Northern Territory Ambient Air Quality Monitoring Report 2019

Compliance with the National Environment Protection (Ambient Air Quality) Measure

ntepa Northern Territory Environment Protection Authority

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Acronyms	Full form
AAQ NEPM	National Environment Protection (Ambient Air Quality) Measure
ABS	Australian Bureau of Statistics
AQMS	Air Quality Monitoring Station
BoM	Bureau of Meteorology
CBD	Central Business District
CO	Carbon monoxide
DENR	Department of Environment and Natural Resources
DEPWS	Department of Environment, Parks and Water Security
EWG	Expert Working Group (NEPC)
GRUB	Generally representative upper bound (AQMS)
NAFI	North Australian Fire Information
NASA	National Aeronautics and Space Administration (USA)
NATA	National Association of Testing Authorities
NEPC	National Environment Protection Council
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
NT	Northern Territory
NT EPA	Northern Territory Environment Protection Authority
O_3	Ozone
PM_{10}	Particulate matter with aerodynamic diameter less than or equal to 10 μm
$PM_{2.5}$	Particulate matter with aerodynamic diameter less than or equal to 2.5 μm
ppm	Parts per million by volume
PRC	Peer Review Committee (NEPC)
SA2	Statistical Area Level 2
SO_2	Sulfur dioxide
TEOM	Tapered element oscillating microbalance
$\mu g/m^3$	Micrograms per cubic metre referenced to a temperature of 0 degrees Celsius and an absolute pressure of 101.325 kilopascals
μm	Micrometres (10^{-6} metres)
WMPCA	Waste Management and Pollution Control Act 1998

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1 Summary

This report presents Northern Territory air quality monitoring data for the 2019 calendar year and assesses them against the requirements for *National Environment Protection (Ambient Air Quality) Measure* (AAQ NEPM).

During 2019, the Northern Territory Environment Protection Authority (NT EPA) operated three designated ambient air quality monitoring stations in the Darwin region. These stations, located at Palmerston, Winnellie and Stokes Hill measure and report real-time data on the concentrations of six AAQ NEPM air pollutants: sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), photochemical oxidants as ozone (O_3), and particulate matter with sizes of 10 micrometres or less (PM_{10}) and 2.5 micrometres or less ($PM_{2.5}$).

This is the second year that the newest station, located at Stokes Hill and established in May 2017, has provided a whole calendar year of data to enable assessment of its compliance with the AAQ NEPM. Meteorological instruments for measuring parameters such as wind speed and direction, ambient temperature and relative humidity are located at the sites.

Assessment of goal compliance: Between 1 January and 31 December 2019, all the designated ambient air quality monitoring stations in the Darwin region complied with the AAQ NEPM goal for CO, NO_2, SO_2, and O_3 by not recording any exceedances of the AAQ NEPM standards for these air pollutants. As explained below, although some exceedances of short-term standards were recorded for PM_{10} and $PM_{2.5}$, all the stations were compliant with the AAQ NEPM short-term goals. Conversely, compliance with the long-term AAQ NEPM standard for $PM_{2.5}$ was not met at any of the stations.

Carbon monoxide: During 2019, all the stations met the AAQ NEPM goal for carbon monoxide - there was no exceedance of the 8-hour rolling average standard for CO.

Nitrogen dioxide: The AAQ NEPM goal for NO_2 was met in 2019, since there were no exceedances of the 1-hour or 1-year NO_2 standards.

Sulfur dioxide: The AAQ NEPM goal for SO_2 was met in 2019, since there were no recorded exceedances of the SO_2 1-hour, 1-day or 1-year standards.

Ozone: During 2019 no exceedances of the 1-hour average O_3 standard or the 4-hour rolling average O_3 standards were recorded at any of the stations – all the stations met the AAQ NEPM goal for ozone.

PM_{10}: To comply with the AAQ NEPM goal for particulates as PM_{10}, no exceedance of the 1-day average standard of 50 $\mu g/m^3$ is allowed, unless determined as an exceptional event, and there must be no

exceedance of the 1-year average standard. Winnellie recorded 15 exceedances, Stokes Hill recorded 11 exceedances and Palmerston recorded 10 exceedances of the 1-day standard, but these exceedances were linked to smoke from bushfires, which are exceptional events.

No exceedances of the PM_{10} 1-year average standard of 25 $\mu g/m^3$ occurred at any of the stations in 2019.

$PM_{2.5}$: To comply with the AAQ NEPM goal for particulates as $PM_{2.5}$, no exceedances of the 1-day average standard of 25 $\mu g/m^3$ is allowed, unless determined as an exceptional event, and there must be no exceedance of the 1-year average standard. During 2019, all exceedances of the $PM_{2.5}$ 1-day standard (21 at Palmerston, 20 at Stokes Hill and 17 at Winnellie) were linked to smoke from bushfires, which are classified as exceptional events. There were eight consecutive days from 31 May 2019, when the $PM_{2.5}$ 1-day standard was exceeded at all the stations as a result of bushfire smoke.

The AAQ NEPM goal for $PM_{2.5}$ was not met in 2019 since $PM_{2.5}$ 1-year averages of 9.8, 9.2 and 8.9 $\mu g/m^3$ respectively at Palmerston, Stokes Hill and Winnellie were above the AAQ NEPM standard of 8 $\mu g/m^3$.

It is now a requirement by the AAQ NEPM that jurisdictions should report population exposure for particles as $PM_{2.5}$. Using a simplified approach, a population-weighted annual average $PM_{2.5}$ concentration of 9.3 $\mu g/m^3$ was estimated for the Greater Darwin Region in 2019.

2 Background

The Department of Environment, Parks and Water Security (DEPWS)[1] provides services to the Northern Territory Environment Protection Authority (NT EPA) which is responsible for implementing the *National Environment Protection (Ambient Air Quality) Measure* (AAQ NEPM) in the Northern Territory through the provisions of the *Waste Management and Pollution Control Act 1998* (WMPCA) and the *National Environment Protection Council (Northern Territory) Act 1994*.

Clause 18 of the *National Environment Protection (Ambient Air Quality) Measure* (AAQ NEPM) as amended requires jurisdictions to submit a report on their compliance with the AAQ NEPM for each calendar year. The content of the jurisdictional report is prescribed in clause 17 of the AAQ NEPM.

Consistent with the reporting period defined in the AAQ NEPM, this report covers the calendar year ending on 31 December 2019 for data collected from the Northern Territory Environment Protection Authority (NT EPA) monitoring stations located at Palmerston, Winnellie and Stokes Hill (Figure 1). The report is based on Technical Papers No. 8 - Annual Reports (PRC 2002) and No. 5 - Data Collection and Handling (PRC 2001) which detail the format and data requirements of the Annual Report. It is a technical report to the National Environment Protection Council (NEPC) and supplements the annual summary report provided each year by each jurisdiction under the *National Environment Protection Council Act 1994* on the overall implementation of the AAQ NEPM.

This technical report, *Northern Territory Ambient Air Quality Monitoring Report 2019 - Compliance with the National Environment Protection (Ambient Air Quality) Measure*, is available on the NT EPA website at https://ntepa.nt.gov.au/your-environment/air-quality/ambient-air-quality-reports.

[1] Name changed from Department of Environment and Natural Resources (DENR) in 2020

3 Overview of the 2019 AAQ NEPM monitoring network and activities

Figure 1: Locations of Palmerston, Winnellie and Stokes Hill Air Quality Monitoring Stations (AQMS).

3.1 Monitoring requirements

The results of air quality monitoring in 2000-2001 were used to determine the monitoring requirements for the Northern Territory over the longer term. This monitoring identified fine particles from landscape fires affecting the Darwin region as the primary air pollutant of concern in the Northern Territory. Analysis of the 2000-2001 data against the AAQ NEPM standards indicated that nitrogen oxides, sulfur dioxide, carbon monoxide, ozone and lead aerosols were not a cause for concern in the Darwin/Palmerston region or regional population centres.

Since the initial monitoring, the population and industrial activities in Darwin have increased and more detailed monitoring of airborne pollutants is required. In 2010, the establishment and operation of a comprehensive air quality monitoring system for the Darwin region commenced. This was completed in July 2012 allowing for monitoring of all pollutants identified in the AAQ NEPM with the exception of lead. Monitoring for lead was not deemed necessary as there are no significant sources close to populated areas in the region and the sale of unleaded petrol ceased in 2002.

The network of ambient air quality monitoring stations in the Darwin Region comprises of three stations (Figure 1): a performance monitoring station located near Palmerston has been operational since the beginning of 2011; a long-term trend monitoring station located at the Bureau of Meteorology (BoM) site in Winnellie has been operational since the second half of 2012; and the newest station near Stokes Hill Wharf started operating in May 2017.

3.2 Current monitoring stations for the purposes of this report

Winnellie air quality monitoring station (AQMS) meets requirements as a generally representative upper bound (GRUB) station. It is located between Darwin's northern suburbs and Darwin CBD, the two most densely populated areas in the Northern Territory (Figure 1). The station consists of an air-conditioned instrument shed, which houses all instrumentation. Ambient air is continuously analysed for ozone (O_3), sulphur dioxide (SO_2), carbon monoxide (CO) and oxides of nitrogen (NO_x) concentrations by various instruments which are connected to a single gas-sampling manifold protruding through the station roof. NO_x is measured as the sum of nitrogen dioxide (NO_2) and nitric oxide (NO) concentrations. Air for particulate sampling is drawn through a separate mast attached to the station roof. The mast is fitted with appropriate size selection inlets to sample specific particle size ranges (i.e., PM_{10} which are particles with aerodynamic diameters of 10 μm or less and $PM_{2.5}$ which are particles with aerodynamic diameters of 2.5 μm or less). Sampled air is drawn into a dichotomous tapered element oscillating microbalance (TEOM) which provides near real-time PM_{10} and $PM_{2.5}$ concentrations in ambient air. Meteorological data is obtained from BoM instruments located at the site.

The Palmerston AQMS has been located to provide information on airborne pollutants, which may be moving from industrial sites in the middle harbour to populations in the Palmerston area. This station meets all siting and instrumentation requirements for reporting under the AAQ NEPM. It is located in light bushland approximately 4km south-west of Palmerston (Figure 1). The station houses the same gas and particulate sampling instruments as Winnellie, but has meteorological instruments.

Stokes Hill AQMS (Figure 1) is located about 1 km southeast of the CBD on the Darwin Waterfront and meets all siting and instrumentation requirements for reporting under the AAQ NEPM. This station was established to monitor potential air quality impacts from industrial development and increased shipping traffic in Darwin Harbour. The station houses similar gas and particulate sampling instruments as the other stations and has instruments for collection of meteorological data.

Instrumentation and siting details for all stations are shown in Tables 1 and 2 in subsection 3.3.

3.3 Determination of exposed population for performance monitoring stations

Two areas within the Northern Territory exceed or are close to the population threshold of 25,000 required for establishing at least one performance air quality monitoring in the areas as required by the AAQ NEPM. These are the Greater Darwin region (137,000) and Alice Springs (25,000).

The major air pollutant of concern for Darwin and Palmerston is particulate matter from bushfire smoke in the Dry Season (May - October). Prevailing winds during the Dry Season are south-easterly to easterly, causing the population of the region to be frequently exposed to particulate pollution from relatively small fires in local bushland and more distant large-scale savannah fires.

Monitoring for particulates has been conducted at several sites in the Darwin/Palmerston region since 2002. From 2012, monitoring was conducted at two sites, whilst monitoring at the third site commenced in 2017. Results from simultaneous monitoring have shown that aside from spikes attributable to local fire events, particulate levels are reasonably uniform across the region on a seasonal basis. This was supported by the 2019 data: $PM_{2.5}$ annual average levels were 9.8, 9.2 and 8.9 $\mu g/m^3$ respectively at Palmerston, Stokes Hill and Winnellie. As industrial development increases, divergence in particulate and other pollutant levels may occur between sites.

Table 1: Summary of station siting in compliance with AS/NZS 3580

Station	Location Category	Height above ground	Clear Sky Angle	Unrestricted airflow of 360°	20m from trees	No boilers/ incinerators nearby	Minimum distance from road or traffic
Winnellie AQMS	Bushland	Yes	Yes	Yes	Yes	Yes	Yes
Palmerston AQMS	Bushland	Yes	Yes	Yes	Yes	Yes	Yes
Stokes Hill AQMS	Coastal	Yes	Yes	Yes	Yes	Yes	Yes

No monitoring was undertaken in the Alice Springs region during the reporting period. The NT EPA intends to conduct monitoring of particulates in Alice Springs and other regional centres such as Katherine and Tennant Creek in future years.

