Northern Territory Ambient Air Quality Monitoring Report 2023

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

ntepa Northern Territory Environment Protection Authority

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1.0	30 September 2024	Environmental Regulation	First version

Acronyms	Full form
AAQ NEPM	National Environment Protection (Ambient Air Quality) Measure
ABS	Australian Bureau of Statistics
AQMS	Air Quality Monitoring Station
ASGS	Australian Statistical Geography Standard
BoM	Bureau of Meteorology
CBD	Central Business District
CO	Carbon monoxide
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEPWS	Department of Environment, Parks and Water Security
DLPE	Department of Lands, Planning and Environment
EWG	Expert Working Group (NEPC)
FDMS	Filter Dynamics Measurement System (used by the TEOM)
GRUB	Generally representative upper bound (AQMS)
KTC	Katherine Town Council
NAFI	North Australian Fire Information
NASA	National Aeronautics and Space Administration (USA)
NATA	National Association of Testing Authorities
NEPC	National Environment Protection Council
NO/ NO_2/ NO_x	Nitric oxide/ Nitrogen dioxide/ Oxides of nitrogen
NT EPA	Northern Territory Environment Protection Authority
O_3	Ozone
PM_{10}	Particulate matter (PM) 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
µg/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)
WMPC Act	Waste Management and Pollution Control Act 1998

Contents

1 Summary

The National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM or NEPM) is the Commonwealth legislation that sets national standards and goals for air quality. This NEPM is implemented in the Northern Territory under *Waste Management and Pollution Control Act 1998* (WMPC Act 1998). This annual compliance report is required under clause 18 of the NEPM. It presents the Territory's ambient air quality monitoring data for the 2023 calendar year and assesses them for compliance with the standards and goals in the AAQ NEPM. Compliance with the NEPM requires that air quality standards are not exceeded, as outlined in Schedule 2 of the AAQ NEPM.

During 2023, the Northern Territory Environment Protection Authority (NT EPA) operated three designated ambient air quality monitoring stations (AQMS) in the Darwin region. These stations, Palmerston AQMS, Winnellie AQMS and Stokes Hill AQMS 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 ($PM_{2.5}$). Katherine Town Council operates an air quality monitoring station at Katherine under a performance agreement with the NT EPA: Katherine AQMS monitors PM_{10} and $PM_{2.5}$ only. Meteorological instruments for measuring parameters such as wind speed and direction, ambient temperature, relative humidity and atmospheric pressure are located at the sites.

Measured concentrations of these air pollutants have been assessed against their corresponding national environment protection standards and goals, and compliance determined and reported in accordance with the national environment protection protocol set out in the AAQ NEPM.

Assessment of goal compliance: During 2023, none of the designated ambient air quality monitoring stations in the Darwin region recorded any exceedances of the national standards for NO_2, SO_2, O_3 and CO; sufficient data was collected to demonstrate compliance with the AAQ NEPM goal for these air pollutants. A large number of exceedances of the short-term standards were recorded for PM_{10} and $PM_{2.5}$, but these exceedances were directly associated with exceptional events such as bushfire smoke (as per the AAQNEPM definition (AAQ NEPM 2021)). All the stations recorded exceedances of the 1-year average $PM_{2.5}$ standard, but the 1-year average PM_{10} standard was exceeded only at Winnellie AQMS.

Carbon monoxide: During 2023, no exceedances of the 8-hour rolling average standard for CO were recorded at any of the stations, compliance with the AAQ NEPM was demonstrated at all the stations.

Nitrogen dioxide: No exceedances of the 1-hour or 1-year NO_2 standards were recorded at the stations during 2023. All the stations demonstrated compliance with the AAQ NEPM goal for NO_2.

Ozone: During 2023, no exceedances of the 8-hour rolling average O_3 standard were recorded at any of the stations. All the stations demonstrated compliance with the AAQ NEPM goal for O_3.

Sulfur dioxide: There were no recorded exceedances of the SO_2 1-hour and 1-day standards at any of the stations. Compliance with the AAQ NEPM goal for SO_2 was demonstrated at all the stations during 2023.

PM_{10}: To comply with the AAQ NEPM 1-day standard for particles 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. Winnellie recorded 35 exceedances, Katherine recorded 7 exceedances, Palmerston recorded 5 exceedances, and Stokes Hill recorded 3 exceedances of the 1-day standard, but these exceedances were linked to exceptional events such as smoke from bushfires. The PM_{10} 1-year averages of 17.1, 18.5 and 20.9 $\mu g/m^3$ recorded at Katherine, Palmerston and Stokes Hill AQMS respectively, were below the AAQ NEPM standard of 25 $\mu g/m^3$; however, Winnellie exceeded the standard with a value of 29.5 $\mu g/m^3$. Thus during 2023, all the stations except Winnellie complied with the AAQ NEPM goal for PM_{10}.

$PM_{2.5}$: To comply with the AAQ NEPM 1-day standard for particles 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. During 2023, exceedances of the $PM_{2.5}$ 1-day standard (16 at Katherine, 34 at Palmerston, 3 at Stokes Hill and 67 at Winnellie) were linked to exceptional events such as smoke from bushfires. The $PM_{2.5}$ 1-year averages of 8.4, 12.2, 9.2 and 17.0 $\mu g/m^3$ recorded at Katherine, Palmerston, Stokes Hill and Winnellie respectively, were all above the AAQ NEPM standard of 8 $\mu g/m^3$: as such, none of the stations complied with the AAQ NEPM goal for $PM_{2.5}$.

It is now a requirement by the AAQ NEPM that jurisdictions should evaluate and report population exposures to particles as $PM_{2.5}$ as well as to NO_2 and O_3. Using a simplified approach, a population-weighted annual average concentration of 13.9 $\mu g/m^3$ was calculated for $PM_{2.5}$; 0.0022 ppm for NO_2; and 0.014 ppm for O_3 in the Greater Darwin Region in 2023.

2 Background

The Department of Lands, Planning and Environment (DLPE)[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. The AAQ NEPM is implemented through the provisions of the *Waste Management and Pollution Control Act 1998* (WMPC Act 1998) and the *National Environment Protection Council (Northern Territory) Act 1994* (NEPC Act 1994).

Figure 1a: Locations of Palmerston, Winnellie and Stokes Hill Air Quality Monitoring Stations (AQMS) in the Greater Darwin Region (Stokes Hill AQMS was previously located at -12.466983, 130.850584▲)

[1] Formerly Department of Environment, Parks and Water Security (DEPWS)

Procedures for measuring and reporting pollutant concentrations are set out in the national environment protection protocol (Part 4 of the AAQ NEPM). Clause 18 of the AAQ NEPM requires jurisdictions to submit a report on their compliance with the AAQ NEPM for each calendar year. Clause 17 prescribes the content of the jurisdictional report.

Consistent with the reporting period defined in the AAQ NEPM, this report covers the calendar year ending on 31 December 2023 for data collected from the NT EPA ambient air quality monitoring stations (AQMS) at Palmerston, Winnellie and Stokes Hill[2] (Figure 1a), and from the Katherine Town Council station located in Katherine (Figure 1b). Technical Papers No. 8 - Annual Reports (PRC 2002) and No. 5 - Data Collection and Handling (PRC 2001) detail the format and data requirements for 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 NEPC Act 1994 on the overall implementation of the NEPM.

This technical report, *Northern Territory Ambient Air Quality Monitoring Report 2023 - 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.

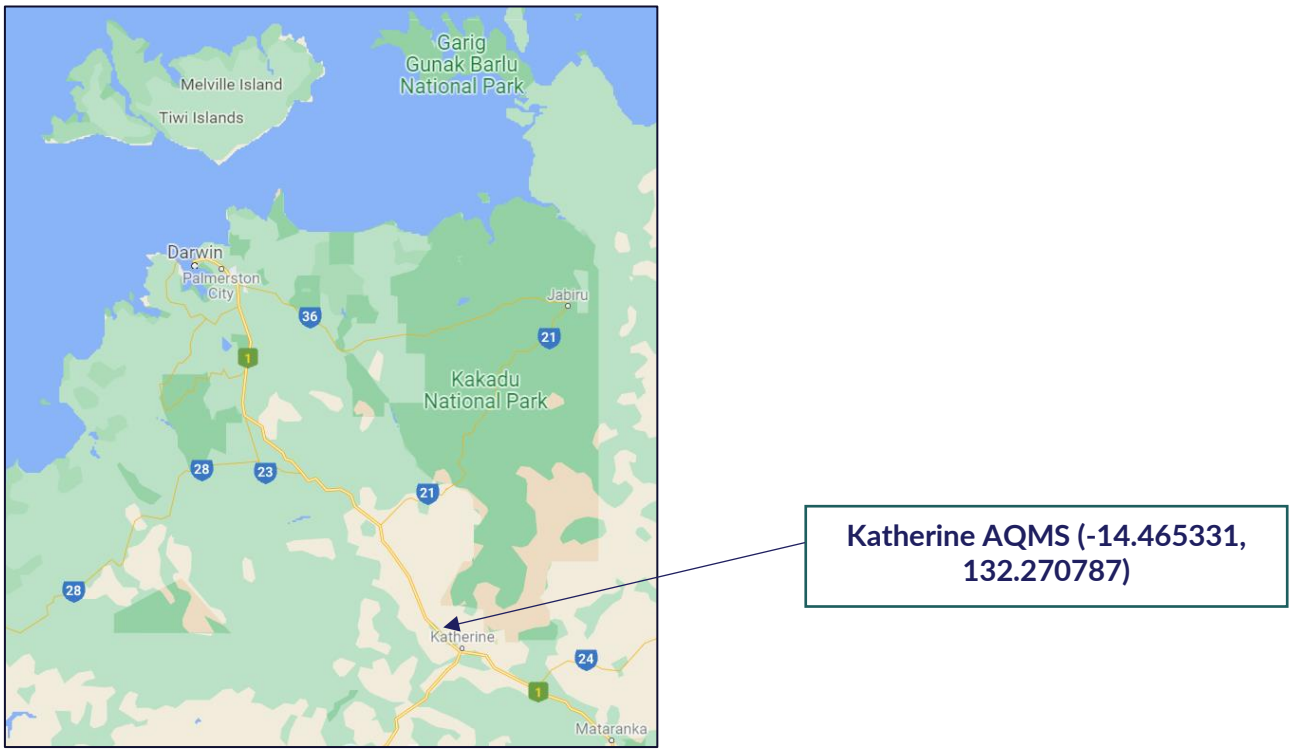

Figure 1b. Katherine AQMS - operated by Katherine Town Council

[2] This station was relocated to Frances Bay in 2021, but will still be referred to as Stokes Hill AQMS

3 Overview of the 2023 AAQ NEPM monitoring network and activities

3.1 Monitoring requirements

The monitoring requirements for the Northern Territory over the longer term were determined from the results of air quality monitoring conducted in 2000-2001, and included in an approved monitoring plan (NTG, 2001). This monitoring identified fine particles from landscape fires affecting the Darwin region as the primary air pollutant of concern in the 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 (Gras *et al.*, 2001).

Since the initial monitoring, the population and industrial activities in Darwin have increased and more detailed monitoring of airborne pollutants is required. The establishment and operation of a comprehensive air quality monitoring system for the Darwin region commenced in 2010 and 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 necessary as there are no significant sources close to populated areas in the region and the sale of leaded petrol ceased in 2002.

The network of ambient air quality monitoring stations comprises of three stations in the Greater Darwin Region (Figure 1a), and one located at Katherine (Figure 1b). 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; the station at Stokes Hill started operating in May 2017; and the latest station, Katherine, was commissioned in September 2020.

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 1a). 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 connected to a single gas-sampling manifold protruding through the station roof. NO_x represents the sum of nitrogen dioxide (NO_2) and nitric oxide (NO) concentrations. A separate mast protruding through the station roof serves as a conduit for drawing air into the particulate sampler. This 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). A dichotomous tapered element oscillating microbalance (TEOM) instrument samples air through the mast to provide near real-time PM_{10} and $PM_{2.5}$ concentrations in ambient air. BoM instruments located at the site provide meteorological data for the station.

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 4 km south-west of Palmerston (Figure 1a). The station houses the same gas and particulate sampling instruments as Winnellie but has meteorological instruments.

Stokes Hill AQMS (Figure 1a) was initially located about 1 km southeast of the CBD on the Darwin Waterfront, off Stokes Hill Road, in 2017; it was relocated to a site about 600 m east of the CDB (~800 m north of original site) and off Frances Bay Drive in May 2021, as the original site was required for redevelopment. The site meets all siting and instrumentation requirements for reporting under the AAQ NEPM. This station, located in a coastal area, monitors 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.

In September 2020, Katherine Town Council (KTC) commissioned the Katherine AQMS (Figure 1b) to monitor particulates in air, as part of a performance agreement with the NT EPA. The station only measures the concentrations of PM_{10} and $PM_{2.5}$ and various meteorological parameters.

Tables 1 and 2 in subsection 3.3 provide details of instrumentation and siting details for all the stations.

