Report to General Manager

Attachments:
1. SLR Western Harbour Tunnel & Beaches Link – Air Quality Monitoring Report

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SUBJECT: Proposed Western Harbour Tunnel and Warringah Freeway Upgrade Link – Air Quality Monitoring Report

AUTHOR: Fiona Mulcahy, Team Leader Environmental Health

ENDORSED BY: Joseph Hill, Director City Strategy

EXECUTIVE SUMMARY:

At its meeting of 25 June 2018 Council resolved as follows:

> ***1. THAT*** *Council note the report and endorse the urgent engagement of a specialist to scope an appropriate and cost effective air monitoring system prior to seeking tenders from relevant suppliers.*

SLR Consulting Australia Pty Ltd (SLR) was commissioned by Council to provide advice on a proposed ambient air quality monitoring program to establish baseline air quality in North Sydney around the proposed location of the tunnel ventilation stack associated with the Western Harbour Tunnel and Warringah Freeway Upgrade.

A report was prepared which advised on, amongst other matters, the pollutants to monitor for, and offers three options for carrying out an air quality monitoring program along with siting locations for the monitoring equipment.

The options are:

- Option 1 – Compliant Monitoring Station.
- Option 2 – Equivalent Monitoring Station.
- Option 3 – Non-Compliant Monitoring Station.

The Option of installing a Compliance Monitoring station is the preferred option as this equipment is compliant with current Australian Standards for ambient monitoring of the relevant pollutants and uses methods outlined in the Approved Methods for Sampling. This method will stand up to third party scrutiny.

FINANCIAL IMPLICATIONS:

An air quality monitoring program is currently unfunded in the adopted Delivery Program. The indicative cost for the preferred option is $160,000 + GST per annum. Should this program proceed, a budget reallocation will need to be considered in the next quarterly budget review.

RECOMMENDATION:
1. THAT Council determines its position on this matter.

LINK TO COMMUNITY STRATEGIC PLAN

The relationship with the Community Strategic Plan is as follows:

Direction:	1. Our Living Environment
Outcome:	1.1 Protected and enhanced natural environment and biodiversity

BACKGROUND

SLR Consulting Australia Pty Ltd (SLR) was commissioned by Council to provide advice on a proposed ambient air quality monitoring program, to establish baseline air quality in North Sydney around the proposed location of the tunnel ventilation stack associated with the Western Harbour Tunnel and Warringah Freeway Upgrade (the Project).

The Project comprises a new motorway tunnel connection across Sydney Harbour and the Warringah Freeway Upgrade, to integrate the new motorway infrastructure with the existing road network and to connect to the Beaches Link and Gore Hill Freeway Connection.

Detailed design information for the Project is not publicly available at this time. The following documents have been reviewed as part of the SLR report to gain an understanding of the Project and its potential air quality impacts:

- Western Harbour Tunnel and Warringah Freeway Upgrade Scoping Report (RMS, 2017)
- Western Harbour Tunnel Project Update – July 2018 (RMS, 2018)

According to the information available, the Project tunnels would be equipped with ventilation systems to capture and disperse vehicle emissions. The tunnel ventilation system is proposed to be designed to direct all tunnel air to ventilation stacks located near the Warringah Freeway and Ernest Street intersection and to avoid the release of any tunnel air from the road portals. No information regarding the specifications of the ventilation stacks (height, velocities, etc.) which are critical to emission dispersion, is publicly available at this time.

As detailed design information for the proposed tunnel is not yet publicly available, the anticipated extent of local air quality impacts cannot be determined. However, it can be expected that changes in the distribution of surface traffic and the operation of tunnel ventilation facilities would have an impact on local air quality.

The proximity of the proposed tunnel ventilation stack to nearby sensitive receptors means that tunnel emissions have the potential to lead to stack downwash, which occurs when the plume is sucked downwards into the wake behind the stack. Moreover, the presence of structures and buildings in close proximity to the stack can create turbulent wake zones within the atmosphere, where an otherwise elevated plume can be forced to the ground (building downwash).
A tall stack will help avoid excessive downwind concentrations due to building downwash effects.

CONSULTATION REQUIREMENTS

Community engagement is not required.

SUSTAINABILITY STATEMENT

The sustainability implications are of a minor nature and did not warrant a detailed assessment.

DETAIL

The SLR report submitted to Council includes a review of the *National Pollutant Inventory Emission Technique Manual for Combustion Engines* which identifies the primary pollutants from combustion engines. Based on this review the SLR report recommends the relevant pollutants for Council to monitor in the proposed air quality monitoring program.

SLR examined regional topography, regional meteorology, atmospheric stability, surrounding land use and sensitive receptors and air quality in the region in forming the submitted report.

The report examines the regulatory framework being the *Approved Methods for the Sampling and Analysis of Air Pollutants in NSW*. It goes on to summarise the advantages and disadvantages of various monitoring systems commonly used in Australia and compares them.

In accordance with the subject terms of engagement, SLR set out three (3) options for monitoring ambient air quality in North Sydney to establish baseline air quality in the area surrounding the proposed location of the tunnel ventilation stacks associated with the Western Harbour Tunnel and Warringah Freeway Upgrade as follows:

- Option 1 – Compliant Monitoring Station.
- Option 2 – Equivalent Monitoring Station.
- Option 3 – Non-Compliant Monitoring Station.

Option 1 is the option recommended by SLR as it uses methods outlined in the Approved Methods of Sampling and complies with current Australian Standards for the ambient monitoring of the relevant pollutants. This means that the monitoring data would stand up to scrutiny by third parties. The indicative cost for this Option including data hosting/project management of the program is $127,200 + GST, plus estimated reporting costs of $32,000 + GST.

The methods proposed for Option 2, while considered suitable for a baseline monitoring program, do not appear in the Approved Methods for Sampling.

Option 3 has been included because it provides a number of advantages, including smaller footprint and lower cost. However, use of a non-compliant monitoring station is not recommended as the data would be subject to critique by third parties.

SLR presented indicative costs for each of the three options. It should be noted that these costs exclude quarterly reporting which is estimated to be approximately $8,000 per quarter.

SLR deems St Leonards Park to be the most appropriate location for the baseline monitoring station (it has a power supply, space and complies with the siting criteria). As it is a baseline program, monitoring at one location is considered to be reasonable. St Leonards Park is located in close vicinity to the Warringah Freeway. Concentrations measured at this location can be expected to be representative of the levels that would be expected as similar distances from the motorway further to the north (i.e. Anzac Park Public School and residential receptors in the vicinity of the proposed WHTBL ventilation stack(s)).

Should air quality monitoring be undertaken by North Sydney Council in relation to the proposed WHTBL Project, background data collected over an initial 12-month period can be used to inform the Council's position and submission to the State Government on the Project.

SLR recommends that once the Environmental Impact Statement (EIS) for the Project is released for public comment, an independent peer review of the Air Quality Impact Assessment, prepared as part of the EIS, be conducted in order to compare the data collected as part of the air quality monitoring campaign, with the baseline/background data used in the EIS. The peer review should also review and comment on the air quality modelling methodology as well as assumptions made.

In order to identify the incremental impacts from the Project, it is also recommended that a second monitoring campaign be carried out, commencing 12 months prior to the completion of the Project and continuing for 12 months after the tunnel is operational. This would ensure that any changes in ambient air pollutant concentrations between now and opening of the WHTBL would be captured. This monitoring program would need to consider any impacts associated with the construction activities (i.e. it may need to occur prior to construction starting or at a location not expected to be affected by the construction works).

As this is a State project, Council may be of a mind to again ask for an undertaking from the RMS to either fund this proposal or at the very least reassure the Council and community of its intentions pertaining to the more localised air quality monitoring.

CONCLUSION

Given that the information obtained from the sampling program is intended to be used in submissions to the State Government regarding air quality in the area around the proposed tunnel and ventilation stacks, it is considered prudent to opt for a Compliance Monitoring Station (Option 1 in the attached report) as this equipment is compliant with current Australian Standards for ambient monitoring of the relevant pollutants and uses methods outlined in the Approved Methods for Sampling.

The data captured would be available (in real-time) on an external server which could be accessed via a link online. This data would then be interpreted and compared to relevant standards in the quarterly reports. The indicative cost including data hosting/project management of the program is $127,200 + GST plus estimated reporting costs of $32,000 + GST.

SLR

12 October 2018

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North Sydney Council
200 Miller Street
North Sydney
NSW 2060

Attention: Fiona Mulcahy

Dear Fiona

Western Harbour Tunnel & Beaches Link
Air Quality Monitoring

SLR has proposed three options for monitoring of ambient air quality in North Sydney to establish baseline air quality in the area surrounding the proposed location of the tunnel ventilation stacks associated with the Western Harbour Tunnel and Warringah Freeway Upgrade (the Project). Details on the three options are presented in an air quality monitoring report prepared by SLR for baseline air quality monitoring in North Sydney, dated 12 October 2018 (the Report). This letter presents indicative monthly costs for each option and should be read in conjunction with the Report.

The indicative costs presented in the tables below do not include consultant costs for data analysis and interpretation. Moreover, the costs are based on a single station operated on mains power. If additional stations are required, the monthly service and calibration costs may be lower for the additional stations, depending on how the project is managed.

