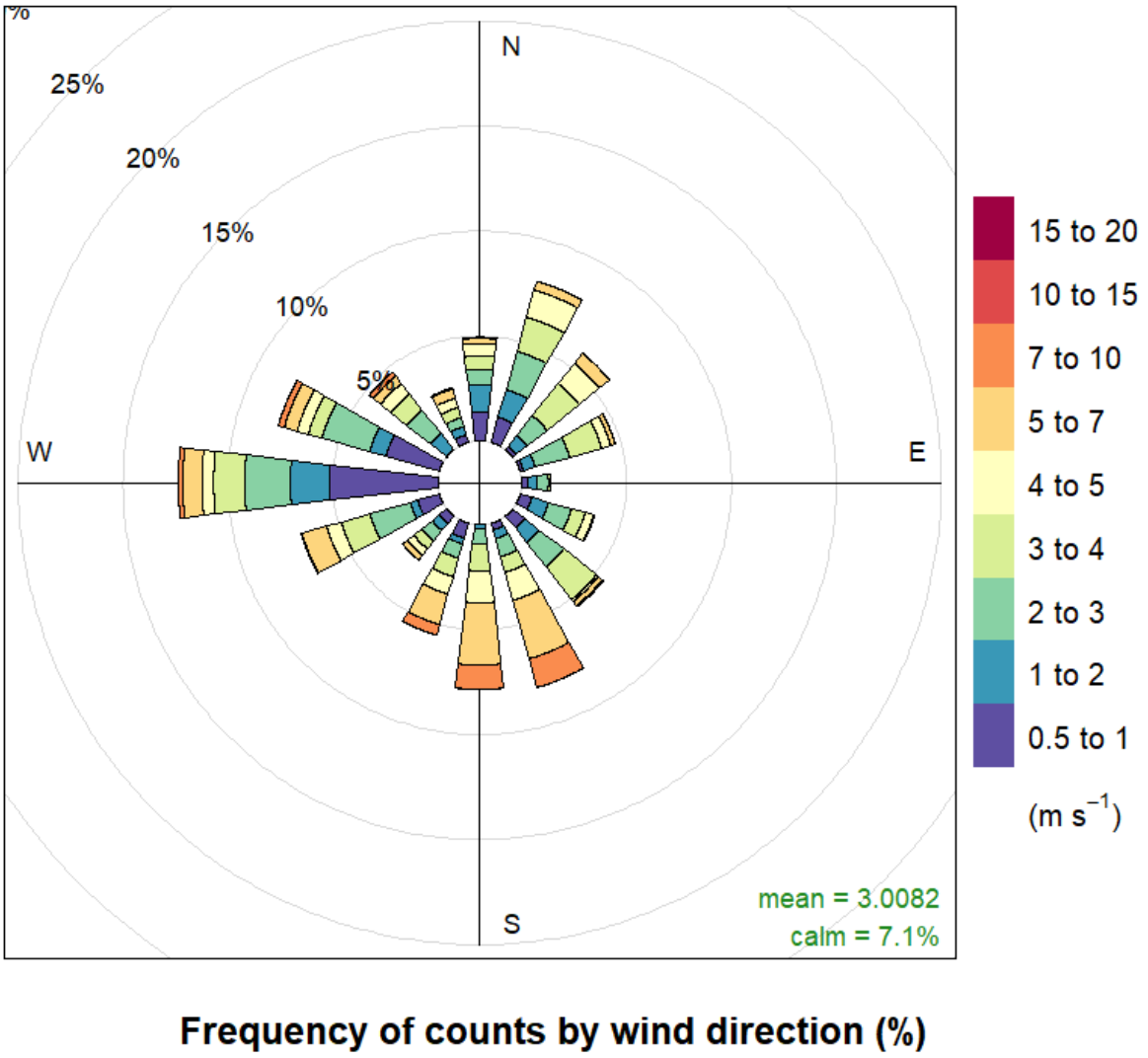

Figure 7 GRAMM Annual Wind Rose for Central Barangaroo (2022)

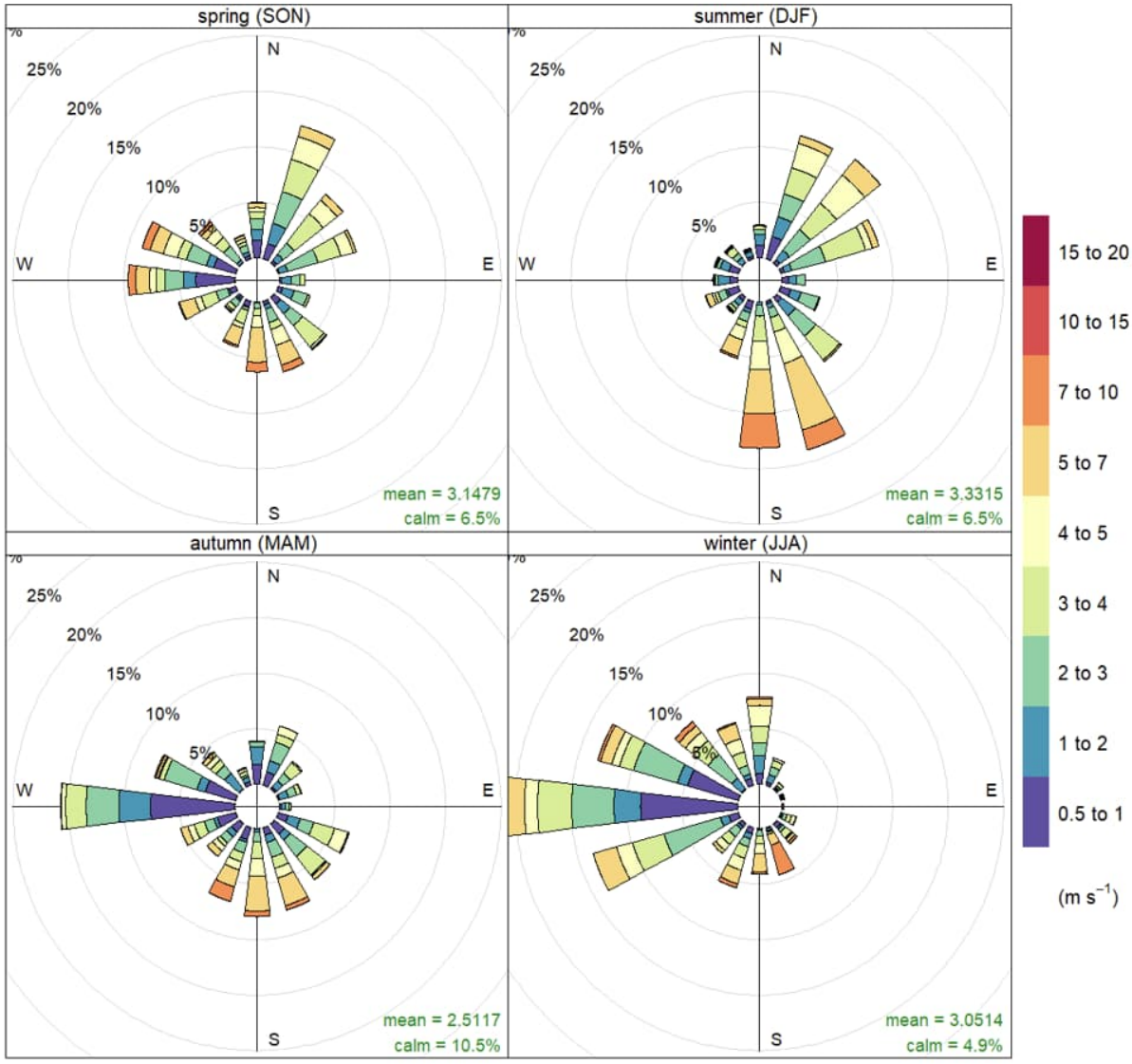

Figure 8 GRAMM Seasonal Wind Roses for Central Barangaroo (2022)

5.2 Climatic Conditions

The BoM meteorological station at Observatory Hill records climate data for a range of meteorological parameters including, temperature, humidity, rainfall, wind speed and wind direction. Temperature, humidity and rainfall data are currently collected at Observatory Hill, while wind speed and wind direction data for the monitoring location have only been recorded up until April 1992 when the sites site anemometer was decommissioned. A summary of the long-term data recorded at this station between 1955 and August 2020 is shown in Table 7when the site was decommissioned. The data provide an indication of the regional climate of the area. Long term wind roses for Observatory Hill are provided in **Appendix A**.

