Pacific Environment Limited

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Final Report

WHITE BAY CRUISE TERMINAL: AIR QUALITY AND METEOROLOGICAL MONITORING REPORT - SEPTEMBER 2015

PORT AUTHORITY OF NSW

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GLOSSARY

Term	Description
AS	Australian Standard
AAQ NEPM	National Environment Protection (Ambient Air Quality) Measure
BAM	Beta attenuation monitor
EnviroSuite	Pacific Environment's proprietary data management software
EPA	New South Wales Environment Protection Authority
$\mu g/m^3$	Micrograms per cubic metre
GLB	Glebe Island berths
GMR	NSW Greater Metropolitan Region
m/s	Metres per second
NATA	National Association of Testing Authorities
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
OEH	NSW Office of Environment and Heritage
ppb	Parts per billion
$PM_{2.5}$	Airborne particulate matter with an aerodynamic diameter of less than 2.5 micrometres (µm)
QA	Quality assurance
QC	Quality control
SO_2	Sulfur dioxide
TEOM	Tapered Element Oscillating Microbalance
WBCT	White Bay Cruise Terminal
WHT	White Bay berths
W/m^2	Watts per square metre

1 INTRODUCTION

The Port Authority has committed to undertaking additional air quality monitoring in the residential area adjacent to the WBCT, and has worked with the EPA to determine: the parameters to be monitored, an appropriate location for the monitoring station, and the duration of the monitoring programme. The monitored parameters are sulfur dioxide (SO_2) and particulate matter less than 2.5 micrometres in diameter ($PM_{2.5}$). The monitoring also includes local wind speed and direction.

The monitoring station samples SO_2 data every ten seconds and records data at 5-minute averaging periods. $PM_{2.5}$ is observed as hourly averages. These data are used to assess whether local air quality standards are met.

The NSW air quality criteria for SO_2 are 712, 570, and 228 µg/m^3 for 10-minute, 1-hour and 24-hour averages respectively (**NSW DEC, 2005**). For $PM_{2.5}$, the National Environment Protection Council (NEPC) released a variation to the National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM) to include advisory reporting standards for $PM_{2.5}$ (**NEPC, 2003**). The AAQ NEPM advisory standard for the 24-hour average is 25 µg/m^3.

Pacific Environment has been commissioned to provide monthly reports for 12 months from September 2015 onwards. Any exceedances of the NSW air quality criteria or the AAQ NEPM advisory standard for ground-level concentrations will be reported and discussed. The $PM_{2.5}$ and SO_2 concentrations at WBCT will be compared with those at monitoring sites around Sydney operated by the NSW Office of Environment and Heritage (OEH). These are located at Bargo, Bringelly, Campbelltown West, Chullora, Earlwood, Liverpool, Richmond and Rozelle.

This report provides the monitoring results for the period from 1 September 2015 to 30 September 2015. This represents the last month preceding the introduction of the Protection of the Environment Operations (Clean Air) Amendment (Cruise Ships) Regulation 2015, which requires cruise ships to use low sulfur fuel while berthed in Sydney Harbour from 1 October 2015 onwards. This will include any place within the boundaries of Sydney Harbour from 1 July 2016.

2 METHODOLOGY

A monitoring location was installed following consultation with the EPA and Leichhardt Municipal Council to measure $PM_{2.5}$ and SO_2, as well as local wind speed and direction.

The monitoring station is located immediately north of WBCT on the corner of Adolphus Street and Grafton Street, Balmain (33.860142° S, 151.187413°E), approximately 14 m above sea level (**Figure 2-1**).

As far as practicable, this site complies with the requirements of *Australian Standard AS/NZS 3580.1.1:2007 - Methods for sampling and analysis of ambient air - Guide to siting air monitoring equipment*. The site represents the best available location, but does not fully comply as there are trees within 20 m of the site. The non-compliance is not expected to significantly affect the results from the monitoring station.

Instrument calibration is performed in accordance with relevant Australian Standards and National Association of Testing Authorities (NATA) procedures. Details of the quality assurance procedures, including calibration and equipment maintenance, are given in **Appendix B**.

Figure 2-1: Location of White Bay Cruise Terminal monitoring station and berths

3 MONITORING DATA

The results of the monitoring are presented below and are compared to EPA ambient air quality criteria. These are 10-minute, 1-hour and 24-hour average concentrations for SO_2, and 24-hour average concentrations for $PM_{2.5}$.

The 24-hour average SO_2 and $PM_{2.5}$ are compared with data from OEH monitoring sites. Polar bivariate plots are also presented that show 5-minute average SO_2 and $PM_{2.5}$ concentrations as a function of wind speed and wind direction.

3.1 10-minute average sulfur dioxide concentrations

A time-series plot of the 10-minute average SO_2 concentration for September 2015 is shown in **Figure** 3-1.

There was no exceedance of the 10-minute average air quality criterion for SO_2 during the reporting period as 10-minute-average SO_2 concentrations were generally less than 10 µg/m^3.

The highest SO_2 concentrations correlate with days that ships were berthed at WBCT e.g. 17 and 18 September 2015 when maximum SO_2 concentration reached 500 µg/m^3 (monitoring during these days is discussed in **Section 3.1**).

SO_2 concentrations above background were also observed on 30 September. This coincided with the *Pacific Jewel* being berthed at WBCT from approximately 07:00 to 16:00.

Such SO_2 levels are possibly attributable to cruise ships in Sydney Harbour burning high sulfur fuels. However, there were also days where ships were berthed at WBCT and SO_2 concentrations remained low e.g. 6, 7, 20, and 21 September 2015. Moreover, there were also days with SO_2 concentrations above background levels, but with no ships berthed at WBCT (e.g. 29 September 2015). This suggests there may be other sources of SO_2 emissions in the local area.