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 station in the areas as required by the AAQ NEPM. These are the Greater Darwin region and Alice Springs.

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 southeasterly to easterly, frequently exposing the population of the region to particulate pollution from relatively small fires in local bushland and more distant large-scale savannah fires.

Particulate monitoring at several different sites in the Darwin/Palmerston region started in 2002. Monitoring for particulates as well as other air pollutants, started at two sites in 2012 (Palmerston and Winnellie), a third site was added in 2017 (Stokes Hill), then at Katherine in 2020 (which only monitors particulates). Results from simultaneous monitoring have shown that aside from spikes attributable to local fire events, particulate levels are reasonably uniform across the Darwin region on a seasonal basis. As supported by the 2023 data: $PM_{2.5}$ annual average levels were 12.2, 9.2 and 17.0 $\mu g/m^3$ at Palmerston, Stokes Hill and Winnellie respectively. 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
Katherine AQMS	Bushland	Yes	Yes	Yes	Yes	Yes	Yes

The NT EPA intends to conduct monitoring of particulates in Alice Springs and other regional centres such as Tennant Creek in future years.

Table 1 shows that all the stations were sited in compliance with the requirements for Australian Standard AS/NZS 3580.1.1:2016 (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 and the parameters measured.

The anemometer is on a 10 m mast at Palmerston and on a 5 m mast at Stokes Hill (the base of the mast is 5 m from the ground). Meteorological data for Winnellie Station is sourced from BoM instruments located at the site. Environics Multi-Gas Calibrator/Diluter instruments and Environics Zero Air generators are located at the Darwin stations for conducting daily automatic zero/span checks and remote calibrations of the NO_2, SO_2, O_3 and CO gas analysers. Currently all the stations use a Tapered Element Oscillating Microbalance (TEOM) model 1405DF which has a Filter Dynamics Measurement System (FDMS) to measure PM_{10} and $PM_{2.5}$. The FDMS unit measures and accounts for evaporative losses and does not require application of a correction factor to account for the loss of volatiles from the filter paper in the instrument.

Meteorological instruments for measuring ambient temperature, humidity, wind speed/direction and atmospheric pressure are located at the stations. Palmerston AQMS measures solar radiation and rainfall, and the Darwin BoM station provides Winnellie AQMS with meteorological data.

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) 02/09/20 (Katherine)	present	TEOM 1405DF[1] TEOM 1405DF[2] TEOM 1405DF[3] TEOM 1405DF	continuous
$PM_{2.5}$	01/01/11 (Palmerston) 18/07/12 (Winnellie) 03/07/17 (Stokes Hill) 02/09/20 (Katherine)	present	TEOM 1405DF[1] TEOM 1405DF[2] TEOM 1405DF[3] TEOM 1405DF	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) 02/09/20 (Katherine)	present	RM Young, 2D ultra-sonic anemometer model 85000	continuous
Wind speed	01/01/12 (Palmerston) 04/05/17 (Stokes Hill) 02/09/20 (Katherine)	present	RM Young, 2D ultra-sonic anemometer model 85000	continuous
Sigma Theta	05/05/17 (Stokes Hill) 02/09/20 (Katherine)	present	RM Young, 2D ultra-sonic anemometer model 85000	continuous
Temperature	01/01/12 (Palmerston) 05/05/17 (Stokes Hill) 02/09/20 (Katherine)	present	RM Young, model 41382LC TEOM sensor TEOM sensor	continuous
Relative Humidity	01/01/12 (Palmerston) 05/05/17 (Stokes Hill) 02/09/20 (Katherine)	present	RM Young, model 41382LC TEOM sensor TEOM sensor	continuous

Parameter	Data available from	Data available to	Current Instrument	Sampling frequency
Atmospheric Pressure	01/01/12 (Palmerston) 05/05/17 (Stokes Hill) 02/09/20 (Katherine)	present	RM Young, model 61302v TEOM sensor 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

[1]*TEOM at Palmerston AQMS was upgraded from 1405D to 1405DF on 18/02/2021.*
[2]*TEOM at Winnellie AQMS was upgraded from 1405D to 1405DF on 21/01/2021.*
[3]*TEOM at Stokes Hill AQMS was upgraded from 1405D to 1405DF on 21/08/2023.*

3.4 Monitoring during the reporting period

Palmerston, Winnellie and Stokes Hill stations monitor the same suite of air pollutants; Katherine only monitors particulates. During 2023, all of the instruments (including meteorological instruments) provided valid data for more than 75% of the time during the reporting period to enable assessment of compliance with the AAQ NEPM.

3.5 Changes to the approved monitoring plan

There were no changes to approved monitoring plan this year.

3.6 Unresolved issues

The reporting period did not have any unresolved issues.

3.7 Status of NATA accreditation

A National Association of Testing Authorities (NATA) accredited contractor conducted all data collection and validation processes. The contractor 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	AS 3580.7.1	Determination of Carbon Monoxide – Direct Reading Instrument Method	Gas filter correlation/ infra-red analyser
Nitrogen dioxide	AS 3580.5.1	Determination of Oxides of Nitrogen – Chemiluminescence Method	Gas-phase chemiluminescence analyser
Photochemical oxidant (ozone)	AS 3580.6.1	Determination of Ozone – Direct Reading Instrument Method	Non-dispersive ultra-violet analyser
Sulfur dioxide	AS 3580.4.1	Determination of Sulfur Dioxide – Direct Reading Instrument Method	Pulsed fluorescence analyser
Particles as PM_{10}	AS 3580.9.8 AS/NZS 3580.9.16:2016	Determination of Suspended Particulate Matter – PM_{10} continuous direct mass method using tapered element oscillating microbalance analyser Determination of suspended particulate matter – PM_{10} continuous direct mass method using a tapered element oscillating microbalance monitor incorporating a filter dynamic measurement system (FDMS) unit	Tapered element oscillating microbalance (TEOM) dichotomous air monitor Tapered element oscillating microbalance (TEOM) dichotomous air monitor with FDMS
Particles as $PM_{2.5}$	AS/NZS 3580.9.13:2013	Determination of Suspended Particulate Matter – $PM_{2.5}$ continuous direct mass method using a tapered element oscillating microbalance monitor	Tapered element oscillating microbalance (TEOM) dichotomous air monitor with or without FDMS

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 existing National Environment Protection Standards shown in Table 4 below (Schedule 2 of the AAQ NEPM). The AAQ NEPM, varied in April 2021, does not allow exceedances of any of the standards.

Table 4: Ambient Air Quality NEPM Standards (as amended)

Pollutant	Averaging period	Maximum concentration standard	Maximum allowable exceedances
Carbon monoxide	8 hours	9.0 ppm	None
Nitrogen dioxide	1 hour	0.08 ppm	None
	1 year	0.015 ppm	None
Photochemical oxidants (as ozone)	8 hours	0.065 ppm	*None
Sulfur dioxide	1 hour	0.10 ppm	None
	1 day	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 and O_3 8-hr average standards, monitoring data that has been determined as being directly associated with an exceptional event (such as bushfires) are excluded.*

The AAQ NEPM defines an exceptional event as:

"… a fire or dust occurrence that adversely affects air quality at a particular location that:

(a) causes an exceedance of one or more of the following that is in excess of normal historical fluctuations and background levels:

(i) 1 day average standard for particles as PM_{10};

(ii) 1 day average standard for particles as $PM_{2.5}$;

(iii) 8 hour average standard for photochemical oxidants (as ozone); and

(b) is directly related to bushfire, jurisdiction authorised hazard reduction burning or continental scale windblown dust."

The following tables (Table 5 to Table 10) summarise compliance with the standards and goals of the AAQ NEPM. For each air pollutant, the tables show data availability (quarterly and annually), the number of exceedance days, the annual mean (where an annual standard exists) and an assessment of compliance. The corresponding figures (Figure 2 to Figure 9) provide graphs of pollutants concentrations.

A station's performance is assessed as meeting standards and goal of the AAQ NEPM ("Met") for a pollutant if there are no exceedances of the standards specified in Table 4 for that pollutant and data availability for the year was at least 75%.

Performance is assessed as not meeting standards and goal of the AAQ NEPM ("Not Met") for a pollutant, if there are any exceedances of the standards specified in Table 4 for that pollutant.

If there was insufficient data, then performance is assessed as not demonstrated (ND), even if there were no exceedances recorded.

4.1 Carbon monoxide compliance

Table 5: 2023 compliance summary for CO in the Northern Territory

AAQ NEPM Standard

9.0 ppm (8-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		
Palmerston	95	99	99	81	93	0	met
Stokes Hill	98	99	99	98	99	0	met
Winnellie	54	94	99	76	81	0	met

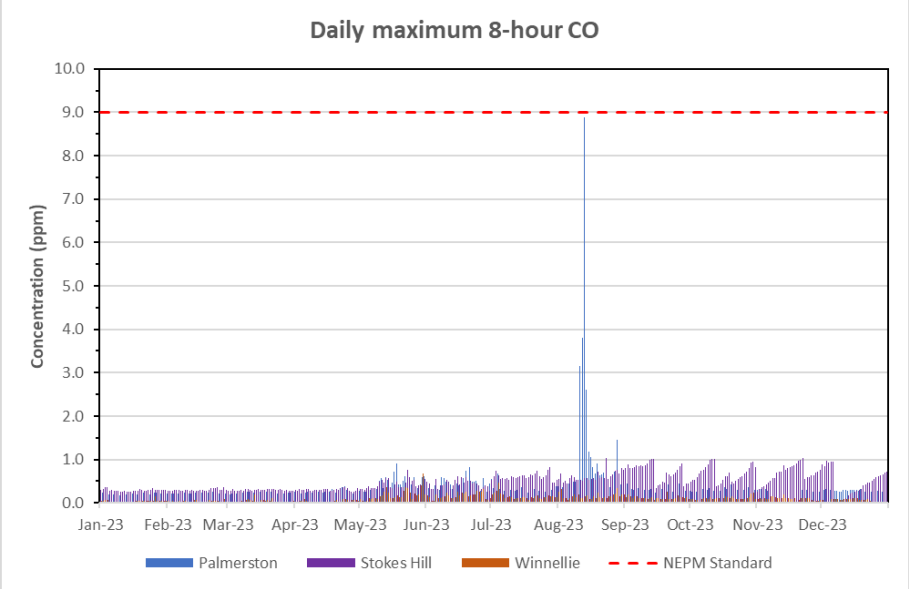

Figure 2: Daily maximum carbon monoxide 8-hour averages for Palmerston, Stokes Hill and Winnellie in 2023

During 2023, none of the stations recorded any exceedance of the carbon monoxide (CO) standard. All the stations demonstrated compliance with the AAQ NEPM goal for CO.

4.2 Nitrogen dioxide compliance

Table 6: 2023 compliance summary for NO_2 in the Northern Territory

AAQ NEPM Standard

0.08 ppm (1-hour average)

0.015 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	1y
Palmerston	91	91	91	69	85	0	0.0017	met	met
Stokes Hill	95	95	95	94	95	0	0.0040	met	met
Winnellie	95	89	94	75	88	0	0.0021	met	met

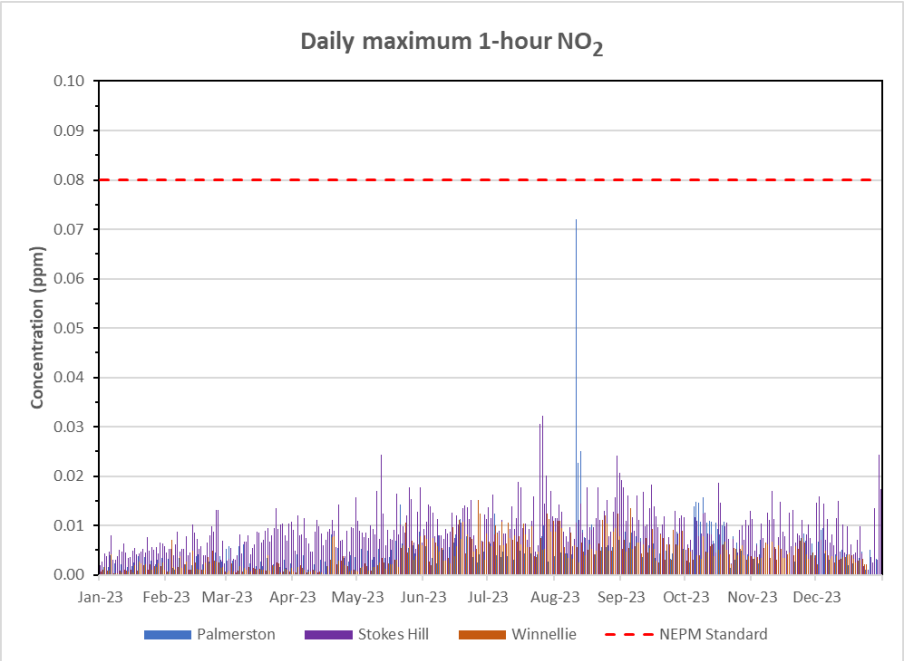

Figure 3: Daily maximum nitrogen dioxide 1-hour averages for Palmerston, Stokes Hill and Winnellie in 2023

In 2023, none of the stations recorded any exceedance of the nitrogen dioxide (NO_2) 1-hour and 1-year standards. All the stations captured sufficient data to demonstrate compliance with the AAQ NEPM goal for NO_2.