Table 7 Climate Summary, BOM Monitoring Station at Observatory Hill, 1955 to 2020

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean maximum temperature (°C)	26.0	25.8	24.8	22.5	19.5	17.0	16.4	17.9	20.1	22.2	23.7	25.3
Mean minimum temperature (°C)	18.8	18.9	17.6	14.8	11.6	9.3	8.1	9.0	11.1	13.6	15.7	17.6
Mean rainfall (mm)	102	119	132	127	117	133	96	80	68	77	84	77
Decile 5 (median) rainfall (mm)	78	94	102	95	90	103	72	55	52	55	67	60
Mean number of days of rain ≥ 1 mm	9	9	10	9	9	9	7	7	7	8	8	8
Mean number of clear days	7	5	7	9	10	9	12	13	11	8	6	7
Mean number of cloudy days	13	13	13	11	11	11	9	8	9	11	13	13
Mean 9am temperature (°C)	22.5	22.3	21.1	18.2	14.6	11.9	10.9	12.5	15.7	18.5	19.9	21.6
Mean 9am relative humidity (%)	71.0	74.0	74.0	72.0	74.0	74.0	71.0	66.0	62.0	61.0	66.0	67.0
Mean 9am wind speed (km/h)	8.6	8.2	7.9	8.8	10.5	11.9	13.1	13.3	12.4	12.2	11.0	9.8
Mean 3pm temperature (°C)	24.8	24.9	24.0	22.0	19.4	16.9	16.4	17.5	19.2	20.7	22.1	23.8
Mean 3pm relative humidity (%)	62.0	64.0	62.0	59.0	57.0	57.0	51.0	49.0	51.0	56.0	58.0	59.0
Mean 3pm wind speed (km/h)	17.9	16.8	15.2	13.8	12.7	13.6	15.3	17.6	18.3	19.1	19.4	19.5

As shown in **Table 7**, the warmest temperatures occur during the summer months, with the highest average maximum temperature (26.0ºC) occurring in January. July is the coldest month, with a recorded average minimum temperature of 8.1ºC. June is the wettest month, with an average rainfall of 133 millimetres, while September is driest month with an average rainfall of 68 millimetres. Humidity follows a diurnal cycle, with higher humidity in the morning compared to the afternoon. Wind speeds are higher in the afternoon compared to the morning, with the highest average wind speeds occurring in December (19.5 km/h).

5.3 Existing Air Quality

5.3.1 EPA Background Air Quality Data

The DPIE operates a network of air quality monitoring stations around the state. The closest station is the Cook and Philip Sydney CBD air quality monitoring station. This station has been operational since September 2019 and data has been reported below for the last three years between 2020 and 2022. It is noted however due to the high level of particulates in the summer of 2019-2020 caused by bushfires; followed by a reduction in ambient pollutant concentrations in 2020 due to reduced activity such as vehicle emissions as a result of Covid-19. Therefore the year 2020 data is not considered representative of typical background concentrations. The location of the DPE Cook and Phillip Station is shown in **Figure 9**.

Figure 9 Location of DPE Cook and Phillip Ambient Air Quality Monitoring Station

Satellite imagery sourced from Google Earth 2023.

Ambient pollutant concentrations recorded at this station between 2020 and 2022 has been reported below in

Table 8. Monitoring data recorded during this period show:

- Annual average TSP concentrations are below the criterion of 90 µg/m^3 with the highest average of 39.3µg/m^3 recorded at in 2020,
- Annual average concentrations for PM_{10} and $PM_{2.5}$ recorded were below EPA criteria for all monitored years.
- Exceedances were recorded for 24-hour average PM_{10} and $PM_{2.5}$ for all monitored years since 2020. Specifically:
  - For PM_{10} the following exceedances were noted:
    - There were 23 exceedances of the 24-hour average occurred in 2023, 11 exceedances in 2020, 2 exceedances in 2022.
    - The highest recorded maximums for each year below the criterion of 50µg/m^3 were 47.9µg/m^3 in 2020, 48.6µg/m^3 for 2021 and 44.6µg/m^3 in 2022.
  - For $PM_{2.5}$ the following exceedances were noted:
    - There were 45 exceedances of the 24-hour average occurred in 2020, 25 exceedances in 2021 and five in 2022.
    - The highest recorded maximums for each year below the criterion of 25µg/m^3 were 24.7µg/m^3 in 2020, 24.8µg/m^3 for 2021 and 24.6µg/m^3 in 2022.
  - A large proportion of exceedances of the 24-hour criterion in 2020 were likely attributed to bushfire events. The Cook and Philip Sydney CBD air quality monitoring station is likely also likely to experience temporary elevated dust levels from construction activities as it is cited to monitor NSW Public Works.

The maximum 1 hour and annual average concentration for NO_2 µg/m^3 for 2020 to 2022 were below the respective criteria of 164µg/m^3 and 31 µg/m^3.

Table 8 Ambient Pollutant Concentrations, Cook and Phillip Monitoring Station (DPE 2023)

Pollutant	Averaging Period	Background Concentration (µg/m^3)			Criteria (µg/m^3)
		2020	2021	2022	
TSP[1]	Annual Average	39.3	33.5	24.8	90
PM_{10}	Maximum 24 Hour	258.3[2]	108	84.3	50
	Annual Average	15.7	13.4	9.9	25
$PM_{2.5}$	Maximum 24 Hour	224.7[2]	97.7	36.2	25
	Annual Average	7.8	6.4	4.3	8
NO_2	1 Hour Average	94.3	96.4	82.0	164
	Annual Average	16.4	14.4	12.2	31

Pollutant	Averaging Period	Background Concentration (µg/m³)			Criteria (µg/m³)
		2020	2021	2022	
1. Ambient TSP concentrations have not been monitored at Rozelle since 2004. As PM_{10} is a sub-component of TSP, the annual average concentration of PM_{10} along with the TSP:PM_{10} ratio can be used to calculate the expected background TSP concentration. A TSP:PM_{10} ratio of 0.4 has been used for the calculation of the TSP concentration. This is a common ratio for dust in NSW and is considered appropriate in the absence of recently monitored data. 2. Highly elevated PM_{10} and $PM_{2.5}$ concentrations; and large number of exceedances in 2020 were largely attributed to the black summer bushfires which occurred over the 2019-2020 summer and are not indicative of typical background concetrations.					

There are no known recent ambient air quality measurement studies undertaken in the immediate vicinity of the Project site that may be used to define the background concentrations of VOC's, PAHs or Heavy Metals. In addition, unless there are known significant sources of these pollutants in the environment surrounding a project, the pollutants need only be assessed in isolation and not considered cumulatively. On this basis, no background concentrations have been included in the assessment.

5.4 Terrain and Land Use

Barangaroo is bordered by Sydney Harbour on the northern and western sides and by Hickson/Sussex Streets to the east. The existing ground surface of Barangaroo is at an elevation of approximately 2 - 5 m (AHD). The surrounding landform (outside the bounds of the site) rises rapidly to the east, with a 10 m high sandstone cliff situated east of Hickson Road and Sussex Street. This is the most substantial natural terrain feature in the area; high rise buildings may potentially also affect wind patterns in the project site.

Sensitive receptors are identified by the EPA as anywhere someone works or resides or may work or reside, including residential areas, hospitals, hotels, shopping centres, playgrounds, recreational centres, and the like. Sensitive receptors associated with the site currently include:

- Residential and commercial receptors approximately 20m to the east of Block 5, 6 and 7 on the adjacent side of Hickson Road,
- Residential and commercial towers at Barangaroo South to the south of Block 5,
- The Barangaroo Guardian Early Learning Childcare Centre, located on Level 1 of Tower 1 on Barangaroo Avenue on the corner of Shipwright Walk and Hickson Road,
- Presence of low sensitivity receptors, where human exposure is transient such as footpaths and walkways within 20m of the project boundary.
- Receptors of high sensitivity associated with the Crown Sydney Hotel Resort located to the South Block (Block Y). The resort contains 350 rooms and suites as well as restaurants and retail outlets and is expected to be opened by early 2021
- Hickson Park adjacent to Block 5, which would be classified as a low sensitive receptor due to the transient nature of the land use (recreational).

6.0 Impact Assessment

6.1 Potential Construction Impacts

Section 6.1.1 to **Section 6.1.4** of this chapter provides an assessment of potential air quality impacts from construction that include:

- Dust emissions from excavation, materials handling and land forming activities,
- Heavy metals detected within the soil may be released to the air attached to the dust,
- Combustion emissions from mobile and plant equipment during construction; and
- Odour impacts from exposure of soil contaminants during excavation activities and treatment of contaminated ground water during excavation

It should be noted that worst case impacts from the site are likely to be experienced during excavation works; which are semi quantified in terms of potential dust impacts in **Section 6.1.1** and qualitatively assessed in terms of potential odour impacts in **Section 6.1.4**.

6.1.1 Potential Dust Impacts

6.1.1.1 Methodology Overview

A qualitative risk assessment of potential dust impacts on surrounding sensitive receptors has been undertaken for the construction phase. The assessment has been based on the methodology described in the UK Institute of Air Quality Management (IAQM) document, *Guidance on the assessment of dust from demolition and construction*. The risk of dust soiling and human health impacts due to particulate matter (PM_{10}) on surrounding areas were determined based on the scale of activities and proximity to sensitive receptors. The IAQM method uses a four-step process to assess dust impacts:

- Step 1: Screening based on distance to nearest sensitive receptors.
- Step 2: Assess risk of dust impacts from activities based on:
  - Scale and nature of the works, which determines the potential dust emission magnitude; and
  - Sensitivity of the area.
- Step 3: Determine site-specific mitigation for dust-emitting activities.
- Step 4: Reassess risk of dust impacts after mitigation has been considered.

6.1.1.2 Step 1: Screening Assessment

The IAQM method recommends further assessment of dust impacts for construction activities where sensitive receptors are located closer than:

- 350m from the boundary of the site.
- 50m from the route used by construction vehicles on public roads more than 500m from the site entrance.