Table 1 shows that all the stations were sited in compliance with the requirements for Australian Standard AS/NZS 3580.1.1:2007 (Methods for sampling and analysis of ambient air – Guide to siting air monitoring equipment); and Table 2 lists the status of instruments located at the stations.

Table 2: Air quality and meteorological instruments at ambient air quality stations

Parameter	Data available from	Data available to	Current Instrument	Sampling frequency
PM_{10}	01/01/11 (Palmerston) 18/07/12 (Winnellie) 03/07/17 (Stokes Hill)	present	TEOM 1405D	continuous
$PM_{2.5}$	01/01/11 (Palmerston) 18/07/12 (Winnellie) 03/07/17 (Stokes Hill)	present	TEOM 1405D	continuous
SO_2	01/01/11 (Palmerston) 18/07/12 (Winnellie) 05/05/17 (Stokes Hill)	present	Thermo Model 43i	continuous
NOx, NO, NO_2	01/01/11 (Palmerston) 18/07/12 (Winnellie) 05/05/17 (Stokes Hill)	present	Thermo Model 42i	continuous
O_3	01/01/11 (Palmerston) 18/07/12 (Winnellie) 05/05/17 (Stokes Hill)	present	Thermo Model 49i	continuous
CO	01/01/11 (Palmerston) 18/07/12 (Winnellie) 05/05/17 (Stokes Hill)	present	Thermo Model 48i	continuous

Wind direction	01/01/12 (Palmerston) 05/05/17 (Stokes Hill)	present	RM Young, 2D ultra-sonic anemometer model 85000	continuous
Wind speed	01/01/12 (Palmerston) 04/05/17 (Stokes Hill)	present	RM Young, 2D ultra-sonic anemometer model 85000	continuous
Sigma Theta	05/05/17 (Stokes Hill)	present	RM Young, 2D ultra-sonic anemometer model 85000	continuous
Temperature	01/01/12 (Palmerston) 05/05/17 (Stokes Hill)	present	RM Young, model 41382LC TEOM sensor	continuous
Relative Humidity	01/01/12 (Palmerston) 05/05/17 (Stokes Hill)	present	RM Young, model 41382LC TEOM sensor	continuous
Atmospheric Pressure	01/01/12 (Palmerston) 05/05/17 (Stokes Hill)	present	RM Young, model 61302v TEOM sensor	continuous
Solar Radiation	01/01/12 (Palmerston)	present	Middleton Solar Pyranometer, model EQ08	continuous
Rainfall	01/01/12 (Palmerston)	present	RM Young, Tipping Bucket Rain Gauge	continuous

The anemometer is on a 10m mast at Palmerston; and on a 5m mast at Stokes Hill (the base of the mast is 5m from the ground). Meteorological data for Winnellie Station are sourced from BoM instruments located at the site. Each station has an Environics Multi-Gas Calibrator/Diluter instrument and an Environics Zero Air generators for conducting daily automatic zero/span checks and remote calibrations.

3.4 Monitoring during the reporting period

Palmerston, Winnellie and Stokes Hill stations monitor the same suite of air pollutants. Almost all of the instruments (including meteorological instruments) at the three stations provided valid data for more than seventy-five per cent of the time during the reporting period. This is the second year that the newest station, located at Stokes Hill and established in May 2017, has provided a whole calendar year of data enable assessment of compliance with the AAQ NEPM.

3.5 Changes to the approved monitoring plan

No changes were made to the approved monitoring plan this year.

3.6 Unresolved issues

There are no unresolved issues in the reporting period.

3.7 Status of NATA accreditation

All data collection and validation processes were conducted by a National Association of Testing Authorities (NATA) accredited contractor who used Australian Standard methods/instruments for monitoring the air pollutants (Table 3), as prescribed in Clause 16 of the AAQ NEPM.

Table 3: Australian Standards and monitoring instruments used for air pollutant monitoring

Pollutant	Standard	Title	Instruments used
Carbon monoxide	AS3580.7.1	Ambient Air – Determination of Carbon Monoxide – Direct Reading Instrument Method	Gas filter correlation/ infra-red analyser
Nitrogen dioxide	AS3580.5.1	Ambient Air – Determination of Oxides of Nitrogen – Chemiluminescence Method	Gas-phase chemiluminescence analyser
Photochemical oxidant (ozone)	AS3580.6.1	Ambient Air – Determination of Ozone – Direct Reading Instrument Method	Non-dispersive ultra-violet analyser
Sulfur dioxide	AS3580.4.1	Ambient Air – Determination of Sulfur Dioxide – Direct Reading Instrument Method	Pulsed fluorescence analyser
Particles as PM_{10}	AS3580.9.8	Determination of Suspended Particulate Matter – PM_{10} continuous direct mass method using a TEOM	Tapered element oscillating microbalance (TEOM) dichotomous air monitor
Particles as $PM_{2.5}$	AS/NZS 3580.9.13	Determination of Suspended Particulate Matter – $PM_{2.5}$ continuous direct mass method using a TEOM	Tapered element oscillating microbalance (TEOM) dichotomous air monitor

3.8 Methods other than physical monitoring

No other methods were used in the reporting period.

4 Assessment of compliance with the AAQ NEPM standards and goals

A goal of the National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM) is to achieve the current National Environment Protection Standards shown in Table 4.

Table 4: Ambient Air Quality NEPM Standards

Pollutant	Averaging period	Maximum concentration standard	Maximum allowable exceedances
Carbon monoxide	8 hour	9.0 ppm	1 day a year
Nitrogen dioxide	1 hour	0.12 ppm	1 day a year
	1 year	0.03 ppm	None
Photochemical oxidants (as ozone)	1 hour	0.10 ppm	1 day a year
	4 hours	0.08 ppm	1 day a year
Sulfur dioxide	1 hour	0.20 ppm	1 day a year
	1 day	0.08 ppm	1 day a year
	1 year	0.02 ppm	None
*Particles as PM_{10}	1 day	50 µg/m^3	None
	1 year	25 µg/m^3	None
*Particles as $PM_{2.5}$	1 day	25 µg/m^3	None
	1 year	8 µg/m3	None

**For the purpose of reporting compliance against PM_{10} and $PM_{2.5}$ 1-day average standards, monitoring data that has been determined as being directly associated with an exceptional event (such as bushfires) are excluded.*

The following tables (5-10) summarise compliance with the standards and goals of the AAQ NEPM. Data availability (quarterly and annually), the number of days when standards were exceeded, the annual mean (where an annual standard exists) and an assessment of compliance are given for each pollutant.

A station's performance is assessed as complying with the AAQ NEPM (i.e. 'Met') for a pollutant if there were no exceedances or the number exceedances was no more than the "Maximum allowable exceedances" specified in Table 4 above and data availability was at least 75%.

Performance is assessed as not complying (i.e. 'Not Met') if there were exceedances and the number exceedances was more than the "Maximum allowable exceedances" specified in Table 4 above. If there

was insufficient data (less than 75% availability) then performance is assessed as 'Not Demonstrated' ('ND').

4.1 Carbon monoxide compliance

Table 5: 2019 compliance summary for CO in the Northern Territory

Region/ Performance monitoring station	Data Availability Rates (% of Days)					Number of exceedances (days)	Performance against the standard and goal
	Q1	Q2	Q3	Q4	Annual		
						AAQ NEPM Standard	
						9.0 ppm (8-hour average)	
Winnellie	86	93	93	96	92	0	Met
Palmerston	100	98	100	100	99	0	Met
Stokes Hill	100	98	100	100	99	0	Met

During 2019, no exceedance of the carbon monoxide (CO) standard was recorded; compliance with the AAQ NEPM goal for CO was demonstrated at all the stations.

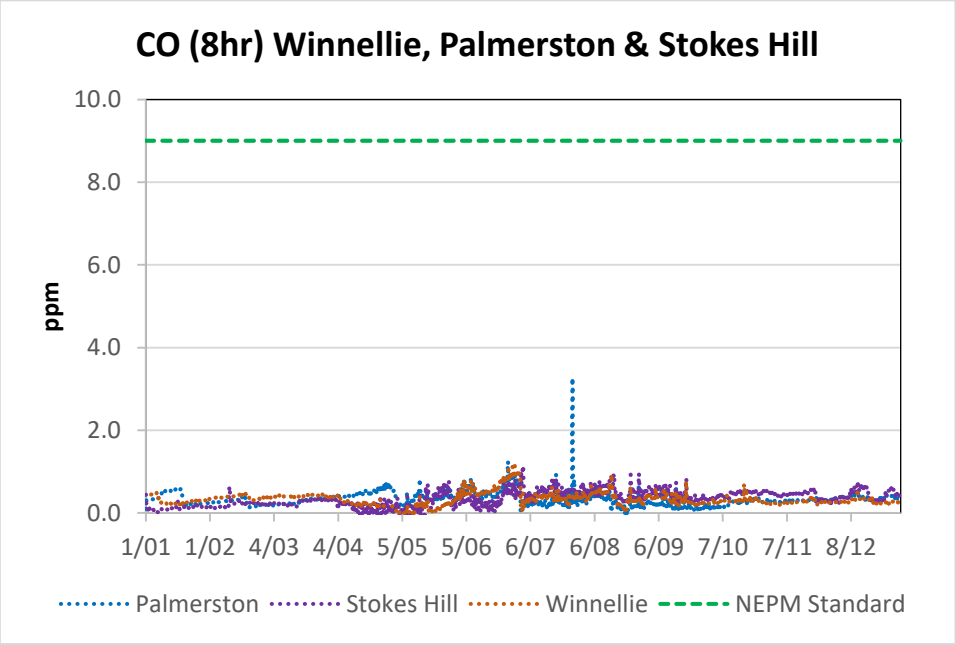

Figure 2: CO 8-hour averages 2019

4.2 Nitrogen dioxide compliance

Table 6: 2019 compliance summary for NO_2 in the Northern Territory

Region/ Performance monitoring station	Data Availability Rates (% of Days)					Number of exceedances (days)	Annual mean (ppm)	Performance against the standard and goal	
	Q1	Q2	Q3	Q4	Annual			1h	1y
								AAQ NEPM Standard	
								0.12 ppm (1-hour average)	
								0.03 ppm (1-year average)	
Winnellie	84	83	71	96	84	0	0.0017	Met	Met
Palmerston	100	97	80	100	94	0	0.0022	Met	Met
Stokes Hill	100	98	100	96	98	0	0.0018	Met	Met

In 2019, no exceedances of the nitrogen dioxide (NO_2) 1-hour and 1-year standards were recorded in the Darwin region. During the third quarter, Winnellie did not meet 75% data recovery to demonstrate compliance; however, due to the very low concentrations measured at the stations during that quarter, no exceedances are expected. Compliance with the AAQ NEPM goal for NO_2 was met at all sites.