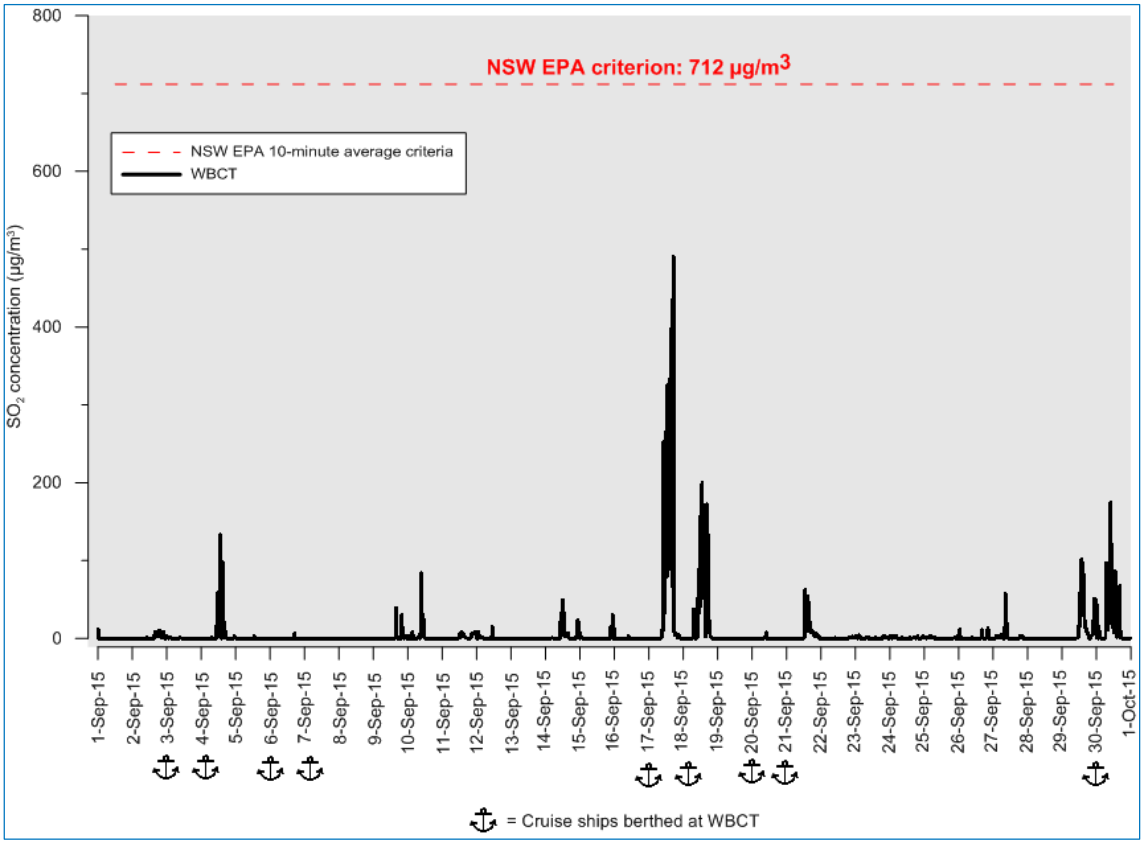

Figure 3-1: 10-minute average SO_2 concentrations for September 2015

Figure 3-2 shows the ship activity at WBCT on 17 and 18 September 2015 when SO_2 concentrations were elevated. The red shaded areas indicate the period in which cruise ships were berthed at WBCT.

The *Pacific Jewel* arrived at WBCT at around 07:00 on 17 September 2015, but SO_2 concentrations did not increase until the winds changed to a south-southeasterly direction at around 09:00, during which time the ship was upwind of the WBCT monitoring station. The SO_2 concentrations then increased until shortly after the ship left WBCT at around 16:50 on 17 September 2015. The SO_2 concentrations continued to increase for around thirty minutes after the ship's departure, which may be attributed to the time spent by the ship manoeuvring and navigating away from WBCT. High SO_2 concentrations on 18 September 2015 are attributed to the *Dawn Princess* being berthed at WBCT.

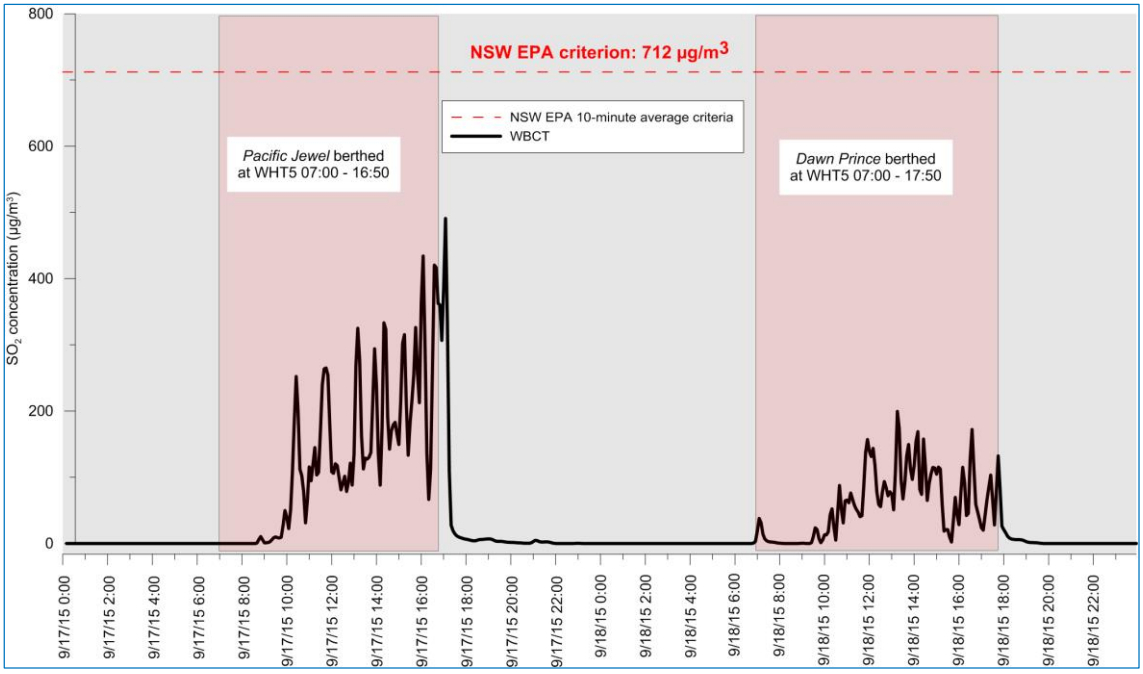

Figure 3-2: 10-minute average SO_2 concentrations on 17 and 18 September 2015

3.2 1-hour average sulfur dioxide concentrations

A time series plot of the 1-hour average SO_2 concentration is shown in **Figure 3-3**. No exceedances of the 1-hour air quality criterion for SO_2 were recorded during the reporting period. Higher SO_2 concentrations on the 17, 18 and 30 September 2015 coincided with ships being berthed at WBCT, as discussed in **Section 3.1**.