There are several sensitive receptors located within 350m of the boundary of the Project site and therefore further assessment of dust impacts was undertaken for the Project.

6.1.1.3 Step 2: Risk Assessment of Unmitigated Impacts

6.1.1.3.1 Step 2A: Dust Emission Magnitude

Dust emission magnitudes are estimated according to the scale of works being undertaken and other considerations such as meteorology, types of material being used, or general construction methodology. The IAQM guidance provides examples to aid classification and these are presented in **Appendix B**.

Potential dust emission magnitudes for the Project were estimated based on the IAQM examples listed in **Appendix B**. Justification and the factors used in determining the magnitudes are presented in **Table 9**.

Table 9 Dust Emission Magnitudes in Accordance with IAQM Guidance

Activity	Potential Dust Emission Magnitude	Justification
Demolition	Small	• No demolition of buildings anticipated during construction. Removal of existing pavement and removal of onsite temporary sheds only. • Potential removal of dusty material (concrete) however no concrete crushing or screening onsite is anticipated. • Demolition activities <10m above ground. • Total material volume < 20,000m^3 (based on approximate slab area of 30,000 m^2 and slab thickness of 0.2m).
Earthworks	Large	• Proposed development footprint is approximately 30,000m^2, • Estimated total bulk waste volume of 387,000 m^3 • Excavation areas to include Block 5, Block 6, Block 7 and potentially underneath some retail and cultural. • Depth of excavation varies from RL-3 to RL-12 • Approximately an additional 20,000m^3 of fill to be required for land forming activities on Foreshore Blocks. • Approximately 5-10 heavy earth moving vehicles active at one time, including 30 tonne excavators • Average of 1200 m^3 of fill excavated and removed offsite per day.
Construction	Large	• 92,908 m^2 GFA of above ground primarily for Blocks 5, 6 and 7. • 11,092 m^2 GFA of below ground primarily within Blocks 5, 6 and 7. • 6939 m^2 of open space and public domain within the site boundary. • Total building volume >100,000m^3 for individual blocks (Block 5, 6 and 7) • Assumed no onsite concrete batching. • Assumed wide range of construction materials with variable dust generating potential, including concrete, steel, cladding and timber
Trackout	Large	• Estimated between 60-120 (>3.5t) outward truck movements per day during excavation of basement areas. • Outward truck movements during construction would include from delivery trucks, concrete agitators etc. • Access to site via paved road (Hickson Road), thus low potential for wheel generated dust accessing the site. • Potential for wheel generated dust from onsite vehicle during excavation and construction following removal of pavement.

6.1.1.3.2 Step 2B: Sensitivity of the Surrounding Area

The IAQM methodology allows the sensitivity of an area to dust soiling, human health impacts due to PM_{10}, and ecological effects to be classified as high, medium, or low. Surrounding vegetation within 100m from the bulk of dust-emitting activities are likely to take place is largely limited to street scaping on Hickson Road and the future Hickson Park south of Block 5. The sensitivity of the surrounding area due to ecological effects was therefore not assessed further. The classifications are determined according to matrix tables provided in the IAQM guidance document. Individual matrix tables for dust soiling and human health impacts are provided. Factors used in the matrix tables to determine the sensitivity of the surrounding area are described as follows:

- Receptor sensitivity (for individual receptors in the area):
  - High sensitivity – locations where members of the public are likely to be exposed to elevated concentrations of PM_{10} for eight hours or more in a day. For example, private residences, hospitals, schools, or aged care homes,
  - Medium sensitivity - places of work where exposure is likely to be eight hours or more in a day; and
  - Low sensitivity – locations where exposure is transient – i.e. one or two hours maximum. For example, parks, footpaths, shopping streets, playing fields.
- Ambient annual mean PM_{10} concentrations (only applicable to the human health impact matrix).
- Number of receptors in the area (categorised as 1-10, 10-100 or >100).
- Proximity of receptors to dust sources based on radii of 20m, 50m 100m and 350m from the source.

According to the IAQM guidance listed above, the overall sensitivity of the site to both dust soiling and human health impacts is classified as high. The justification for this classification is provided in **Table 10**. The assessment also takes into account that the Barangaroo area would be considered an area of high sensitivity due to past and ongoing localised dust generating activities at Barangaroo South and Sydney Metro Station.

Table 10 Sensitivity of the Area in Accordance with IAQM Guidance

Potential Impact	Sensitivity of the Area	Justification
Dust Soiling	High	• Area of high sensitivity due to existing dust generating activities at Barangaroo South and at Sydney Metro Station. **Receptors** • >100 receptors including residential (high sensitivity) and commercial (moderate sensitivity) to the east of Block 5, 6 and 7 on the adjacent side of Hickson Road < 20m of the project boundary. • >100 receptors including residential (high sensitivity) and commercial (moderate sensitivity) towers at Barangaroo South to the south of Block 5 < 350m of the project boundary. • Presence of low sensitivity receptors, where human exposure is transient such as footpaths < 20m of the project boundary. • Potential transient and medium sensitivity receptors associated with operation of Barangaroo Station once operational in 2024. • Receptors of high sensitivity associated with the Crown Sydney Hotel Resort located to the South Block (Block Y). The resort contains 350 rooms and suites as well as restaurants and retail outlets. • Hickson Park adjacent to Block 5, which would be classified as a low sensitive receptor due to the transient nature of the land use (recreational).

Potential Impact	Sensitivity of the Area	Justification
		Meteorological Conditions • The high occurrence of westerly winds (see Section 5.0) indicates that sensitive receptors along Hickson Road are more likely to be susceptible to air quality impacts during construction works
Human Health (PM_{10})	High	• Area of high sensitivity due to existing dust generating activities at Barangaroo South and at Barangaroo Station. • Annual average PM_{10} concentration in the area between 16µg/m^3 and 18µg/m^3 which is below the EPA criterion of 25 µg/m^3 (see Section 5.3) **Receptors** • >100 receptors including residential (high sensitivity) and commercial (moderate sensitivity) to the east of Block 5, 6 and 7 on the adjacent side of Hickson Road < 20m of the project boundary. • >100 receptors including residential (high sensitivity) and commercial (moderate sensitivity) towers at Barangaroo South to the south of Block 5 < 350m of the project boundary. • Presence of low sensitivity receptors, where human exposure is transient such as footpaths < 20m of the project boundary. • Potential transient and medium sensitivity receptors associated with operation of Barangaroo Station once operational in 2024. • Receptors of high sensitivity associated with the Crown Sydney Hotel Resort located to the South Block (Block Y). The resort contains 350 rooms and suites as well as restaurants and retail outlets. • Hickson Park adjacent to Block 5, which would be classified as a low sensitive receptor due to the transient nature of the land use (recreational). **Meteorological Conditions** • The high occurrence of westerly winds (see **Section 5.0**) indicates that sensitive receptors along Hickson Road are more likely to be susceptible to air quality impacts during construction works

6.1.1.3.3 Step 2C: Unmitigated Risks of Impacts

The dust emission magnitudes for each activity in **Section 6.1.1.3.1** were combined with the sensitivity of the area in **Table 10** to determine the risk of construction dust air quality impacts, with no mitigation applied. The risk of impacts for each activity is assessed according to the IAQM risk matrix methodology. An example of the IAQM earthworks risk matrix is provided in **Table 11**. The without mitigation dust risk impacts for each activity are summarised in **Table 12**.

Table 11 Example IAQM Risk Matrix - Earthworks

Sensitivity of Area	Dust Emission Magnitude		
	Large	Medium	Small
High	High Risk	Medium Risk	Low Risk
Medium	Medium Risk	Medium Risk	Low Risk
Low	Low Risk	Low Risk	Negligible

Table 12 Summary of Project Dust Risks

Potential Impact	Risk of Dust Impacts on Sensitive Receptors – Without Mitigation			
	Demolition	Earthworks	Construction	Trackout
Dust Soiling	Low Risk	High Risk	High Risk	High Risk
Human Health (PM_{10})	Low Risk	High Risk	High Risk	High Risk

The outcome of Step 2C is used to determine the level of management that is required to ensure that dust impacts on surrounding sensitive receptors are maintained at an acceptable level. A high or medium-level risk rating means that suitable management measures must be implemented during the project.

The outcome of the semi-quantitative air quality risk assessment shows that the unmitigated air emissions from the construction, track out and construction activities poses a high risk of dust soiling and a high risk of human health impacts. Once mitigation measures are applied (as discussed in **Section 6.1.1.4** and **Section 7.0**), the residual impacts, post mitigation, arising from a proposed development are as described in **Section 6.1.1.5**.

6.1.1.4 Step 3: Mitigation Strategies

A range of in-principle and site-specific mitigation strategies aimed at reducing the likelihood of air quality impacts to offsite sensitive receptors were identified. These mitigation strategies should be considered for all work elements during construction activities carried out on site. Recommended mitigation strategies are discussed in **Section 7.1**. Additionally further air quality impacts assessment would be required at the individual development application stage for each parcel of work to ensure no significant impacts occur as a result of construction and is detailed in **Section 7.4**.