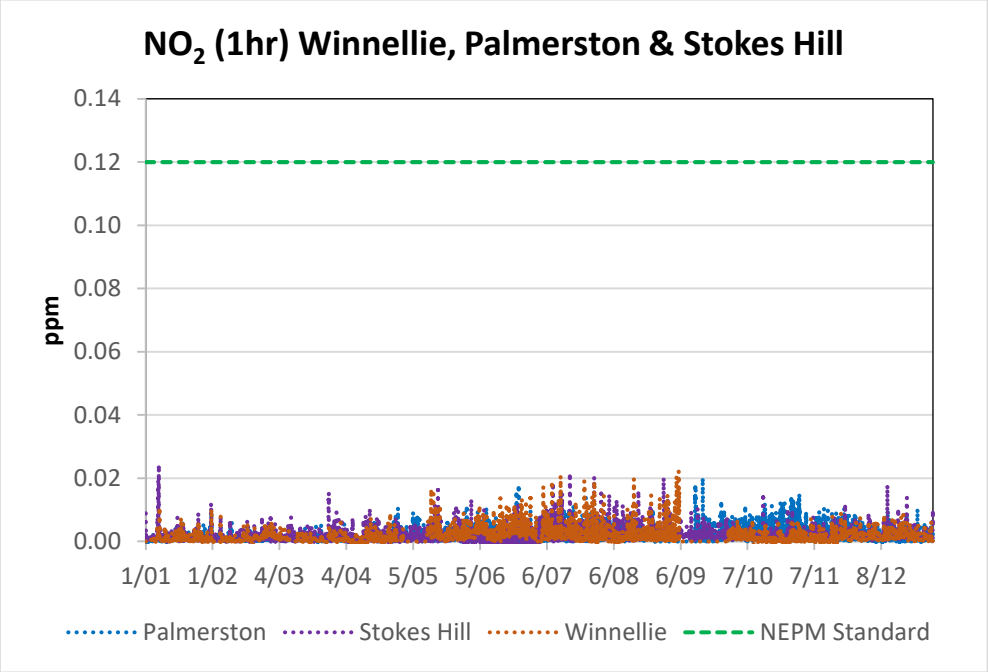

Figure 3: NO_2 1-hour averages 2019

4.3 Ozone compliance

Table 7: 2019 compliance summary for O_3 in the Northern Territory

AAQ NEPM Standard

0.10 ppm (1-hour average)

0.08 ppm (4-hour average)

Region/ Performance monitoring station	Data Availability Rates (% of Days)					Number of exceedances (days)		Performance against the standard and goal	
	Q1	Q2	Q3	Q4	Annual	1h	4h	1h	4h
Winnellie	86	96	100	96	95	0	0	Met	Met
Palmerston	100	100	100	100	100	0	0	Met	Met
Stokes Hill	100	100	100	100	100	0	0	Met	Met

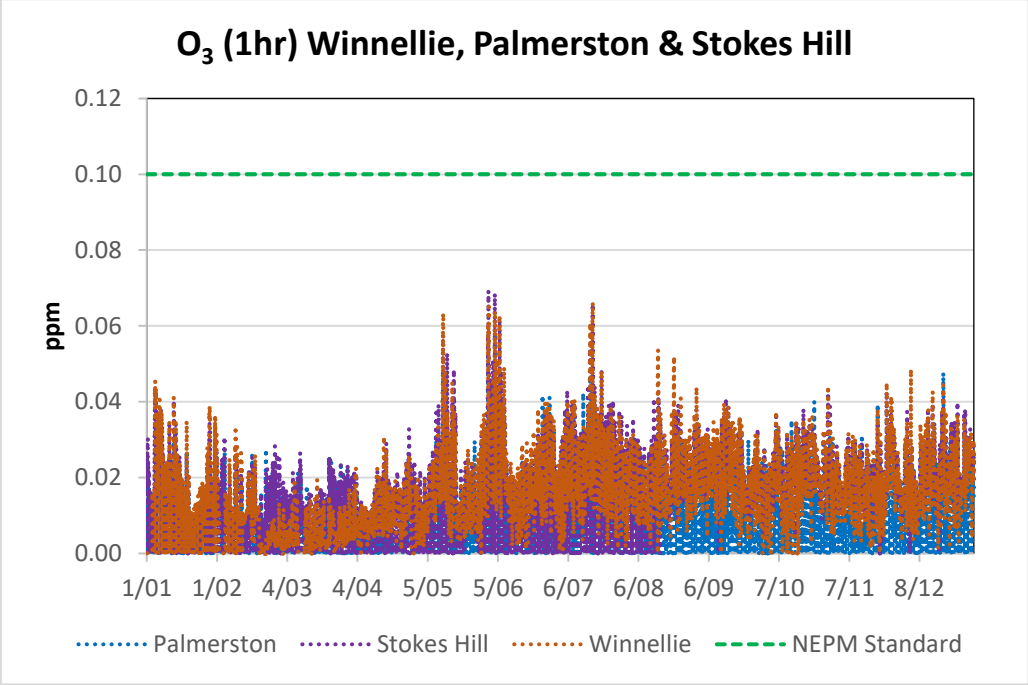

Figure 4: O_3 1-hour averages 2019

During 2019, no exceedance of the ozone (O_3) 1-hour average standard or 4-hour rolling average standard was recorded in the Darwin region. Compliance with the AAQ NEPM O_3 goal was demonstrated at all sites.

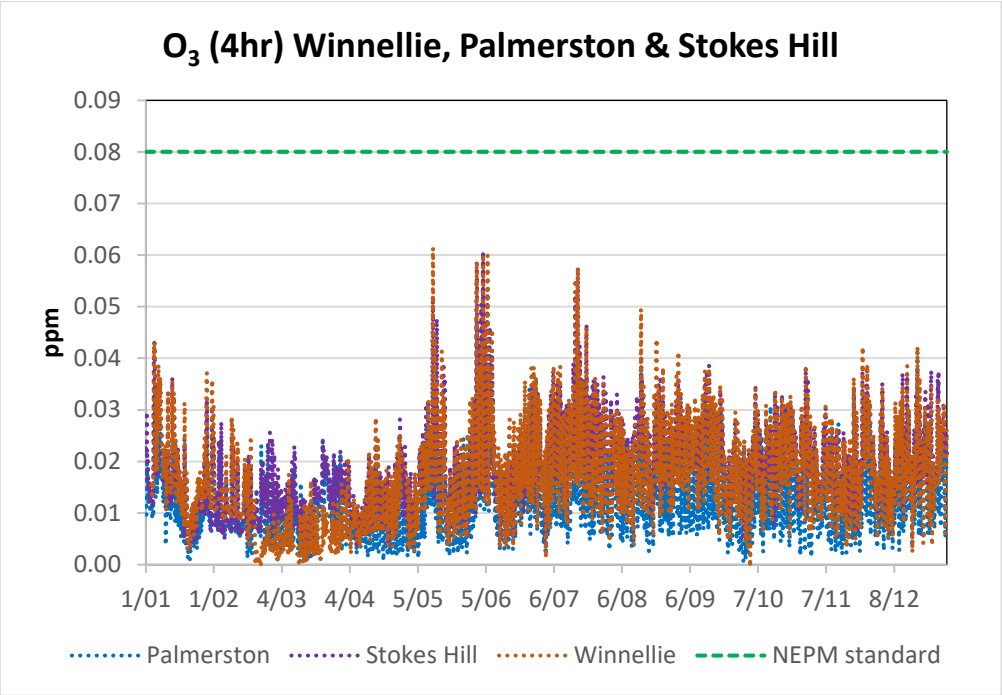

Figure 5: O_3 4-hour averages 2019

4.4 Sulfur dioxide compliance

Table 8: 2019 compliance summary for SO_2 in the Northern Territory

AAQ NEPM Standard

0.20 ppm (1-hour average)

0.08 ppm (1-day average)

0.02 ppm (1-year average)

Region/ Performance monitoring station	Data Availability Rates (% of Days)					Number of exceedances (days)		Annual mean (ppm)	Performance against the standard and goal		
	Q1	Q2	Q3	Q4	Annual	1h	24h		1h	24h	1y
Winnellie	78	94	95	96	91	0	0	0.00045	Met	Met	Met
Palmerston	100	98	84	100	95	0	0	0.00059	Met	Met	Met
Stokes Hill	83	98	100	100	95	0	0	0.00056	Met	Met	Met

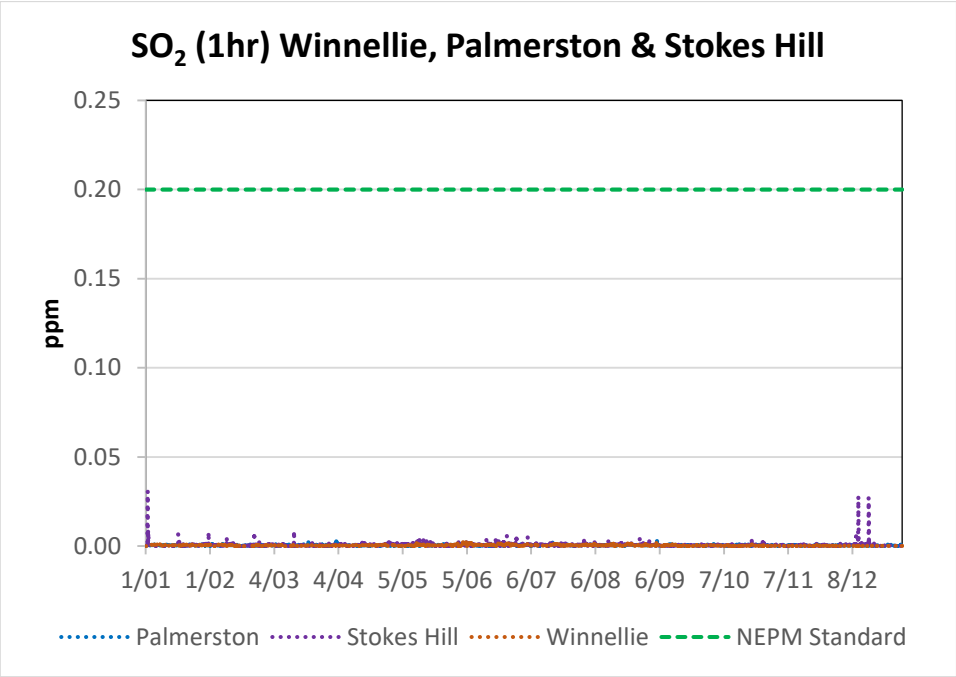

Figure 6: SO_2 1-hour averages 2019

During 2019, no exceedances of the sulfur dioxide (SO_2) 1-hour, 1-day or 1-year standards were recorded in the Darwin region. Compliance with the AAQ NEPM goal for SO_2 was demonstrated at all sites.

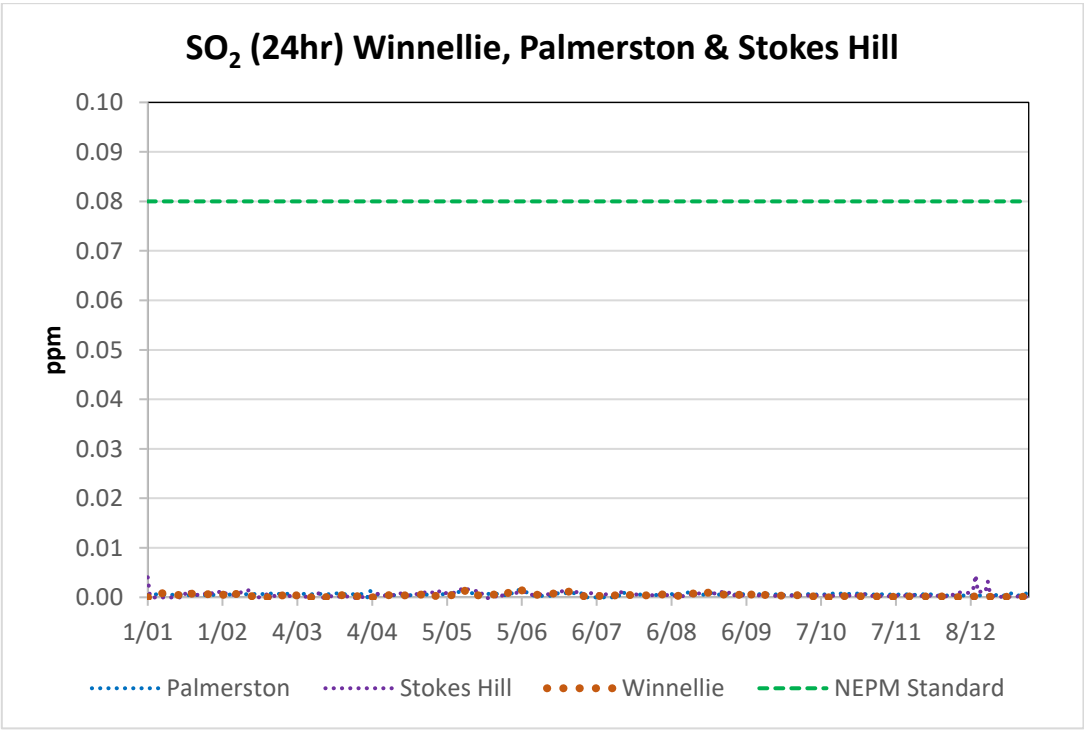

Figure 7: SO_2 1-day averages 2019

4.5 Particulates (PM_{10}) compliance

Table 9: 2019 compliance summary for PM_{10} in the Northern Territory

AAQ NEPM Standard

50 µg/m³ (1-day average)

25 µg/m³ (1-year average)

Region/ Performance monitoring station	Data Availability Rates (% of Days)					Number of exceedances (days)	Annual average (µg/m³)	Performance against the standard and goal	
	Q1	Q2	Q3	Q4	Annual			24h	1y
Winnellie	86	94	100	96	94	15	23.0	Met	Met
Palmerston	100	97	100	100	99	10	22.0	Met	Met
Stokes Hill	100	97	100	100	99	11	22.4	Met	Met