4.3 Ozone compliance

Table 7: 2023 compliance summary for O_3 in the Northern Territory

AAQ NEPM Standard

0.065 ppm (8-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	8h	8h
Palmerston	98	99	99	81	95	0	met
Stokes Hill	98	85	99	98	95	0	met
Winnellie	98	94	100	75	92	0	met

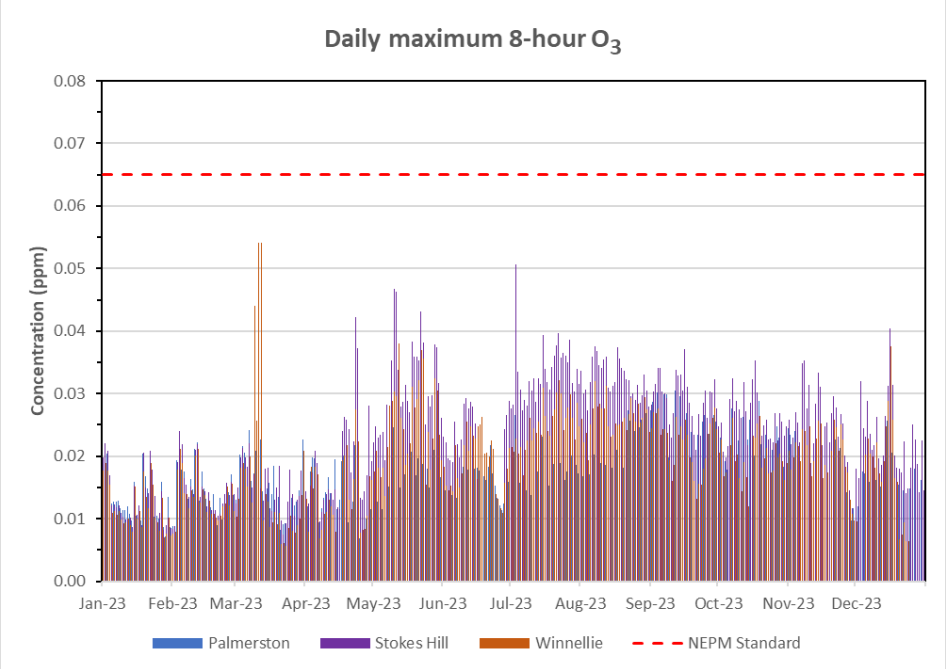

Figure 4: Daily maximum ozone 8-hour averages for Palmerston, Stokes Hill and Winnellie in 2023

During 2023, none of the monitoring stations recorded any exceedance of the ozone (O_3) 8-hour rolling average standard. Sufficient data was collected at all the stations to demonstrate compliance with the AAQ NEPM O_3 goal for each station. There is no 1-hour average standard for ozone.

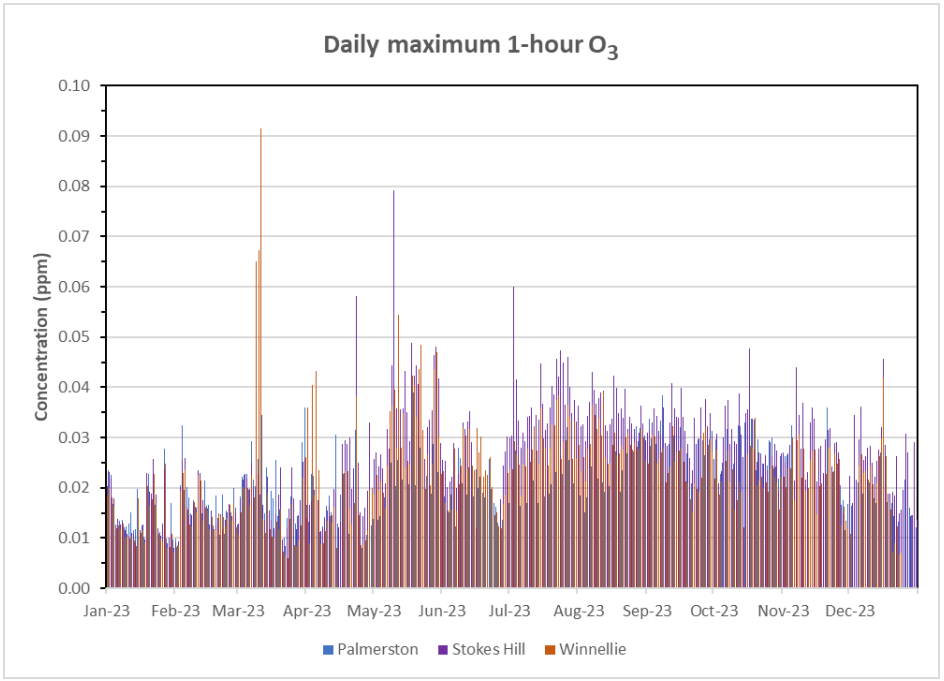

Figure 5: Daily maximum ozone 1-hour averages for Palmerston, Stokes Hill and Winnellie in 2023

4.4 Sulfur dioxide compliance

Table 8: 2023 compliance summary for SO_2 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	1h	24h	1h	24h
						AAQ NEPM Standard			
						0.10 ppm (1-hour average)			
						0.02 ppm (1-day average)			
Palmerston	96	99	99	79	93	0	0	met	met
Stokes Hill	98	100	96	98	98	0	0	met	met
Winnellie	52	93	98	70	78	0	0	met	met

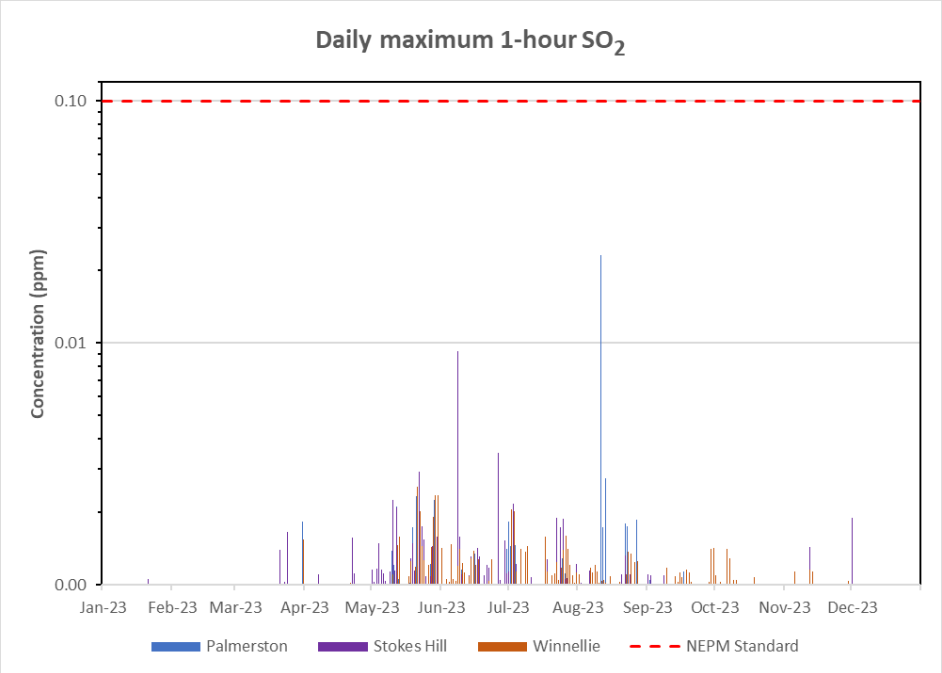

Figure 6: Daily maximum sulfur dioxide 1-hour averages for Palmerston, Stokes Hill and Winnellie in 2023

During 2023, none of the stations recorded any exceedance of the sulfur dioxide (SO_2) 1-hour or 1-day standards. Compliance with the AAQ NEPM goal for SO_2 was demonstrated at all the stations.

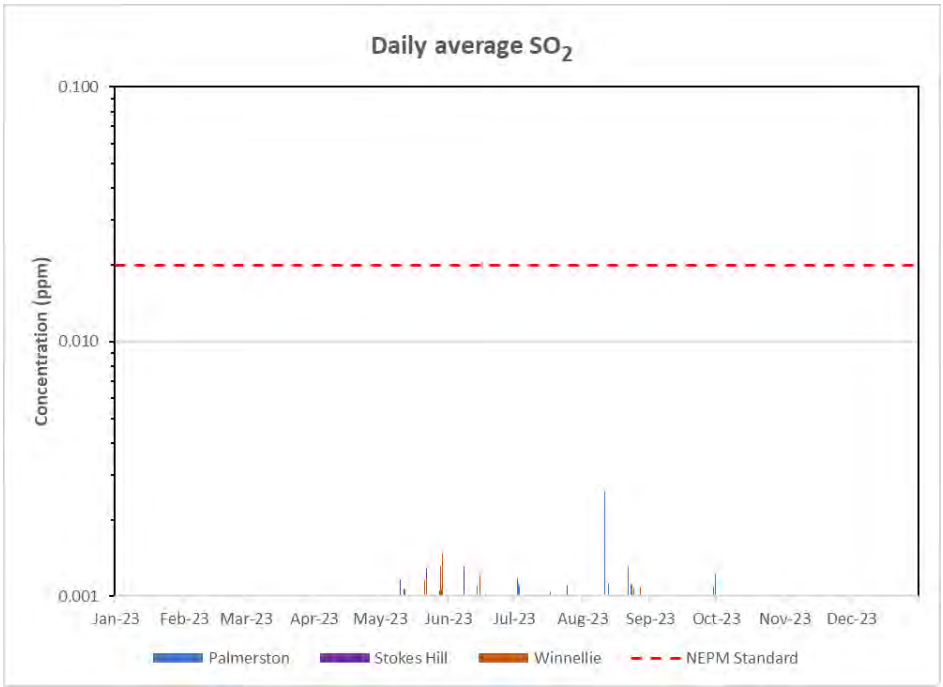

Figure 7: Sulfur dioxide 1-day averages for Palmerston, Stokes Hill and Winnellie in 2023

4.5 Particulates (PM_{10}) compliance

Table 9: 2023 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 (%)					Number of exceedances (days)	Annual average (µg/m³)	Performance against the standard and goal	
	Q1	Q2	Q3	Q4	Annual			24h	1y
Katherine:									
Katherine	84	95	88	87	88	7	17.1	met	met
Darwin:									
Palmerston	93	98	100	91	96	5	18.5	met	met
Stokes Hill	97	98	98	64	89	3	20.9	met	met
Winnellie	59	91	99	64	78	35	29.5	met	not met

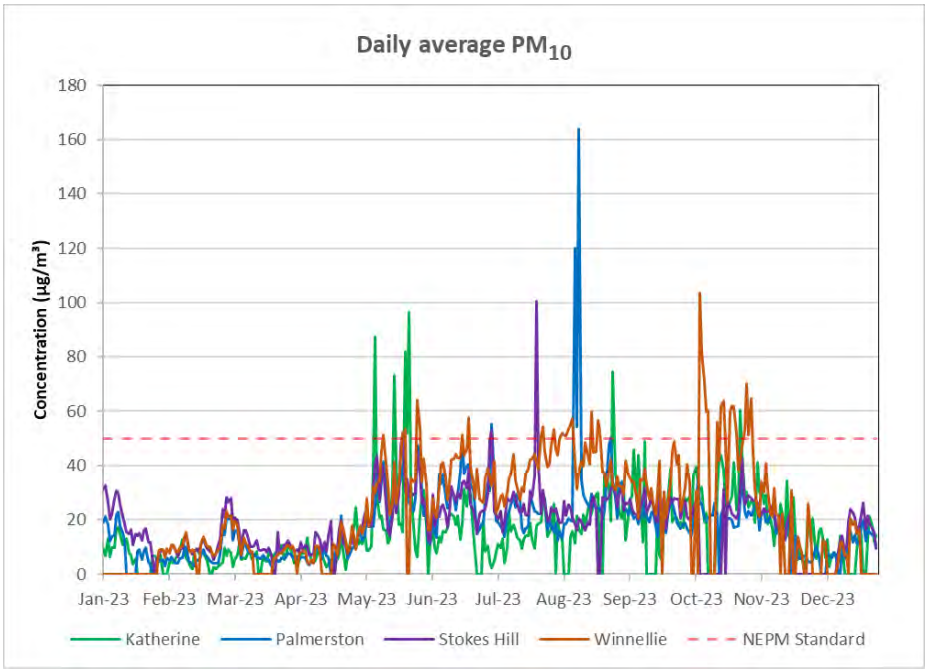

Figure 8: PM_{10} 1-day averages for Katherine, Palmerston, Stokes Hill and Winnellie in 2023

During 2023, the stations recorded several exceedances of the PM_{10} 1-day standard in the Darwin region and in Katherine, but 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. The annual average recorded at Winnellie was above the 1-year standard. All the stations, except Winnellie demonstrated compliance with the AAQ NEPM goal for PM_{10}; Winnellie exceeded the annual standard of 25 µg/m^3.