6.1.1.5 Step 4: Reassessment

The final step of the IAQM methodology is to determine whether there are significant residual impacts, post mitigation, arising from a proposed development. The guidance states:

"For almost all construction activity, the aim should be to prevent significant effects on receptors through the use of effective mitigation. Experience shows that this is normally possible. Hence the residual effect will normally be 'not significant'."

Future development applications will require the preparation of an air quality impact assessment in accordance with approval conditions of the modification to the Concept Plan. Provided that appropriate project-specific mitigation strategies aimed at reducing the likelihood of air quality impacts to offsite sensitive receptors are implemented, the Project would not constitute an atypical case as defined under the IAQM. As such residual effect (impacts) would be "**not significant**" at all locations for both dust

soiling and human health impacts. Mitigation strategies listed in **Section 7.1** should be incorporated into a future Construction Environmental Management Plan (CEMP) to ensure the measures are implemented during construction of the site.

Central Barangaroo Concept Plan MOD 9

6.1.2 Potential BTEXN, Heavy Metal and PAH Impacts from Dust Generation

There is the potential for soil contaminants such as BETXN, heavy metals; PAHs (as benzo(α)pyrene) to become airborne during excavation works as it attaches to dust particulates with remediation works scheduled for the site prior to completion of the north and south basements in 2028 and 2029.

The proportion of these contaminants within the soil within the proposal area are relatively low as discussed in **Section 2.1.2** and generally limited to small, isolated hotpot areas within the site primarily located within the southern end adjacent to the former EPA Declaration area. While significant impacts to ambient air quality from BETEXN, heavy metals and PAH are unlikely; assessment of potential air quality impacts from earthworks; particularly for the southern basement are recommended in **Section 7.4**.

6.1.3 Potential Combustion Impacts

The works will primarily use electrical and diesel and/or petrol-powered plant and equipment. The combustion of diesel fuel generates a range of pollutant emissions, primarily oxides of nitrogen (NO_X) and particulate matter (including PM_{10} and TSP), as well as volatile organic compounds (VOCs) (particularly benzene, toluene, ethylbenzene, and xylenes, which are known collectively as BTEX). Other minor emissions, such as carbon monoxide and sulfur dioxide, are also emitted from combustion engines, but are considered to be lower risk than particulate and NO_X emissions due to their generally higher trigger values.

At the time of writing this report, it was assumed that onsite generators would not be required during construction works. Should onsite generators be required, assessment of air quality impacts associated with combustion emissions from onsite diesel generator(s) would be required at the DA Stage(s).

Proposed mitigation and management measures for reducing potential impacts from combustion emissions during construction are discussed in **Section 7.1**.

6.1.4 Potential Odour Impacts

There is the potential for odour emissions to be generated during construction activities including both excavation of soil and from the onsite treatment of groundwater (if required). The waste classification assessment for the proposed Central Barangaroo site (EDP 2023) of the in-situ material for the proposed basement footprint within Block 5, 6 and 7 identified fill across the site having a hydrocarbon odour. The intensity of the odour varied across the site with higher odour emissions generally noted within hotspot areas in the southern portion of the site adjacent to the former declaration area.

Relocation of wastewater infrastructure including potential relocation of sewer pumping station may result in temporary odour impacts during construction and would need to be considered during the development application stage once utility and infrastructure have been confirmed.

There is also the potential for odour emissions associated with the liberation of acid sulphate soils during excavation works. ASS would require treatment with agricultural lime and neutralisation prior to off-site disposal.

Additional consideration to potential odour impacts may need to be taken into account at the DA stage(s) to account for additional sensitive receptors within the adjoining Barangaroo South development, Block Y and Barangaroo Station (once operational in 2024).

6.2 Potential Operational Impact Assessment

The following subsections discuss the potential impacts associated with the operation of the Central Barangaroo development. **Section 6.2.1** provides a discussion of the potential adverse operational air quality impacts, while **Section 6.2.2** provides a discussion of the potential beneficial air quality impacts associated with the development

6.2.1 Potential Adverse Impacts

Potential air emissions during operation of the Central Barangaroo Development would include combustion emissions from traffic generating development discussed in **Section 6.2.1.1** and potentially minor air emissions from commercial businesses discussed in **Section 6.2.1.2**.

6.2.1.1 Emissions from Traffic Generating Development

The proposed changes in land use based on the Concept Plan; including the introduction of commercial and retail space, and residential apartments and the additional public domain and cultural spaces proposed as part of the foreshore would influence road vehicle movements to and from the study area. Changes to traffic movements along Hickson Road and the newly proposed Barangaroo Avenue would result in changes to motor vehicle emissions from fuel combustion, fluid evaporation, brake and tyre wear, and re-suspended road dust. Emissions from motor vehicles would comprise mainly hydrocarbons, PM_{10}, $PM_{2.5}$, CO, NO_x and SO_2.

The initial planning approval for Barangaroo aimed at achieving high usage of public transport, walking and cycling as a method of travel to work; with a targeted journey to work mode share by car of four percent. ARUP (2023) have prepared a Transport Management Accessibility Plan (TMAP) for Mod 9 which compares the traffic generation forecast under Mod 8 TMAP as amended for the Mod 10 Supplementary TMAP[2] and GFA (ARUP 2019 cited in ARUP 2023) with the proposed modification (Mod 9).

Previous and proposed traffic generation forecasts are provided in **Table 13** and indicated under the proposed modification the total volume of traffic generated by the entire precinct will be slightly lower when compared with that previously assessed in the Mod 10 Supplementary TMAP (ARUP 2019 cited in ARUP 2023). The slight reduction in predicted traffic volumes for Mod 9 are associated with the a reduction in commercial and increase in residential GFAs, the introduction of Sydney Metro Station and revised future bus numbers on Hickson Road.

Table 13 Traffic generation comparison (ARUP 2023)

Time Period	Direction	Mod 8/10	Mod 9	Change
AM Peak Hour	In	346	321	-25
	Out	355	350	-5
	Two-way	**701**	**671**	**-30**
PM Peak Hour	In	415	395	-20
	Out	395	382	-13
	Two-way	**810**	**778**	**-32**

Based on the revised traffic numbers Mod 9 would result in a slight decrease in traffic volumes; changes to associated vehicle emission rates between Mod 10 and Mod 9 would be relatively minor based on the proposed forecast traffic volumes. Additionally, the proposed modifications to Barangaroo's movement network to redirect and reduce the impact of vehicular traffic, specifically the removal of vehicular traffic from Block 5 and 6 would aid in limiting vehicle emissions at this location.

[2] In 2020 an additional supplementary TMAP was prepared by ARUP for MOD 11; a minor modification to Barton Street and Hickson Street. Traffic modelling for the MOD 11 TMAP was not used for comparison with the MOD9 TMAP as it assesses traffic arrangements for the Hickson Road and Waterman's key intersection before completion of Central Barangaroo. Therefore, a comparison with MOD 8 TMAP as amended by MOD 10 Supplementary TMAP has been provided.

Urban Canyons

Ground level concentrations of combustion pollutants adjacent to roads are influenced directly by the fleet mix or ratio of light to heavy vehicles, fuel type mix (for example, petrol and diesel), and the distribution of vehicles by age of manufacture. They are also influenced by air circulation and set back distances, and heights of adjacent buildings. Dispersion of vehicle emissions is less affective when development along a road corridor is confined restricting airflow which would typically disperse and transport air pollutants from vehicles away from the source area. The degree to which pollutants disperse is influenced by the orientation and continuity of open spaces, their dimension and shape, topography and the layout of buildings surrounding the subject area. Urban canyons for example where a road is flanked by high density development on each site may channel plumes and prevent them from reaching road level depending on their shape, dimension and orientation. The more confined a space is by buildings, walls or embankments adjacent to or over a roadway, the less opportunity air pollutants have to disperse (DoP 2008).

The MOD 9 Concept Plan proposes six building blocks separated by two public spaces running east to west and a laneway running north to south. Building heights are relatively consistent, with a height of 35m. The exception to this is the southeast block fronting Hickson Street with a height of 42.45m and the southern portion of the envelop which has been lowered to 22m. The proposed building heights are shown in **Figure 10**.

Figure 10 shows the corridors that may promote air circulation. Corridors of Hickson Road running east to west include the Southern Plaza, which is 20m wide between Block 5 and Block 6; and the Northern Plaza between Block 6 and Block 7 varies in width between 12m and 20m. There is also a partially open 6m wide laneway through Bloc 5. Running north to south an 18m laneway runs through the proposed development.

Building heights fronting Hickson Road are relatively consistent at around 35 to 42.45m. The adjacent side of Hickson Road includes both a pedestrian walkway and the High Street cutting, which is approximately 10m in height, The potential for built form within the proposed massing envelope to create urban canyon effects along Hickson Road will need to be addressed during the detailed design and associated development application stage.