Table 1 Option 1 - Compliant Ambient Air Quality Monitoring Station

Parameters	Monthly Rental	Average Monthly Service / Calibration#	Average Monthly Data Hosting / Licences
TEOM with $PM_{2.5}$ Inlet	$ 1,250	$ 600	$ 100
TEOM with PM_{10} Inlet	$ 1,250	$ 600	$ 100
NO_X Chemiluminescence analyser	$ 1,700	$ 1,250	$ 100
AS Compliant Meteorological Station	$ 1,800	$ 750	$ 100
Environmental Enclosure	$ 1,000	-	-
Subtotal (Annual cost)	**$84,000**	**$38,400**	**$4,800**
Total Annual Cost	**$127,200**		

\# includes installation/decommissioning costs

Table 2 Option 2 - Equivalent Ambient Air Quality Monitoring Station

Parameters	Monthly Rental	Average Monthly Service / Calibration#	Average Monthly Data Hosting / Licences
E-BAM with $PM_{2.5}$ Inlet	$ 1,000	$ 600	$ 100
E-BAM with PM_{10} Inlet	$ 1,000	$ 600	$ 100
Chemiluminescence analyser	$ 1,700	$ 1,250	$ 100
AS Compliant Meteorological Station	$ 1,800	$ 750	$ 100
Environmental Enclosure	$ 1,000	-	-
Subtotal (Annual cost)	**$78,000**	**$38,400**	**$4,800**
Total Annual Cost	**$121,200**		

\# includes installation/decommissioning costs

Table 3 Option 3 – Near Reference Ambient Air Quality Monitoring Station

Parameters	Monthly Rental	Average Monthly Service / Calibration#	Average Monthly Data Hosting / Licences
Aeroqual Sentry with $PM_{2.5}$ Inlet*	$ 900	$ 400	$ 100
Aeroqual Sentry with PM_{10} Inlet*	$ 900	$ 400	$ 100
Aeroqual AQM 65 with NO_x Sensor*	$ 2,000	$ 650	$ 100
AS Compliant Meteorological Station	$ 1,800	$ 750	$ 100
Environmental Enclosure	-	-	-
Subtotal (Annual cost)	**$67,200**	**$26,400**	**$4,800**
Total Annual Cost	**$98,400**		

* or equivalent near reference instrument
\# includes installation/decommissioning costs

Yours sincerely

ALI NAGHIZADEH
Associate

Checked/
Authorised by: GS/KL/MB

WESTERN HARBOUR TUNNEL & BEACHES LINK

Air Quality Monitoring

Prepared for:

North Sydney Council
200 Miller Street
North Sydney
NSW 2060

SLR Ref: 610.18164-R01
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PREPARED BY

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BASIS OF REPORT

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

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
610.18164-R01-v1.0	12 October 2018	A Naghizadeh	K Lawrence	A Naghizadeh
610.18164-R01-v0.1	10 October 2018	A Naghizadeh	K Lawrence	DRAFT

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1 Introduction

SLR Consulting Australia Pty Ltd (SLR) has been commissioned by North Sydney Council (the Council) to provide advice on a proposed ambient air quality monitoring programme to establish baseline air quality in North Sydney around the proposed location of the tunnel ventilation stack associated with the Western Harbour Tunnel and Warringah Freeway Upgrade (the Project). The information gathered by the monitoring programme will form part of Council's position and submission to the State Government on the Project.

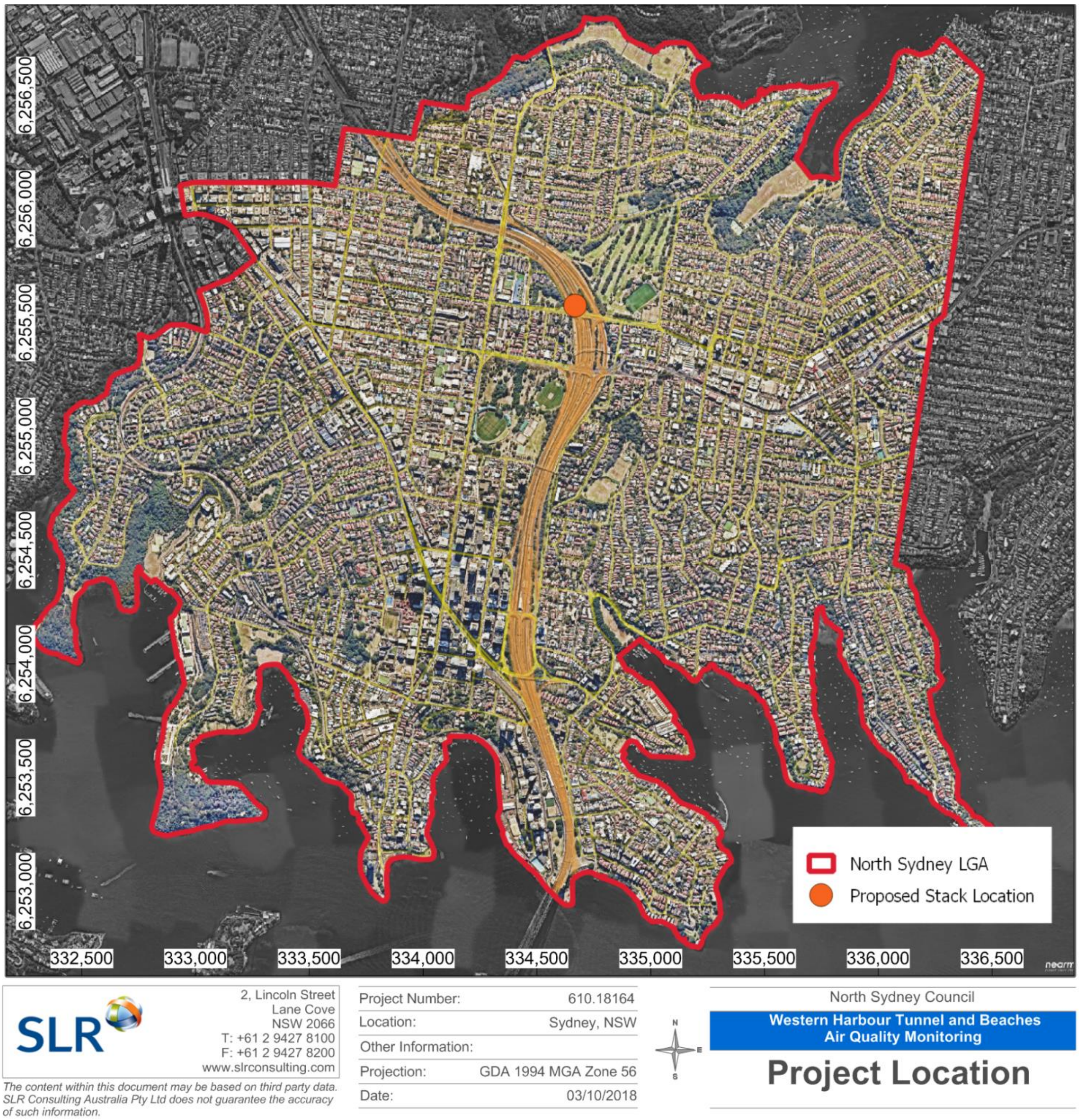
The Project comprises a new motorway tunnel connection across Sydney Harbour, and the Warringah Freeway Upgrade to integrate the new motorway infrastructure with the existing road network and to connect to the Beaches Link and Gore Hill Freeway Connection.

Detailed design information for the Project is not publicly available. The following documents have been reviewed as part of this report to gain an understanding of the Project and its potential air quality impacts.

- Western Harbour Tunnel and Warringah Freeway Upgrade Scoping Report (RMS, 2017)
- Western Harbour Tunnel Project Update - July 2018 (RMS, 2018)

According to the information available, the Project tunnels would be equipped with ventilation systems to capture and disperse vehicle emissions. The tunnel ventilation system is proposed to be designed to direct all tunnel air to ventilation stacks located near the Warringah Freeway and Ernest Street intersection (see **Figure 1**) and to avoid the release of any tunnel air from the road portals. No information regarding the specifications of the ventilation stacks (heights, velocities, etc.), which are critical to emission dispersion, is publicly available at the time of writing this report.

Figure 1 Project Location



2 Potential Impacts and Pollutants of Concern

As outlined in **Section 1**, detailed design information for the proposed Western Harbour Tunnel (including specifications of ventilation facilities, impact on traffic volumes and design of ramps and surface road widenings) is not yet publicly available. While the anticipated extent of local air quality impacts cannot be determined without this information, it can be expected that changes in the distribution of surface traffic and the operation of tunnel ventilation facilities would have an impact on local air quality.

The proximity of the proposed tunnel ventilation stack to nearby sensitive receptors means that tunnel emissions have the potential to result in elevated air pollutant concentrations during peak periods in areas within the North Sydney LGA closest to the proposed tunnel ventilation stacks.

It is noted that factors such as stack height and exit velocity could have a significant effect on the dispersion of pollutants from the proposed stack(s). A low vertical discharge velocity relative to wind speed at the stack exit has the potential to lead to stack downwash, which occurs when the plume is sucked downward into the wake behind the stack. Moreover, the presence of structures and buildings in close proximity to the stack can create turbulent wake zones within the atmosphere, where an otherwise elevated plume can be forced to the ground (building downwash). A tall stack will help avoid excessive downwind concentrations due to building downwash effects.

A review of the *National Pollutant Inventory Emission Estimation Technique Manual* (NPI EET) *for Combustion Engines* (DEWHA , 2008) identifies the primary pollutants from combustion engines as:

- Oxides of nitrogen (NO_x)
- Particulate matter less than 2.5 µm in aerodynamic diameter ($PM_{2.5}$)
- Particulate matter less than 10 µm in aerodynamic diameter (PM_{10})
- Volatile Organic Compounds (VOCs)
- Carbon monoxide (CO)
- Sulfur dioxide (SO_2)

Other substances that are also emitted from vehicle exhausts in trace amounts include products of incomplete combustion, such as metallic additives which contribute to the particulate content of the exhaust (DEWHA , 2008). In addition, ozone (O_3) is formed as a secondary pollutant from reactions between VOCs and NO_x, and is used as a key indicator of smog in urban environments.

The rate and composition of air pollutant emissions from road vehicles is a function of a number of factors, including the type, size and age of vehicles within the fleet, the type of fuel combusted, number and speed of vehicles and the road gradient.

It is also noted that during the construction works associated with the WHTBL Project, there will be potential for emissions of fugitive particulate matter, which have potential to give rise to nuisance impacts as well as adverse health impacts. These impacts will be of a limited duration, and the location and extent of the construction sites associated with the Project are not known at this time. However baseline monitoring of ambient PM_{10} concentrations in North Sydney could be used to assess the incremental impacts of the construction activities on ambient suspended particulate concentrations based on the results of construction phase monitoring programmes.

The following sections outline the potential health and amenity issues associated with the above pollutants of concern, while **Section 4.2** outlines relevant air quality assessment criteria.

2.1 Particulate Matter

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

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

2.2 Combustion Gases

Gas emissions associated with the combustion of automotive fuel (diesel, petrol, etc.) will include NO_x, SO_2, CO and VOCs.

(NO_X is a general term used to describe any mixture of nitrogen oxides formed during combustion. In atmospheric chemistry, NO_X generally refers to the total concentration of nitric oxide (NO) and nitrogen dioxide (NO_2). NO is a colourless and odourless gas that does not significantly affect human health. However, in the presence of oxygen, NO can be oxidised to NO_2 which can have significant health effects including damage to the respiratory tract and increased susceptibility to respiratory infections and asthma. NO will be converted to NO_2 soon after leaving a vehicle exhaust.