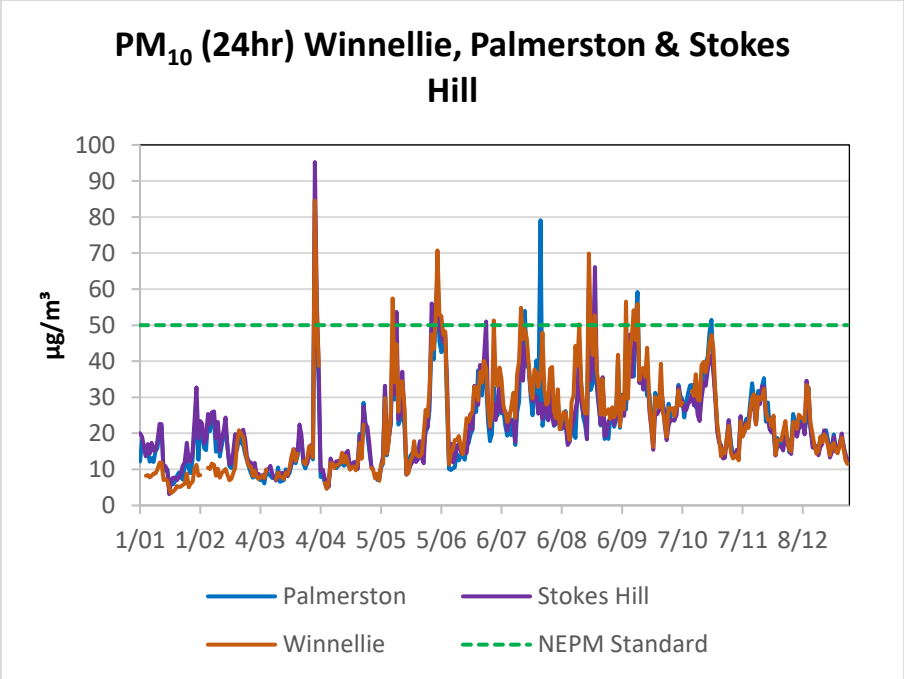

Figure 8: PM_{10} 1-day averages 2019

During 2019, exceedances of the PM_{10} 1-day standard were recorded. However, these exceedances were attributed to exceptional events such as smoke from small-scale local bush/grass fires or more distant large-scale savannah fire activity such as hazard reduction burns. The AAQ NEPM excludes monitoring

data associated with exceptional events for reporting compliance against PM_{10} and $PM_{2.5}$ 1-day average standards. Since annual averages were below the 1-year standard. Compliance with the AAQ NEPM goal for PM_{10} was demonstrated at all sites.

The AAQ NEPM as amended, defines an exceptional event as:

…. a fire or dust occurrence that adversely affects air quality at a particular location, and causes an exceedance of 1 day average standards in excess of normal historical fluctuations and background levels, and is directly related to: bushfire; jurisdiction authorised hazard reduction burning; or continental scale windblown dust.

4.6 Particulates ($PM_{2.5}$) compliance

Table 10: 2019 compliance summary for $PM_{2.5}$ in the Northern Territory

AAQ NEPM Standard

25 µg/m³ (1-day average)

8 µg/m³ (1-year average)

Region/ Performance monitoring station	Data Availability Rates(% of Days)					Number of exceedances (days)	Annual average µg/m³	Performance against the standard and goal	
	Q1	Q2	Q3	Q4	Annual			24h	1y
Winnellie	86	94	100	96	94	17	8.9	Met	Not Met
Palmerston	100	97	100	100	99	21	9.8	Met	Not Met
Stokes Hill	100	97	100	100	99	20	9.2	Met	Not Met

During 2019, several exceedances of the $PM_{2.5}$ 1-day standard were recorded. However, these were all attributed to exceptional events such as smoke from small-scale local bush/grass fires or more distant large-scale savannah fire activity such as hazard reduction burns. 1-year averages were above the AAQ standard at all the stations.

Although compliance with the 1-day average standard was met at all the sites; compliance with the AAQ NEPM goal for $PM_{2.5}$ was not met at any sites since the annual averages exceeded the 1-year average standard. The AAQ NEPM does not exclude monitoring data associated with exceptional events for reporting compliance against PM_{10} and $PM_{2.5}$ 1-year average standards.

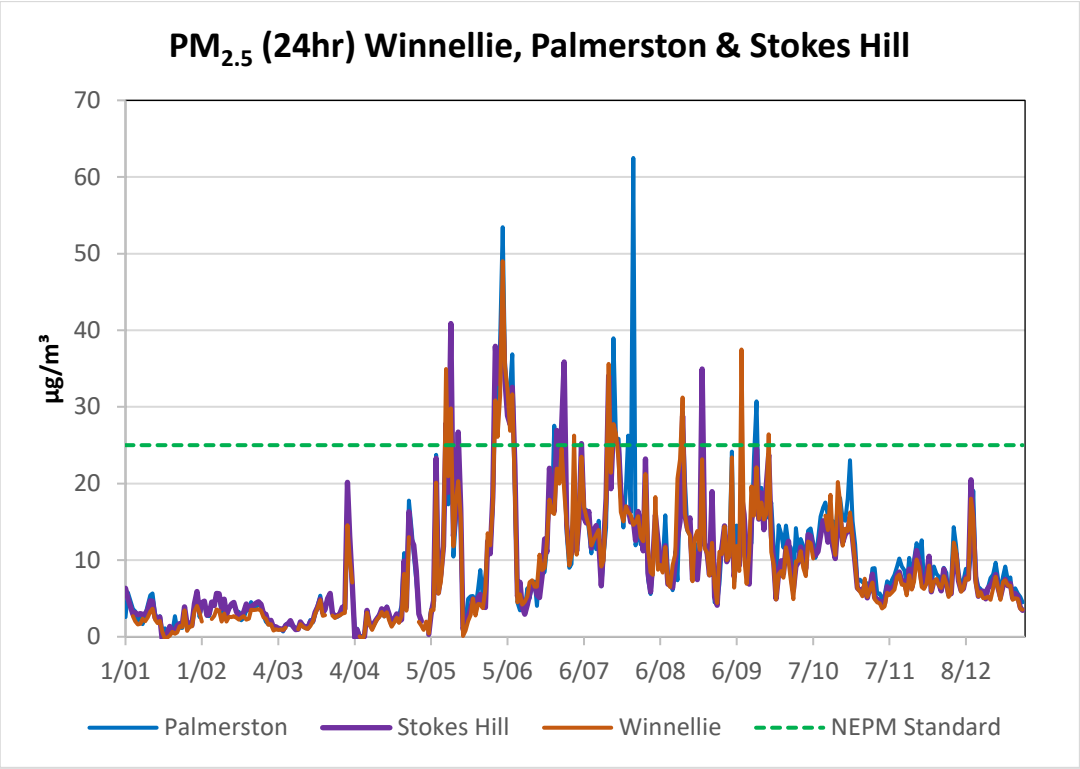

Figure 9: $PM_{2.5}$ 1-day averages 2019

5 Analysis of air quality data

Annual summary statistics are presented in this section. The AAQ NEPM states that short-term standards should not be exceeded on more than one day for carbon monoxide, nitrogen dioxide, ozone and sulfur dioxide or on any day for PM_{10} and $PM_{2.5}$ (except when caused by exceptional events such as bushfires). Figures 2, 3, 6 & 7, in the previous section, show that with the exception of a few events, levels of carbon monoxide, nitrogen dioxide and particularly sulfur dioxide, were significantly below the AAQ NEPM standards, and there were no exceedances recorded.

In this section, data availability is presented as the number of valid days; this value represents the number of days during the year when at least 75% of averaging periods during the day had valid data.

There must be a minimum of 75% data availability in any averaging period for the data to be reported against the corresponding AAQ NEPM standard. For example, the 4-hour ozone AAQ NEPM standard is based on four-hour rolling averages. A valid 4-hour rolling average is calculated as the average of the valid one-hour averages over the preceding 4 hours - when at least three of those hours (75%) had valid data. In the case of the carbon monoxide 8-hour rolling average, the minimum number of valid hours required for averaging is six.

5.1 Carbon monoxide statistics

Table 11: 2019 summary statistics for daily peak 8 hour CO in the Northern Territory

			AAQ NEPM Standard		
			9.0 ppm (8-hour average)		
Region/ Performance monitoring station	**Number of valid days**	**Highest (ppm)**	**Highest (date:hour)**	**2nd highest (ppm)**	**2nd Highest (date:hour)**
Winnellie	334	1.14	28/06:11	1.13	27/06:10
Palmerston	350	3.28	26/07:08	1.25	25/06:04
Stokes Hill	349	1.15	02/07:08	1.02	01/07:09

Carbon monoxide (CO) levels at all the stations were substantially below the CO 8-hour rolling average standard for most days with the exception of one day when a significant CO event was recorded. The highest event, recorded at Palmerston (3.28 ppm, 8am on 26/07/2019) was less than 50% of the AAQ NEPM standard. The plume which had significant oxides of nitrogen and particulates content, originated from south of the station.

5.2 Nitrogen dioxide statistics

Table 12: 2019 summary statistics for daily peak 1 hour NO_2 in the Northern Territory

AAQ NEPM Standard

0.12 ppm (1-hour average)

Region/ Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date:hour)	2nd highest (ppm)	2nd Highest (date:hour)
Winnellie	307	0.023	05/09:03	0.021	12/07:09
Palmerston	345	0.020	16/09:07	0.018	12/09:19
Stokes Hill	361	0.024	16/01:24	0.022	16/07:17

Nitrogen dioxide (NO_2) levels were below the AAQ NEPM 1-hour nitrogen dioxide standard. The highest recorded reading (0.024 ppm) was recorded at Stokes Hill at 12pm on 16/01/2019, and was not very different from the highest peaks recorded at the other two stations.

5.3 Ozone statistics

Table 13: 2019 summary statistics for daily peak 1 hour O_3 in the Northern Territory

AAQ NEPM Standard

0.10 ppm (1-hour average)

Region/ Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date:hour)	2nd highest (ppm)	2nd Highest (date:hour)
Winnellie	347	0.066	16/07:19	0.065	31/05:21
Palmerston	365	0.059	03/06:15	0.053	31/05:17
Stokes Hill	365	0.069	31/05:20	0.069	03/06:15

There were no exceedances of the 1-hour or 4-hour ozone standards at any of the monitoring sites. The highest 1-hour peak of 0.069 ppm was recorded at Stokes Hill at 8pm on 31 May 2019. Other stations also recorded high ozone levels on this day and on 3 June 2019. These event days were characterised by high temperatures (26 - 32 ^{o}C), low wind speeds (2 m/s, average) and high solar radiation (800 W/m^2, maximum). The stations also recorded high particulate levels from bushfire smoke on those days.

Table 14: 2019 summary statistics for daily peak 4 hour O_3 in the Northern Territory

AAQ NEPM Standard

0.08 ppm (4-hour average)

Region/ Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date:hour)	2nd highest (ppm)	2nd Highest (date:hour)
Winnellie	347	0.061	11/05:21	0.060	03/06:17
Palmerston	365	0.052	03/06:16	0.048	31/05:18
Stokes Hill	365	0.061	03/06:16	0.058	31/05:20

5.4 Sulfur dioxide statistics

Sulfur dioxide (SO_2) levels in the Darwin region were substantially below the AAQ NEPM 1-hour and 1-day sulfur dioxide standards. The highest recorded 1-hour reading was at Stokes Hill (0.0308 ppm) at 9pm on 1/01/2019. This value and the second highest recorded value (0.0278 ppm), also recorded at Stokes Hill, were about an order of magnitude higher than the highest concentrations recorded at the other stations. The highest recorded 1-day average was also at Stokes Hill (0.0045 ppm), on 10/12/2019.