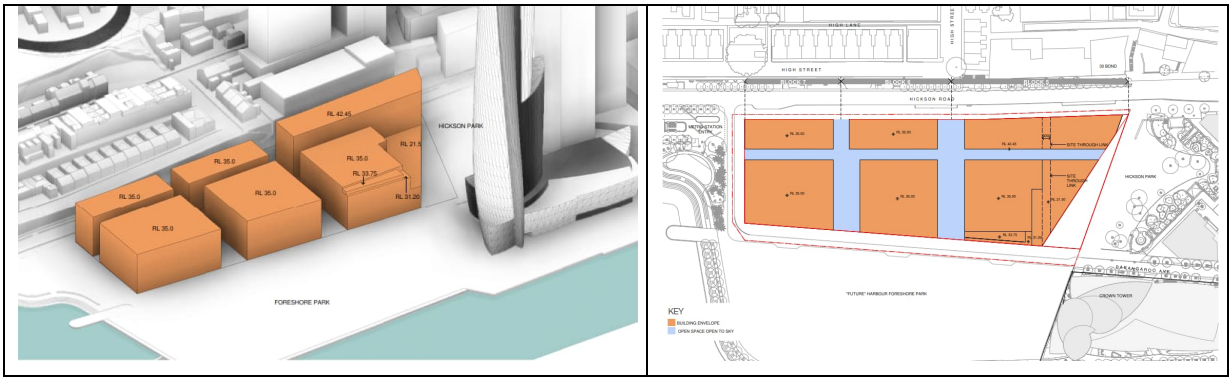

Figure 10 Proposed building envelopes including height and block dimensions

Note: Figures obtained from Draft Central Barangaroo Urban Design Report and Guidelines (SJB Architects 2023)

The proposed building forms are likely to influence micrometeorology at a local scale, which in turn affect pollutant dispersal patterns. Vehicle emissions are likely to be the primary source of pollutants within the study area and would be affected the most by the urban canyon formation.

Changes to wind flow fields are presented in Figure 10 for several representative wind conditions. Higher wind speeds are shown in red shading with lower wind speeds depicted in green shading. The built forms in the development influence both the directional flow and speed of air moving through the site. For example, Figure 10 shows that for westerly winds, the North and South Plazas experience higher wind speeds along Hickson road which may aid in the dispersal of traffic emissions (through higher levels of turbulence). Conversely, under regional south westerly and southerly winds, wind

speeds are lower at the northern end of Hickson Road, resulting in poorer dispersal conditions, which may be exacerbated by the urban canyon effects near Barangaroo South.

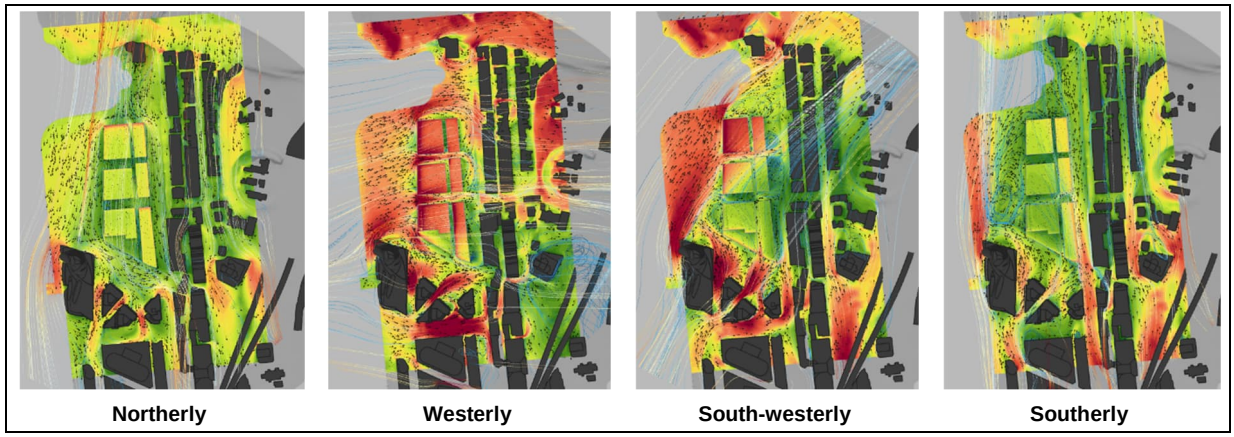

Figure 11 Wind analysis for proposed Concept Plan envelope

Note: Figures obtained from Draft Central Barangaroo Urban Design Report and Guidelines (SJB Architects 2023)

As discussed above, currently proposed building design characteristics have the potential to minimise adverse air quality impacts on sensitive receptors from vehicle emissions. These characteristics include:

- Northern and Southern plazas between Block 5, Block 6 and Block 7 and north to south laneway promotes crossflow which works to minimise the deleterious effects of urban canyons.
- Modifications to Barangaroo's movement network to redirect and reduce the impact of vehicular traffic including the removal of vehicular traffic from Block 5 and 6 would be expected to remove potential vehicle emissions from this location.
- Tallest multi storey building of 42.45m is set on Hickson Road on the south corner of Block 5. The height of the building directly to the west has been lowered to 22m; and open space has been proposed between Hickson Park to the south, which would facilitate dispersion of pollutants before reaching this building.
- Open areas of landscaped public domain at the north and south ends of the 3 blocks (Nawi Cove and Hickson Park) will facilitate dispersion and contribute to improved air quality. The extension of Central Barangaroo's Harbour Park would also facilitate dispersion.
- Public and community facilities would largely be sited within the proposed Foreshore Park area to the west of Block 5, 6 and 7 away from Hickson Road vehicle pollution source; and
- Additionally proposed, landscaping and provision of green roofs (see **Section 6.2.2**) would aid in in maintaining ambient air quality.

The above concept design features are consistent with the Department of Planning and Environment's (DP&E) design guidelines outlined in *Development Near Rail Corridors and Busy Roads – Interim Guideline*, (DoP 2008; which is discussed in **Section 7.3** of this report.

6.2.1.2 Emissions from Commercial Activities

The Central Barangaroo Concept plan allows for a number of retail and commercial outlets within the development precinct; including within Block 5, 6 and 7 and Foreshore North (retail only). Many commercial businesses include potential air emission sources from various processes including combustion, fuel and organic liquid storage and handling operations, process fugitive emissions and surface coating operations. Potential pollutants may generally include particulates, NOx, SO_2, CO and VOCs (DECC & PAE 2007).

The particulars on commercial properties occupying the future development are currently unknown; however, they may include minor potential air emissions from sources such as food product

manufacture, laundries and dry cleaners and printing, publishing and recorded media establishments. The proposed revised Mod 9 has a lower GFA dedicated to commercial use that the previously exhibited Mod 9 as discussed in Section 1.3.p

In general emissions from commercial facilities only contribute a minor proportion of air emissions to the Sydney region when compared to other major sources such as vehicle and industrial emissions. Commercial activities also typically do not require environmental protection licences (EPL) under the *Protection of the Environment Operations Act 1997 (NSW)* POEO Act. As such no significant air quality emissions are anticipated from the operation of commercial facilities within the development area at this stage.

6.2.2 Potential Beneficial Impacts

The Proposed Concept Plan makes provision for the future incorporation of green roof spaces. Green roofs entail growing plants on rooftops; which partially replaces vegetation that was removed prior to urbanisation; providing a number of environmental benefits; including to air quality while enhancing local aesthetics.

Urban vegetation has the potential to reduce air pollutant concentrations through both direct and indirect pathways (Yang *et al*. 2008, *Currie and Bass* 2008 and *Rowe* 2010):

- Urban vegetation directly affects local air pollutant concentrations by:
  - Increasing surface roughness due to the presence of foliage, branches and twigs; which raises dry deposition rates of particulates; and
  - Uptake of gaseous pollutants through stomata on plant leaves; which then react with water to form acids and other compounds; and breaking down of certain organic compounds such as polycyclic hydrocarbons (PAHs) in plant tissue and in soil.
- Urban vegetation also has the potential to modify the existing microclimate indirectly reducing pollution by:
  - Lowering indoor temperatures through shading; resulting in a reduction in electricity usage for cooling purposes; and
  - Lowering ambient temperatures by changing the albedo of urban surfaces and evapotranspiration cooling; which in turn slows down photochemical reactions and leads to less secondary air pollutants such as ozone

The effectiveness of green roofs as a pollutant abatement strategy is largely dependent on the area and type of vegetation. Green roofs can be classified as ‘intensive’ or ‘extensive’ based on their design and intended use. Intensive green roofs a generally designed as public spaces and generally include a mix of trees, shrubs and hardscapes. Extensive green roofs are designed to be low maintenance and are generally comprised of grasses, herbaceous perennials, annuals and drought tolerant succulents (Rowe 2010).

In 2008 Yang *et al.* used big-leaf resistance model used to quantify dry deposition of air pollutants from green roof tops in Chicago, United States of America. The study examined the effectiveness of three vegetation types ‘short grass’ ‘tall herbaceous plants’ and ‘deciduous trees’ to remove SO_2, NO_2, PM_{10} and O_3 from the local air shed. The results of the study are presented in **Table 14**; and are consistent with other studies such as Currie and Bass (2008) that show a higher pollutant load removal rate for trees and shrubs typically found in intensive green roofs (largely due to greater leaf surface area), compared to extensive green roofs, predominantly comprised of grass.