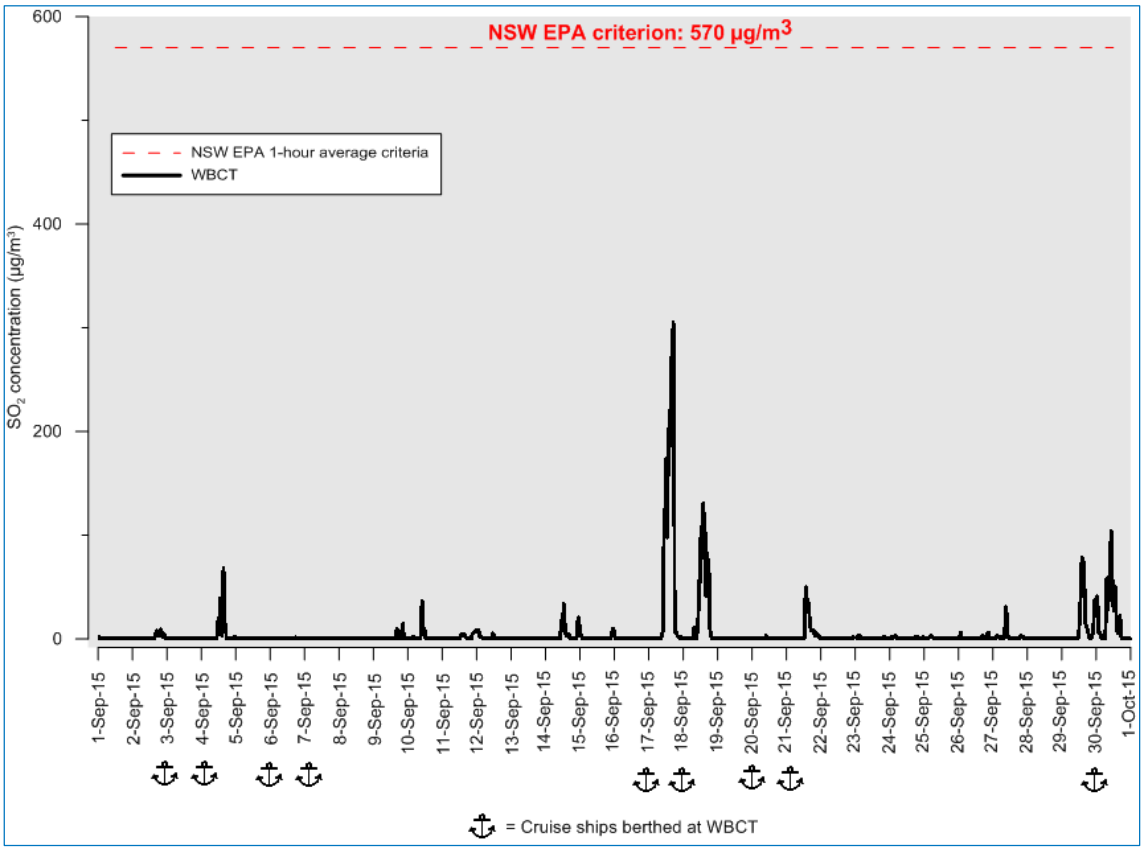

Figure 3-3: 1-hour average SO_2 concentrations for September 2015

3.3 24-hour average sulfur dioxide concentrations

Time-series plots of 24-hour average SO_2 concentrations at WBCT and selected OEH sites in Sydney are shown in **Figure 3-4**. The selected OEH sites that measure SO_2 comprise Rozelle, Bargo, Bringelly, Campbelltown West, Chullora, Earlwood, Liverpool and Richmond.

SO_2 concentrations at WBCT were generally higher than those at the OEH monitoring sites, including nearby Rozelle. The highest SO_2 concentrations were recorded on days with cruise ships berthed at WBCT: 17, 18, and 30 September 2015. Higher SO_2 concentrations on the 17, 18 and 30 September 2015 are attributed to cruise ships berthed at WBCT, as discussed in **Section 3.1**.

Elevated SO_2 concentrations were recorded at WBCT on 29 September compared to other OEH sites, despite no ships being berthed at WBCT. This suggests there may be another source of SO_2 emissions in the local area.

No exceedances of the 24-hour ambient air quality criterion for SO_2 were recorded during the reporting period.