Table 15: 2019 summary statistics for daily peak 1 hour SO_2 in the Northern Territory

AAQ NEPM Standard

0.20 ppm (1-hour average)

Region/ Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date:hour)	2nd highest (ppm)	2nd Highest (date:hour)
Winnellie	334	0.0027	04/09:07	0.0026	04/06:16
Palmerston	350	0.0045	02/04:17	0.0029	04/09:18
Stokes Hill	349	0.0308	01/01:21	0.0278	10/12:21

Table 16: 2019 summary statistics for 24 hour SO_2 in the Northern Territory

AAQ NEPM Standard

0.08 ppm (1-day average)

Region/ Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date)	2nd highest (ppm)	2nd Highest (date)
Winnellie	334	0.0017	03/06	0.0016	04/06
Palmerston	350	0.0016	12/05	0.0015	11/05
Stokes Hill	349	0.0045	10/12	0.0040	01/01

5.5 Particulates statistics

The highest PM_{10} events recorded at the stations occurred on the same date (01/04/2019) for all the three stations. The plume responsible for the event had elevated levels of $PM_{2.5}$, but very low levels of combustion products such as carbon monoxide or oxides of nitrogen. This suggests a dust plume, which was wide spread over the Greater Darwin Region; however, there is no evidence that a dust storm occurred in Darwin on that day. The second highest PM_{10} events recorded at the stations had plumes associated with smoke events and contained substantial levels of $PM_{2.5}$ (see also Appendix A: Particulates Events for 2019). Although these PM_{10} levels exceeded the AAQ standard, they are considered as exceptional events since they are associated with natural events such as smoke from bushfires.

Table 17: 2019 summary statistics for 24 hour PM_{10} in the Northern Territory

AAQ NEPM Standard

50 µg/m³ (1-day average)

Region/ Performance monitoring station	Number of valid days	Highest (µg/m³)	Highest (date)	2nd highest (µg/m³)	2nd Highest (date)
Winnellie	345	84.6	01/04	70.7	03/06
Palmerston	363	84.5	01/04	79.1	26/07
Stokes Hill	363	95.2	01/04	66.1	23/08

The highest $PM_{2.5}$ concentration (62.5 µg/m³) was recorded at Palmerston on 26/07/2019, and the second highest (53.5 µg/m³) was also recorded at Palmerston; these and the other high peaks shown the table all exceeded the AAQ NEPM standard. These exceedances and others were due to bushfire activity, which

the AAQ NEPM classifies as exceptional events. High fine particle levels are typical of the Darwin airshed during the Dry season.

Since all exceedances of particulate standards were attributed to exceptional events, particulate levels complied with the AAQ NEPM 1-day standards for particulates.

Table 18: 2019 summary statistics for 24 hour $PM_{2.5}$ in the Northern Territory

AAQ NEPM Standard

25 µg/m^3 (1-day average)

Region/ Performance monitoring station	Number of valid days	Highest (µg/m^3)	Highest (date)	2nd highest (µg/m^3)	2nd Highest (date)
Winnellie	345	49.0	03/06	37.5	08/09
Palmerston	363	62.5	26/07	53.5	03/06
Stokes Hill	363	42.8	03/06	40.9	13/05

6 Analysis of exceedances and population exposure

This section will analyse exceedance events that occurred during 2019 and were recorded at the three ambient air quality monitoring stations.

6.1 Particulates exceedances

Particulates generated by vegetation burning are the primary air pollutants in the Darwin region. This results in significant variation in air quality between the Dry (May-October) and the Wet (November-April). In general, air quality was excellent during the Wet, but poor during the Dry of 2019. Averaged daily levels of $PM_{2.5}$ across all stations over the six months of the Dry was 13.9 $\mu g/m^3$, well above the AAQ NEPM annual standard of 8 $\mu g/m^3$ and significantly higher than levels in several Australian cities. Averaged daily $PM_{2.5}$ levels during the Wet was 4.6 $\mu g/m^3$. The elevated $PM_{2.5}$ levels during the Dry are unavoidable and people with respiratory or cardiopulmonary issues may be impacted.

The 1-day standard for $PM_{2.5}$ had multiple exceedances in 2019 (Figure 9). There were 21 exceedances of the 1-day standard at Palmerston station, and the annual limit was exceeded. Stokes Hill station had 20 exceedances of the 1-day standard, and exceeded the annual limit. Winnellie recorded the lowest number of exceedances of the 1-day standard (17) and likewise exceeded the annual limit. There were eight consecutive days from 31 May 2019, when the $PM_{2.5}$ 1-day standard was exceeded at all the stations. Palmerston recorded nine consecutive days of exceedances.

The AAQ NEPM 1-day standard for PM_{10} was exceeded on 10 days at Palmerston; 11 days at Winnellie; and 15 days at Stokes Hill; however, the annual PM_{10} limit was not exceeded at any of the stations. As explained in previous sections of this report, since the $PM_{2.5}$ and PM_{10} exceedances were caused by natural events such as bushfire activity, they are considered exceptional events under the AAQ NEPM.

Tables 19 - 24 show dates and inferred causes of particulate exceedances for all stations.

Table 19: 2019 PM_{10} exceedances of AAQ NEPM reporting level at Palmerston

Date	PM_{10} ($\mu g/m^3$)	Inferred Cause
01/04	84.5	smoke
02/06	50.1	smoke
03/06	65.4	smoke
18/07	54.0	smoke

26/07	79.1	smoke
20/08	60.2	smoke
23/08	50.9	smoke
13/09	50.7	smoke
14/09	59.2	smoke
22/10	51.5	smoke

Table 20: 2019 PM_{10} exceedances of AAQ NEPM reporting level at Winnellie

Date	PM_{10} ($\mu g/m^3$)	Inferred Cause
01/04	84.6	smoke
02/04	53.9	smoke
11/05	57.4	smoke
02/06	50.4	smoke
03/06	70.7	smoke
04/06	52.9	smoke
05/06	52.5	smoke
02/07	51.3	smoke
16/07	54.9	smoke
15/08	50.3	smoke
20/08	69.9	smoke
23/08	52.8	smoke
08/09	56.5	smoke
12/09	54.1	smoke
14/09	55.9	smoke

Table 21: 2019 PM_{10} exceedances of AAQ NEPM reporting level at Stokes Hill

Date	PM_{10} ($\mu g/m^3$)	Inferred Cause
01/04	95.2	smoke
02/04	56.8	smoke
13/05	53.7	smoke
31/05	56.0	smoke
01/06	51.3	smoke
02/06	53.3	smoke
03/06	62.3	smoke
28/06	51.0	smoke
16/07	51.7	smoke
20/08	59.9	smoke
23/08	66.1	smoke

Table 22: 2019 $PM_{2.5}$ exceedances of AAQ NEPM reporting level at Palmerston

Date	$PM_{2.5}$ ($\mu g/m^3$)	Inferred Cause
11/05	27.7	smoke
13/05	33.4	smoke
31/05	35.0	smoke
01/06	29.0	smoke
02/06	38.8	smoke
03/06	53.5	smoke
04/06	35.9	smoke
05/06	30.9	smoke
06/06	32.5	smoke
07/06	36.9	smoke
24/06	27.6	smoke

27/06	27.6	smoke
16/07	32.1	smoke
18/07	39.0	smoke
19/07	25.6	smoke
20/07	25.8	smoke
24/07	26.3	smoke
26/07	62.5	smoke
15/08	29.4	smoke
23/08	27.1	smoke
14/09	30.7	smoke

Table 23: 2019 $PM_{2.5}$ exceedances of AAQ NEPM reporting level at Winnellie

Date	$PM_{2.5}$ ($\mu g/m^3$)	Inferred Cause
11/05	34.9	smoke
13/05	29.8	smoke
31/05	30.9	smoke
01/06	26.1	smoke
02/06	31.5	smoke
03/06	49.0	smoke
04/06	35.3	smoke
05/06	32.3	smoke
06/06	26.9	smoke
07/06	31.6	smoke
02/07	26.2	smoke
16/07	35.6	smoke
18/07	27.8	smoke
19/07	26.4	smoke

15/08	31.2	smoke
08/09	37.5	smoke
19/09	26.4	smoke

Table 24: 2019 $PM_{2.5}$ exceedances of AAQ NEPM reporting level at Stokes Hill

Date	$PM_{2.5}$ ($\mu g/m^3$)	Inferred Cause
11/05	27.9	smoke
13/05	40.9	smoke
16/05	26.7	smoke
31/05	37.9	smoke
01/06	33.1	smoke
02/06	35.0	smoke
03/06	42.8	smoke
04/06	33.5	smoke
05/06	28.8	smoke
06/06	27.7	smoke
07/06	32.6	smoke
25/06	26.9	smoke
27/06	27.4	smoke
28/06	35.9	smoke
05/07	25.2	smoke
16/07	34.1	smoke
18/07	27.6	smoke
19/07	25.6	smoke
15/08	28.8	smoke
23/08	35.0	smoke

Smoke from burning vegetation contains PM_{10} and $PM_{2.5}$, Figures 10 - 12 show the close relationship between these parameters at all stations during the Dry Season.