CO is an odourless, colourless gas formed from the incomplete burning of fuels in motor vehicles. It can be a common pollutant at the roadside. CO concentrations decrease rapidly with increasing distance from the source. CO in urban areas results almost entirely from vehicle emissions and its spatial distribution follows that of traffic flow. The incomplete combustion of fuel in diesel powered vehicles can generate particulate in the form of black soot.

Vehicle exhausts can contain emissions of sulfur dioxide (SO_2) due to impurities in the fuel. The sulfur content in diesel fuel has significantly reduced over the years and a timeline of the sulfur content in diesel fuels in Australia is shown in **Table 1**.

Table 1 The Environmental and Operability Standard in Australia – Diesel Fuel Quality Standard

Pollutant	National Standard	Date of Effect	Test Method
Sulfur Content of Fuel	10 ppm (max)	1-Jan-09	ASTM D5453
	50 ppm (max)	1-Jan-06	
	500 ppm (max)	31-Dec-02	

Source: http://www.environment.gov.au/topics/environment-protection/fuel-quality/standards/diesel, accessed on 8 October 2018.

VOCs may be emitted as a result of the incomplete combustion of fuel. VOCs emitted from vehicles include benzene, toluene and 1,3-butadiene, which influence human health due to their toxicity. As mentioned above, VOCs also play an important role in the formation of ground-level O_3 and photochemical oxidants associated with urban smog. Traffic-related VOC emissions have reduced significantly in recent years due to the improved combustion processes offered by modern engines.

2.3 Recommended Pollutants for Monitoring

Recommended pollutants for monitoring are suspended particulate matter (PM_{10}, $PM_{2.5}$) and NO_x.

While monitoring of other combustion-related gases (including VOCs, SO_2,CO and O_3) is possible, it is not proposed that they be included in the monitoring programme at this stage.

With regard to VOCs, available monitoring methods are either not continuous (grab samples), not accurate, or prohibitively costly. Ambient CO and SO_2 concentrations in the Sydney region are well below guideline levels and at levels that do not significantly influence human health. As outlined above, O_3 is a secondary pollutant formed from reactions between VOCs and NO_x that are dependent on the presence of sunlight and the mass ratio between NOx and VOCs in the ambient air. As a result there is a delay between the time the combustion gas emissions occur and the time ozone is generated, and elevated O_3 concentrations can therefore occur some distance away from the original source of the primary pollutants, depending on wind conditions at the time. It is therefore not possible to attribute changes in O_3 levels to a specific section of road or tunnel stack based on a near-source monitoring programme. Moreover, like VOCs, the less costly methods for monitoring ground-level O_3 are either not continuous (grab samples) or not accurate. The costs of including these pollutants in the monitoring programme are therefore not considered to be justified.

Given the above, it is recommended that NO_x be used as an indicator of any changes in ambient air quality due to gaseous combustion emissions from the WHTBL Project. This is deemed appropriate as vehicle emissions are the main source of combustion gases in the area surrounding the proposed tunnel ventilation stacks.

3 Characterisation of the Existing Environment

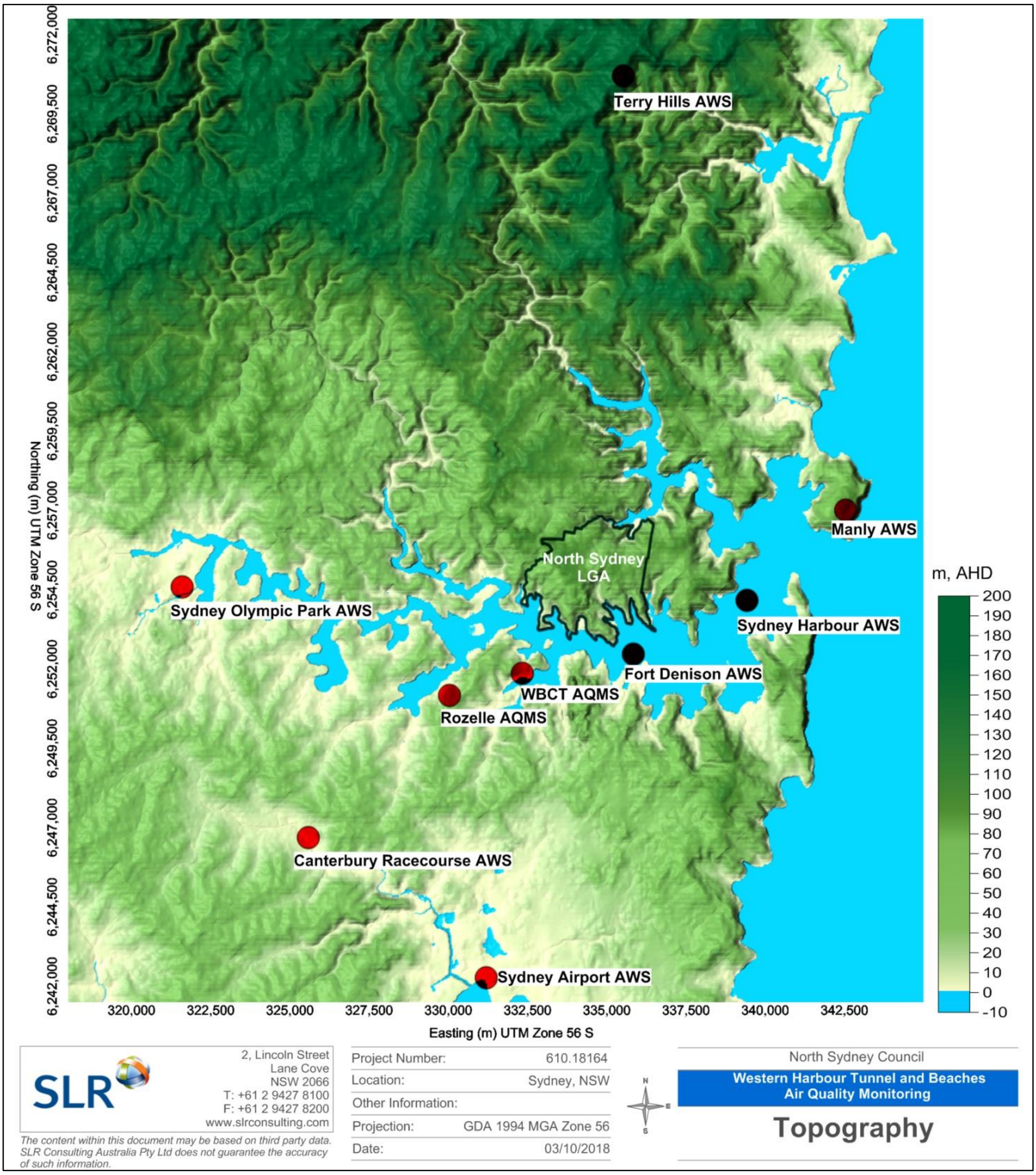
3.1 Regional Topography

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

A three dimensional representation of the region surrounding the North Sydney LGA is provided in **Figure 2**. The topography of the area illustrated in **Figure 2** ranges from an approximate elevation of -10 metres (m) to 200 m Australian Height Datum (AHD).

The area immediately surrounding the proposed tunnel ventilation stack is currently relatively open, which will facilitate the dispersion of air emissions and prevent 'pooling' of air pollutants.

Figure 2 Topography of Area Surrounding the North Sydney LGA



3.2 Regional Meteorology

The Bureau of Meteorology (BoM) maintains and publishes data from weather stations across Australia. The closest BoM Automatic Weather Stations (AWS) to the Project area are the Fort Denison, Sydney Harbour and Manly AWSs, as shown in **Figure 2**. Considering the significant terrain features between the North Sydney LGA and these locations, the recordings from these AWSs are not considered to be a reasonable representation of the wind conditions likely to be experienced in the area surrounding the proposed tunnel ventilation stacks. Therefore, in order to compile a site-representative dataset, The Air Pollution Model (TAPM) meteorological model (Version 4.0.4) has been used.

TAPM, developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) of Australia, is a prognostic model which can be used to compile a site-representative meteorological dataset in areas where there is limited observational data available, and has been widely used for meteorological and pollutant dispersion modelling studies throughout Australia. The model allows the user to generate synthetic observations by referencing databases (covering terrain, vegetation and soil type, sea surface temperature and synoptic scale meteorological analyses).

The CSIRO has a global data set of synoptic meteorological data that is required as input to the TAPM model. It is derived from analysis data used by meteorological services for weather forecasting. The synoptic meteorological data used in the modelling has been obtained from the CSIRO for the Asia-Pacific region for the years of 2013-2017 (inclusive). **Table 2** details the parameters used in the TAPM meteorological model for this assessment.

Additionally, TAPM may assimilate actual local wind observations so that they can optionally be included in a model solution. In this assessment, TAPM predictions have been nudged with the locally monitored observational data, as shown in **Table 2**.

Table 2 TAPM Input Parameters Used in this Study

Parameter	North Sydney
Number of grids (spacing)	5 (30 km, 10 km, 3 km, 1 km, 0.3 km)
Number of grid points	25 x 25 x 25
Year of analysis	2013-2017
Data assimilation	Sydney Airport AWS (Station # 66037) Sydney Olympic Park AWS (Station # 66212) Terrey Hills AWS (Station # 66059) Canterbury Racecourse AWS (Station # 66194)
Centre of analysis	334,210 mE 6,254,879 mS (UTM zone 56 S)

3.2.1 Wind Speed and Direction

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

A summary of the average annual and seasonal wind behaviour predicted by TAPM for the modelled years (2013-2017) extracted at a location near the proposed stacks is presented as wind roses in **Figure 3**.

Wind roses show the frequency of occurrence of winds by direction and strength. The bars correspond to the 16 compass points (degrees from North). The bar at the top of each wind rose diagram represents winds blowing from the north (i.e. northerly winds), and so on. The length of the bar represents the frequency of occurrence of winds from that direction, and the widths of the bar sections correspond to wind speed categories, the narrowest representing the lightest winds. Thus it is possible to visualise how often winds of a certain direction and strength occur over a long period, either for all hours of the day, or for particular periods during the day.