Table 14 Annual Removal Rate of Air Pollutants per canopy cover by different vegetation type (Yang *et al*, 2008)

Vegetation Type	Annual Removal Rate ($g/m^2/y$)				
	SO_2	NO_2	PM_{10}	O_3	Total
Short Grass	0.65	2.33	1.12	4.49	8.59
Tall Herbaceous plants	0.83	2.94	1.52	5.81	11.10
Deciduous Trees	1.01	3.57	2.16	7.17	13.91

The proposed green roofs on Block 5, 6 and 7 may incorporate intensive and or extensive designs including a mix of trees, shrubs and grass. Potential pollutant abatement rates for green roofs may be loosely approximated for each block and assessed semi-quantitatively using the values in **Table 14** once surface vegetation types and coverage are known. It should be noted that estimated pollutant abatement values would be indicative only as localised pollutant deposition rates would be influenced by a number of factors including vegetation type, pollution concentration, length of growing season and local meteorological conditions. The rate at which pollutants would be removed would also vary seasonally with higher rates observed in spring (when the greatest amount of growth would be expected) and the lowest rates of removal where observed during winter when plants may be dominant or slow growing.

Green roofs are just one form of Green Infrastructure (GI) that may be included as part of Central Barangaroo development. As part of the proposed development GI provisions include:

- Allowance for roof levels on all buildings sized to contain green roofs
- Approximately 1434m^3 of open space as part of the Hickson Park Promenade
- Street planting along Hickson Road and opportunities to provide green spaces within the North and South Plaza including provision of deep planting areas.
- Opportunities for greenspaces in courtyards of buildings 2B, 3B and 4B.

The strategic placement of Green Infrastructure (GI) such as open areas and vegetated areas such as street scaping would need to be considered as part of the development. Placement of GI in urban canyons can used to manage roadside pollutant concentrations at the local scale. Introduction of GI can however promote or disrupt the dispersion of air pollution by either exerting additional mechanical turbulence or decreasing turbulent kinetic energy. Within urban canyons trees have the potential to reduce wind speeds and reduce air exchange between the air above rooftops and within the canyon leading to the accumulation of pollutants inside the street canyon. For street canyons, the aspect ratio is critical to the appropriate GI form. **Table 15** provides a general guide for the determination of appropriate green infrastructure for street canyons based on Aspect Ratio.

Table 15 Determination of Appropriate Green Infrastructure for Street Canyons Based on Aspect Ratio

Classification	Aspect Ratio	GI Recommendation
Deep Street Canyon	H/W ≥ 2	• Green walls only
Mid-Depth Street Canyon	H/W 0.5-2	• Green walls • Low-level vegetation (shrubs and low hedges)
Shallow Street Canyon	H/W ≥ 0.5	• Green walls • Low-level vegetation (shrubs and low hedges) • Small and open-crowned trees on the windward side of the canyon spaced broadly apart.
Source: Barwise & Kumar 2020		

The aspect ratio is determined by the average height-to-width (H/W) ratio of the street canyon. Aspect ratios for Hickson Road at Block 5, Block 6 and Block 7 are estimated in **Table 16**, as well as for the plaza areas which would offer cross flow benefits for Hickson Road. Hickson Road adjacent to Central Barangaroo would likely be classified as a Mid-Depth Street Canyon. GI such as green walls or low-

level vegetation including shrubs and low hedges are recommended to aid in the reduction in air pollution. Where possible planting of large street trees with dense foliage and large crowns that may limit pollutant dispersal of vehicle emissions under canopies should be limited. Similarly deep planting areas within the North and South Plaza should avoid planting large trees with dense foliage and large crown that may impede fresh air circulation. Further investigation of potential impacts associated with urban canyons (and GI) may be undertaken at the detailed design stage as described in **Section 7.4**.

Table 16 Height Aspect Ratio's and Green Infrastructure Recommendations

Classification	Classification	Aspect Ratio	Green Infrastructure Recommendation
Hickson Road (Block 5)	Mid-Depth Street Canyon	1.2	• Green walls or low-level vegetation including shrubs and low hedges recommended. • Where possible avoid planting large street trees with dense foliage and large crown that may cause vehicle emissions to become trapped under canopies.
Hickson Road (Block 6)	Mid-Depth Street Canyon	1.2	• Green walls or low-level vegetation including shrubs and low hedges recommended. • Where possible avoid planting large street trees with dense foliage and large crown that may cause vehicle emissions to become trapped under canopies.
Hickson Road (Block 7)	Mid-Depth Street Canyon	1.4	• Urban canyon effects likely to be greatest for this section of Hickson Road due to adjacent building heights; strategic planning of vegetation is required to minimise potential for pollutant hotspots. • Green walls or low-level vegetation including shrubs and low hedges recommended. • Where possible avoid planting large street trees with dense foliage and large crown that may cause vehicle emissions to become trapped under canopies.
South Plaza	Mid-Depth Street Canyon	1.8	• Recommended green walls or low-level vegetation including shrubs and low hedges • Where possible avoid planting large trees with dense foliage and large crown that may impede fresh air circulation
North Plaza	Mid-Depth Street Canyon	1.8	• Recommended green walls or low-level vegetation including shrubs and low hedges • Where possible avoid planting large trees with dense foliage and large crown that may impede fresh air circulation
Height aspect rations have been estimated based on a building height for all buildings and height of 35m with exception to southeast building on Block 5 with a height of 42.5m. Width between building facades and high street heritage wall was assumed to be 30m.			

The location of green roofs and/or other GI would be confirmed a part of the detailed design process as part of future development applications for Central Barangaroo.

6.3 Potential Cumulative Impacts

There is the potential for cumulative air quality impacts to occur where construction of Central Barangaroo coincides with the construction works associated with nearby projects including:

- Barangaroo Metro Station due for completion in 2024
- Harbour Park scheduled for completion in 2027
- Barangaroo Reserve, scheduled for completion in 2025.

Construction of Barangaroo Metro Station is due for completion in 2024; with major dust generating works including realignment of Hickson Road, and landscaping due for completion in the first quarter of 2024 (Sydney Metro 2023). As such there are unlikely to be significant cumulative impacts from construction. Once the Barangaroo Metro Station becomes operational this would be considered a sensitive receptor; however, patrons are likely to be expected to reside in the area for long periods of time and would therefore be considered transient.

There is the potential for cumulative dust impacts associated with the construction of Harbour Park and Barangaroo Reserve, however provided appropriate construction dust mitigation measures are employed as part of a construction dust management plan for the site no significant cumulative impacts are anticipated. Both Barangaroo Reserve and Harbour Park upon completion would be considered transient sensitive receptors.

7.0 Recommended Air Quality Management and Mitigation

7.1 Construction Mitigation Measures

Air quality mitigation measures to be applied during construction should be detailed in the site Construction Environmental Management Plan (CEMP). Proposed safeguards against air quality impacts during construction for inclusion in the CEMP should include:

- Implement an Air Quality Monitoring Program, similar to air quality monitoring practices undertaken for the Barangaroo South; particularly for site excavation works (refer to **Section 7.2**). The program should include air monitoring locations along the southern and eastern boundaries.
- Watering of stockpiles, exposed areas and roads when required to maintain a moisture content that minimises dust generation.
- Use water sprays and/or surfactants wherever and whenever necessary.
- Promptly removing and disposing of spilled materials which may cause a dust nuisance.
- Restrict vehicle movements to within designated access paths; and minimise haul road lengths where possible.
- Ensure machinery is working correctly.
- Remove excavated material and any dust generating materials from site as soon as possible, unless being reused onsite.
- Dust suppression of exposed areas and stockpiles would be undertaken as required using a water cart or equivalent piece of equipment.
- Erect windbreak barriers at the site boundary if required.
- Implement site speed limits
- Cover loads during transport.
- Maintain the complaints management system.
- Adjust work practices (as required) based on wind observations and real time monitoring results.
- Undertake good housekeeping practices to minimise dust on hardstand areas.
- In the event odours material is encountered during excavation works such as tar impacted soil odour control measures should be applied to minimise potential offsite odour impacts including aapplying odour suppression foams to stockpiles and exposed surfaces and/or boundary misting systems.
- Implementation of any additional mitigation options as required by the Project's Environmental Manager or as identified in future development applications.

7.2 Air Quality Monitoring

An Air Quality Monitoring Plan should be developed as part of the Air Quality Management Plan for the site. The Air Quality Monitoring Plan should allow for real time assessment of various construction activities onsite which can then be related back to operational changes to reduce off-site impacts, and allow reactive dust mitigation measures to be implemented based on real time monitoring data.

A detailed monitoring pan has not been developed as part of this document (a detailed plan is premature at this stage of the development process). When a plan is developed however, the monitoring should be undertaken generally in accordance with the following guidelines and Australian Standards:

- The EPA's Approved Methods for Sampling and Analysis of Air Pollutants in New South Wales (DEC, 2005a),
- AS/NZS 3580.9.3:2003 Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - Total suspended particulate matter (TSP) - High volume sampler gravimetric method,
- AS 3580.9.8-2008 Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - PM_{10} continuous direct mass method using a tapered element oscillating microbalance analyser,
- AS/NZS 3580.1.1:2007 Methods for sampling and analysis of ambient air - Guide to siting air monitoring equipment; and
- AS 2923-1987 Ambient air - Guide for measurement of horizontal wind for air quality applications.