4.6 Particulates ($PM_{2.5}$) compliance

During 2023, the Darwin region and Katherine recorded several exceedances of the $PM_{2.5}$ 1-day standard. These exceedances 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.

None of the stations met the AAQ NEPM $PM_{2.5}$ goal, as their 1-year averages were all above the AAQ NEPM standard of 8 µg/m^3.

Table 10: 2023 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 (%)					Number of exceedances (days)	Annual average (µg/m³)	Performance against the standard and goal	
	Q1	Q2	Q3	Q4	Annual			24h	1y
Katherine:									
Katherine	84	96	89	87	89	16	8.4	met	not met
Darwin:									
Palmerston	93	98	100	93	96	34	12.2	met	not met
Stokes Hill	99	98	98	87	95	3	9.2	met	not met
Winnellie	59	92	99	64	79	67	17.0	met	not met

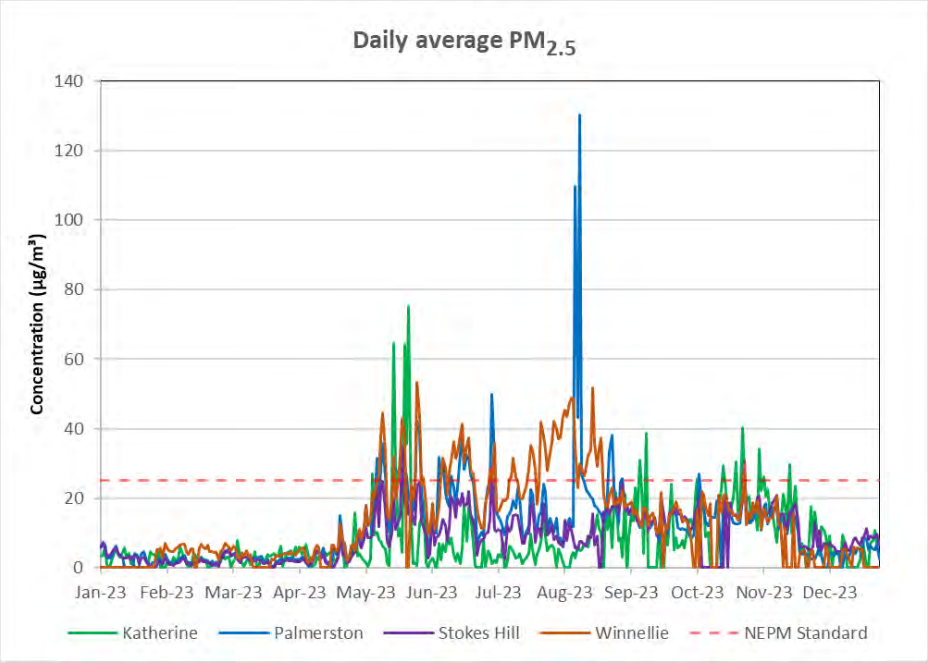

Figure 9: $PM_{2.5}$ 1-day averages for Katherine, Palmerston, Stokes Hill and Winnellie in 2023

5 Analysis of air quality data

This section presents summary statistics of pollutants concentrations recorded in 2023. The AAQ NEPM does not permit exceedances of any of the standards for all the air pollutants. The NEPM excludes compliance reporting for exceedances of short-term PM_{10}, $PM_{2.5}$ and O_3 standards caused by exceptional events such as bushfires. Data presented in the previous section show that levels of CO and SO_2 were generally significantly below the AAQ NEPM standards and there were no exceedances recorded for CO, NO_2, O_3 and SO_2.

This section presents data availability as the number of valid days in a year; 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 8-hour ozone AAQ NEPM standard is based on eight-hour rolling averages: a valid 8-hour rolling average is calculated as the average of the valid one-hour averages over the preceding 8 hours - when at least six of those hours (75%) had valid data.

5.1 Carbon monoxide statistics

Table 11: 2023 summary statistics for daily peak 8-hour CO

	AAQ NEPM Standard				
	9.0 ppm (8-hour average)				
Performance monitoring station	**Number of valid days**	**Highest (ppm)**	**Highest (date/hour)**	**2nd highest (ppm)**	**2nd Highest (date/hour)**
Palmerston	340	8.90	13/08/2023 06:00	3.81	12/08/2023 01:00
Stokes Hill	360	0.89	23/08/2023 18:00	0.62	15/06/2023 08:00
Winnellie	295	0.67	30/05/2023 03:00	0.46	04/07/2023 07:00

Carbon monoxide levels at all the stations were below the CO 8-hour rolling average standard during the year. The highest event, recorded at Palmerston (8.90 ppm, 6 am on 13 August 2023) was just below AAQ NEPM standard. The plume contained elevated levels of NOx and particulates, as well as above background levels of SO_2 and O_3. Concentrations of pollutants in the plume began rising above background

levels around 9 pm on the previous day and peaking after midnight. Zero-span calibration checks conducted from 12 am to 1 am prevents determination of the exact time when concentrations of CO, NO_2 and SO_2 peaked; however, measured particulates data indicate that concentrations peaked around 1 am. The wind direction was mostly southerly, suggesting that the plume originated from the hydrocarbon industries to the south.

Palmerston also recorded the next highest event on the previous day (3.81 ppm, 1 am on 12 August 2023), it also had elevated levels of the other pollutants, and the plume peaked around 6 pm on 11 August, but the wind was northeasterly.

5.2 Nitrogen dioxide statistics

Table 12: 2023 summary statistics for daily peak 1-hour NO_2 in the Northern Territory

AAQ NEPM Standard

0.08 ppm (1-hour average)

Region/ Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date/hour)	2nd highest (ppm)	2nd Highest (date/hour)
Palmerston	311	0.072	11/08/2023 18:00	0.025	13/08/2023 02:00
Stokes Hill	345	0.032	26/07/2023 22:00	0.031	25/07/2023 21:00
Winnellie	322	0.015	26/06/2023 13:00	0.014	05/09/2023 07:00

Nitrogen dioxide levels were below the AAQ NEPM 1-hour NO_2 standard of 0.08 ppm. The highest recorded reading (0.072 ppm) was recorded at Palmerston at 6 pm on 11 August 2023, this was 90% of the standard; the second highest peak was also recorded at Palmerston (0.025 ppm, 2 am on 13 August 2023). Both concentrations were associated with the plumes containing high CO levels discussed in the previous section.

5.3 Ozone statistics

There were no exceedances of the 8-hour O_3 standard at any of the monitoring sites. The highest concentration of 0.054 ppm, recorded at Winnellie on 11 March, was greater than 80% of the standard; no other stations recorded elevated ozone levels on that day. The second highest concentration occurred at Stokes Hill on 3 July. The other stations also recorded elevated ozone levels on that day, which was characterised by high temperatures (~30 °C, maximum) and high solar radiation (~800 W/m^2, maximum). All

the Darwin stations recorded high particulate levels from bushfire smoke on 3 July 2023; elevated ozone concentrations have been associated with bushfires.

Table 13: 2023 summary statistics for daily peak 8-hour O_3 in the Northern Territory

AAQ NEPM Standard

0.065 ppm (8-hour average)

Region/ Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date/hour)	2nd highest (ppm)	2nd Highest (date/hour)
Palmerston	345	0.031	12/09/2023 18:00	0.030	16/09/2023 18:00
Stokes Hill	348	0.051	03/07/2023 17:00	0.047	10/05/2023 22:00
Winnellie	335	0.054	11/03/2023 23:00	0.044	09/03/2023 09:00

There is no 1-hour AAQ NEPM standard for O_3; summary statistics provided below is for information only.

Table 14: 2023 summary statistics for daily peak 1-hour O_3 in the Northern Territory

No AAQ NEPM Standard

Region/ Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date/hour)	2nd highest (ppm)	2nd Highest (date/hour)
Palmerston	329	0.039	19/05/2023 17:00	0.038	08/09/2023 15:00
Stokes Hill	350	0.079	10/05/2023 20:00	0.060	03/07/2023 16:00
Winnellie	321	0.092	11/03/2023 21:00	0.067	10/03/2023 06:00

5.4 Sulfur dioxide statistics

Table 15: 2023 summary statistics for daily peak 1-hour SO_2 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)
Palmerston	356	0.0231	11/08/2023 18:00	0.0028	13/08/2023 02:00
Stokes Hill	337	0.0092	08/06/2023 14:00	0.0035	26/06/2023 16:00
Winnellie	352	0.0025	21/05/2023 22:00	0.0024	29/05/2023 20:00

Sulfur dioxide levels in the Darwin region were substantially below the AAQ NEPM 1-hour and 1-day SO_2 standards for most days. The highest recorded 1-hour reading was at Palmerston (0.0231 ppm) at 6 pm on 11 August; the second highest was at Stokes Hill 0.0092 pm on 8 June at 2 pm. Palmerston also recorded the highest daily average SO_2 concentration (0.0026 ppm) on 11 August. The plume on 11 August also had high concentrations of other pollutants as discussed in the previous sections.

Table 16: 2023 summary statistics for 24-hour SO_2 in the Northern Territory

AAQ NEPM Standard

0.02 ppm (1-day average)

Region/ Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date)	2nd highest (ppm)	2nd Highest (date)
Palmerston	340	0.0026	11/08/2023	0.0013	22/08/2023
Stokes Hill	357	0.0013	08/06/2023	0.0013	22/05/2023
Winnellie	286	0.0015	29/05/2023	0.0013	28/05/2023

5.5 Particulates statistics

Palmerston recorded the highest PM_{10} event (164 $\mu g/m^3$) on 13 August 2023 (Table 17); this was the highest PM_{10} concentration ever recorded in Darwin. The plume responsible, which has been discussed in previous sections of this report, contained elevated levels of $PM_{2.5}$ (see also Appendix A: Particulates Events for 2023), as well as elevated levels of CO, NO_x, O_3, and SO_2. The presence of SO_2 in the plume suggests an industrial source, but O_3 has been associated with bushfire smoke events. Winnellie recorded high particulates concentration on that day.

Palmerston also recorded the next highest PM_{10} event (120 $\mu g/m^3$) on 11 August 2023; the plume was associated with a smoke event as it had substantial levels of $PM_{2.5}$ (see Appendix A) as well as CO and NOx as described previously. The highest peak recorded at Katherine AQMS was 96 $\mu g/m^3$ (25 May 2023). Although the PM_{10} events (shown in Table 17) exceeded the AAQ NEPM standard, they are considered as exceptional events since they are associated with natural events such as smoke from bushfires.

Table 17: 2023 summary statistics for 24-hour PM_{10} in the Northern Territory

				AAQ NEPM Standard	
				50 $\mu g/m^3$ (1-day average)	
Region/ Performance monitoring station	**Number of valid days**	**Highest ($\mu g/m^3$)**	**Highest (date)**	**2nd highest ($\mu g/m^3$)**	**2nd Highest (date)**
Katherine	323	96.3	25/05/2023	87.4	09/05/2023
Palmerston	349	164.0	13/08/2023	120.1	11/08/2023
Stokes Hill	325	100.4	24/07/2023	52.9	03/07/2023
Winnellie	286	103.5	09/10/2023	82.0	10/10/2023

The highest $PM_{2.5}$ concentration (130 $\mu g/m^3$) was recorded at Palmerston on 13 August 2023, this was the highest concentration ever recorded in Darwin. The next highest (110 $\mu g/m^3$) was also recorded at Palmerston on 11 August 2023. Both plumes have been discussed previously; these and the other events for the Darwin and Katherine stations shown in Table 18 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: 2023 summary statistics for 24-hour $PM_{2.5}$ in the Northern Territory

Region/ Performance monitoring station	Number of valid days	Highest (µg/m³)	Highest (date)	2nd highest (µg/m³)	2nd Highest (date)
				AAQ NEPM Standard	
				25 µg/m³ (1-day average)	
Katherine	325	75.2	25/05/2023	64.4	18/05/2023
Palmerston	351	130.1	13/08/2023	109.6	11/08/2023
Stokes Hill	348	35.1	22/05/2023	31.0	29/10/2023
Winnellie	287	53.3	29/05/2023	51.8	19/08/2023

6 Analysis of exceedances and population exposure

This section will analyse exceedance events that occurred during 2023 and recorded at the 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 to October) and the Wet (November to April). In general, air quality was excellent during the Wet, but poor during the Dry of 2023. Averaged daily levels of $PM_{2.5}$ across all the Darwin stations over the six months of the Dry was 19 $\mu g/m^3$; compared to 5 $\mu g/m^3$ during the Wet. In Katherine the average for the Dry was 11 $\mu g/m^3$ and for the Wet was 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. $PM_{2.5}$ annual average concentration across all Darwin stations for 2023 was 12 $\mu g/m^3$, which is greater than the AAQ NEPM standard. The $PM_{2.5}$ annual average across all Darwin stations for 2022 was 8 $\mu g/m^3$. These averages are different from population-weighted averages discussed in the next subsection.