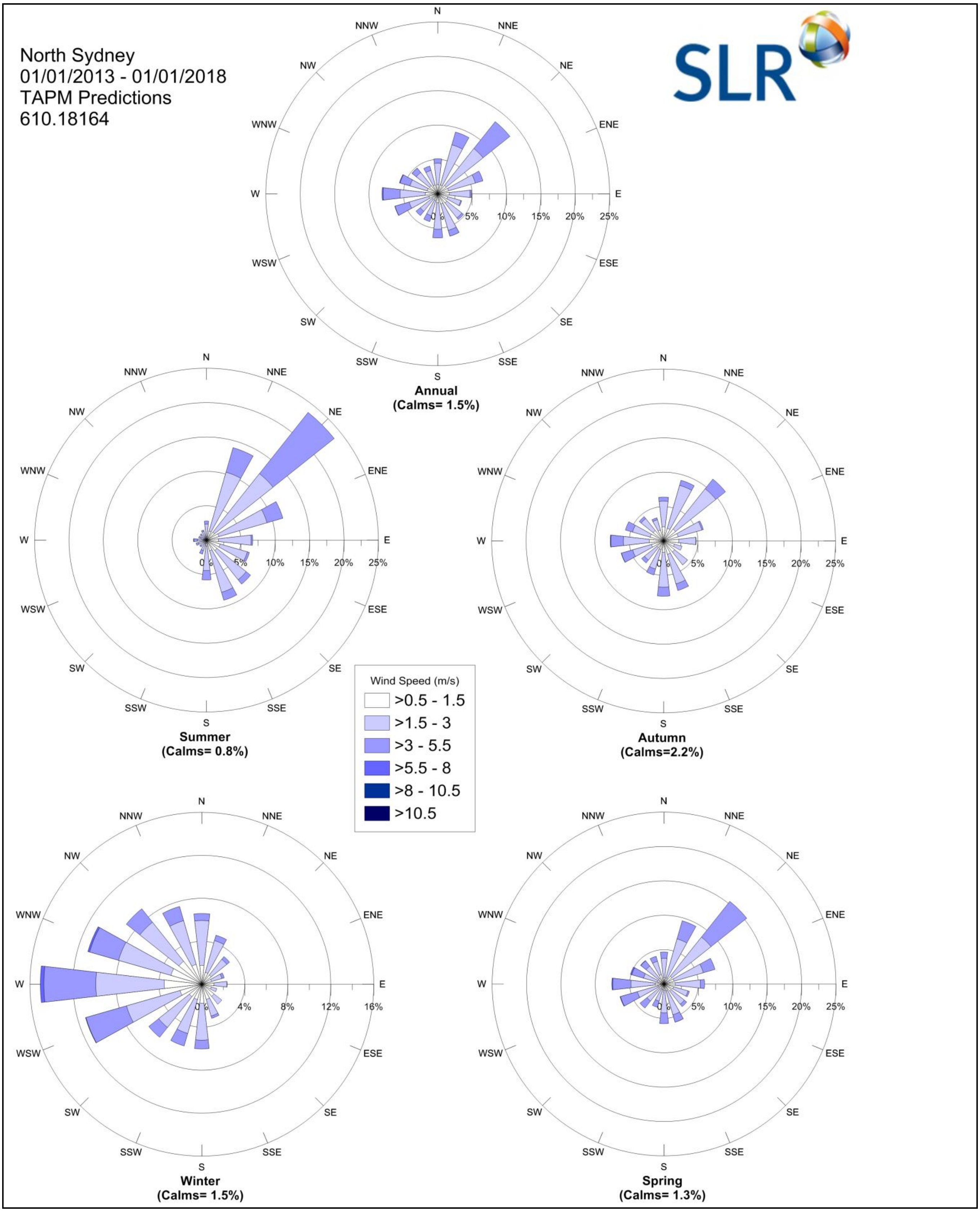
The annual wind rose for the years 2013-2017 indicates that throughout the year, winds are mostly light to gentle (between 1.5 m/s and 5.5 m/s) and blow from all directions, with the highest frequency of winds from the northeast quadrant. Calm wind conditions (wind speed less than 0.5 m/s) were predicted to occur approximately 1.5% of the time throughout the modelling period.

The seasonal wind roses for the years 2013-2017 indicate that:

- In summer, winds are predicted to be light to gentle, occurring predominantly from the northeast, with the smallest percentage of winds blowing from the western quadrant. Calm winds were predicted 0.8% of the time during summer.
- In autumn, winds are predicted to be light to gentle and blow from all directions with the highest frequency of winds from the northeast quadrant. Calm winds were predicted 2.2% of the time during autumn.
- In winter, winds are predicted to be light to gentle and predominantly from the western quadrant, with very few winds from the eastern quadrant. Calm winds were predicted 1.5% of the time during winter.
- In spring, winds are predicted to be light to gentle, predominantly from the northeastern quadrant. Calm winds were predicted 1.3% of the time during spring.

The closest existing sensitive receptors (refer to **Section 3.2.2** below) are located southwest, northwest and west of the proposed stacks. Winds from between the northeast and southeast directions, which would blow air emissions from the proposed stacks towards the nearest existing receptors, occur approximately 55% of the time.

Figure 3 North Sydney Annual and Seasonal Wind Roses, 2013-2017



3.2.2 Atmospheric Stability

Atmospheric stability refers to the tendency of the atmosphere to resist or enhance vertical motion. The Pasquill-Gifford-Turner (PGT) assignment scheme identifies six stability classes, A to F, to categorise the degree of atmospheric stability as follows:

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

The meteorological conditions defining each PGT stability class are shown in **Table 3**.

Table 3 Meteorological Conditions Defining PGT Stability Classes

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

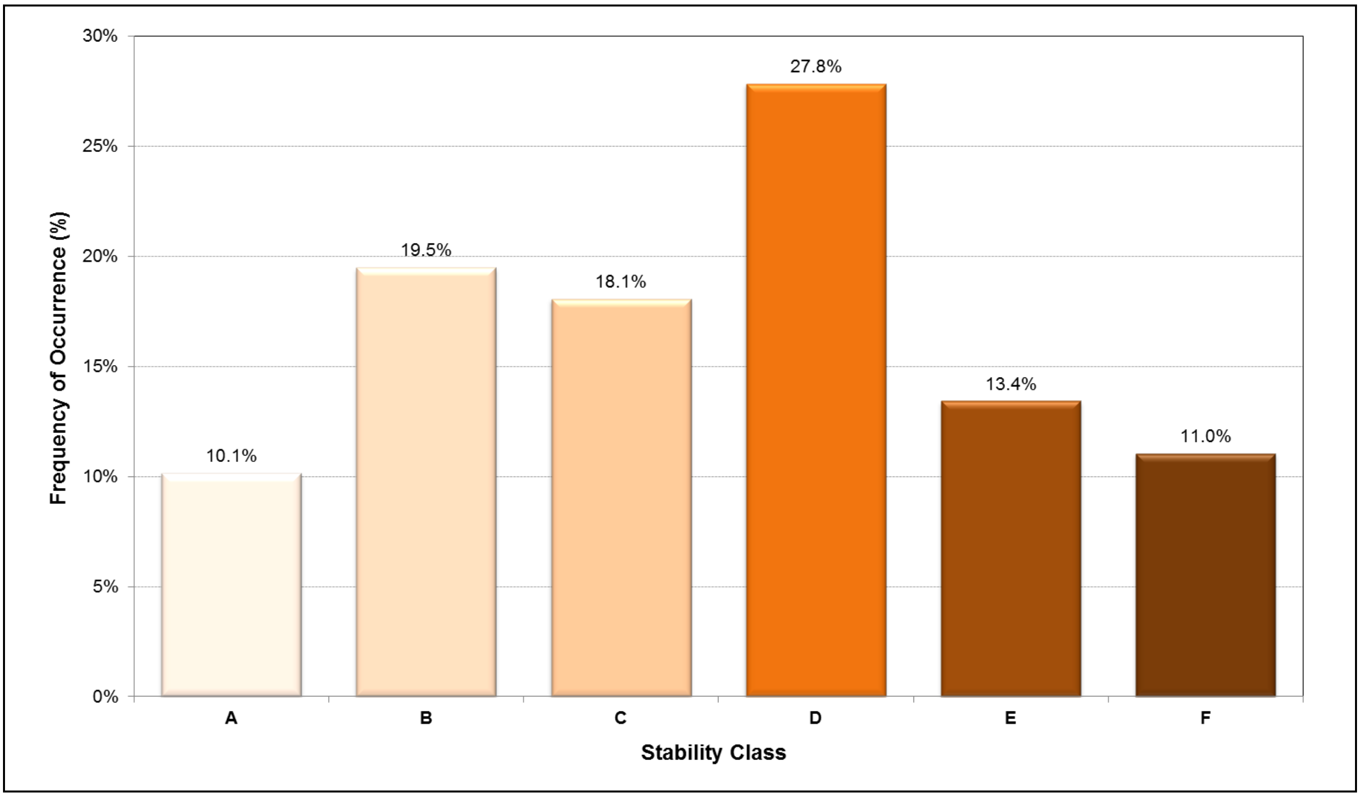
Source: (NOAA, 2018)

Notes:

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

The frequency of each stability class predicted by TAPM, extracted at North Sydney, during the modelling period is presented in **Figure 4**. The results indicate a high frequency of conditions typical to Stability Class D. Stability Class D is indicative of neutral conditions, conducive to a moderate level of pollutant dispersion due to mechanical mixing.