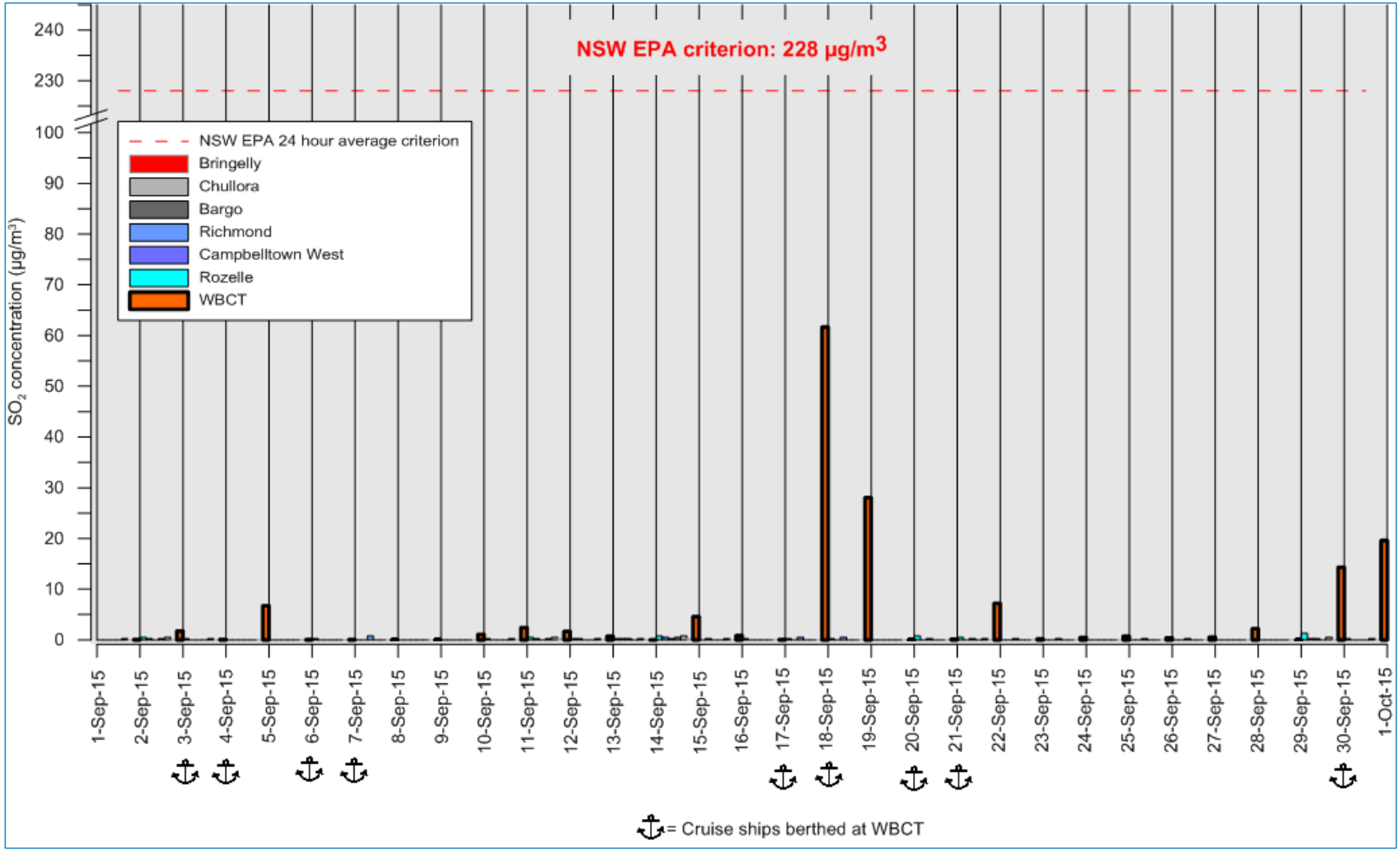

Figure 3-4: 24-hour average SO_2 concentrations at WBCT and nearby OEH monitoring sites. Note the broken axis from 100 – 220 µg/m³.

3.4 24-hour average $PM_{2.5}$ concentrations

Time-series plots of 24-hour average $PM_{2.5}$ concentrations at WBCT and selected OEH sites are shown in **Figure 3-5**. Of the OEH sites, $PM_{2.5}$ is measured at Chullora, Earlwood, Liverpool, Richmond and Rozelle.

The 24-hour average $PM_{2.5}$ concentrations at WBCT were similar to those at the OEH sites, and maximum concentrations at all sites were less than 15 µg/m^3. Compared to the OEH sites, relatively high $PM_{2.5}$ concentrations were recorded at WBCT on 18 and 30 September 2015, which may be in part attributable to cruise ships berthed at WBCT on these days. There are additionally several days where $PM_{2.5}$ concentrations at WBCT were higher than the OEH reference sites, but no cruise ship was berthed at WBCT. The data also shows that there were cruise days at WBCT where the $PM_{2.5}$ concentration was higher at other OEH reference sites compared to WBCT (e.g. 3, 7, 21 September 2015).

No exceedances of the 24-hour average AAQ NEPM air quality advisory standard for $PM_{2.5}$ were recorded during the reporting period.

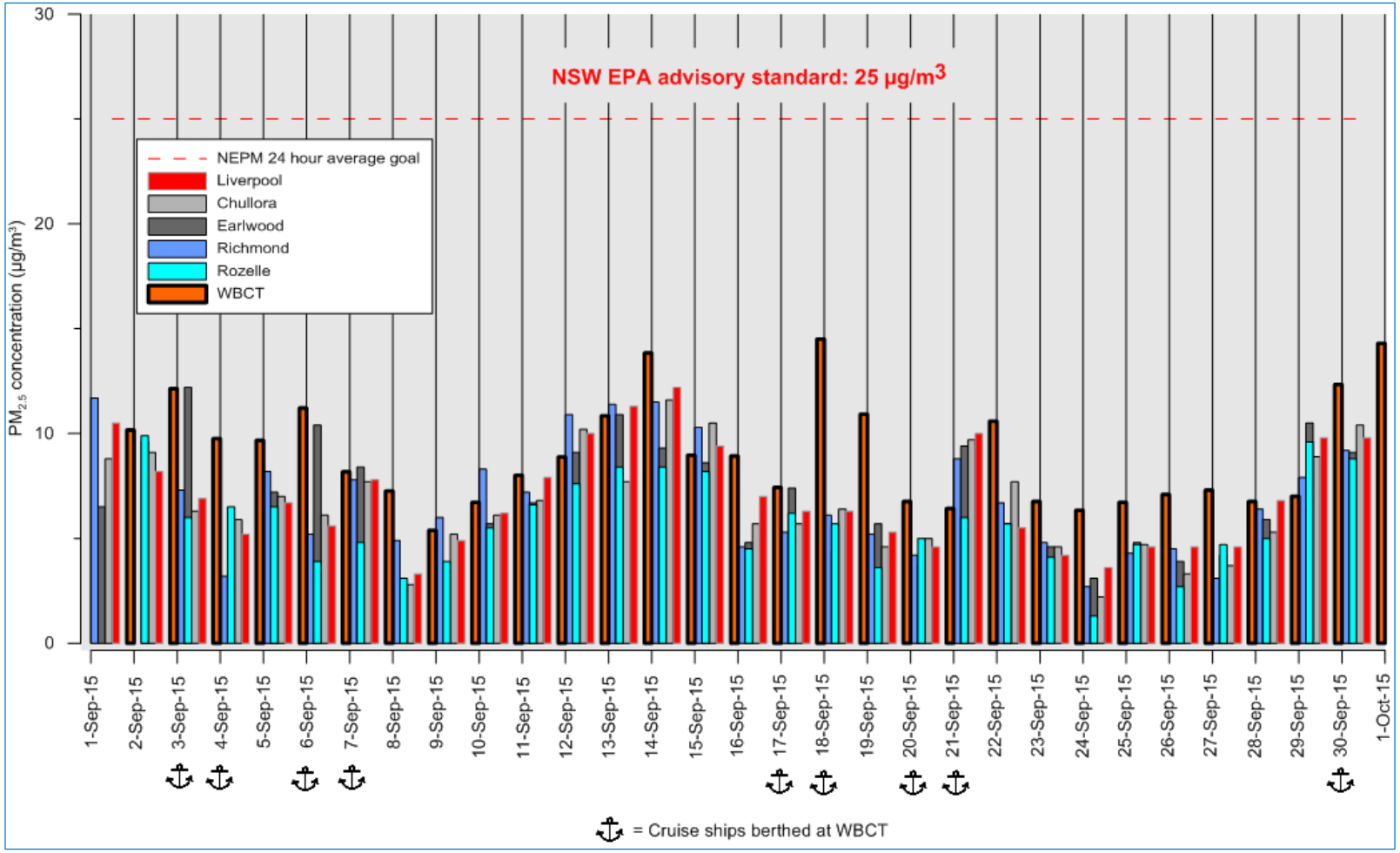

Figure 3-5: 24-hour average $PM_{2.5}$ concentrations at WBCT and nearby OEH sites