Table 19: Summary of $PM_{2.5}$ and PM_{10} exceedances of the 24-hour standards in 2023

AQMS	Number of exceedances	
	$PM_{2.5}$	PM_{10}
Katherine	16	7
Palmerston	34	5
Stokes Hill	3	3
Winnellie	67	35

Table 19 shows that there were record numbers of exceedances of the 24-hour standard for $PM_{2.5}$ at most of the stations in 2023. There was also a record number of PM_{10} exceedances at Winnellie. All these exceedances have been associated with smoke from bushfires. Details of dates and inferred causes of each particulate exceedance are in Tables 26 to 33 of Appendix B.

During the Dry, there were several instances when the 1-day standard was exceeded on three or more consecutive days at some of the stations. For example, 12 to 18 June, 22 to 24 July and 21 to 23 August at Winnellie; 17 to 19 May at Katherine; and 12 to 18 June at Palmerston (see Appendix A: Particulates events for 2023).

There were several consecutive days when PM_{10} levels were above the AAQ NEPM standard at Winnellie from October to November. This was initially attributed to dust emissions from nearby soil stockpiles being used for the construction of the Darwin airport tarmac. However, although the plumes causing these exceedances had lower $PM_{2.5}$ content (consistent with dust emissions), most of the plumes had elevated levels of combustion products such as NO_x. These high PM_{10} levels could be due to a combination of dust and smoke emissions.

As explained in previous sections of this report, since natural events such as bushfire activity caused the $PM_{2.5}$ and PM_{10} exceedances, the exceedances are exceptional events under the AAQ NEPM.

Smoke from burning vegetation contains PM_{10} and $PM_{2.5}$, Figures 10 - 13 show the close relationship between these parameters at all stations, especially during the Dry Season.

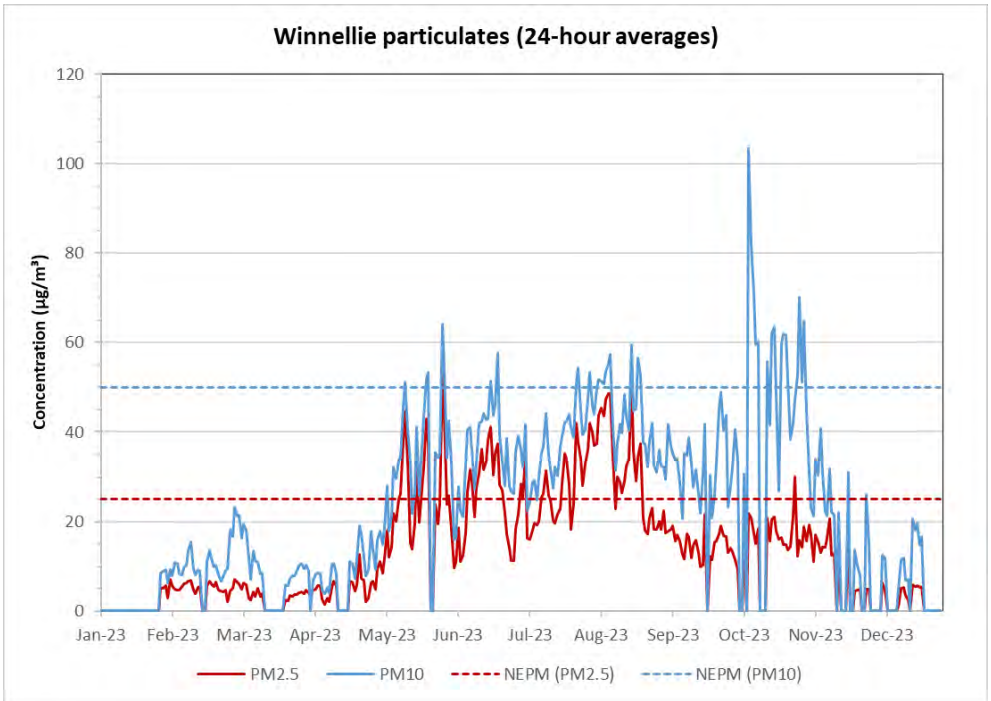

Figure 10: Particulate Matter concentration at Winnellie AQMS during 2023

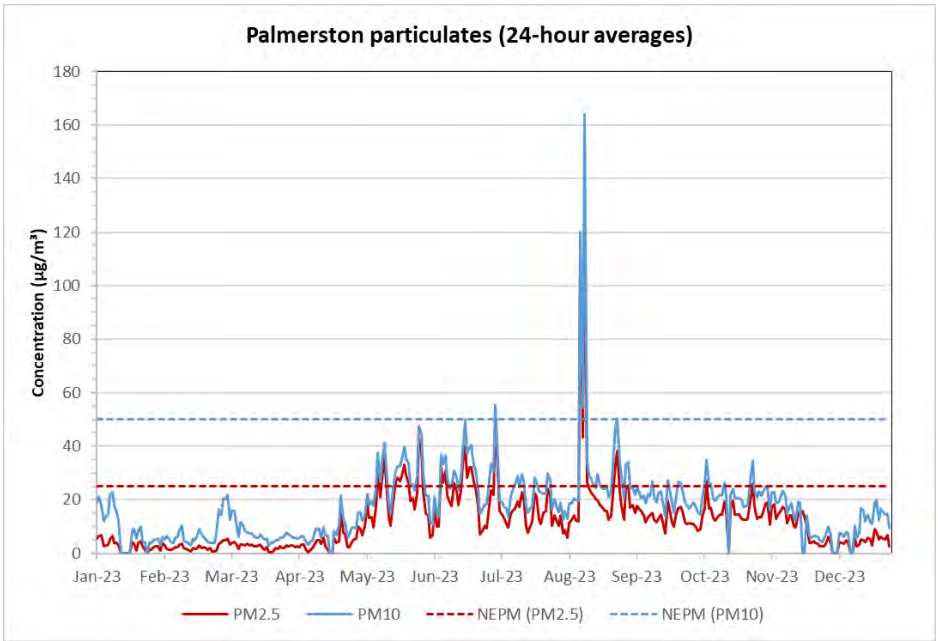

Figure 11: Particulate Matter concentration at Palmerston AQMS during 2023

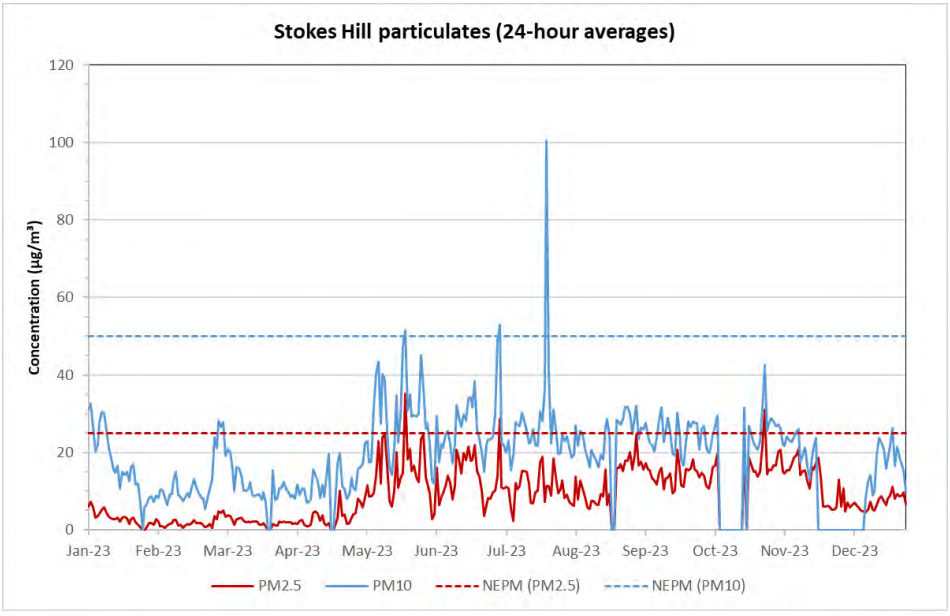

Figure 12: Particulate Matter concentration at Stokes Hill AQMS during 2023

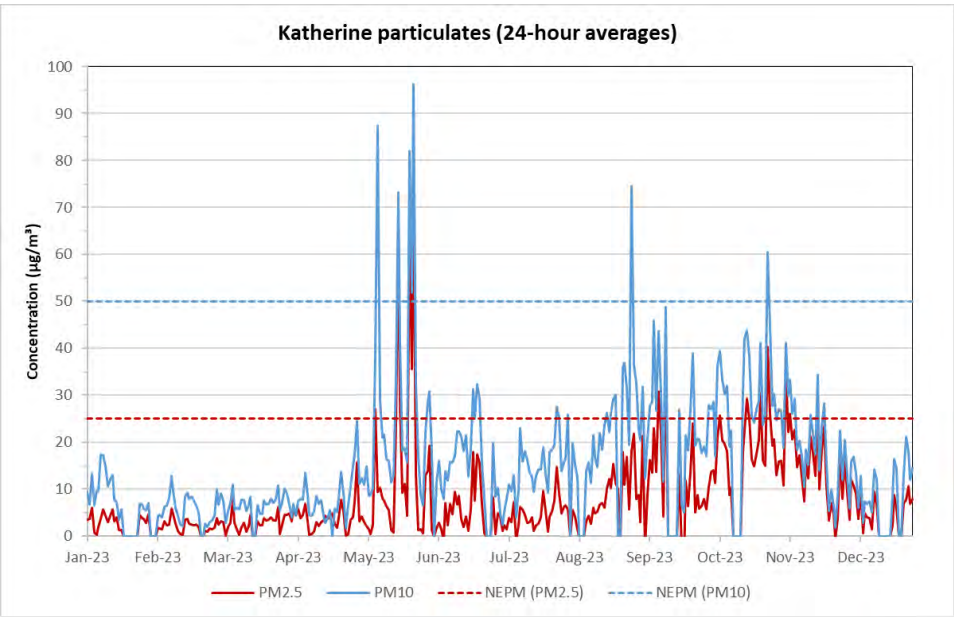

Figure 13: Particulate Matter concentration at Katherine AQMS during 2023

6.2 Population exposure to $PM_{2.5}$, NO_2 and O_3

It is a requirement of the AAQ NEPM that participating jurisdictions evaluate and report annual population exposure to:

(a) particles as $PM_{2.5}$ from June 2018; and

(b) NO_2 and O_3 from June 2021.

Population exposure refers to the exposure of the population as a whole to ambient air pollution. It is not a measure of personal exposure of individuals. During the 2011 AAQ NEPM review, population exposure and risk were flagged as better parameters for assessing air quality, rather than the number of exceedances of the standards (NEPC 2011).

The review recommended to "*Develop nationally consistent approaches to assess population exposure, including appropriate modelling and emissions inventories*".

In practice, determining population exposure estimates requires information on the average distribution of air pollution and the population density in the area or region of interest, along with other information. Accurate estimation of population exposure requires a significant investment, not only in monitoring and airshed modelling and data assimilation, but also in the development of comprehensive inventories of sources across each airshed (NEPC 2011).

A practical, cost-constrained Base Method for annually evaluating population exposures to air pollutant concentrations that uses readily available data and can be adopted nationally has been developed (EWG 2017). The simplified Base Method, which outputs a single population-weighted annual average pollutant concentration for each jurisdiction for which it is implemented, has been used for the data collected in the Greater Darwin Region. Due to limited resources, the intermediate Base Method, which requires interpolating concentrations between stations to also calculate a single population-weighted annual average pollutant concentration was not used.

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 2023 (ABS 2024). SA2 is an area defined in the Australian Statistical Geography Standard (ASGS), usually based on officially gazetted State/Territory suburbs and localities.

SA2s are medium-sized general-purpose areas built to represent communities that interact together socially and economically. Most SA2s have a population range of 3,000 to 25,000 people.

The Australian Statistical Geography Standard (ASGS) is a classification of Australia into a hierarchy of statistical areas. It is a social geography, developed to reflect the location of people and communities. It is used for the publication and analysis of official statistics and other data. The ASGS is updated every 5 years to account for growth and change in Australia's population, economy and infrastructure.

Annual average $PM_{2.5}$, NO_2 and O_3 concentrations for each of the three air quality monitoring stations: Stokes Hill, Winnellie and Palmerston, were assigned to each of the identified SA2 areas based on their proximity to the nearest station.

It was assumed that:

1. People living in the SA2 areas of Darwin City, Fannie Bay - The Gardens, Larrakeyah and Stuart Park would be exposed to $PM_{2.5}$, NO_2 and O_3 levels represented by concentrations measured at Stokes Hill AQMS.
2. All other Darwin SA2 areas would be exposed to $PM_{2.5}$, NO_2 and O_3 levels measured at Winnellie AQMS.
3. People living in SA2 areas in Palmerston would be exposed to $PM_{2.5}$, NO_2 and O_3 levels measured at Palmerston AQMS.