7.3 Planning and Design Considerations

Strategic planning should ensure that sensitive land use developments are sited to avoid or appropriately manage vehicle emissions from Hickson Road at the site planning and building construction stages. Planning and design considerations to minimise exposure to vehicle emissions, are presented in **Table 17**. The planning and design considerations in **Table 17** are in line with the DP&E's *Development Near Rail Corridors and Busy Roads – Interim Guideline*, (DoP 2008) and supports the specific rail and road provisions of the *Infrastructure State Environmental Planning Policy (SEPP)* 2007.

Table 17 Planning and Design Considerations for Development near Busy Roads

Consideration	Comment
Building Siting, Heights and Orientation	• Incorporating an appropriate separation distance between sensitive uses and the road using broad scale site planning principles such as building siting and orientation. The location of living areas, outdoor space and bedrooms should be as far away as practicable from the major source of air pollution • Building heights adjacent to busy roads should be varied and interspersed with open areas to minimise the formation of urban canyons; • Where possible step back the upper stories of roadside buildings to increase dispersion of air pollutants and minimise cannoning effects of tall buildings close to the road.
Landscaping	• Using vegetative screens, air amenity barriers or earth mounds where appropriate to assist in maintaining ambient air quality. This may include planting trees and other vegetation in the public domain to assist in maintaining ambient air quality • Any GI planned for Hickson Road would need to take into account the street aspect ratio to ensure trees, hedges and shrubs are avoided along the streetscape; as these may restrict dispersion of air pollutants from vehicle emissions. GI in this location should generally be limited to green walls and low lying shrubs where possible. • Landscaping has the added benefit of improving aesthetics and minimising visual intrusion from an adjacent roadway. • Where possible maximise the amount of space used for green roofs as an air quality abatement strategy. Where possible intensive green roofs that include tall herbaceous plants and/or deciduous trees should be included to maximise potential beneficial air quality impacts.

Consideration	Comment
Ventilation	• For ventilation of indoor areas, adjacent to Hickson Road or the proposed Barangaroo Avenue mechanical ventilation air inlet ports should be sited to maximise the distance from the road to reduce inflows of air pollutants • The location of open-able windows should be considered in the design of the development located adjacent to the roadway emission sources. • Additional mitigation measures may include the consideration of the use of winter gardens as an alternative to conventional balconies •
Zoning	• Propose less sensitive land use for development that will front Hickson Road such as open space or for commercial or retail use. Here buildings may act as a barrier that shields and protects highly sensitive areas from high-emission zones.

7.4 Additional Studies

Following approval of the Concept Plan Mod 9; Individual development applications for proposed development within the site would require an environmental impact assessment in accordance with the *Environmental Planning and Assessment Act 1979* (NSW) (EP&A Act). A component of the environmental assessment would involve identifying and assessing potential air quality impacts associated with development. **Table 18** provided a brief outline of potential assessments that may be required for future development of the site, with regards to assessment of air quality impacts.

Table 18 Potential Future Assessment Requirements

Item	Requirements
Development Impacts	Future development at the site would be required to assess the air quality impacts from individual development applications. The level of assessment for each development would be determined on a case by case basis. Where there is the potential for negligible or only minor air quality impacts from proposed developments only a qualitative assessment may be required. Otherwise a quantitative assessment of potential air quality impacts will be required in accordance with the Protection of the Environment Operations Act 1997 (NSW) and the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (DEC 2005)*. The Approved Methods lists the statutory methods for modelling and assessing emissions of air pollutants from stationary sources in NSW and can be used to predict whether emissions from a proposed development would comply with the EPA ambient air quality criteria.
Construction Impacts	Assessment of construction air quality impacts would be required for development applications at the site including earthworks, specifically for basement excavation activities and earthmoving and land forming required for the Foreshore. The level of assessment would depend on the nature of the works and may involve: • A semi-quantitative assessment using the methodology outlined in the UK Institute of Air Quality Management (IAQM) document Guidance on the assessment of dust from demolition and construction; or • Quantitative assessment in accordance with the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (EPA 2017)*; and • Quantitative assessment of potential odour impacts in accordance with the *Assessment and Management of Odour from stationary sources in NSW, Technical framework (and notes)* (DEC 2006); and The following items would need to considered as part of the construction impact assessment: • Potential impacts of air quality and odour impacts to existing sensitive receptors onsite including adjacent to Hickson Road and sensitive receptors at Barangaroo South including Block 4 and Block Y.

Item	Requirements
	• Potential odour impacts from potential relocation of sewage pumping station if required. • Potential impacts to future receptors during dust generating works such as those at Barangaroo Station once operational. • Potential air quality impacts if contaminated soil containing BETXN, heavy metals; PAHs is encountered during excavation works. • Potential cumulative and staging impacts associated including: - Dust generation from earthworks, construction and/or demolition works that may coincide with existing dust generating activities within Central Barangaroo (as a separate DA) or wider Barangaroo Precinct - Dust generation from excavation and construction works occur concurrently to construction works of the Harbour Park and Barangaroo Reserve. - Potential cumulative odour impacts from operation of water treatment plant at Central Barangaroo - Cumulative impacts associated with any other nearby proposed development construction works. - In the event contaminated fill is discovered during excavation works appropriate safeguard measures would be required to prevent/minimise generation of airborne contaminants. Further assessment may also be required for onsite stabilisation works where required.
Vehicle Emissions	Proposed development, particularly multi story buildings adjacent to busy roads may require further assessment of vehicle emissions, where formation of urban canyons have the potential to impact receptors, particularly highly sensitive receptors such as childcare facilities. Air dispersion modelling using the lagrangian particle model GRAL developed at the Institute for Internal Combustion Engines and Thermodynamics, Technical University Graz, Austria would be recommended. The GRAL model has algorithms which effectively consider dispersion in low wind speed conditions and allows for very fine scale consideration of buildings to predict receptor concentrations at building facades both fronting and facing away from road corridors.
Reverse Amenity Impacts	Assessment of air quality impacts for future development applications within Barangaroo Central should consider any reverse amenity impacts of sensitive receptors within Central Barangaroo from surrounding development.

8.0 Conclusion

A qualitative air quality impact assessment has been prepared for the proposed modification and development program for the Central Barangaroo development which identified the potential impacts to air quality at nearby existing and future sensitive receptors during construction and operation.

Potential dust generating impacts (and associated minor impacts from soil contaminants) during construction; particularly during excavation activities pose the greatest potential air quality impacts from the project to nearby receptors. There is also the potential for cumulative impacts associated with construction of Barangaroo Station and other development projects within Barangaroo. Dust generating impacts from individual development applications within the Central Barangaroo site would need to be assessed in accordance with the EP&A Act with the level of assessment dependant on the nature of the works involved at the detailed Development Application stage.

Other potential air quality impacts during construction would include fuel combustion from mobile and stationary plant equipment which may be managed appropriately by maintaining equipment and using standard management practices. There is also the potential for minor odour impacts during operation of the water treatment plant, potential relocation of wastewater infrastructure or in the event tar impacted soils are encountered. Further assessment of odour impacts from the water treatment plant and any relocation of wastewater infrastructure during construction is recommended at the development application stage. Potential odour impacts from encountering contaminated soil may be mitigated by applying standard safeguards applied in the Construction Environmental Management Plan.

Potential operational impacts may include minor air quality impacts from commercial properties and vehicle emissions from traffic generating development, particularly along Hickson Road and to a smaller extent Barangaroo Avenue. These may be managed with appropriate planning and design considerations and current traffic generation estimates predicted slightly lower vehicle numbers for the proposed modification when compared to previous estimates for Mod 10. The concept plan also allows for the provision of large landscaped areas and green roofs which would have potentially beneficial impact on local air quality by reducing air pollutant concentrations through both direct and indirect pathways.

In conclusion provided that a detailed AQIA for each individual Development Applications specific to the Central Barangaroo is undertaken and appropriate project-specific mitigation strategies are implemented, no adverse effects on local air quality are expected to occur as a result of the proposed modifications to the Concept Plan.

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Appendix A

Meteorological Modelling

Appendix A Meteorological Modelling

GRAMM Inputs

Meteorology for the assessment was based on observational data from several Bureau of Meteorology (BOM) monitoring stations in the eastern Sydney region for 2022. Monitoring stations included:

- Fort Denison
- Canterbury Racecourse
- Mascot
- Sydney Olympic Park
- North Head

In accordance with GRAMM assessment methodology approved by the NSW Chief Scientist, the GRAMM Match to Observation (MTO) function was used along with observed and synthetic meteorological data set to predict the meteorological conditions in the Sydney Region. GRAMM settings were selected based on available data and the settings outlined in the guidance document *Recommendations when using the GRAL / GRAMM modelling system* (Government of Styria, 2017). Settings for the GRAMM modelling run are presented in **Table 19**.