3.5 Polar bivariate plots

Polar bivariate plots that show 10-minute average SO_2 concentrations and 1-hour $PM_{2.5}$ concentrations as a function of wind speed and wind direction are presented in **Figure 3-6** to **Figure 3-8**. These plots interpolate between data points to show concentrations as a continuous surface and represent the average concentration at a given wind speed and wind direction for the given period. Note that there is no 1-hour average air quality criterion for $PM_{2.5}$ referenced in NSW.

SO_2 concentrations (interpolated from 10-minute average values) were highest (greater than 50 µg/m^3) with moderate (2 – 4 m/s) south-easterly winds (**Figure 3-6**). Such elevated SO_2 concentrations are likely attributable to cruise ships berthed at WBCT (berth WHT5, **Figure 2-1**). There was also a source of SO_2 emissions under moderate (2 – 4 m/s) south-westerly winds. Such elevated SO_2 concentrations may be attributable to other non-cruise ships berthed at White Bay and Glebe Island (berths WHT3 and WHT4 and GLB7 and GLB8, **Figure 2-1**). SO_2 concentrations were low (less than 20 µg/m^3) when northerly and westerly winds were observed.

Figure 3-7 presents polar bivariate plots for two days when high SO_2 concentrations were observed. These were 17 September 2015 when a cruise ship was berthed at WBCT, and 29 September 2015 when no cruise ships were berthed at WBCT.

The plot for the 17 September 2015 indicates that the upwind source of SO_2 emissions under south-easterly winds may be attributable to cruise ships berthed at WBCT.

However, the plot for the 29 September 2015 indicates that there was an unknown upwind source of SO_2 emissions under east-southeasterly wind conditions when there were no ships berthed at the WBCT.

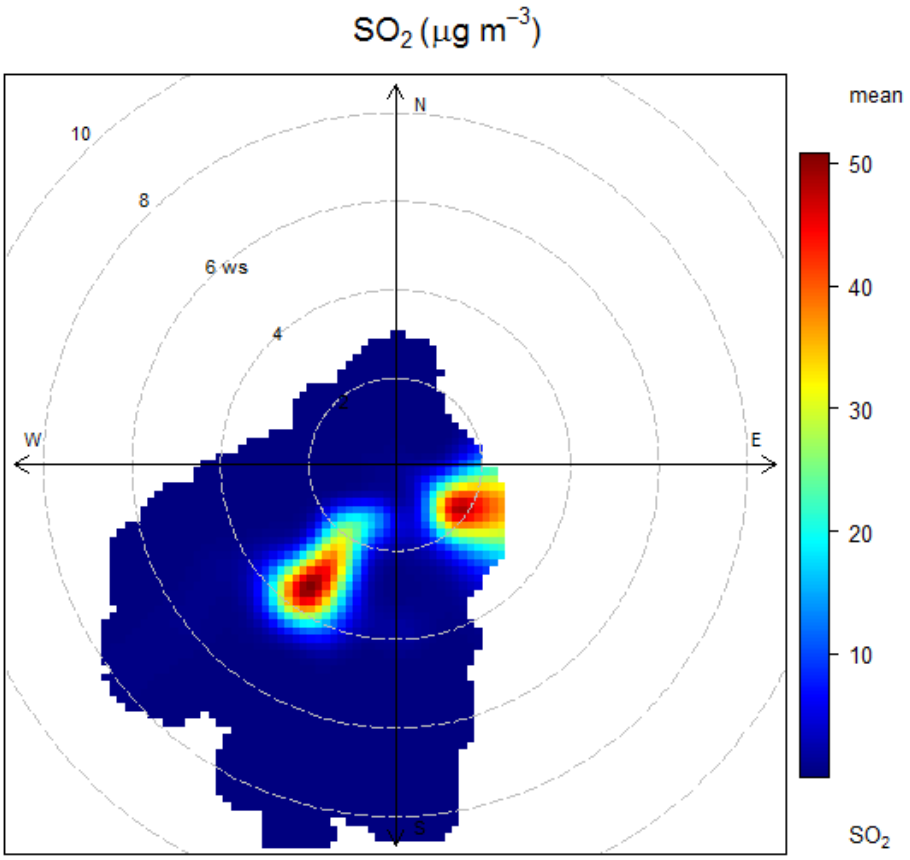

Figure 3-6: Polar bivariate plot for 10-minute average SO_2 concentrations in September 2015

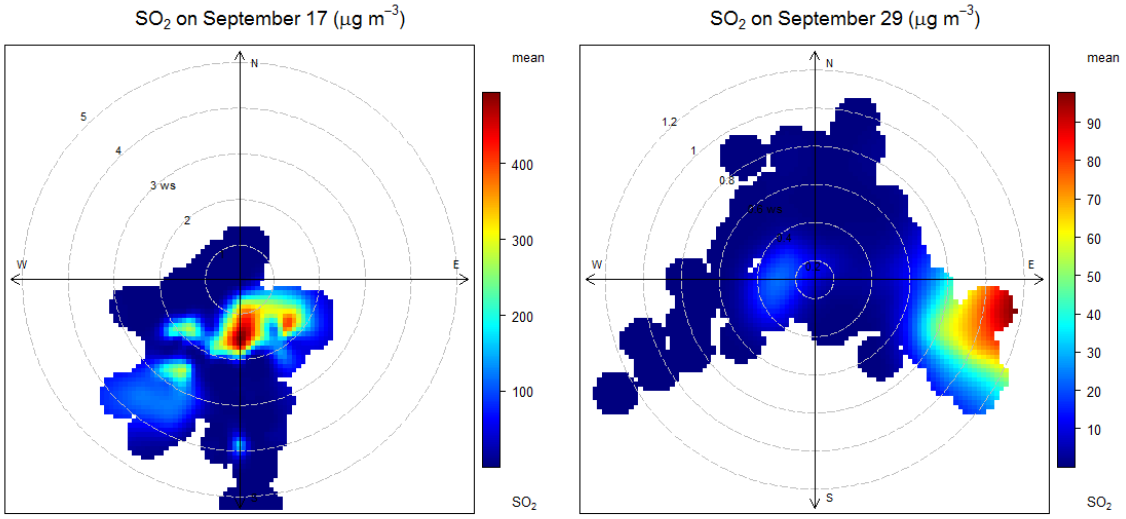

Figure 3-7: Polar bivariate plot for 10-minute average SO_2 concentrations on 17 and 29 September 2015

$PM_{2.5}$ concentrations (interpolated from 1-hour average values) were higher (greater than 12 µg/m³) with moderate (2 – 4 m/s) south-easterly winds (**Figure 3-8**). As with SO_2 concentration data, this source of $PM_{2.5}$ emissions may be attributable to cruise ships berthed at WBCT (berth WHT5, **Figure 2-1**).