The population-weighted annual average concentration was calculated by multiplying the annual average 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.

A population-weighted annual average concentration of 13.9 μg/m^3 was estimated for $PM_{2.5}$; 0.0022 ppm for NO_2; and 0.014 ppm for O_3 in the Greater Darwin Region in 2023 (see Appendix C for details of the calculations). Population-weighted exposure data for 2023 are compared to data from previous years in Table 20.

Table 20: Historical population-weighted annual concentrations for Greater Darwin Region

Year	$PM_{2.5}$ (μg/m^3)	NO_2 (ppm)	O_3 (ppm)
2023	13.9	0.0022	0.014
2022	9.0	0.0022	0.015
2021	9.7	0.0040	0.016
2020	6.7	n/a	n/a
2019	9.3	n/a	n/a

'n/a' – not applicable

7 Data analysis and trends

Tables 21 to 24 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. The Partisol dichotomous sampler, which measured both PM_{10} and $PM_{2.5}$ was normally operating at Charles Darwin University in Casuarina and was collocated with a TEOM, which measured PM_{10}.

7.1 Trends in historical particulate data

Issues with historical data include:

- 2004 - Data collection for this year did not commence until the second quarter.
- 2004 & 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.
- 2011 – Validated data available from Palmerston AQMS from 1 January (PM_{10} & $PM_{2.5}$ now measured with a dichotomous TEOM).
- 2012 – Winnellie AQMS started operating on 18 July (PM_{10} & $PM_{2.5}$ measured with a dichotomous TEOM).
- 2013 - Palmerston TEOM was offline for several months during the Wet 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.
- 2016 - Data has not been analysed.
- 2017 - Stokes Hill AQMS started operating in May; TEOM data was only available from July.
- 2020 – Katherine AQMS started operating in September, measuring particulates using a TEOM fitted with FDMS.
- 2021 – TEOMs at Palmerston AQMS and Winnellie AQMS upgraded to models fitted with FDMS.

- 2021 – Stokes Hill AQMS was decommissioned at Stokes Hill Road (Darwin Waterfront) in May and relocated to Frances Bay Drive (Hornibrooks Wharf) – commissioned in June.
- 2023 – TEOM at Stokes Hill upgraded to a model fitted with FDMS.

Table 21: Casuarina 24-hour PM_{10} & $PM_{2.5}$ Trends (2004 -2010)

Year	*PM_{10}			**$PM_{2.5}$		
	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m³)	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m³)
2004	69	*1*	*54*	60	5	37
2005	98	2	63	98	5	58
2006	97	0	44	97	5	30
2007	95	0	45	-	-	-
2008	97	1	65	72	2	32
2009	90	0	50	87	1	26
2010	78	1	54	62	2	30

- *TEOM data (but Partisol dichotomous PM_{10} data used for 2006)
- **$PM_{2.5}$ data from Partisol dichotomous sampler

Table 22: 24-hour PM_{10} Trends (2011-2023)

Year	Palmerston			Winnellie			Stokes Hill			Katherine		
	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)
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	-	-	-	-	-	-

Year	Palmerston			Winnellie			Stokes Hill			Katherine		
	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)
2016	-	-	-	-	-	-	-	-	-	-	-	-
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	-	-	-
2020	96	1	52	98	1	53	98	0	46	26	0	45
2021	85	3	120	75	2	52	82	4	95	84	6	94
2022	83	2	71	93	4	66	95	5	90	85	10	71
2023	96	5	164	78	35	104	89	3	100	88	7	96

Table 23: 24-hour $PM_{2.5}$ Trends (2011-2023)

Year	Palmerston			Winnellie			Stokes Hill			Katherine		
	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)
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	-	-	-	-	-	-
2016	-	-	-	-	-	-	-	-	-	-	-	-
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	-	-	-
2020	96	7	38	98	7	39	96	4	34	26	1	33
2021	85	12	40	75	27	48	85	12	33	83	15	56

Year	Palmerston			Winnellie			Stokes Hill			Katherine		
	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)
2022	83	12	67	93	19	63	95	5	37	85	19	50
2023	96	34	130	79	67	53	95	3	35	89	16	75

Table 24: Averaged Particulates Key Metrics 2004-2023 (across all historical & current monitoring locations)

	Data Availability (%)	Number of Exceedances	Maximum Concentration (µg/m^3)
PM_{10}	86	5	75
$PM_{2.5}$	84	13	50

Historical data for the 2004 to 2023 period, presented in Figures 14 to 19, show that there is no clear trend in $PM_{2.5}$ or PM_{10} in the Darwin region over the period. There were increases in the number of exceedances and the maximum concentrations recorded at most of the stations in 2023 compared to 2022; but a general trend cannot be established across all the years.

The population of the Greater Darwin region has increased steadily from approximately 108,000 in 2001 to ~150,000 in 2023 showing a clear upward trend in population; however, a relationship has not been established between population and particulate levels.