Table 19 GRAMM modelling domain parameters

Parameter	Value
Version	March 2022
Meteorological grid domain	22.6km x 22.5km
Horizontal grid resolution	100m
Reference grid coordinate (origin)	318600m, 6240400m (SW corner)
Vertical thickness of first layer	10m
Number of vertical layers	15
Vertical stretching factor	1.3
Relative layer height	1683m (Layer 15)
Surface meteorology	Fort Denison Canterbury Racecourse Mascot Sydney Olympic Park North Head
Simulation length	1 Year (2022)
Number of synthetic wind speed categories	24
Synthetic wind speed categories	0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 8.0, 9.0, 10.0, 12.0, 14.0, 16.0m/s
Number of meteorological conditions[1]	594
Maximum time step	10 seconds
Modelling time	3600 seconds
[1] Number of meteorological conditions reflects the number of individual wind conditions in the simulation period, i.e.: individual wind condition can occur multiple times within an 8760-hour timeseries, with statistics calculated from the 8760 hour timeseries of receptor concentrations.	

Comparison of Meteorological Data

The following provides a comparison of annual average wind roses from the GRAMM meteorological modelling data for 2022 at Central Barangaroo and Fort Denison with BoM data at both Fort Denison and Sydney Airport are presented in **Figure 12.**

GRAMM data for Fort Denison is comparable to BoM data for 2022 recorded at the station with average wind speeds of 4.1 m and 4.5 m/s comparatively, and 2.5% and 0.5% occurrence of calms respectively. Wind direction shows more variability within the GRAMM data set at Fort Denison but still indicates the dominant wind direction is from the west. The GRAMM data is considered more conservative due to the slightly lower annual average wind speed and higher occurrence of calms which would result in less favourable dispersal conditions.

The GRAMM wind rose for Central Barangaroo shows on an annual basis, westerly winds occur most frequently which is similar to both GRAMM and BoM data for Fort Denison. The predicted annual average wind speed at Central Barangaroo was found to be a light to moderate 3.0 m/s and calm conditions were found to occur 7.1% of the time.

The 2022 wind rose for Sydney Airport shows wind direction is more variable at this location when compared to both Fort Denison GRAMM and BoM data and GRAMM data for Central Barangaroo. The moderate annual average wind speed of 5.7 m/s and low percentage of calms (0.5%) indicate that air pollutants are likely to disperse more rapidly at this location due to more favourable meteorological conditions. As such use of the Fort Denison BoM data together with the GRAM Central Barangaroo data is considered a more conservative approach to the assessment.

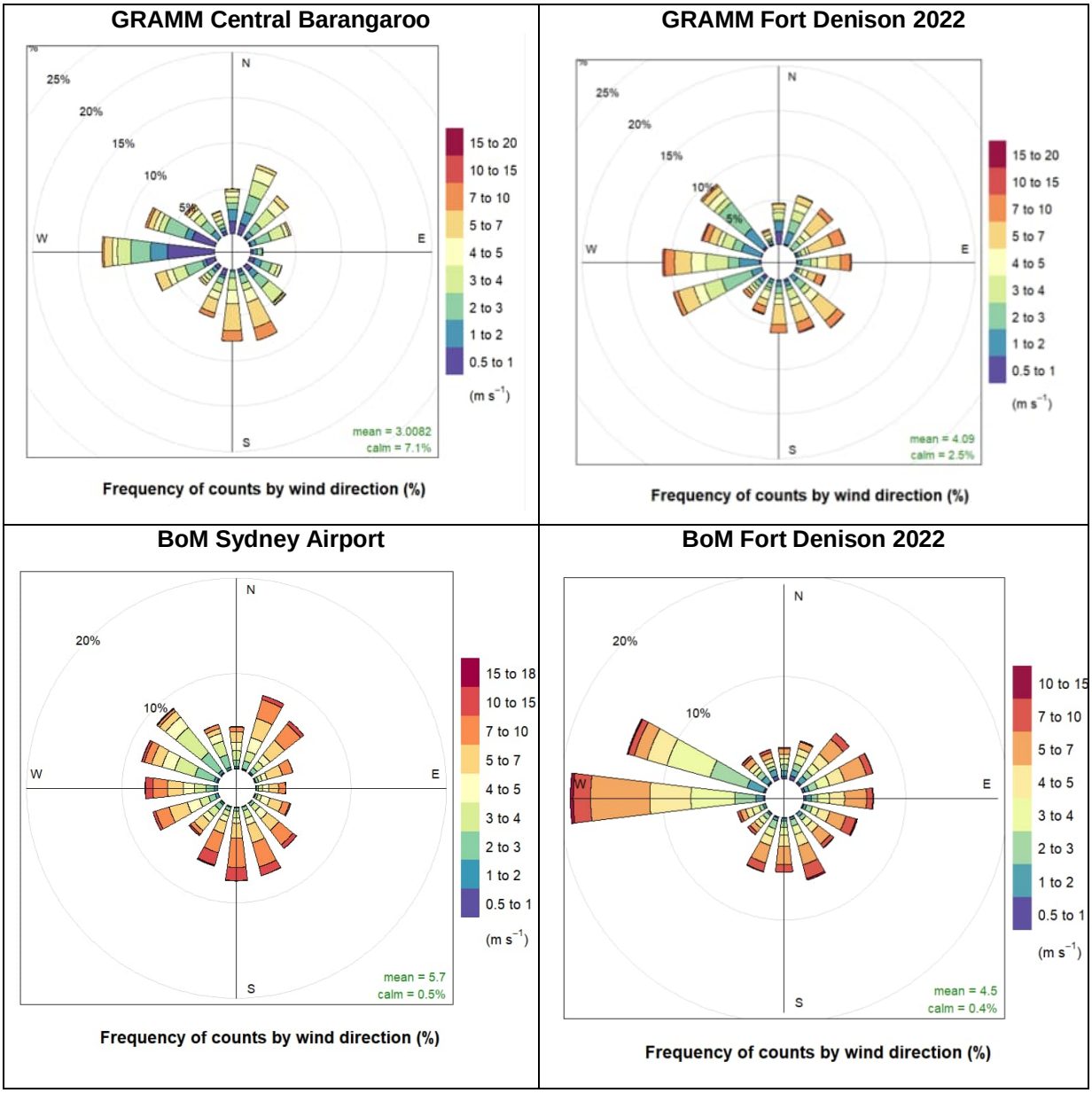

Figure 12 Comparison of GRAMM and BoM Annual Wind Roses for 2022

Appendix B

IAQM Dust Emission Magnitude Classification

Appendix B IAQM Dust Emission Magnitude Classification

Under the UK Institute of Air Quality Management (IAQM) document dust emission magnitudes are estimated according to the scale of works being undertaken and other considerations such as meteorology, types of material being used, or general construction methodology. The IAQM guidance provides examples to aid classification, as presented in the following excerpt from IAQM:

The dust emission magnitude is based on the scale of the anticipated works and should be classified as Small, Medium, or Large. The following are examples of how the potential dust emission magnitude for different activities can be defined. Note that, in each case, not all the criteria need to be met, and that other criteria may be used if justified in the assessment:

Demolition: Example definitions for demolition are:

- Large: Total building volume >50,000m^3, potentially dusty construction material (e.g. concrete), on-site crushing and screening, demolition activities >20m above ground level;
- Medium: Total building volume 20,000m^3 – 50,000m^3 , potentially dusty construction material, demolition activities 10-20m above ground level; and
- Small: Total building volume <20,000m^3, construction material with low potential for dust release (e.g. metal cladding or timber), demolition activities <10m above ground, demolition during wetter months.

Earthworks: Earthworks will primarily involve excavating material, haulage, tipping and stockpiling. This may also involve levelling the site and landscaping. Example definitions for earthworks are:

- Large: Total site area >10,000m^2, potentially dusty soil type (e.g. clay, which will be prone to suspension when dry due to small particle size), >10 heavy earth moving vehicles active at any one time, formation of bunds >8m in height, total material moved >100,000 tonnes;
- Medium: Total site area 2,500m^2 – 10,000m^2, moderately dusty soil type (e.g. silt), 5-10 heavy earth moving vehicles active at any one time, formation of bunds 4m - 8m in height, total material moved 20,000 tonnes – 100,000 tonnes; and
- Small: Total site area <2,000m^2 – soil type with large grain size, e.g. sand, <5 heavy earth moving vehicles at one time, formation of bunds <4m in height, total material moved <20,000 tonnes, earthworks during wetter months.

Construction: The key issues when determining the potential dust emission magnitude during the construction phase include the size of the building(s)/infrastructure, method of construction, construction materials, and duration of build. Example definitions for construction are:

- Large: Total building volume >100, 000m^3, on site concrete batching, sandblasting;
- Medium: Total building volume 25,000m^3 – 100,000m^3, potentially dusty construction material (e.g. concrete), on site concrete batching; and
- Small: Total building volume <25,000m^3, construction material with low potential for dust release (e.g. metal cladding or timber).

Trackout: Factors which determine the dust emission magnitude are vehicle size, vehicle speed, vehicle numbers, geology and duration. As with all other potential sources, professional judgement must be applied when classifying trackout into one of the dust emission magnitude categories. Example definitions for trackout are:

- Large: >50 truck (>3.5t) outward movements in any one day, potentially dusty surface material (e.g. high clay content), unpaved road length >100m;
- Medium: 10-50 truck (>3.5t) outward movements in any one day, moderately dusty surface material (e.g. high clay content), unpaved road length 50m – 100m; and
- Small: <10 truck (>3.5t) outward movements in any one day, surface material with low potential for dust release, unpaved road length <50m.