There was also an upwind source of $PM_{2.5}$ under moderate (2 – 4 m/s) south-westerly winds. This source of $PM_{2.5}$ emissions may be attributable to other non-cruise ships berthed at White Bay and Glebe Island (berths WHT3 and WHT4 and GLB7 and GLB8, **Figure 2-1**).

Compared to the SO_2 concentration data, the polar bivariate plots show that $PM_{2.5}$ sources are more diverse.

$PM_{2.5}$ concentrations were low (less than 5 µg/m³) when northerly and westerly winds were recorded.

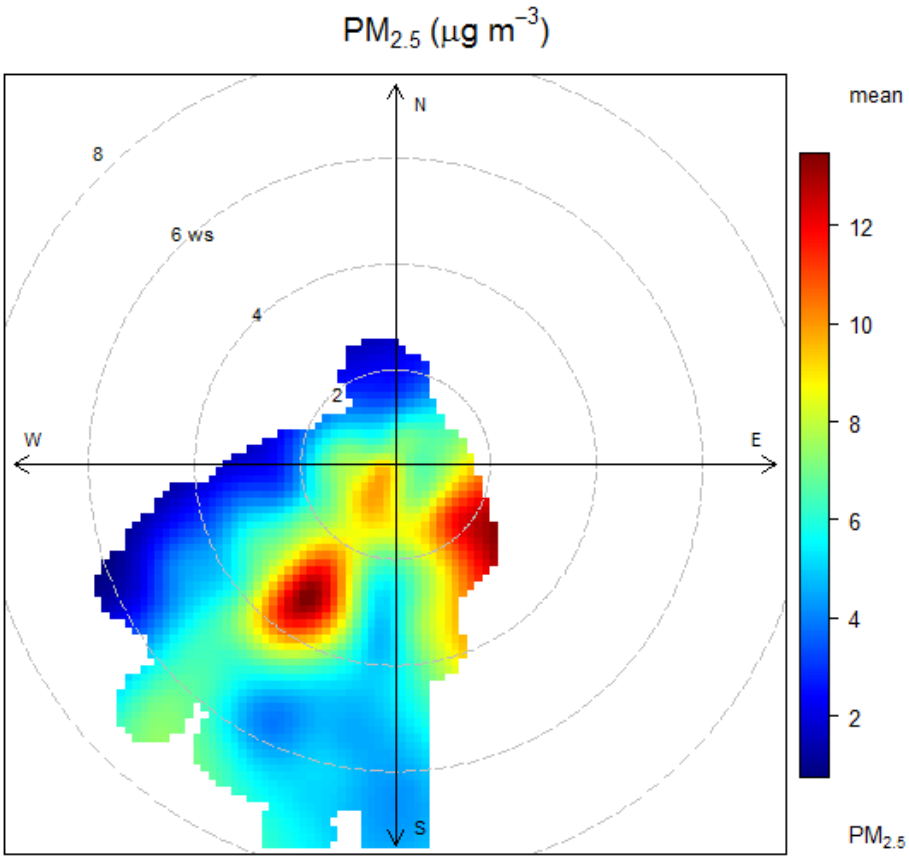

Figure 3-8: Polar bivariate plot for 1-hour average $PM_{2.5}$ concentrations in September 2015

3.6 Summary Statistics

Summary statistics for average values of SO_2 and $PM_{2.5}$ concentrations are shown in **Table 3.1**.

No exceedances of air quality criteria or AAQ NEPM advisory standard were recorded for SO_2 or $PM_{2.5}$ during the reporting period.

Table 3.1: Summary statistics for SO_2 and $PM_{2.5}$ concentrations at WBCT

Pollutant:	SO_2			$PM_{2.5}$
Units:	µg/m³			µg/m³
Averaging period:	10 minute	1 hour	24 hour	24 hour
Criterion:	712	570	228	25[a]
Mean	5	5	5	9
Median	0	0	1	9
Standard deviation	25	23	13	3
Sample variance	645	523	155	7
Range	491	305	62	9
Minimum	0	0	0	5
Maximum	491	305	62	15

[a] AAQ NEPM Advisory Reporting Standard

4 REFERENCES

NEPC (2003). National Environment Protection Measure for Ambient Air Quality, 1988, with amendment in 2003.

NSW DEC (2005). Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales. August, 2005.

Appendix A Monitoring station equipment and technology

A.1 Equipment

Equipment at the WBCT monitoring station and measured parameters are summarised in **Table A-1**.

Table A-1: Parameters and instrumentation for the monitoring station at WBCT

Parameter	Australian Standard	Measurement method	Instrument
Air quality metric			
SO_2	AS 3580.4.1-1990	UV Fluorescence	Serinus 50
$PM_{2.5}$	AS/NZS 3580.9.13-2013	Beta Attenuation Monitor (BAM)[1]	Spirant
Meteorological metric			
Wind speed	AS 3580.14-2011	Ultrasonic	Gill
Wind direction			
Temperature		Temperature sensor	Ecotech Met Station One
Pressure		Barometric pressure sensor	
Relative humidity			
Solar radiation			
Rainfall		Tipping bucket rain gauge	

Equipment that is required in the monitoring station both to meet the relevant Australian Standards and to enable real-time data interrogation/interpretation is outlined in **Table A-2**. All instrumentation was installed in an air conditioned, weather-proof shelter with instrument rack.