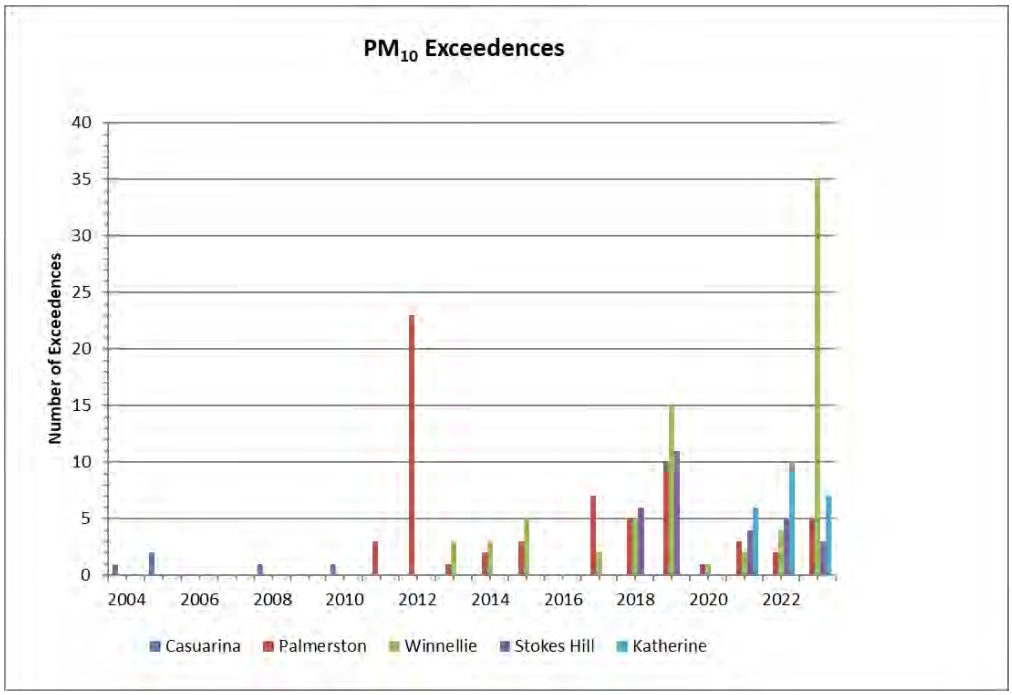

Figure 14: Historical PM_{10} exceedances of 24-hour AAQ NEPM

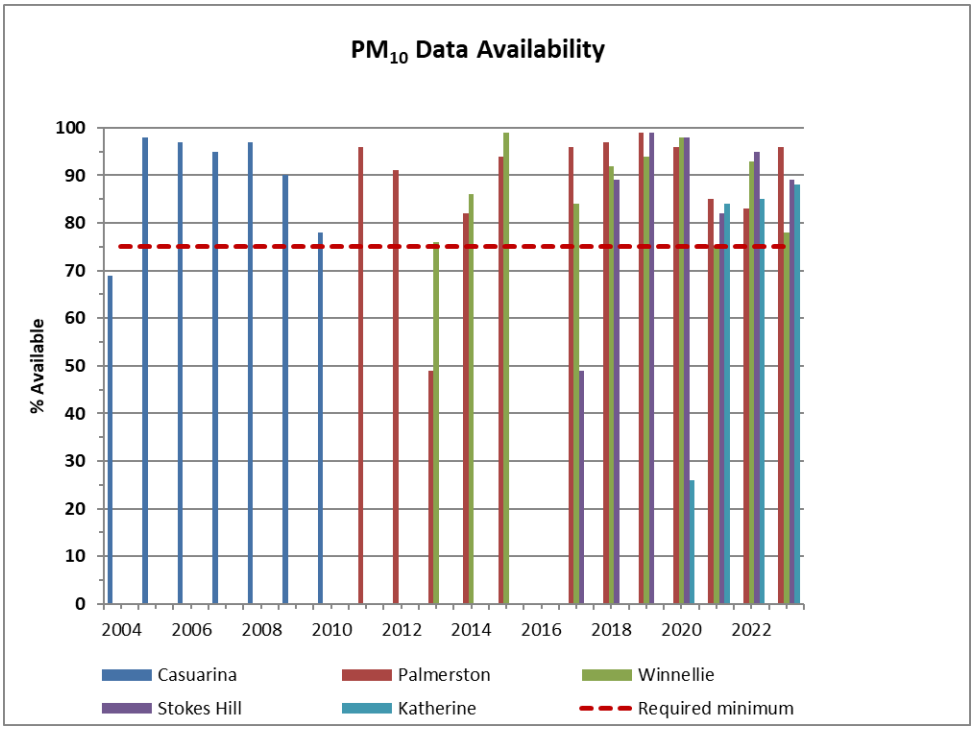

Figure 15: Historical PM_{10} data availability

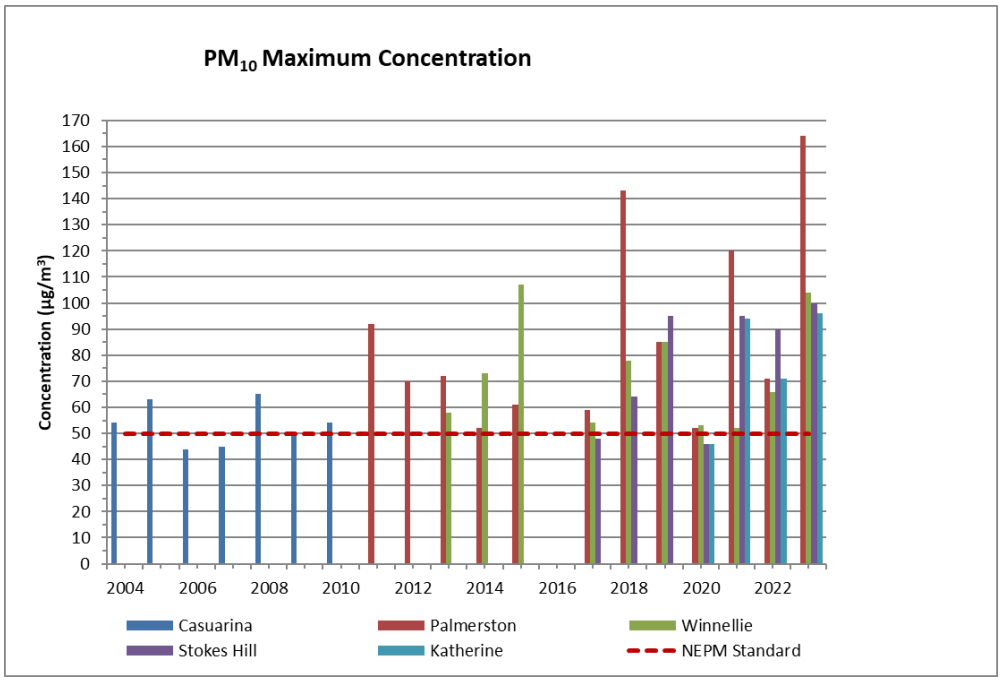

Figure 16: Historical maximum 24-hour PM_{10} concentrations

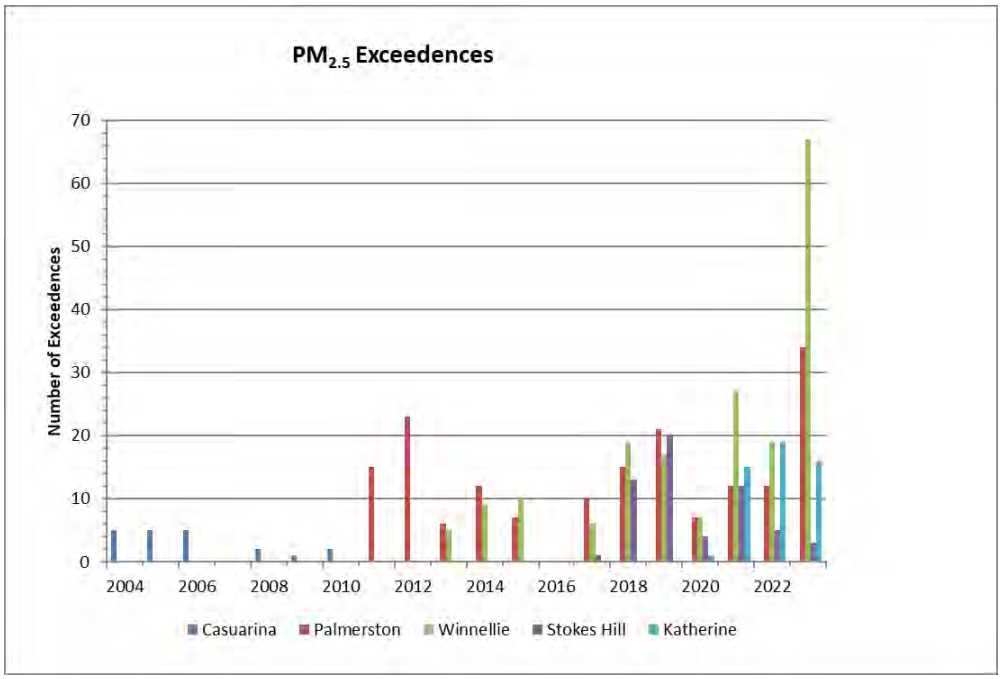

Figure 17: Historical $PM_{2.5}$ exceedances of 24-hour AAQ NEPM

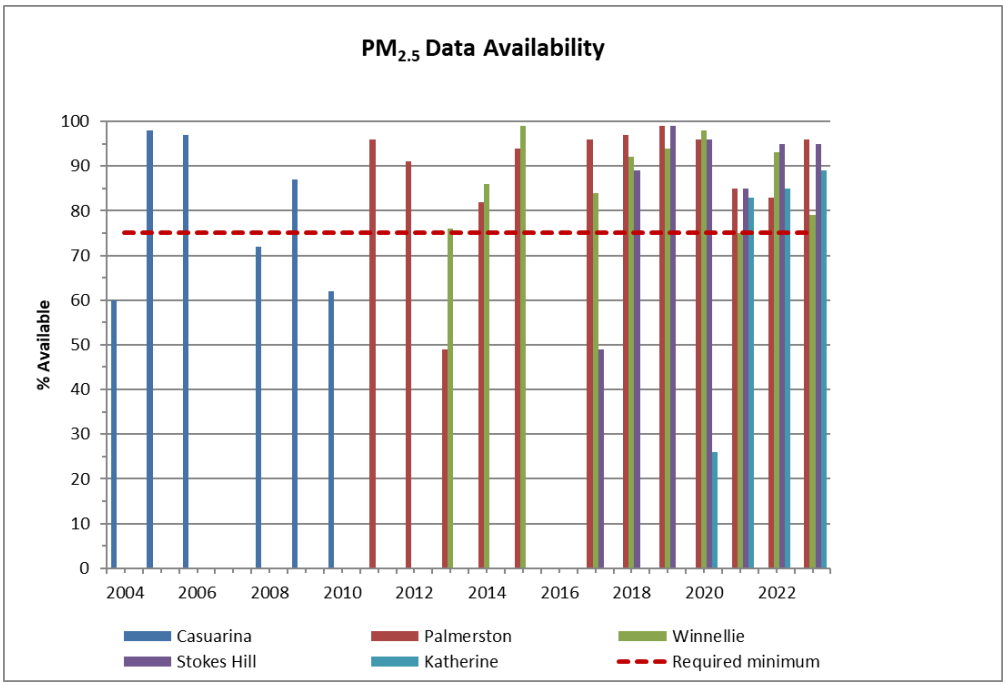

Figure 18: Historical $PM_{2.5}$ data availability

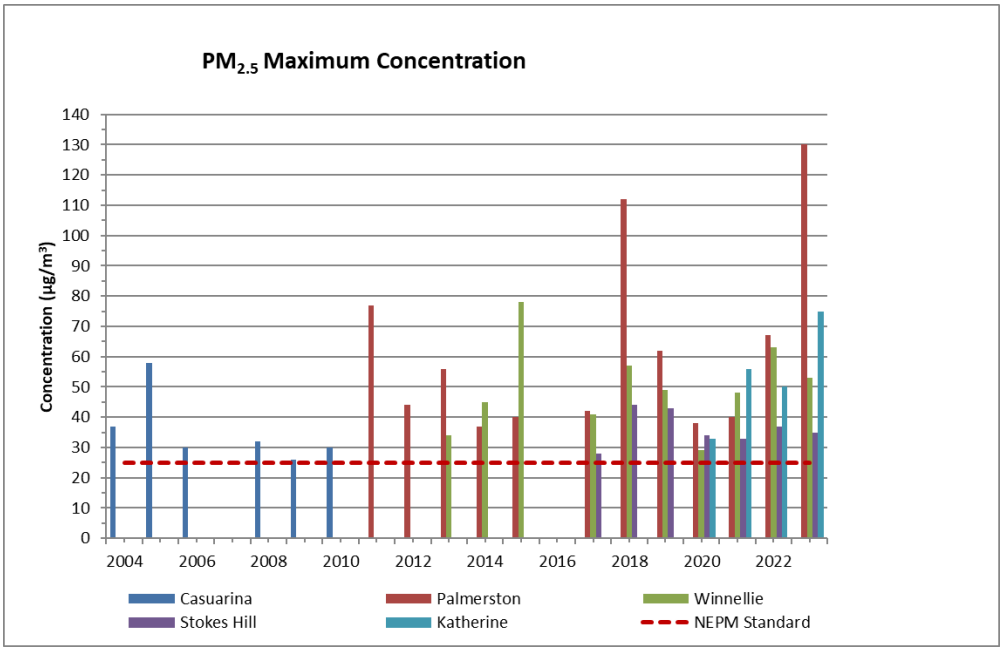

Figure 19: Historical $PM_{2.5}$ 24-hour maximum concentrations

8 Trends in fire-scar data

In the Darwin region, generally, smoke from burning vegetation causes exceedances of the particulate standards. This connection is 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 2024) 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 38.5% of the area was burnt in 2023. A relationship was observed between the monthly area burnt and the monthly averaged $PM_{2.5}$ concentrations measured at the stations. Figure 20 shows that the monthly $PM_{2.5}$ concentrations peaked from May to August for all the stations (15 - 33 μg/m^3) with area burnt (400 - 725 sq km). There was a general decline in both parameters after August.

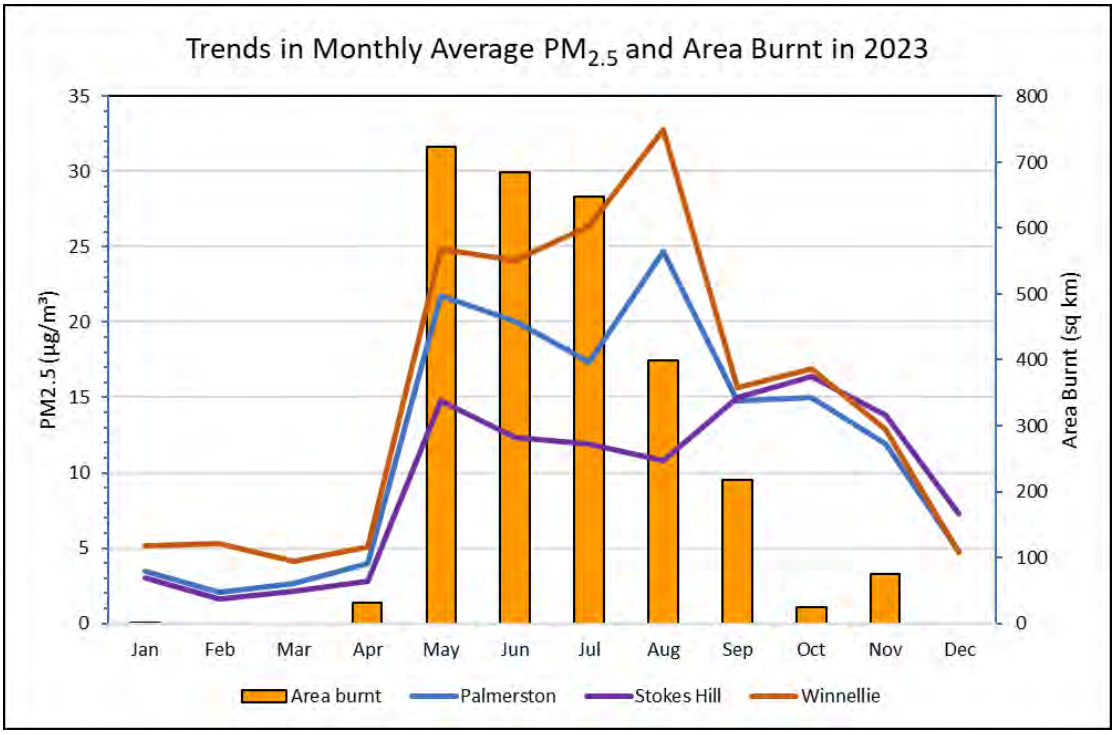

Figure 20: Comparison of $PM_{2.5}$ levels with Area Burnt (50 km radius from McMinns Lagoon)

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. On 22 May 2023, all the Darwin stations recorded $PM_{2.5}$ levels above the AAQ NEPM standard, and the picture in Figure 21 shows smoke blowing towards Darwin from fires burning to the southeast. Katherine also recorded an exceedance due to fires burning from the southeast. As mentioned previously, there were several consecutive days from May to August when one or more stations recorded $PM_{2.5}$ levels above the AAQ NEPM standard (see Appendix A).

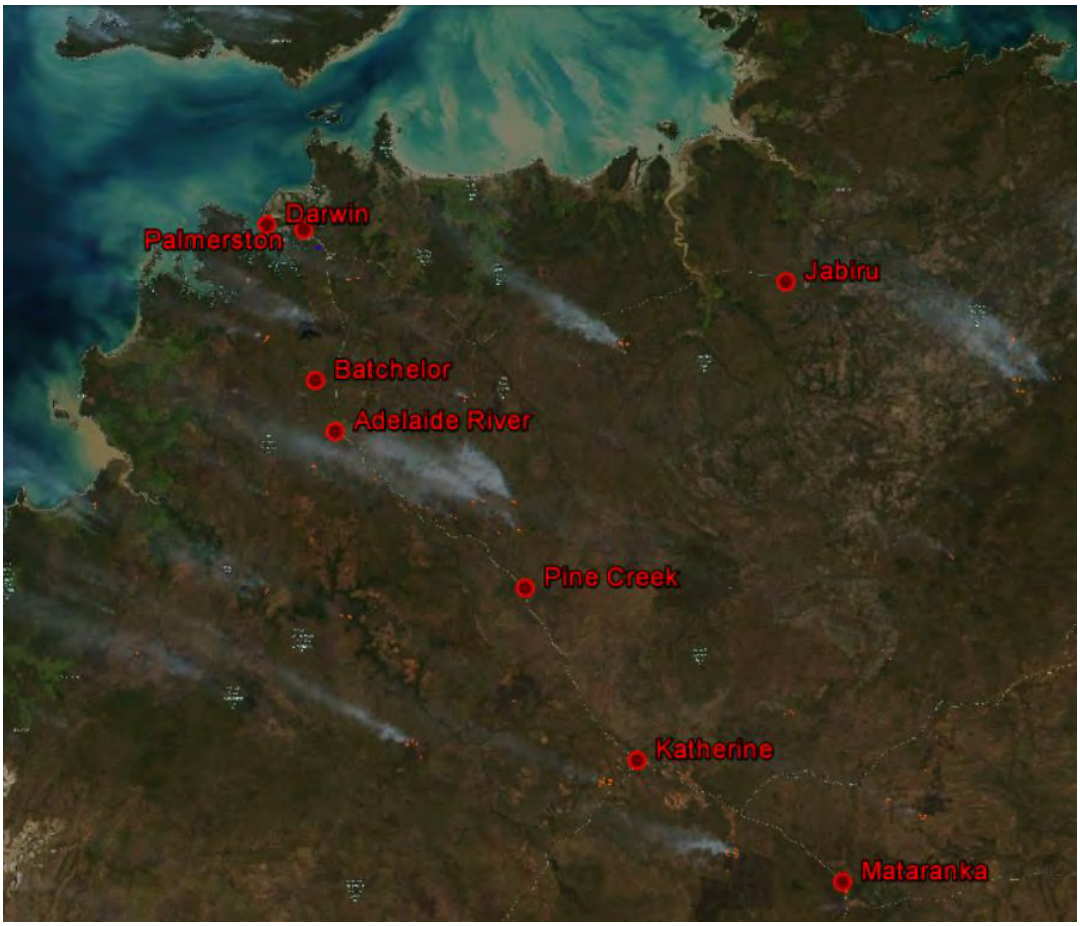

Figure 21: Large-scale fire events impacting the Top End on 22 May 2023 (Source: NASA Worldview)

These fires are due to controlled burns, unintended fires or arson. Controlled burns present opportunities 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.

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.