Figure 4 Predicted Stability Class Frequencies at North Sydney (TAPM predictions, 2013-2017)



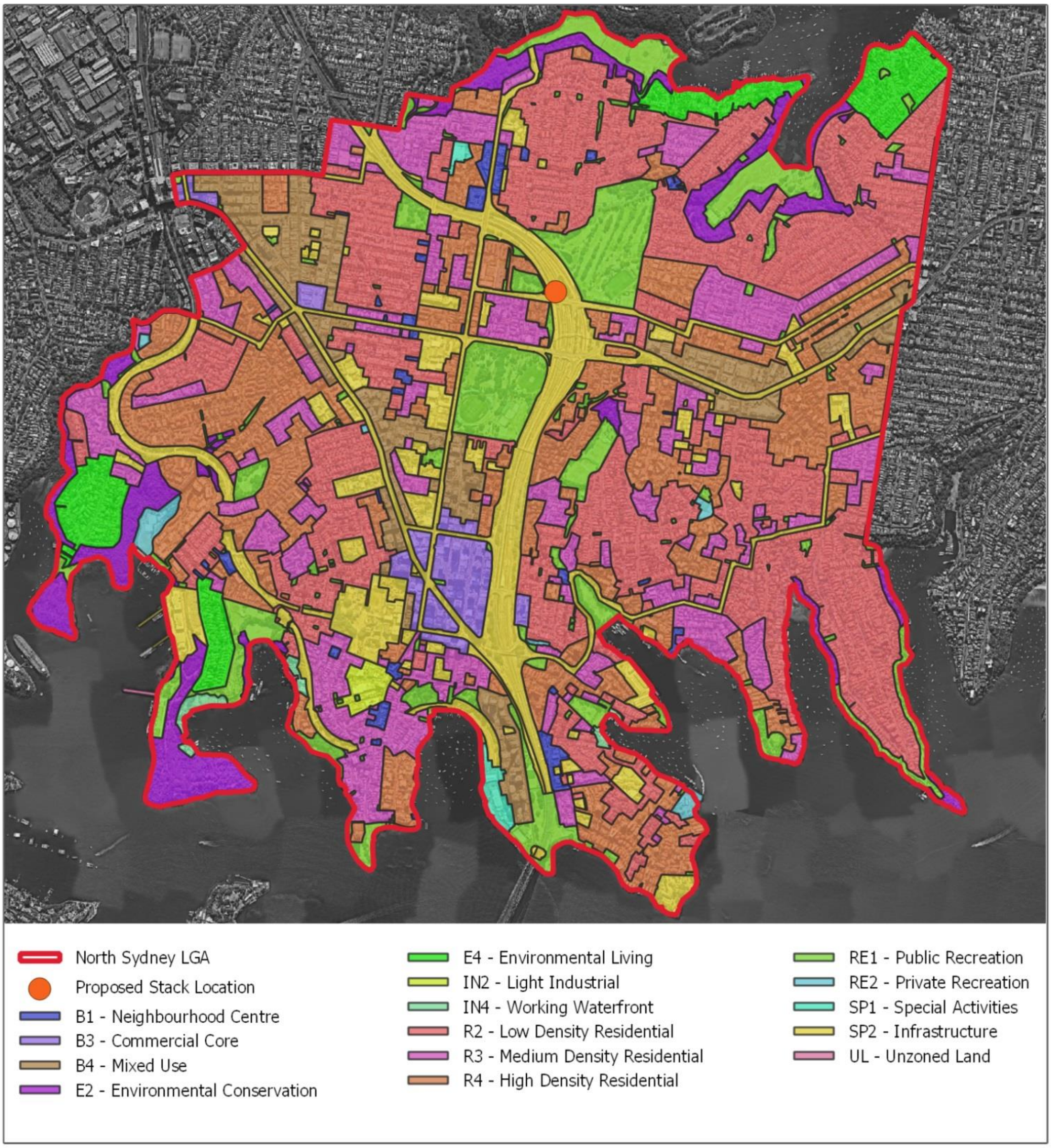
3.3 Surrounding Land Use and Sensitive Receptors

The area surrounding the proposed tunnel ventilation stacks includes lands zoned as high density residential, low density residential, public recreation, medium density residential and infrastructure as zoned by the *North Sydney Local Environmental Plan 2013* (refer **Figure 5**).

The nearest existing residential receptors are located on Ernest Street, approximately 60 m southwest of the proposed tunnel ventilation stacks, and on Cammeray Avenue approximately 100 m northwest of the proposed tunnel ventilation stacks.

In addition to residential receptors, there are a large number of schools and childcare centres located within the North Sydney LGA (refer **Figure 6**), the closest of which is Anzac Park Public School, located approximately 200 m west of the proposed tunnel ventilation stacks.

Figure 5 Surrounding Land Use



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Project Number:	610.18164
Location:	Sydney, NSW
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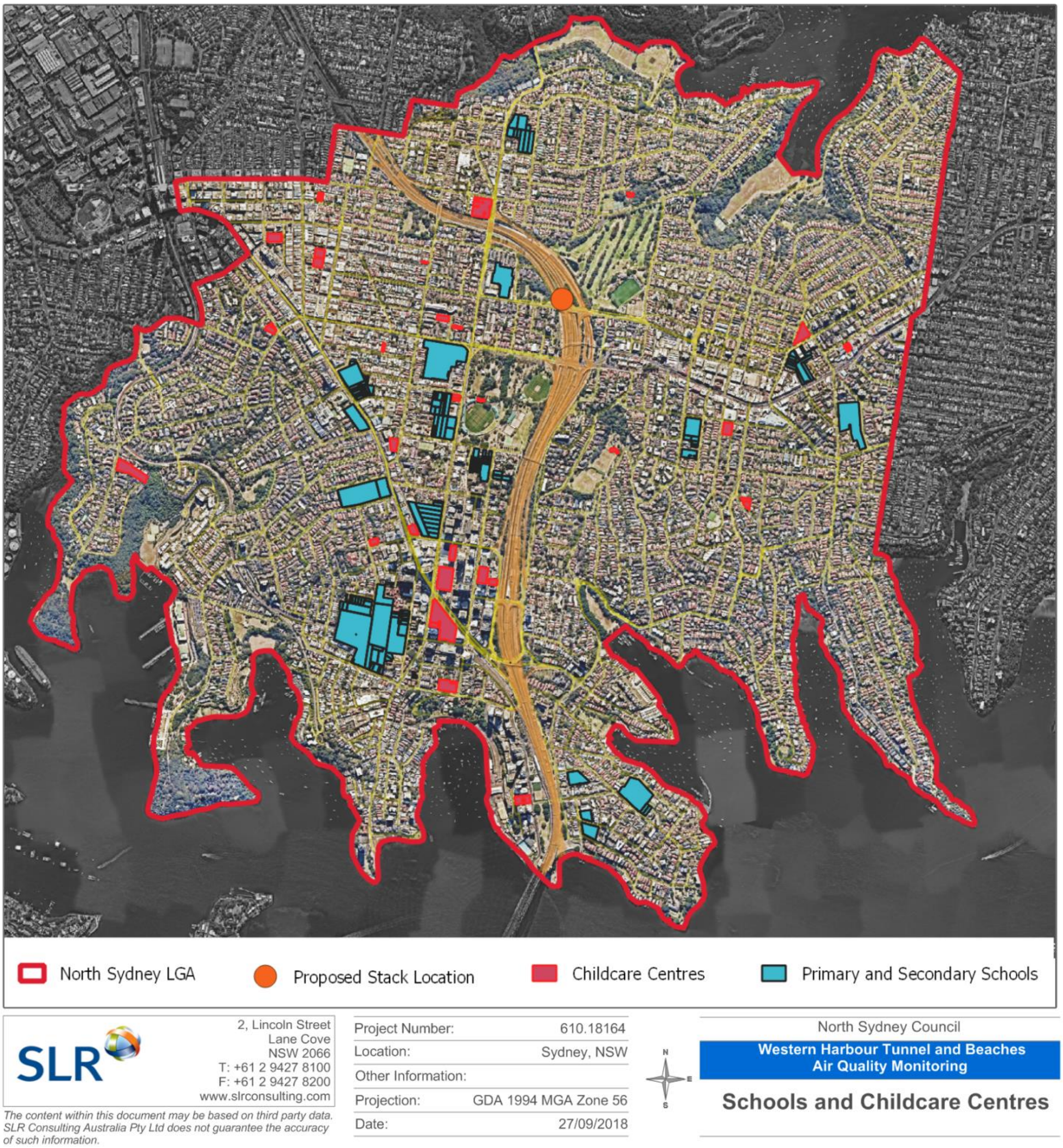
Projection:	GDA 1994 MGA Zone 56
Date:	27/09/2018

N E S

North Sydney Council
Western Harbour Tunnel and Beaches Air Quality Monitoring
Surrounding Land Zoning

Figure 6 North Sydney LGA Schools and Childcare Centres



3.4 Air Quality in the Region

According to the *New South Wales State of the Environment 2015* Report (NSW EPA, 2015), air quality in NSW has improved significantly in the last three decades. The concentrations of a number of the most common air pollutants, including carbon monoxide (CO), lead and sulfur dioxide (SO_2), have significantly reduced and are now at low levels. However, while there have been significant reductions in the ambient concentrations of other pollutants such as particulate matter, oxides of nitrogen (NOx) and Volatile Organic Compounds (VOCs) across the Sydney region, these pollutants continue to impact air quality within metropolitan Sydney.

3.4.1 Available Air Quality Monitoring Data

The NSW Office of Environment and Heritage (OEH) maintains a network of Air Quality Monitoring Stations (AQMSs) across NSW. The nearest such OEH station is located at Rozelle, approximately 3.5 kilometres (km) to the southwest of the North Sydney LGA, and 6.5 km to the southwest of the proposed tunnel ventilation stack (see **Figure 2**). The Rozelle AQMS was commissioned in 1978 and is located in the grounds of Rozelle Hospital, off Balmain Road, Rozelle. It is situated in a residential area in the Parramatta River valley and is at an elevation of 22 m.

Due to the presence of trees within 20 m of the Rozelle station, the clear sky angle is less than 120° which means this stations does not currently comply with Australian Standard AS/NZS 3580.1.1-2016 - *Methods for sampling and analysis of ambient air - Guide to siting air monitoring equipment*. The air pollutants currently measured by Rozelle AQMS include ozone (O_3), oxides of nitrogen (as NO, NO_2 & NO_X), SO_2, fine particles less than 10 microns (PM_{10}), fine particles less than 2.5 microns ($PM_{2.5}$) and CO.

In addition to the air quality monitoring stations operated by NSW OEH, the Port Authority of NSW also runs an air monitoring program to monitor the ambient air quality in the immediate vicinity of the White Bay Cruise Terminal (WBCT). The location of the monitoring site in relation to the North Sydney LGA is shown in **Figure 2**. The pollutants being monitored as part of this program are SO_2 and $PM_{2.5}$ only, in addition to meteorological parameters. Due to the WBCT monitoring location's proximity to the cruise ship terminal and berths, the pollutant concentrations recorded at this monitoring station will be significantly affected by emissions from fuel combustion in cruise ships and other industrial activities surrounding the White Bay terminal, which are not considered to be representative of the emission sources at the Project site.

Considering the above, the two nearest air quality monitoring stations with publicly available data are not deemed representative of air quality conditions in North Sydney. The following sections therefore outline the available options for monitoring ambient air quality in North Sydney to establish baseline air quality at the proposed location of the tunnel ventilation stack.

It is noted that in July 2017, RMS established an air quality monitoring station located at Rhodes Avenue, Naremburn beside the Warringah Freeway. However, data from this station and monitoring campaign details (including monitored parameters and duration) are not publicly available.