Table A-2: Additional equipment provided within air pollution monitoring station

Instrument type / Component	Proposed instrument / Supplier
Dynamic dilution calibrator	Gascal 1100
Zero air generator	Model 8301
Data Logger	WinAQM
3G Cellular Modem	Netcomm
SO_2 calibration gas bottle	Coregas
Gas bottle regulator	Coregas

There is no current approved method for ambient air quality monitoring of $PM_{2.5}$ contained within the NSW EPA's *Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales*. However, there are Australian Standards that are applicable to this parameter. A Beta Attenuation Monitor (BAM) was installed to measure $PM_{2.5}$, as opposed to a Tapered Element Oscillating Microbalance (TEOM) – for the following reasons:

- BAMs have a proven track record as being highly robust and reliable;
- BAM technology is more cost-effective than using TEOMs;
- The use of a BAM removes the known measurement issues associated with using TEOMs for $PM_{2.5}$ monitoring (the TEOM heated inlet is known to remove the semi-volatile component within this size fraction);
- BAM instruments are used for regulatory reporting by the NSW government, and are used for $PM_{2.5}$ monitoring at the following OEH ambient air quality monitoring stations:
    - Chullora, Earlwood, Liverpool, Rozelle and Richmond in Sydney;
    - All sites in OEH's Upper Hunter Ambient Air Quality Monitoring Network; and

- All NSW Roads and Maritime Services particulate monitoring adopted for the WestConnex road tunnel study (twelve locations measuring PM_{10} and $PM_{2.5}$; twenty four BAMs in total).

A.2 Servicing, maintenance and calibration

Routine preventative maintenance is carried out at one, three, six and twelve monthly intervals, as stipulated by the relevant Australian Standards, and Pacific Environment's commitment to work to NATA standards. The regular maintenance program includes, but is not limited to:

- Daily remote data check and attend to any fault identified within 24 hours;
- Filter changes;
- Leak checks;
- Single point calibration;
- Multipoint linearity check;
- Visual inspection;
- Cleaning of sample lines and particulate (BAM) inlet head;
- Advanced six and twelve monthly analyser service and overhaul;
- Annual calibration of meteorological sensors; and
- Alignment check for wind speed/direction sensor.
- Remote daily data checks are performed by a Pacific Environment consultant to ensure the integrity of the system.
- A calibrations span value of 500ppb is used to challenge the SO_2 instrument.

A.3 EnviroSuite

Data from the monitoring station is recorded to a local data logger and is then uploaded near real-time via a secured virtual private network (VPN) to Pacific Environment's proprietary data management software, EnviroSuite. Any instrument or system fault is captured by the data logger and relayed in real time via email and SMS, and/or flagged by EnviroSuite.

Pacific Environment Limited provides and hosts a website that is dedicated to providing air quality and meteorological monitoring data for the project. This webpage for reporting data in near real-time, includes a map of the project area, icons showing the locations of monitoring equipment and recent monitoring data readings. Data for comparison with compliance limits is also presented. The web address for this is: https://es2.envirosuite.com/monitoring/pansw/.

As requested by the Port Authority, public-facing data contains a disclaimer, similar to that presented on the OEH air quality monitoring website:

Disclaimer: The data used in the compilation of this page have undergone only preliminary quality assurance checks. These data may require modification during final stages of validation as a result of calibration changes, power failures, instrument failures etc.

Appendix B Quality assurance and control

B.1 National Association of Testing Authorities accreditation

Pacific Environment is pursuing accreditation by the National Association of Testing Authorities (NATA) for the measurement of all ambient air quality and meteorological parameters. All monitoring is being conducted in accordance with the NATA requirements.

B.2 Data storage and ratification

All monitoring and calibration data are stored on a central software system and on a cloud-based server with multiple replicas. The data are also stored internally on the analysers.

Currently, there are no Australian guidelines for the ratification of air quality monitoring data. The data ratification process has therefore been developed in keeping with best practice guidelines from the USEPA and Defra in the UK. The data ratification process involves steps such as:

- Removal of clearly incorrect data.
- Corrections for instrument drift.
- Corrections for offsets.
- Removal of calibration points.
- Removal of data during servicing and maintenance periods.

Appendix C Data availability and summary

Data availability for SO_2 and $PM_{2.5}$ during the reporting period, based on the 5-minute average values, is shown in **Table C-1**. Summary and distribution of measurements for SO_2, $PM_{2.5}$, wind speed and wind direction are shown in **Figure C-1**.

Table C-1: Data availability and summary statistics for SO_2 and $PM_{2.5}$ (5-minute average reported values)

Statistic	SO_2	$PM_{2.5}$
Valid values	8640	8638
Missing values	295	2
Availability (%)	96.6%	100.0%
Minimum (µg/m³)	0.0	1.3
Maximum (µg/m³)	505.9	33.4
Mean (µg/m³)	5.2	9.0
Median (µg/m³)	0.0	8.4
95th percentile (µg/m³)	21.5	17.4