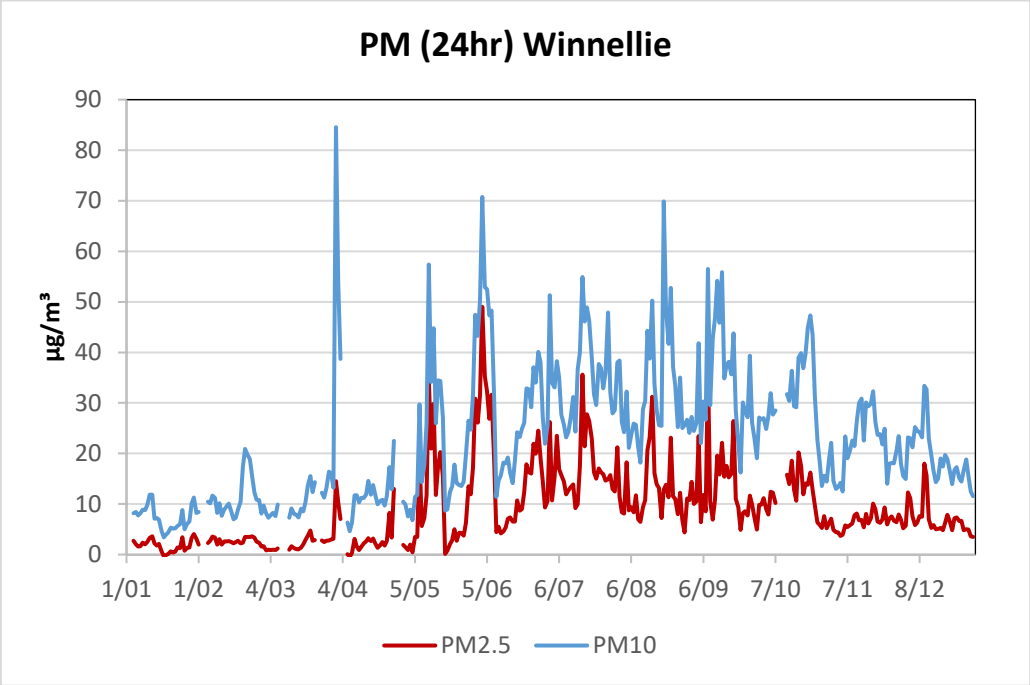

Figure 10: Particulates concentration at Winnellie AQMS 2019

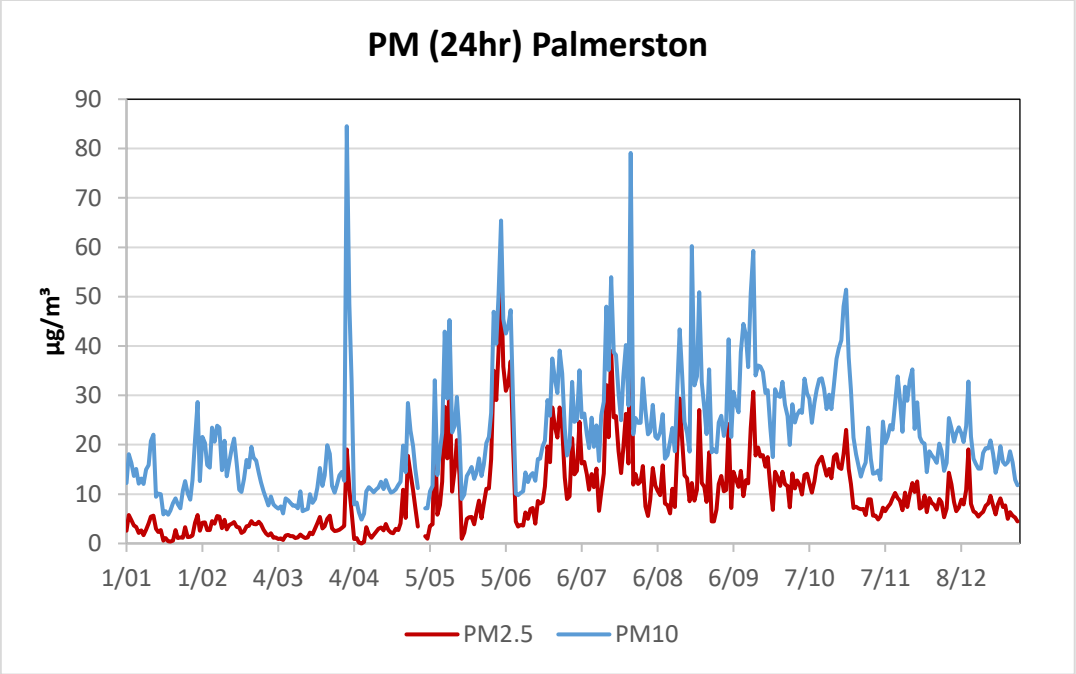

Figure 11: Particulates concentration at Palmerston AQMS 2019

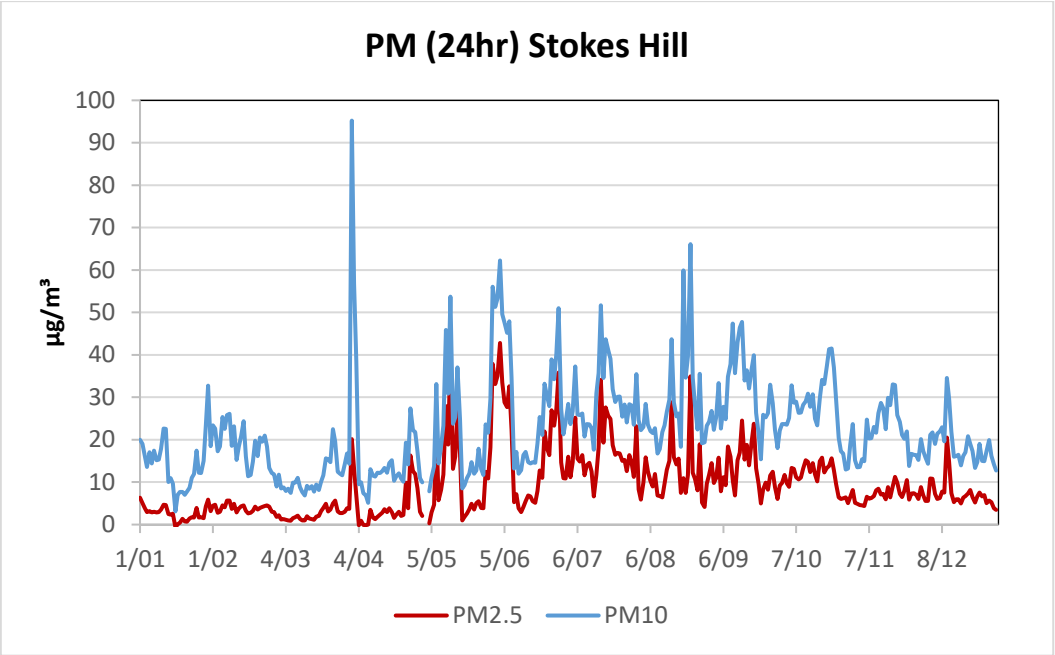

Figure 12: Particulates concentration at Stokes Hill AQMS 2019

6.2 Population exposure to $PM_{2.5}$

It is a requirement of the AAQ NEPM as amended in 2016, for participating jurisdictions to evaluate and report population exposure to particles as $PM_{2.5}$ annually from June 2018.

A simplified approach (EWG 2017) which outputs a single value was used to determine the population-weighted annual average $PM_{2.5}$ concentration for the Greater Darwin Region.

Statistical Area Level 2 (SA2) areas in the Greater Darwin Region and their respective populations were identified from the Australian Bureau of Statistics (ABS) Population Data for 2016 (ABS 2016). SA2 is an area defined in the Australian Statistical Geography Standard and is usually based on officially gazetted State/Territory suburbs and localities.

An annual average $PM_{2.5}$ concentration was calculated for each of the three air quality monitoring stations: Stokes Hill, Winnellie and Palmerston, using available 1-hour average data. These values were assigned to each of the identified SA2 areas based on their proximity to the nearest station. It was assumed that people living in the SA2 areas of Darwin City, Fannie Bay - The Gardens, Larrakeyah and Stuart Park would be exposed to $PM_{2.5}$ levels represented by concentrations measured at Stokes Hill AQMS; all other Darwin SA2 areas would be exposed to $PM_{2.5}$ levels measured at Winnellie AQMS; and people living in SA2 areas in Palmerston would be exposed to $PM_{2.5}$ levels measured at Palmerston AQMS.

The population-weighted annual average $PM_{2.5}$ concentration was calculated by multiplying the annual average $PM_{2.5}$ concentration for each SA2 with the corresponding population of the SA2; then summing the products calculated for each SA2, and dividing by the total population across all identified SA2s.

The 2019 population-weighted annual average $PM_{2.5}$ concentration for the Greater Darwin Region was estimated to be 9.3 $\mu g/m^3$. (See Appendix B for details of the calculations.)

7 Data analysis and trends

Tables 25 to 28 in this section compare the number of particulates exceedances in the NT over a longer period in accordance with AAQ NEPM technical requirements. This comparison is of limited utility in providing an accurate indication of particulate trends as different sampling techniques have been used since monitoring began in 2002; also TEOM and Partisol instruments have not been located consistently throughout the sampling period.

7.1 Trends in historical particulate data

Issues with historical data include:

- 2004 - data collection for this project did not commence until the second quarter.
- 2004 and 2005 - TEOM was located in Palmerston at the Charles Darwin University Palmerston campus.
- 2006 - TEOM data availability was below 75% for each quarter so Partisol data was used.
- 2009 - dust produced from local construction activity in close proximity to the station required that exceedances for a period over the Dry be removed as they were not necessarily representative of air quality in the larger air shed.
- 2010 - there was significant downtime with the Partisol and TEOM instruments.
- 2016 - data has not been analysed
- 2017 - Stokes Hill station started operating in May; TEOM data was only available from July.

Since the establishment of the Palmerston station in 2011 and then the Winnellie station in 2012 data quality has generally improved. During the Wet of 2013, the Palmerston TEOM was offline for a number of months resulting in inadequate data collection for NEPC reporting. As the TEOM was operational for most of the Dry, when particulates are an issue, 2013 data from Palmerston is still useful when considering longer term trends in particulates.

Table 25: Trends - PM_{10} 2004-2019

Year	Casuarina			Palmerston			Winnellie			Stokes Hill		
	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m^3)	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m^3)	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m^3)	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m^3)
2004	*69*	*1*	*54*									
2005	98	2	63									
2006	97	0	44									
2007	95	0	45									
2008	97	1	65									
2009	90	0	50									
2010	78	1	54									
2011				96	3	92						
2012				91	23	70						
2013				49	1	72	76	3	58			
2014				82	2	52	86	3	73			
2015				94	3	61	99	5	107			
2017				96	7	59	84	2	54	49	0	48
2018				97	5	143	92	5	78	89	6	64
2019				99	10	85	94	15	85	99	11	95

Table 26: Averaged PM_{10} Key Metrics 2004-2019

Data Availability (%)	Number of Exceedances	Max Concentration (µg/m^3)
86	5	69

Table 27: Trends $PM_{2.5}$, 2004-2019

Year	Casuarina			Palmerston			Winnellie			Stokes Hill		
	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m³)	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m³)	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m³)	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m³)
2004	60	5	37									
2005	98	5	58									
2006	97	5	30									
2007	-	-	-									
2008	72	2	32									
2009	87	1	26									
2010	62	2	30									
2011				96	15	77						
2012				91	23	44						
2013				49	6	56	76	5	34			
2014				82	12	37	86	9	45			
2015				94	7	40	99	10	78			
2017				96	10	42	84	6	41	49	1	28
2018				97	15	112	92	19	57	89	13	44
2019				99	21	63	94	17	49	99	20	43

Table 28: Averaged $PM_{2.5}$ Key Metrics 2004-2019

Data Availability (%)	Number of Exceedances	Max Concentration (µg/m³)
84	10	46

Trend data for the 2004 to 2019 period is presented in Figures 13 to 18. This data shows that there is no clear trend in $PM_{2.5}$ or PM_{10} in the Darwin region over the period. Population of the greater Darwin region has increased from approximately 105,000 in 2004 to ~140,000 in 2019 showing a clear upward trend. The lack of a relationship between population and particulate levels further demonstrates that the majority of particulate matter in the Darwin airshed derives from natural sources.