4 Regulatory Framework

4.1 Approved Methods for the Sampling and Analysis of Air Pollutants in NSW

The *Approved Methods for the Sampling and Analysis of Air Pollutants in NSW* (DEC, 2006) [hereafter the Approved Methods for Sampling] lists the methods to be used for monitoring meteorological conditions and sampling and analysis of air pollutants in NSW for statutory purposes.

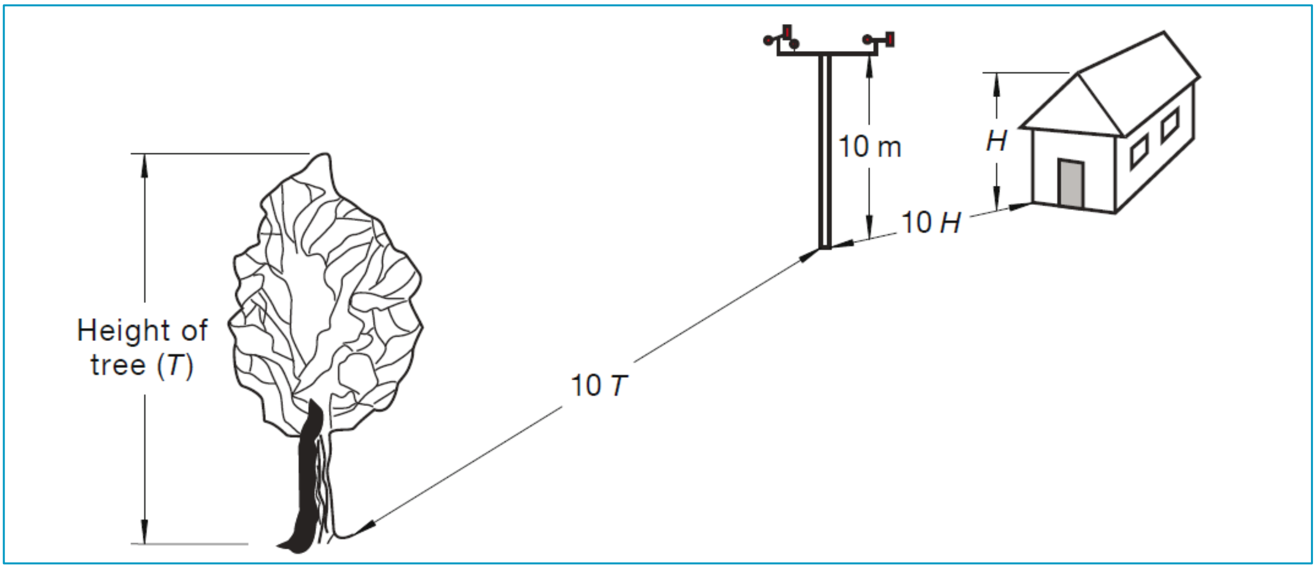
General methods for ambient air monitoring (including meteorological monitoring) listed in the Approved Methods for Sampling are:

- AM-1 *Guide to Siting of Sampling Units* (AS 2922-1987, superseded by AS 3580.1.1-2016).
- AM-2 *Guide for Horizontal Measurement of Wind for Air Quality Applications* (AS 2923- 1987, superseded by AS 3580.14-2014).
- AM-3 *Preparation of reference test atmospheres* (AS 3580.2.1-1990 or AS 3580.2.2-1990 (as appropriate)).
- AM-4 *On-Site Meteorological Monitoring Program Guidance for Regulatory Modelling Applications* (USEPA (2000) EPA 454/R-99-005).

A summary of the siting requirements outlined in AM-1 for wind instruments is shown in **Figure 7**.

A summary of the recommended instrument performance specifications for wind speed, wind direction, temperature and solar radiation systems outlined in AM-2 and AM-4 are shown in **Table 4** and **Table 5**.

Figure 7 Summary of Siting Requirements for Wind Instruments



SOURCE: AS 3580.1.1-2016

Table 4 Recommended Instrument Performance Specifications for Wind Speed and Wind Direction

Parameter	Wind Speed	Wind Direction	Temperature
Range	0.5 to 30 m/s	0 to 360°	-10°C to 50°C
Total Accuracy	3% or ±0.2 m/s	±3°	±0.3°C
Maximum averaging interval	10 min	10 min	NA
Data sampling interval	5 sec	>60 scalar/vector means >360 for sigma theta	NA

Source: AS 3580.14-2014

Table 5 Recommended Instrument Performance Specifications for Solar Radiation

Parameter	Solar Radiation (First Class)
Response time	<30 sec
Directional response	±20 W/m^2
Temperature response	±4%

SOURCE: AS 3580.14-2014

The methods listed in the Approved Methods for Sampling for the monitoring of ambient particulate and gaseous pollutant concentrations identified for sampling in **Section 2.3** are:

- AM-14 - AS 2724.2-1987 *Determination of suspended matter expressed as equivalent black smoke by filter paper soiling* (since withdrawn by Standards Australia);
- AM-15 - AS 2724.3-1984 *Total suspended particulate matter (TSP) - High volume sampler gravimetric method* (superseded by AS 3580.9.3-2015);
- AM-16 - AS 2724.4-1987 *Particulate matter – Determination of light-scattering – Integrating nephelometer method* (superseded by AS 3580.12.1-2015);
- AM-18 - AS 3580.9.6-1990 *Particulate matter – Determination of PM_{10} – High-volume sampler (HVS) with size-selective inlet* (superseded by AS 3580.9.6-2015);
- AM-22 - AS 3580.9.8-2001 *Determination of suspended particulate matter – PM_{10} continuous direct mass method using a tapered element oscillating microbalance (TEOM) analyser* (superseded by AS 3580.10.1-2008).
- AM-12 - AS 3580.5.1-1993 *Methods for sampling and analysis of ambient air – Determination of oxides of nitrogen – Direct-reading instrumental method* (superseded by AS 3580.5.1-2011).

A summary of the recommended sampling inlet positioning criteria for monitoring equipment listed in AM-1 are shown in **Table 6**. As the aim of the WHTBL monitoring program is to understand the existing baseline air quality in the North Sydney LGA, the criteria for a neighbourhood station are considered to be the most relevant.

Table 6 Recommended Sampling Inlet Positioning Criteria

Pollutant	Type of Monitoring Station	Height above Ground to Probe	Other Locating Criteria (minimum requirements)	Relevant Australia Standards
NOx and Particulates	Neighbourhood and background	1.5 m to 15 m	- Clear sky angle 120° - Unrestricted airflow of 270° around sample inlet - 10 m from any object with a height exceeding 2 m below the height of the sample inlet - No extraneous sources nearby - 50 m from road	AS 3580.5.1 AS 3580.9.6 AS 3580.9.8 AS 3580.9.11 * AS 3580.9.12 * AS 3580.9.13 * AS 3580.9.14 *
	Peak	1.5 m to 15 m	- Unrestricted airflow of 180° around sample inlet with no obstruction between the major source and the sample inlet - No extraneous sources nearby - 2 m from road - 10 m from any object with a height exceeding 2 m below the height of the sample inlet - Col-located high volume samplers 2-4 m apart - No trees between sampling inlet and source	AS 3580.5.1 AS 3580.9.6 AS 3580.9.8 AS 3580.9.11 * AS 3580.9.12 * AS 3580.9.13 * AS 3580.9.14 *

* Published after the Approved Methods for Sampling was last updated.

In addition to the recommended siting criteria set out in the standards listed above, siting of the meteorological, particulate and gaseous pollutant monitoring equipment will need to consider land access approvals, as well as power and site security requirements. **Section 5** of this report presents potential locations for the monitoring station(s). A full siting review should be conducted as part of installing the meteorological and monitoring equipment to assess compliance with the abovementioned standards. A suitability qualified consultant should be commissioned for the Installation and maintenance of meteorological station and air quality monitors.

4.2 Ambient Air Quality Criteria

State air quality guidelines specified by the NSW Environmental Protection Agency (EPA) for the pollutants identified in **Section 2** are published in the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (NSW EPA, 2017)[hereafter 'Approved Methods']. The ground level air quality impact assessment criteria listed in Section 7 of the Approved Methods have been established by NSW EPA to achieve appropriate environmental outcomes and to minimise risks to human health. They have been derived from a range of sources and are the defining ambient air quality criteria for NSW, and are considered to be appropriate for the WHTBL.

A summary of the relevant air quality assessment criteria for particulate matter and products of combustion is provided in **Table 7**.

Table 7 NSW EPA Goals for Particulate Matter and Combustion Gases

Pollutant	Averaging Period	Concentration		Source
CO	15 minutes	87 ppm	100 mg/m^3	WHO (2000)
	1 hour	25 ppm	30 mg/m^3	WHO (2000)
	8 hours	9 ppm	10 mg/m^3	NEPC (1998)
NO_2	1 hour	12 pphm	246 µg/m^3	NEPC (1998)
	Annual	3 pphm	62 µg/m^3	NEPC (1998)
Photochemical oxidants (as ozone)	1 Hour	10 pphm	214 µg/m^3	NEPC (1998)
	4 Hours	8 pphm	171 µg/m^3	NEPC (1998)
PM_{10}	24 Hours	-	50 µg/m^3	DoE (2016)
	Annual	-	30 µg/m^3	DoE (2016)
$PM_{2.5}$	24 Hours	-	25 µg/m^3	DoE (2016)
	Annual	-	8 µg/m^3	DoE (2016)
SO_2	10 minutes	25 pphm	712 µg/m^3	NHMRC (1996)
	1 hour	20 pphm	570 µg/m^3	NEPC (1998)
	24 hours	8 pphm	228 µg/m^3	NEPC (1998)
	Annual	2 pphm	60 µg/m^3	NEPC (1998)

Source: EPA 2017

5 Air Quality Monitoring Methods

5.1 Particulate Matter Monitoring

This Section summarises the advantages and disadvantages of various particulate matter monitoring systems commonly used in Australia. A comparison of these methods is shown in **Table 8**.

High Volume Air Sampler (HVAS)

This method is listed in the Approved Methods for Sampling for PM_{10} and has Australian/New Zealand Standards available for PM_{10} and $PM_{2.5}$. A HVAS monitoring system provides data on a 1-in-6 days basis and requires a technician to change the filter between each sampling event. Moreover, a separate monitor needs to be set up for PM_{10} and $PM_{2.5}$. As this method does not provide continuous monitoring data, there is significant delay between the sampling event and the receipt of the laboratory results, and given the significant labour requirements involved, the use of this method is not considered suitable for the baseline monitoring programme.