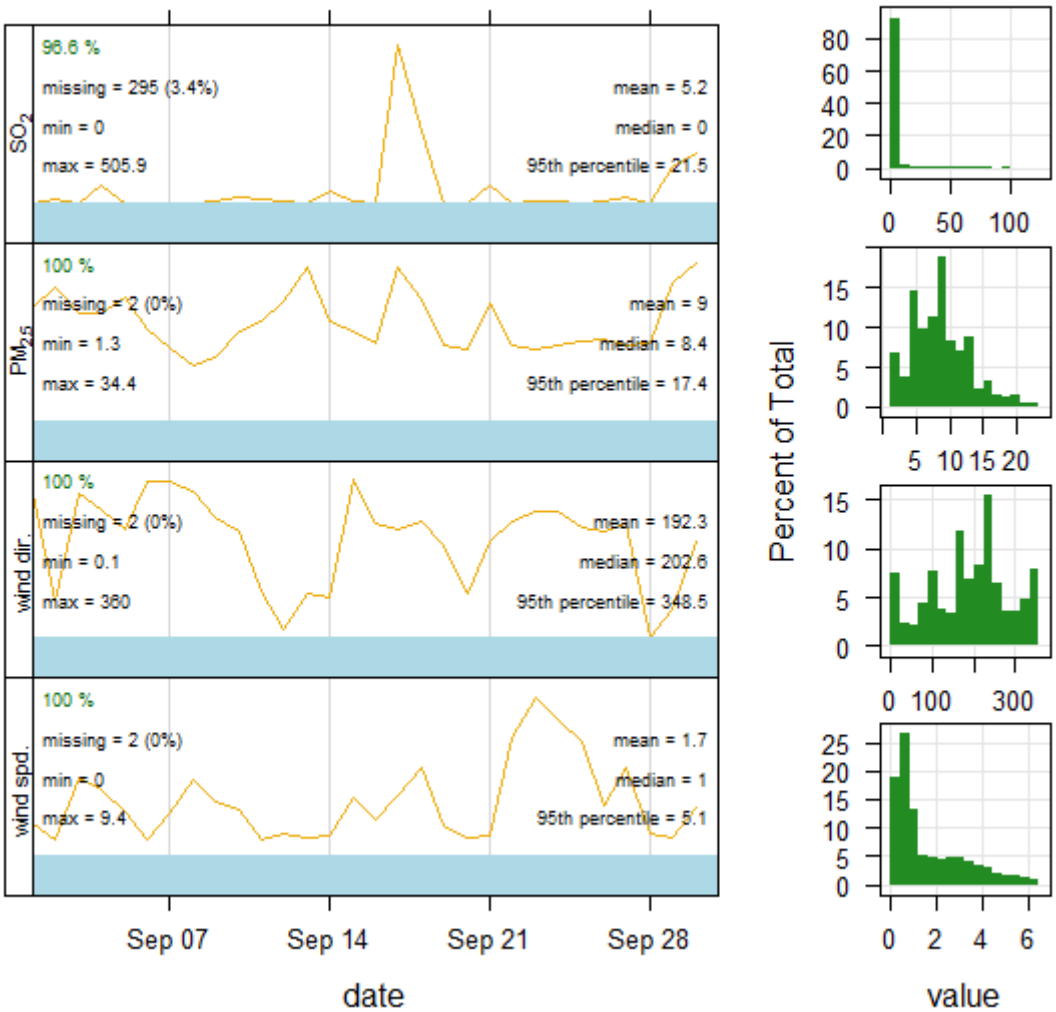

Figure C-1: Output summary and data distribution for 5-minute average SO_2 and $PM_{2.5}$ concentrations in September 2015

Appendix D Wind roses

A wind rose showing the frequency of counts by wind direction for the reporting period are shown in **Figure D-1**. Some guidance on the interpretation of wind roses is provided in **Figure D-2**.

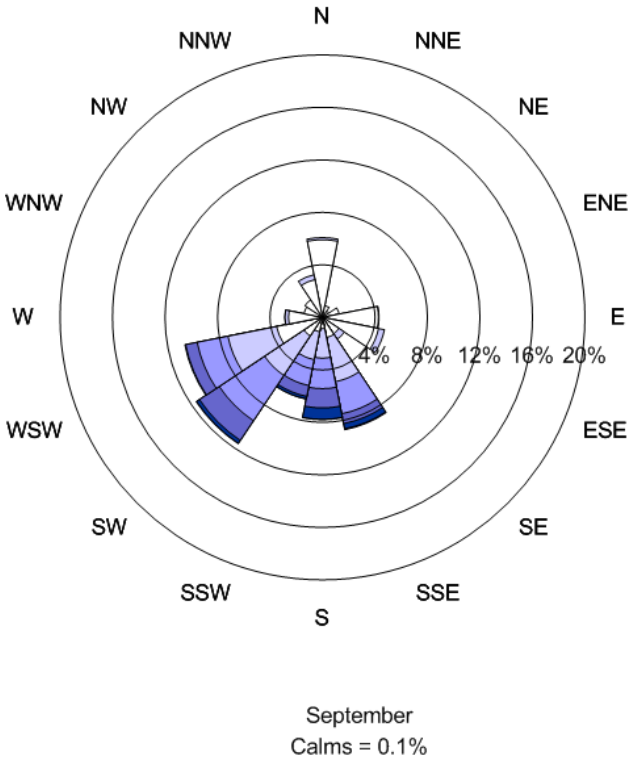

Figure D-1: Wind rose for the WBCT in September 2015

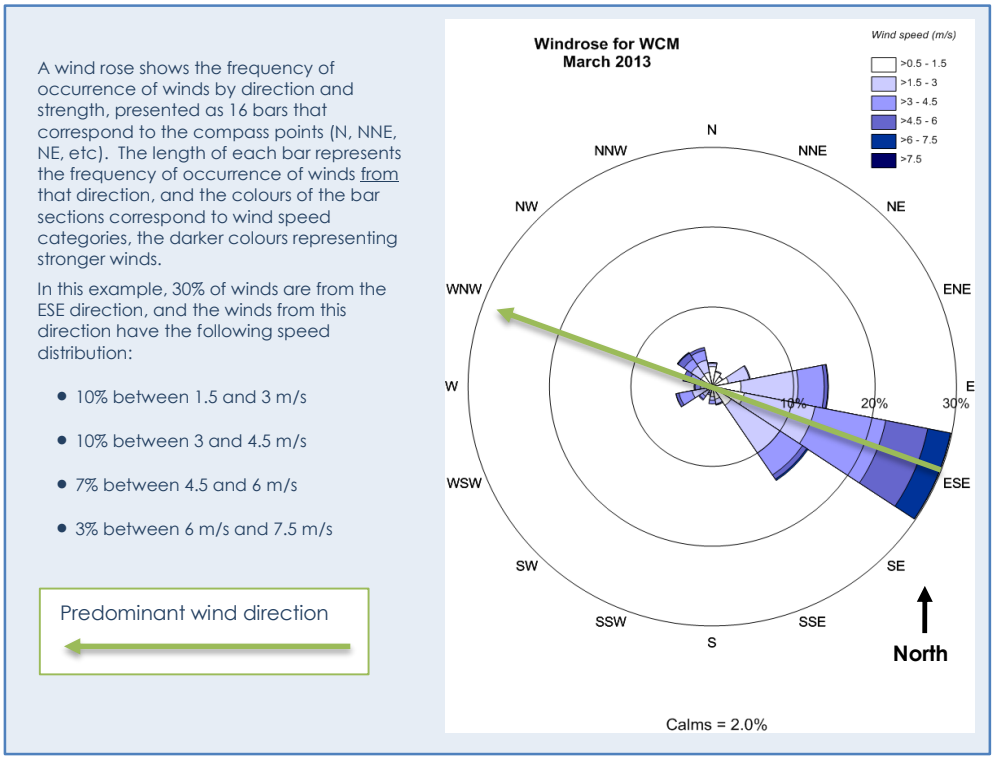

Figure D-2: Interpretation of a wind rose