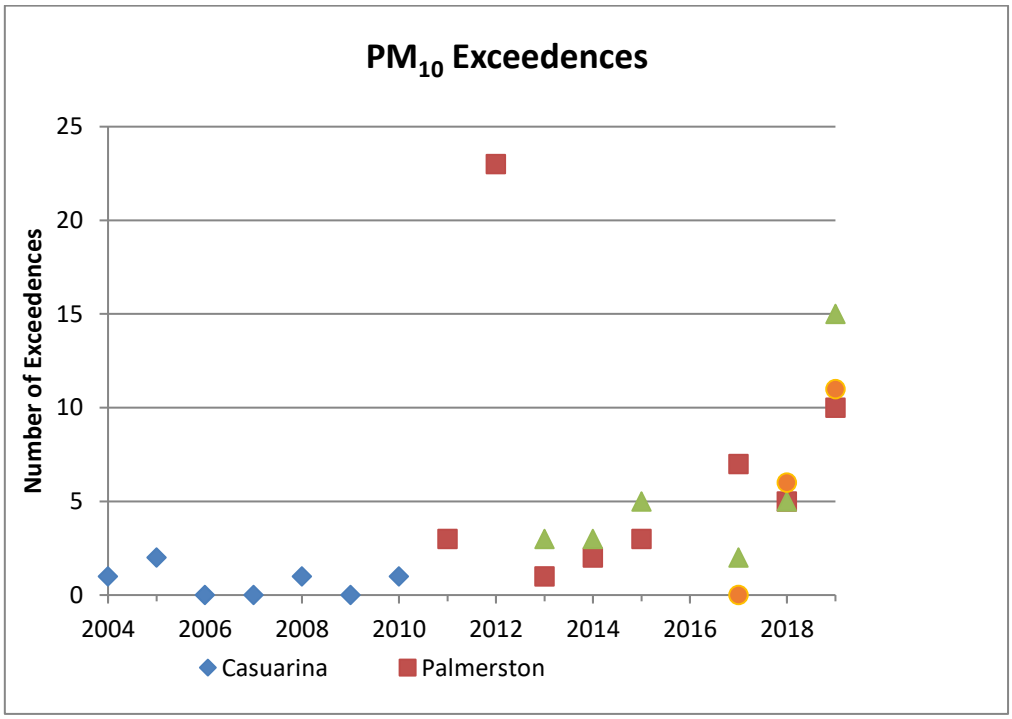

Figure 13: Historical PM_{10} exceedances

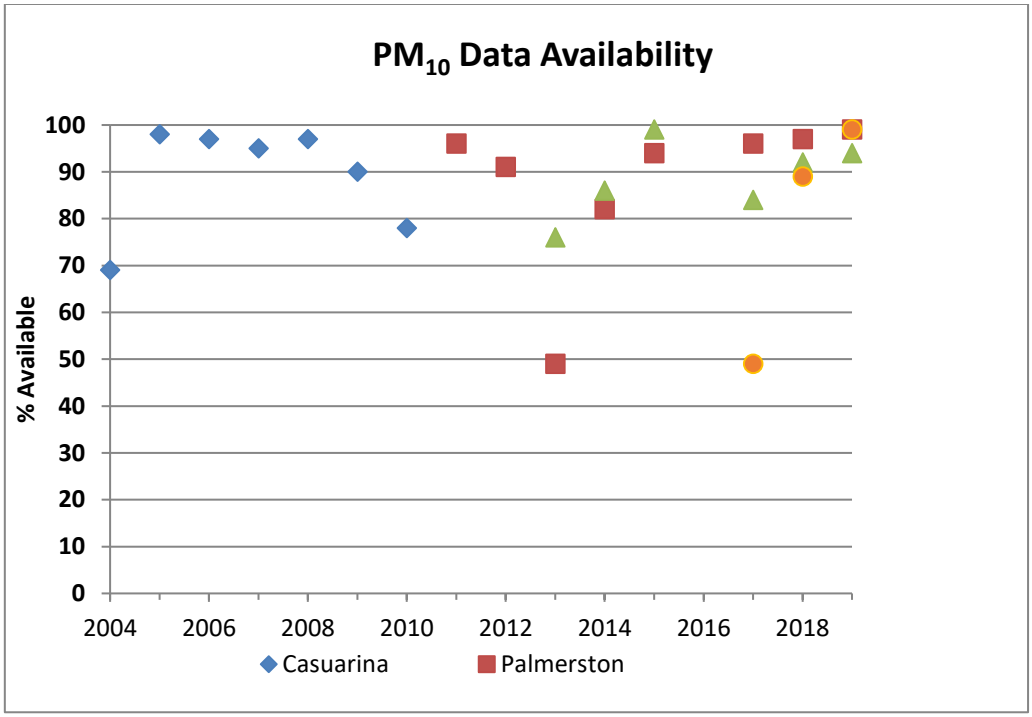

Figure 14: Historical PM_{10} data availability

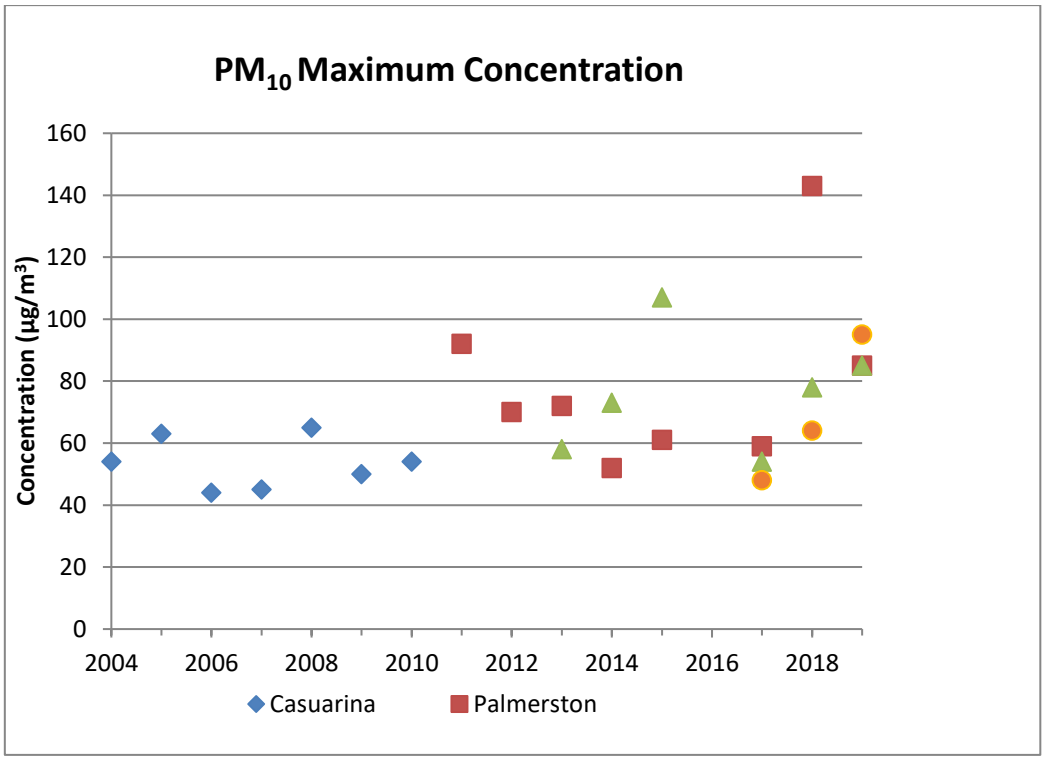

Figure 15: Historical maximum 24-hour PM_{10} concentrations

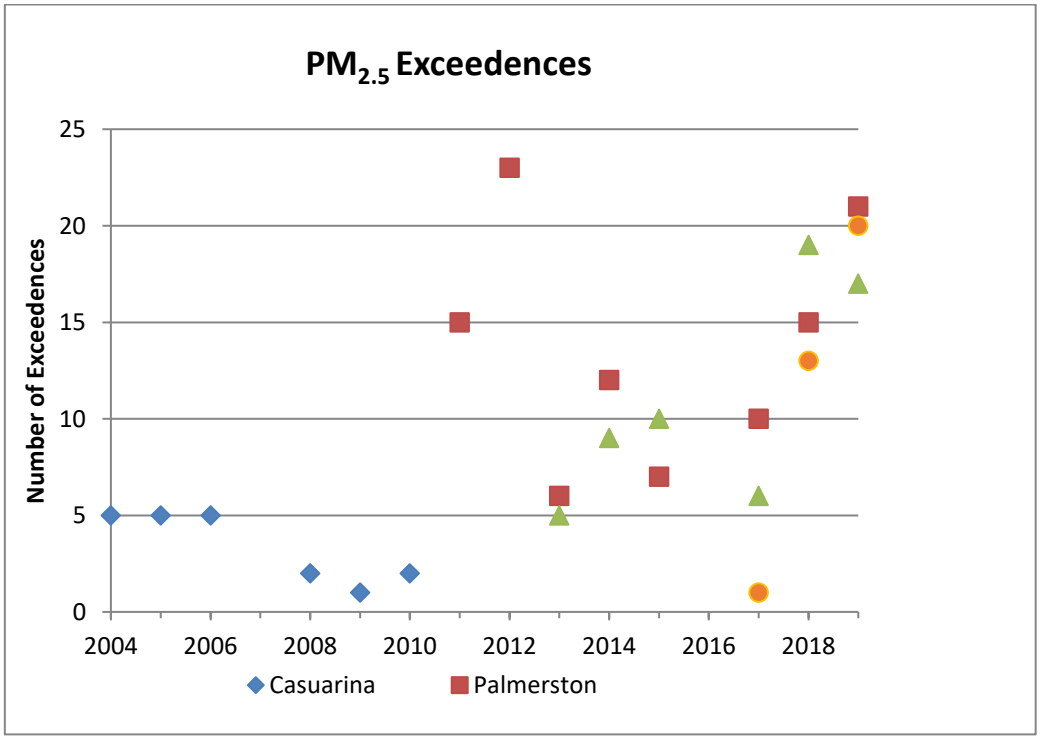

Figure 16: Historical $PM_{2.5}$ exceedances

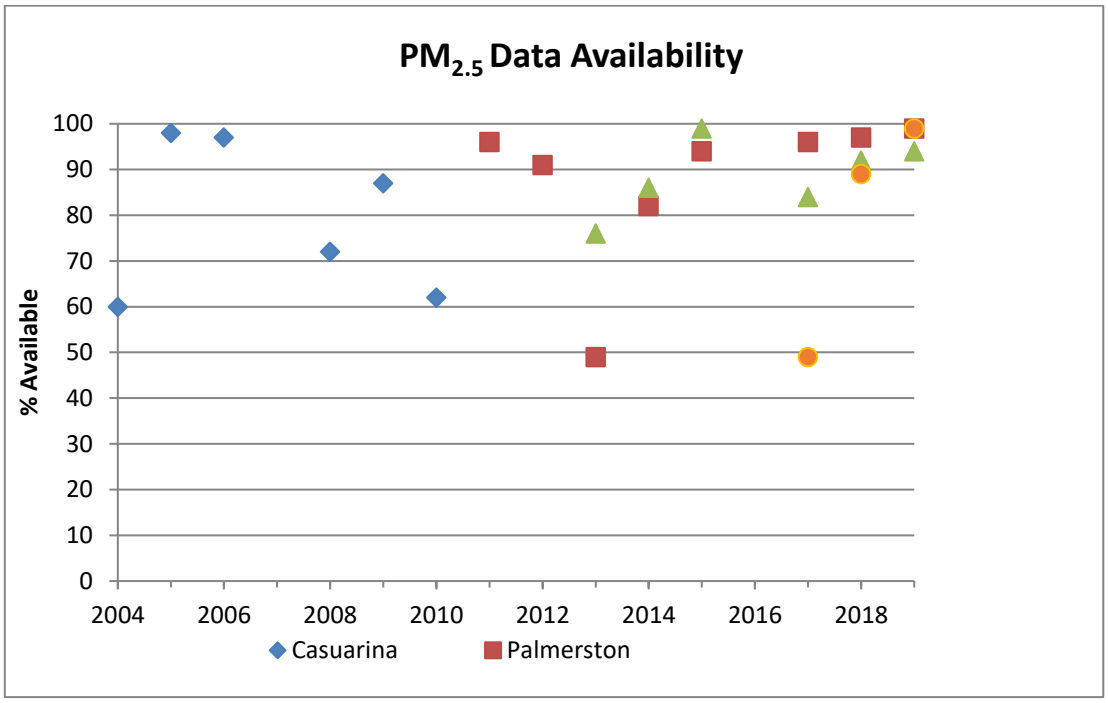

Figure 17: Historical $PM_{2.5}$ data availability

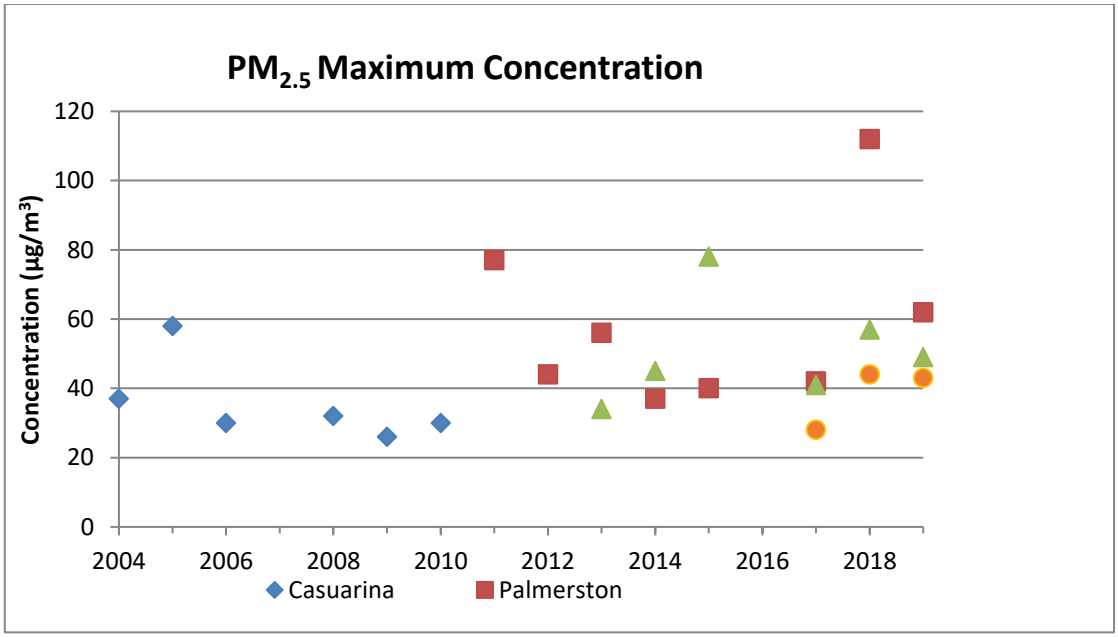

Figure 18: Historical $PM_{2.5}$ 24-hour maximum concentrations

7.2 Trends in fire-scar data

In the Darwin region, exceedances of the particulate standards are generally caused by smoke from burning vegetation. This connection has been made based on analysis of monitoring data, satellite imagery and observation of visible smoke on days when particulate standards have been exceeded.

Fire-scar data (NAFI 2019) provides information on areas burnt in Northern Australia. Fire-scar data obtained for a region with a radius of 50km (~800,000 ha), centred at McMinns Lagoon (southeast of Darwin) showed that 37% of the area was burnt in 2019. A relationship was observed between the monthly area burnt and the monthly averaged $PM_{2.5}$ concentrations measured at the stations. Figure 19 shows that the monthly $PM_{2.5}$ concentrations increased sharply with area burnt in May. Although $PM_{2.5}$ levels peaked in June - July at all the stations (~18 µg/m^3), and the area burnt peaked in May – July (11%), there was a general decline in both parameters after July.