Tapered Element Oscillating Microbalance (TEOM)

This method is listed in the Approved Methods for Sampling for PM_{10} and has Australian/New Zealand Standards available for PM_{10} and $PM_{2.5}$. A TEOM monitoring system provides data on a continuous basis, however it requires a large secure space (3 m x 3 m) on a stable concrete pad, a reliable electricity connection and is very expensive. Like the HVAS system, separate monitors are required for PM_{10} and $PM_{2.5}$.

Beta-Attenuation Monitor (E-BAM)

This method has Australian/New Zealand Standards available for PM_{10} and $PM_{2.5}$. The E-BAM monitoring system offers continuous data, the option to be operated using solar powered batteries, requires a much smaller area compared to a TEOM and is considerably less expensive.

Given the above, this method is considered suitable for the baseline monitoring programme, however it is noted that the E-BAM monitoring system is not listed in the Approved Methods for Sampling. Moreover, Like the HVAS and TEOM systems, separate monitors are required for PM_{10} and $PM_{2.5}$.

Aeroqual Dust Sentry

This method does not have Australian/New Zealand Standards available for PM_{10} and $PM_{2.5}$ and is not listed in the Approved Methods for Sampling. However, various validation studies have been conducted by the manufacturers of the Aeroqual Dust Sentry and the system has been MCERTS-certified by UK Environment Agency for particulate sampling.

The Aeroqual Dust Sentry monitoring system offers continuous data, the option to be operated using solar powered batteries, requires a much smaller area compared to a TEOM and is considerably less expensive than TEOMs and less expensive than E-BAMs. Given the above, the Aeroqual Dust Sentry has been considered as an option for the baseline monitoring programme.

Aeroqual Dust Profiler

This method does not have Australian/New Zealand Standards available for PM_{10} and $PM_{2.5}$ and is not listed in the Approved Methods for Sampling. Unlike the Aeroqual Dust Sentry, it is also not certified by the UK Environment Agency for particulate sampling as it is not as accurate as the Aeroqual Dust Sentry.

The Aeroqual Dust Profiler monitoring system offers continuous data, the option to be operated using solar powered batteries, requires a much smaller area compared to a TEOM, is considerably less expensive than TEOMs and less expensive than E-BAMs and is capable of simultaneously monitoring various size fractions including PM_{10} and $PM_{2.5}$. The lower accuracy of the Aeroqual Dust Profiler and the fact that it is not certified means that any data collected using this instrument would be subject to high level of uncertainty and could easily be disputed by a third party. For this reason, this method is not considered suitable for the baseline monitoring programme.

Table 8 Comparison of Particulate Matter Monitoring Systems Commonly Used in Australia

Monitor	Advantages	Disadvantages
High Volume Air Sampler (HVAS)	Certified Reference Instrument. AS/NZ Standards available for PM_{10}, $PM_{2.5}$. Listed in the Approved Methods for Sampling.	Requires mains power. Requires a stable concrete pad for siting. Requires a technician to manually change the filter paper between each sample -increased labour costs. Much less data can be collected (eg 1 day in 6 sampling regime usually adopted) over the same time period compared to a continuous sampling method. Only 24 hour average concentrations are reported, so analysis against wind direction or time of day not able to be performed. Noise from pump can disturb nearby residents. Separate monitors required for PM_{10} and $PM_{2.5}$ at each location
TEOM (Tapered Element Oscillating Microbalance)	Certified Equivalent Instrument. AS/NZ Standards available for PM_{10}, $PM_{2.5}$. Listed in the Approved Methods for Sampling. Continuous sampler so more data can be collected over the same time period compared to a HVAS. Analysis against wind direction and time of day can be performed differentiate upwind/downwind results. Sample heated to 50°C so volatile mass lost; this can be mitigated by use of FDMS which increases price.	Most expensive option Requires a large air-conditioned environmental enclosure to house the instrument. Requires mains power. Requires a stable concrete pad for siting. Requires a crane truck or forklift to assist with mounting the environmental enclosure into position or a trailer mounted environmental enclosure. Cannot easily be relocated. Noise from air conditioner can disturb nearby residents. Separate monitors required for PM_{10} and $PM_{2.5}$ at each location

Monitor	Advantages	Disadvantages
E-BAM (Beta-Attenuation Monitor)	AS/NZ Standards available for PM_{10}, $PM_{2.5}$. Can be operated from solar power if required (increased reliability if power provided). Portable unit so can easily be relocated to alternate monitoring positions. Continuous sampler so more data can be collected over the same time period compared to a HVAS. Analysis against wind direction and time of day can be performed differentiate upwind/downwind results.	Not listed in the Approved Methods for Sampling. Separate monitors required for PM_{10} and $PM_{2.5}$ at each location
Aeroqual Dust Sentry	Cheaper than other continuous monitors eg E-BAMs and TEOMs Can be operated from solar power if required (increased reliability if power provided). Portable unit so can easily be relocated to alternate monitoring positions. Continuous sampler so more data can be collected over the same time period compared to a HVAS. Analysis against wind direction and time of day can be performed differentiate upwind/downwind results. MCERTS certified by UK Environment Agency for particulate sampling	Not listed in the Approved Methods for Sampling. AS/NZ Standards not available for PM_{10}, $PM_{2.5}$. Separate monitors required for PM_{10} and $PM_{2.5}$ at each location
Aeroqual Dust Profiler	Lowest cost option Can be operated from solar power if required (increased reliability if power provided). Portable unit so can easily be relocated to alternate monitoring positions. Continuous sampler so more data can be collected over the same time period compared to a HVAS. Analysis against wind direction and time of day can be performed differentiate upwind/downwind results. Simultaneous monitoring of PM_{10} and $PM_{2.5}$ possible	Not listed in the Approved Methods for Sampling. AS/NZ Standards not available for PM_{10}, $PM_{2.5}$. Least accurate of all options available

5.2 Combustion Gas Monitoring

This Section summarises the advantages and disadvantages of two combustion gas monitoring systems commonly used in Australia. A comparison of these methods is shown in **Table 9**.

Reference Monitoring Station

The following reference methods are listed in the Approved Methods for Sampling for monitoring combustion gases (including NOx, CO and SO_2) in the ambient atmosphere:

- Chemiluminescence method for NO/NOx;
- Pulsed fluorescent spectrophotometry method for SO_2; and
- Infrared spectrometry method for CO.

Australian/New Zealand Standards are available for the monitoring of these pollutants using the above reference methods. A reference monitoring station provides data on a continuous basis and is well suited for long-term air quality trend analysis, however it requires a large air-conditioned environmental enclosure to house the instrument (approximately 2 m x 2 m), a reliable electricity connection and is more expensive than the near-reference option. Separate analysers are required for each pollutant; however, all analysers are placed in a single enclosure. A reference monitoring station is the recommended option for the baseline monitoring programme as the data captured by such a station can be directly compared with background data used for an air quality impact assessment, and would not be at risk of being disputed by a third party provided the monitoring is performed in compliance with the relevant standards.

Near-Reference Monitoring Station

Near-reference monitoring stations do not comply with methods listed in the Approved Methods for sampling and do not have Australian/New Zealand Standards available for combustion gases. However, such stations are much less expensive to establish, require a smaller footprint and are typically capable of monitoring multiple pollutants simultaneously.

Table 9 Comparison of Combustion Gas Monitoring Systems Commonly Used in Australia

Monitor	Advantages	Disadvantages
AM-12 Compliant Chemiluminescence NO/NOx Analyser	AS/NZ Standards available for NOx Listed in the Approved Methods for Sampling. Continuous sampler Analysis against wind direction and time of day can be performed to differentiate upwind/downwind results.	More expensive than near-reference monitoring stations. Requires a crane truck or forklift to assist with mounting the environmental enclosure into position or a trailer mounted environmental enclosure. Cannot easily be relocated. Noise from air conditioner can disturb nearby residents.

Monitor	Advantages	Disadvantages
Aeroqual AQM 65 near reference Ambient Monitoring Station (or equivalent)	Lower cost Continuous sampler Analysis against wind direction and time of day can be performed to differentiate upwind/downwind results. Simultaneous monitoring of up to 10 pollutants (including NOx, NO_2, CO, SO_2,VOCs,and CO_2) Traceable back to USEPA (40 CFR Part 53) certified equivalent method instruments Smaller enclosure compared to reference monitoring stations allows for easy relocation.	Not listed in the Approved Methods for Sampling. Not compliant with AS/NZ Standards for PM_{10}, $PM_{2.5}$.

6 Air Quality Monitoring Programme

6.1 Air Quality Monitoring Parameters

As noted in **Section 2**, the primary pollutants from combustion of fuels in vehicles include NOx, particulate matter (PM_{10} and $PM_{2.5}$), VOCs, CO and SO_2. As outlined in **Section 3.4**, ambient CO and SO_2 concentrations within the Sydney metropolitan area are well understood through regional ambient air quality monitoring programmes and are low compared to the relevant heath-based air quality criteria. Based on the above, it is recommended that PM_{10}, $PM_{2.5}$ and NOx (as an indicator of combustion gas emissions) be monitored.

6.2 Air Quality Monitoring Locations

A number of potential ambient air quality monitoring locations have been identified through a site visit and desktop review. These locations were selected for consideration based on:

- Proximity to proposed tunnel ventilation stack(s);
- Meteorological conditions typical for North Sydney;
- Area of land available to be occupied by monitoring equipment;
- Existing vegetation and structures and their potential influence on air movements;
- Availability of power supply (where needed);
- Potential for compliance with Australian Standard (AS) 3580.1.1-2016 *Methods for the sampling and analysis of ambient air – Guide to the siting of air monitoring equipment* (Standards Australia 2007); and
- Instrumentation requirements.

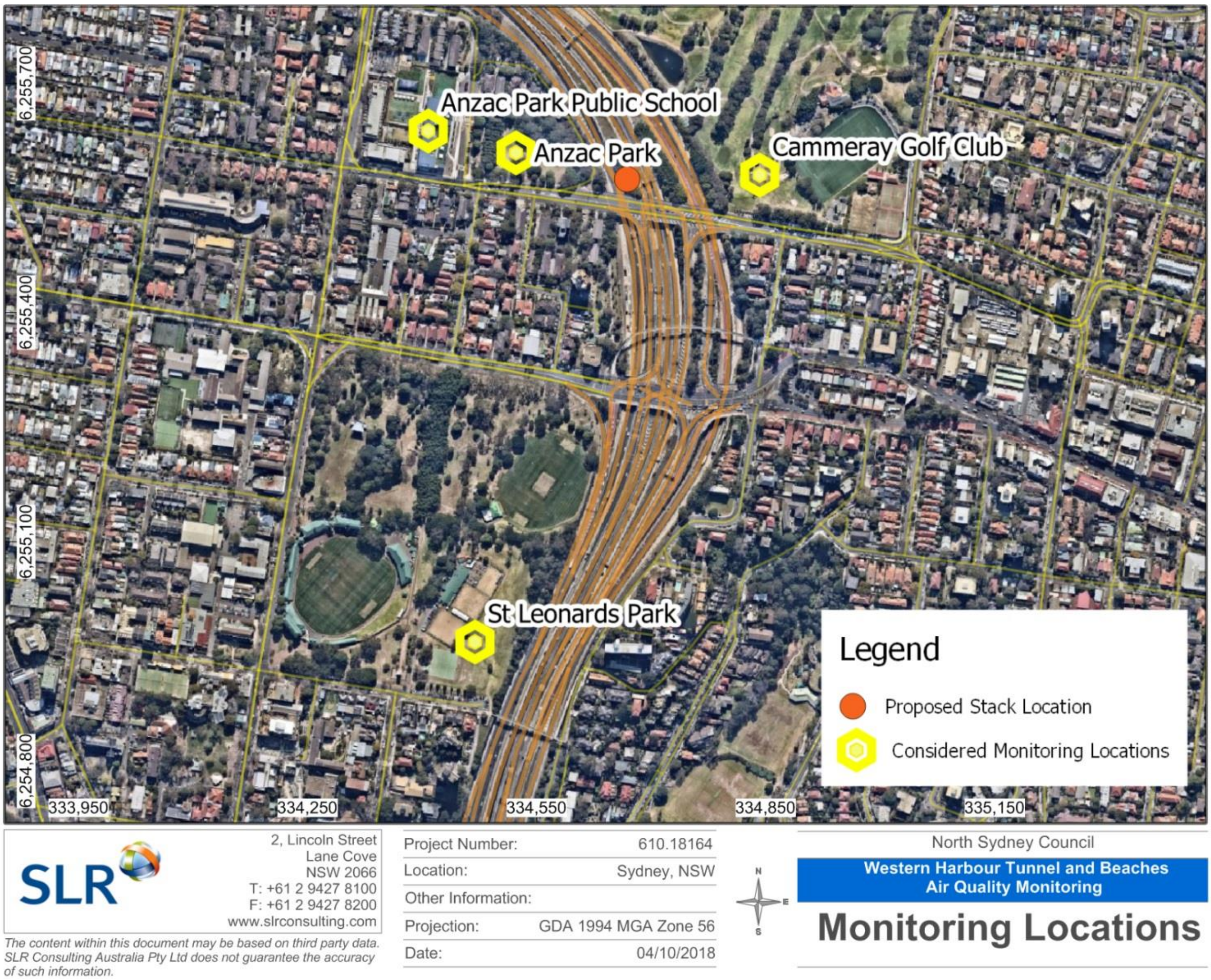
The potential locations are illustrated in **Figure 8.** A comparison of the potential locations is presented in **Table 10**. It is noted that a final review of the precise location will need to be carried out prior to installation of monitoring equipment. For example, in relation to the Cammeray Golf Club, the suitability of the location could only be determined after discussions with the golf club operators. It is further noted that a lease may need to be arranged for sampling at Anzac Park Public School and Cammeray Golf Club.

Table 10 Comparison of Potential Ambient Air Quality Monitoring Stations

Location	Distance to Proposed Stacks	Frequency of Winds Towards Location	Power Supply	Space Available for reference station	Compliance with Siting Criteria
St Leonards Park	300-500 m (south-southeast)	approximately 28% (N to NE winds)	available	available	achievable
Anzac Park	150 m (west)	approximately 14% (E to SE winds)	not available	available	achievable
Anzac Park Public School	250 m (west)	approximately 14% (E to SE winds)	available*	not available	not achievable
Cammeray Golf Club	100 – 200 m (east)	approximately 21% (WSW to WSE winds)	to be confirmed	to be confirmed	to be confirmed

* to be confirmed

Figure 8 Monitoring Locations Considered for the Baseline Monitoring



Considering the above, and based on the information currently available, St Leonards Park is deemed to be the most appropriate location for the baseline monitoring station. As this is a baseline monitoring programme, monitoring at one location is considered to be reasonable. Multiple monitoring sites could be established, however this will have a significant impact on the cost of the monitoring programme. St Leonards Park is located in reasonably close vicinity to the Warringah Freeway, and concentrations measured at this location can be expected to representative of the levels that would be expected at similar distances from the motorway further to the north (ie at Anzac Park Public School and residential receptors in the vicinity of the proposed WHTBL ventilation stack (s).

6.3 Air Quality Monitoring Options

Based on available air quality monitoring methods, three options are presented for Council's consideration namely:

- Option 1 – Compliant Monitoring Station
- Option 2 – Equivalent Monitoring Station
- Option 3 – Non-Compliant Monitoring Station

Option 1 is the recommended option as it uses methods outlined in the Approved Methods for Sampling and complies with current Australian Standards for the ambient monitoring of the relevant pollutants. This means that the monitoring data would stand up to scrutiny by third parties provided that evidence of compliance with the relevant standards is available.

Methods proposed for Option 2 do not appear in the Approved Methods for Sampling, however, these are equivalent methods with Australian/New Zealand Standards available.

Option 3 has been included because it provides a number of advantages, including smaller footprint and lower cost (refer to **Section 5**). However, based on our understanding of the Council's intent for the monitoring campaign, use of a non-compliant monitoring station is not recommended as the data could be subject to significant criticism by third parties.

Table 11 Air Quality Monitoring Options

Parameters	Location	Required Footprint	Monitoring Duration	Monitoring Frequency	Power Supply	Contractor Requirements	Methodology
Option 1 - Compliant Ambient Air Quality Monitoring Station							
$PM_{2.5}$	AS 3580.1.1-2016 compliant location within St Leonards Park (subject to local site constraints)	Approx. 3 m by 3 m	Minimum of 12 months	Continuous	Stable mains connection required	NATA Accredited	AS 3580.9.13-2013 compliant TEOM with $PM_{2.5}$ Inlet
PM_{10}							AS 3580.9.8-2008 compliant TEOM with PM_{10} Inlet
NO_x							AS 3580.5.1-2011 compliant Chemiluminescence analyser
Option 2 - Equivalent Ambient Air Quality Monitoring Station							
$PM_{2.5}$	AS 3580.1.1-2016 compliant location within St Leonards Park (subject to local site constraints)	Approx. 3 m by 3 m	Minimum of 12 months	Continuous	Solar possible for particulate monitoring Stable mains connection required for combustion gas monitoring	NATA Accredited	AS 3580.9.12-2013 compliant E-BAM with $PM_{2.5}$ Inlet
PM_{10}							AS 3580.9.11-2016 compliant E-BAM with PM_{10} Inlet
NO_x							AS 3580.5.1-2011 compliant Chemiluminescence analyser
Option 3 – Non-Compliant Ambient Air Quality Monitoring Station							
$PM_{2.5}$	AS 3580.1.1-2016 compliant location within St Leonards Park (subject to local site constraints)	Approx. 3 m by 3 m	Minimum of 12 months	Continuous	Solar possible for particulate monitoring Stable mains connection required for combustion gas monitoring	-	Aeroqual Sentry with $PM_{2.5}$ Inlet or equivalent near reference instrument
PM_{10}						-	Aeroqual Sentry with PM_{10} Inlet or equivalent near reference instrument
NO_x						-	Aeroqual AQM 65 or equivalent near reference instrument

Parameters	Location	Required Footprint	Monitoring Duration	Monitoring Frequency	Power Supply	Contractor Requirements	Methodology
Options 1 - 3 – AS Compliant Meteorological Station							
Wind speed and direction Ambient temperature Solar radiation Barometric pressure Relative humidity	AS 3580.1.1-2016 compliant location within St Leonards Park (subject to local site constraints)	Unit will be installed within the air quality monitoring station foot print	Minimum of 12 months	Continuous	Solar connection Possible	Instruments to be NATA calibrated	Automated AS 3580.14-2014 compliant Weather Station

6.4 Timing and Duration

Considering the potential changes in ambient air quality between now and opening of the WHTBL (due to increase in traffic volumes, changes in fleet, etc.), the baseline monitoring campaign would ideally be carried out commencing 12 months prior to the completion of the project and continuing for 12 months after the tunnel is operational. Such a dataset would provide the information required to identify the incremental impacts from the Project.

However, in order to inform the Council's position on the Project at the planning stage, it is recommended that an initial monitoring campaign be conducted as soon as practicable so a representative dataset for ambient air quality in North Sydney can be established. Regardless of the option adopted, it is recommended that baseline monitoring is conducted for a minimum of 12 months in order to capture seasonal variations.

6.5 Quality Assurance and Maintenance

Inspection, calibration (monthly, quarterly, six monthly and annual), cleaning and maintenance of air monitoring equipment should be scheduled and performed in accordance with the relevant Australian Standards and the manufacturer's specifications as applicable.

A calibration register should be maintained to ensure the calibration of all equipment is undertaken as per the manufacturer's schedule.

6.6 Reporting

Continuous monitoring data should be validated and results reported on a monthly basis. Considering the raw data from the monitoring station has not been validated, it is recommended that monthly reports are made available to the public through the Council's website rather than real-time raw data. However, if required, monitoring from options provided could be uploaded onto an online host for real-time access.

7 Recommendations for Future Work

As outlined in **Section 6.4**, background data collected over an initial 12 month period can be used to inform the Council's position and submission to the State Government on the Project. It is recommended that once the Environmental Impact Statement (EIS) for the Project is released for public comment, an independent peer review of the Air Quality Impact Assessment prepared as part of the EIS be conducted in order to compare the data collected as part of the air quality monitoring campaign, with the baseline/background data used in the EIS. The peer review should also review and comment on the air quality modelling methodology as well as assumptions made.

In order to identify the incremental impacts from the Project, it is also recommended that a second monitoring campaign be carried out commencing 12 months prior to the completion of the project and continuing for 12 months after the tunnel is operational. This would ensure that any changes in ambient air pollutant concentrations between now and opening of the WHTBL would be captured so that could not be used to question whether any incremental changes measured are due to impacts other than the WHTBL Project. This monitoring programme would need to consider any impacts associated with the construction activities (ie it may need to occur prior to construction starting or at a location not expected to be affected by the construction works).

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