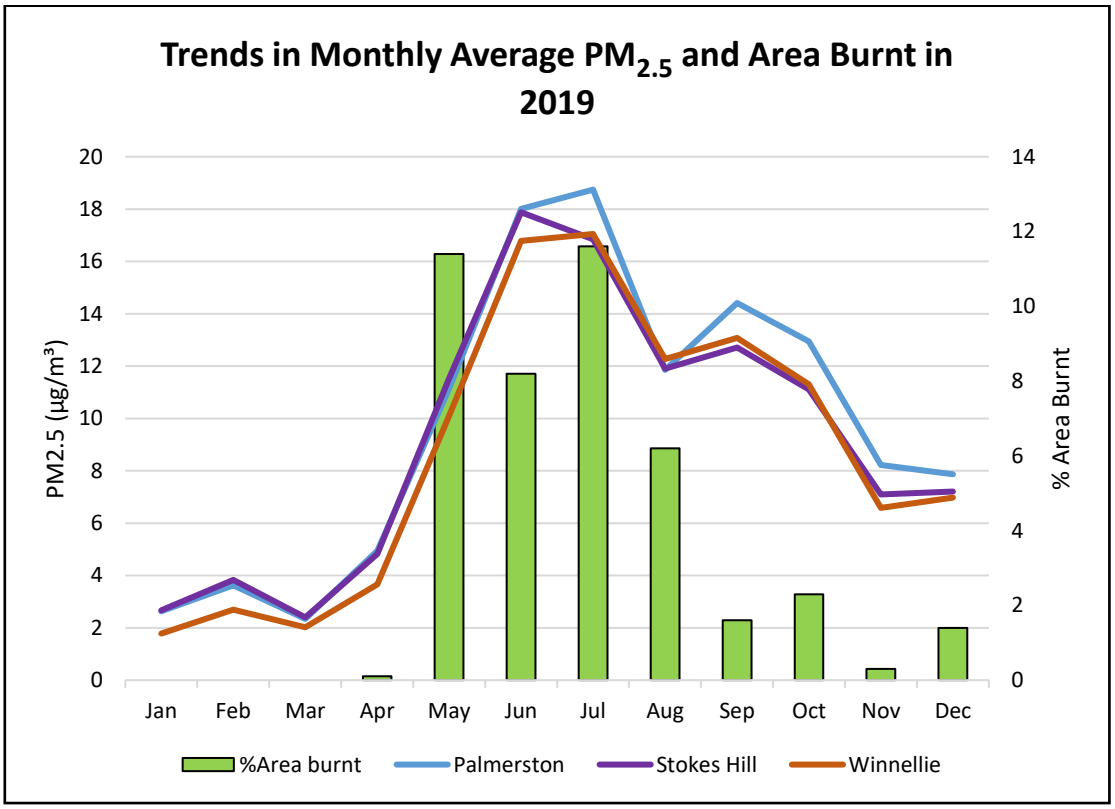

Figure 19: Comparison of $PM_{2.5}$ levels with Area Burnt (50 km radius)

Historical fire-scar data does not depict a clear long-term relationship between area burnt and particulate levels at the monitoring stations. The total area burnt is not the only key driver of particulate impacts on Darwin, other factors such as the timing of burns in relation to meteorological conditions such as wind-

speed/direction and temperature inversions play a significant part in total particulate impacts on population centres.

Analysis of historical fire activity data and particulate monitoring shows that fires greater than 150 km from Darwin are rarely linked to exceedances of the 1-day average AAQ NEPM standards for particulate in the Darwin Region. However, the picture in Figure 20 shows that smoke from fires burning in areas to the east of Adelaide River, about 150 km from Darwin, on 18 May 2019, could have affected air quality in the Darwin region. On that day and the following seven days, all the air quality monitoring stations in Darwin recorded exceedances of the $PM_{2.5}$ AAQ NEPM standard (see the Appendix A).

These fires are due to controlled burns, unintended fires or arson. Controlled burns present some opportunity for managing particulates. Unintended fires can be reduced by pre-emptively burning areas with high fuel loads during favourable meteorological condition which will result in smoke being directed away from population centres.

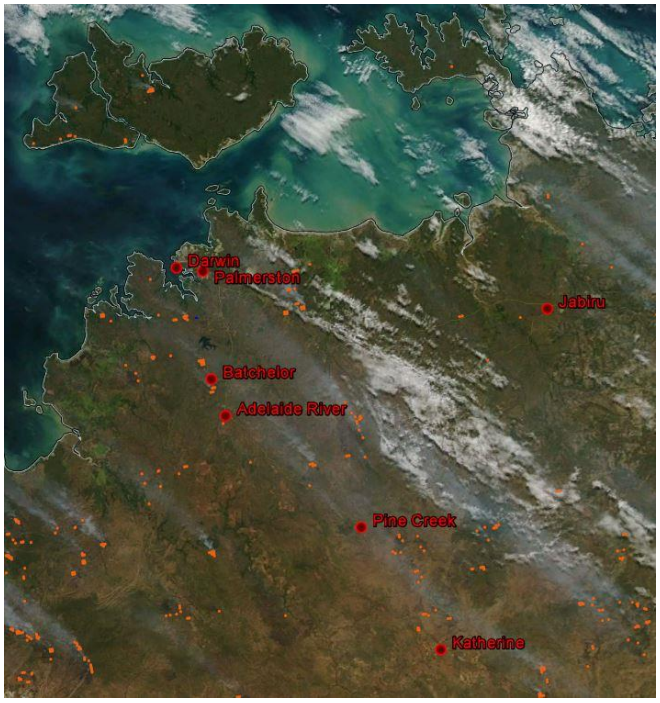

Figure 20: Large-scale fire events impacting Top End on 31 May 2019 (Source: NASA Worldview)

Extending the monitoring of particulates to other regional centres in the NT will contribute towards development of NT Government air quality policy and may provide the basis for the development of management strategies aimed at reducing the impact of particulates on urban populations in the future. Various projects have been proposed to utilise citizen science based low cost sensors to measure particles in air at remote areas of the Territory.

8 References

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9 Appendix A: Particulates events for 2019

A pollution event for particulates occurs when the daily average concentration measured at any of the air quality monitoring stations exceeds any of the AAQ NEPM standards for particulates – 25 µg/m³ for $PM_{2.5}$ and 50 µg/m³ for PM_{10}. (**Red** – $PM_{2.5}$ exceedances; **Blue** – PM_{10} exceedances)

Date	Particulates Concentration (µg/m³)					
	Palmerston		Stokes Hill		Winnellie	
	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10
1-Apr	19.1	84.5	20.2	95.2	14.5	84.6
2-Apr	11.0	48.6	13.1	56.8	10.3	53.9
11-May	27.7	42.9	27.9	45.9	34.9	57.4
13-May	33.4	45.2	40.9	53.7	29.8	44.8
16-May	20.9	29.7	26.7	37.1	20.3	34.3
31-May	35.0	47.0	37.9	56.0	30.9	47.4
1-Jun	29.0	40.5	33.1	51.3	26.1	43.3
2-Jun	38.8	50.1	35.0	53.3	31.5	50.4
3-Jun	53.5	65.4	42.8	62.3	49.0	70.7
4-Jun	35.9	45.5	33.5	49.6	35.3	52.9
5-Jun	30.9	42.5	28.8	47.6	32.3	52.5
6-Jun	32.5	44.2	27.7	45.2	26.9	47.3
7-Jun	36.9	47.3	32.6	47.9	31.6	48.3
24-Jun	27.6	37.5	16.4	27.9	16.0	29.1
25-Jun	23.7	33.4	26.9	39.0	21.9	37.1
27-Jun	27.6	39.1	27.4	40.3	24.5	40.1
28-Jun	23.4	34.4	35.9	51.0	19.1	38.1
2-Jul	21.3	32.8	16.0	28.4	26.2	51.3
5-Jul	24.6	35.1	25.2	37.3	23.5	38.3
16-Jul	32.1	48.0	34.1	51.7	35.6	54.9
18-Jul	39.0	54.0	27.6	43.7	27.8	48.9
19-Jul	25.6	38.7	25.6	41.1	26.4	46.3
20-Jul	25.8	38.2	24.9	39.1	23.0	39.1
24-Jul	26.3	40.2	16.8	30.2	16.3	36.9
26-Jul	62.5	79.1	15.2	28.3	14.6	36.0
15-Aug	29.4	43.4	28.8	43.7	31.2	50.3
20-Aug	12.2	60.2	10.9	59.9	12.8	69.9
23-Aug	27.1	50.9	35.0	66.1	23.2	52.8
8-Sep	11.5	26.6	18.4	34.9	37.5	56.5
12-Sep	12.2	35.7	15.2	42.9	19.6	54.1
13-Sep	23.4	50.7	17.0	46.4	15.8	45.9
14-Sep	30.7	59.2	24.5	47.7	22.1	55.9
19-Sep	15.5	30.5	23.7	39.9	26.4	43.8
22-Oct	23.0	51.5	15.6	41.5	16.2	47.3
Exceedances	**21**	**10**	**20**	**11**	**17**	**15**

10 Appendix B: Population-weighted $PM_{2.5}$ exposure

A simplified approach was used to calculate a single population-weighted annual average PM2.5 concentration for the Greater Darwin Region

SA2 CODE[1]	SA2_NAME_2016	Population[2] (P_i)	$PM_{2.5}$($\mu g/m^3$) (C_i)	$C_i \times P_i$
71001	Darwin Airport	18	8.94	160.92
71002	Darwin City	6464	9.16	59210.24
71003	East Point	14	8.94	125.16
71004	Fannie Bay - The Gardens	3351	9.16	30695.16
71005	Larrakeyah	3729	9.16	34157.64
71006	Ludmilla - The Narrows	2545	8.94	22752.3
71007	Parap	2747	8.94	24558.18
71008	Stuart Park	4149	9.16	38004.84
71009	Woolner - Bayview - Winnellie	2821	8.94	25219.74
71010	Alawa	2127	8.94	19015.38
71011	Anula	2369	8.94	21178.86
71012	Berrimah	1277	8.94	11416.38
71013	Brinkin - Nakara	3581	8.94	32014.14
71014	*Buffalo Creek	0	8.94	0
71015	Charles Darwin	0	8.94	0
71016	Coconut Grove	3050	8.94	27267
71017	East Arm	13	8.94	116.22
71018	Jingili	1757	8.94	15707.58
71019	Karama	4944	8.94	44199.36
71020	Leanyer	4578	8.94	40927.32
71021	Lyons (NT)	4799	8.94	42903.06
71022	Malak - Marrara	4549	8.94	40668.06
71023	Millner	2548	8.94	22779.12
71024	Moil	2000	8.94	17880
71025	Nightcliff	3853	8.94	34445.82
71026	Rapid Creek	3282	8.94	29341.08
71027	Tiwi	2562	8.94	22904.28
71028	Wagaman	2162	8.94	19328.28
71029	Wanguri	1876	8.94	16771.44
71030	Wulagi	2435	8.94	21768.9
71031	Howard Springs	6981	9.76	68134.56
71032	*Humpty Doo	8711	9.76	85019.36
71033	*Koolpinyah	25	9.76	244
71034	Virginia	3292	9.76	32129.92
71035	*Weddell	4527	9.76	44183.52
71036	Bakewell	3069	9.76	29953.44
71037	Driver	2884	9.76	28147.84

71038	Durack - Marlow Lagoon	4287	9.76	41841.12
71039	Gray	3288	9.76	32090.88
71040	Moulden	2959	9.76	28879.84
71041	Palmerston - North	4231	9.76	41294.56
71042	Palmerston - South	3069	9.76	29953.44
71043	Rosebery - Bellamack	6678	9.76	65177.28
71044	Woodroffe	3233	9.76	31554.08
Greater Darwin Region Population		136834		
$PM_{2.5}$ Population Exposure ($\mu g/m^3$)		**9.3**		

*These suburbs were "Not in any Significant Urban Area" for 2016 census, but have been included in the analysis.

[1]SA2 – ABS Statistical Areas Level 2 are normally designed around whole gazetted suburbs

[2]Population from ABS 2016 census for the SA2 area

$$\boldsymbol{Population\ Exposure} = \sum_i \frac{C_i \times P_i}{P_T}$$

C_i = annual average PM2.5 concentration at each suburb

P_i = population at each suburb

P_T = total population in Greater Darwin Region

Annual average $PM_{2.5}$ concentration measured at Winnellie AQMS - 8.94 $\mu g/m^3$

Annual average $PM_{2.5}$ concentration measured at Stokes Hill AQMS - 9.16 $\mu g/m^3$

Annual average $PM_{2.5}$ concentration measured at Palmerston AQMS - 9.76 $\mu g/m^3$