References

ABS 2024. Australian Bureau of Statistics. Population estimates by SA2 and above, 2001 to 2023. Regional population, 2022-23. Released at 11:30am (Canberra Time) 26 March 2024. Retrieved on 11 November 2024. https://www.abs.gov.au/statistics/people/population/regional-population/latest-release#data-downloads

AAQ NEPM 2021. National Environment Protection (Ambient Air Quality) Measure. https://www.legislation.gov.au/Details/F2021C00475

EWG 2017. Annual Evaluation and Reporting Population Exposures to Particles as PM2.5. Expert Working Group.

Gras et al. 2001. *A Pilot Study of Air Quality in Darwin, NT for the Northern Territory Government, Department of Lands Planning and Environment.* Final Report CSIRO Atmospheric Research Aspendale, Victoria Australia, 15 March 2001. https://ntepa.nt.gov.au/__data/assets/pdf_file/0006/284982/aqstudy.pdf

PRC 2001. National Environment Protection (Ambient Air Quality) Measure Technical Paper No. 5: Data Collection and Handling (NEPC Peer Review Committee May 2001). Available at: http://www.nepc.gov.au/resource/ephc-archive-ambient-air-quality-nepm

PRC 2002. National Environment Protection (Ambient Air Quality) Measure Technical Paper No. 8: Annual Reports (NEPC Peer Review Committee October 2002). Available at: http://www.nepc.gov.au/resource/ephc-archive-ambient-air-quality-nepm

NAFI 2024. North Australian Fire Information *Fire Reports*, *Fire History by Year - 2008-2024*, *Darwin region*. https://firenorth.org.au/nafi3/

NASA Worldview application (https://worldview.earthdata.nasa.gov), part of the NASA Earth Observing System Data and Information System (EOSDIS).

NEPC Act 1994. National Environment Protection Council (Northern Territory) Act 1994 https://legislation.nt.gov.au/Legislation/NATIONAL-ENVIRONMENT-PROTECTION-COUNCIL-NORTHERN-TERRITORY-ACT-1994

NEPC 2011. National Environment Protection (Ambient Air Quality) Measure Review, Prepared for the National Environment Protection Council May 2011. https://www.nepc.gov.au/sites/default/files/2022-09/aaq-review-report-2011.pdf

NTG 2001. Monitoring Plan for the Northern Territory, May 2001 https://ntepa.nt.gov.au/__data/assets/pdf_file/0010/284986/monitoringplan.pdf

WMPC Act 1998. Waste Management and Pollution Control Act 1998. https://legislation.nt.gov.au/Legislation/WASTE-MANAGEMENT-AND-POLLUTION-CONTROL-ACT-1998

Appendix A: Particulates events for 2023

Table 25: Pollution events caused by $PM_{2.5}$ and PM_{10} exceedances of 24-hour AAQ NEPM standards

Date	Particulates Concentration (µg/m³)							
	Katherine		Palmerston		Stokes Hill		Winnellie	
	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10
8-May	**27.0**	38.6	9.7	17.6	9.5	31.6	21.7	32.2
9-May	9.5	**87.4**	17.4	24.6	13.9	40.5	20.0	29.7
10-May	10.3	28.7	**31.5**	37.5	23.0	43.4	**25.1**	33.6
11-May	8.0	21.0	21.0	26.8	11.8	27.3	**26.2**	34.4
12-May	7.6	21.6	**28.1**	34.4	23.9	40.2	**38.0**	45.5
13-May	6.3	16.4	**35.7**	41.6	24.7	38.6	**44.5**	**51.1**
14-May	5.5	16.0	**26.2**	31.9	16.3	25.7	**33.4**	40.4
18-May	**64.4**	**73.1**	**26.7**	31.0	20.1	34.7	**31.8**	41.2
19-May	**28.6**	40.9	**28.4**	32.3	11.0	22.4	19.9	25.8
20-May	9.3	18.3	**27.0**	32.3	13.3	29.4	24.7	33.4
21-May	11.1	18.8	**29.1**	35.0	14.8	47.3	**32.3**	43.3
22-May	4.3	15.6	**33.0**	39.9	**35.1**	**51.7**	**42.9**	**51.9**
23-May	**64.3**	**82.0**	**29.2**	35.5	18.1	30.8	**37.7**	**53.4**
24-May	**35.6**	**51.8**	**26.1**	33.3	20.8	35.0	n/a	n/a
25-May	**75.2**	**96.3**	19.5	26.1	15.2	29.1	n/a	n/a
29-May	0.6	6.5	**42.3**	47.4	23.5	45.2	**53.3**	**64.2**
30-May	12.9	22.0	**38.8**	44.8	24.5	36.6	**43.5**	**53.7**
1-Jun	19.3	30.9	14.7	21.4	11.9	27.6	**25.8**	42.6
8-Jun	7.1	13.8	**31.8**	36.8	9.5	21.2	17.5	32.8
9-Jun	2.3	11.9	**26.4**	33.3	11.4	24.5	**26.7**	40.4
10-Jun	6.8	15.8	**30.7**	36.7	13.9	25.6	**31.6**	41.3
11-Jun	4.6	15.6	21.5	28.3	12.1	22.2	**28.9**	35.9
13-Jun	6.7	22.3	17.6	25.4	11.5	22.3	**27.5**	33.1
14-Jun	8.6	22.3	**26.5**	30.8	20.7	32.2	**30.8**	42.0
15-Jun	3.6	21.3	23.1	28.3	18.3	29.1	**36.2**	42.4
16-Jun	2.0	18.1	17.9	23.6	14.5	26.5	**31.6**	44.1
17-Jun	4.2	21.4	23.3	28.9	19.8	29.9	**33.5**	42.8
18-Jun	1.1	12.6	**33.0**	38.1	18.0	28.1	**38.1**	42.9
19-Jun	5.8	18.6	**40.1**	49.9	21.5	33.8	**41.2**	**51.3**
20-Jun	17.9	31.2	**28.4**	37.2	17.8	34.3	**30.5**	43.7
21-Jun	7.6	25.1	**32.3**	39.8	18.1	31.7	**35.2**	45.9
22-Jun	17.4	32.3	**32.1**	40.3	21.9	38.4	**37.4**	**57.7**
23-Jun	15.5	29.3	**26.6**	32.7	15.2	25.7	**28.3**	39.5
24-Jun	6.7	15.5	24.5	31.3	13.7	23.4	**26.9**	33.6
2-Jul	3.9	4.8	21.7	30.6	14.0	49.1	**28.4**	35.7
3-Jul	1.1	2.2	**49.9**	**55.4**	**28.7**	**52.9**	**25.1**	32.2
4-Jul	2.2	5.1	**30.6**	34.9	10.9	22.8	**35.7**	41.7
11-Jul	6.2	23.0	15.6	23.4	10.5	27.2	**25.4**	35.3
12-Jul	5.8	15.8	16.7	25.7	11.3	26.7	**26.3**	36.7
13-Jul	4.5	18.1	19.4	28.9	15.1	30.2	**31.4**	44.2
14-Jul	2.8	16.3	17.2	24.6	15.2	28.0	**25.9**	34.8

Date	Particulates Concentration (µg/m³)							
	Katherine		Palmerston		Stokes Hill		Winnellie	
	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10
20-Jul	4.1	14.2	11.8	17.6	10.1	21.6	**28.5**	38.9
21-Jul	9.6	18.8	22.5	28.3	17.5	30.7	**35.1**	42.2
22-Jul	5.3	13.1	21.2	26.6	18.8	28.0	**34.0**	42.4
23-Jul	0.9	9.3	12.4	23.1	7.3	36.5	**28.3**	44.0
24-Jul	4.1	17.9	11.0	22.9	11.3	**100.4**	18.2	40.9
26-Jul	7.5	19.2	15.6	22.4	8.9	22.3	**42.0**	**50.8**
27-Jul	14.7	27.6	24.1	29.8	18.4	31.0	**37.8**	**54.3**
28-Jul	9.0	25.2	21.6	27.6	13.5	26.0	**34.0**	44.7
29-Jul	4.8	13.8	10.3	16.3	9.5	19.7	**28.1**	39.4
30-Jul	6.2	15.6	14.1	20.2	10.6	19.8	**33.0**	40.5
31-Jul	6.5	16.3	12.5	17.8	12.6	24.7	**36.1**	47.4
1-Aug	5.7	25.9	10.3	15.4	8.2	23.0	**42.1**	**53.4**
2-Aug	n/a	n/a	14.3	18.8	9.1	24.1	**40.1**	45.8
3-Aug	5.5	19.8	7.5	12.5	7.2	21.2	**37.1**	44.0
4-Aug	4.1	15.2	8.7	15.8	6.7	18.7	**37.3**	49.7
5-Aug	1.4	12.4	5.8	13.0	6.2	19.3	**43.9**	**51.8**
6-Aug	n/a	n/a	11.4	18.7	13.8	27.0	**45.4**	**51.3**
7-Aug	n/a	n/a	12.5	18.6	7.9	21.7	**43.5**	**50.8**
8-Aug	n/a	n/a	14.3	20.5	12.8	25.6	**47.4**	**53.7**
9-Aug	3.2	13.9	12.2	19.9	10.7	24.7	**48.7**	**55.1**
10-Aug	4.3	15.7	11.9	19.7	8.5	20.9	**48.5**	**57.3**
11-Aug	2.6	11.3	**109.6**	**120.1**	5.8	18.6	**34.9**	40.7
12-Aug	6.1	21.4	**43.2**	**54.3**	5.4	16.2	22.9	31.3
13-Aug	4.9	16.6	**130.1**	**164.0**	7.5	20.6	**30.0**	37.4
14-Aug	5.2	14.7	**26.6**	34.7	7.5	19.3	**28.7**	41.7
15-Aug	6.8	22.0	24.5	29.3	6.6	17.9	**26.4**	39.8
16-Aug	7.1	18.3	22.3	27.7	6.4	16.2	**29.1**	48.4
17-Aug	6.1	23.6	21.7	25.6	9.2	19.3	**32.4**	43.4
18-Aug	10.2	26.2	20.2	24.6	8.7	18.3	**34.0**	40.4
19-Aug	12.1	22.1	19.8	29.5	15.6	26.6	**51.8**	**59.5**
20-Aug	10.2	26.2	18.0	25.3	6.4	28.6	**35.8**	44.9
21-Aug	15.4	29.1	17.0	24.1	9.2	24.3	**29.1**	45.1
22-Aug	11.3	30.1	16.0	24.1	n/a	n/a	**34.4**	**56.6**
23-Aug	10.2	n/a	15.6	24.4	n/a	n/a	**37.4**	**52.5**
27-Aug	16.9	31.5	**33.2**	47.4	15.2	28.4	20.8	37.9
28-Aug	5.7	19.4	**38.2**	**50.3**	17.8	31.8	23.1	42.0
29-Aug	18.0	**74.5**	23.0	34.0	17.8	31.7	18.2	32.6
2-Sep	3.0	20.5	**25.5**	34.1	24.4	32.0	22.5	32.3
10-Sep	**30.9**	43.7	11.6	18.6	12.7	20.2	12.7	20.6
13-Sep	**38.6**	48.7	15.2	27.0	16.1	31.7	16.7	38.7
7-Oct	**25.7**	39.4	17.2	25.9	16.7	26.8	16.5	30.6
8-Oct	20.5	33.4	**27.0**	35.1	19.7	29.6	n/a	n/a
9-Oct	19.7	30.3	16.8	25.7	n/a	n/a	21.9	**103.5**
10-Oct	18.0	31.9	16.9	26.1	n/a	n/a	20.8	**82.0**
11-Oct	8.8	19.0	13.1	20.5	n/a	n/a	17.4	**70.9**
12-Oct	10.3	22.5	12.1	19.7	n/a	n/a	15.0	**59.6**

Date	Particulates Concentration (µg/m³)							
	Katherine		Palmerston		Stokes Hill		Winnellie	
	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10
13-Oct	n/a	n/a	13.6	21.0	n/a	n/a	18.4	**60.2**
17-Oct	17.9	30.8	15.3	21.8	n/a	n/a	20.8	**55.8**
19-Oct	**29.3**	43.9	16.7	21.8	n/a	n/a	20.5	**62.0**
20-Oct	24.8	38.2	19.7	24.1	19.7	31.4	21.0	**63.5**
23-Oct	17.6	27.0	14.6	20.4	16.7	24.7	16.3	**59.7**
24-Oct	20.4	28.7	12.7	19.9	15.0	22.3	14.9	**61.9**
25-Oct	**30.5**	41.1	12.7	17.2	15.2	21.7	14.9	**61.7**
26-Oct	16.1	23.7	12.5	17.6	13.8	20.6	13.6	**51.7**
28-Oct	**40.3**	**60.4**	19.7	27.1	21.7	31.7	21.2	42.0
29-Oct	**26.1**	44.5	**26.0**	34.5	**31.0**	42.6	**30.0**	47.1
30-Oct	19.2	27.8	17.2	23.1	14.3	25.5	12.3	**52.8**
31-Oct	20.6	30.3	13.0	21.0	15.6	27.4	15.8	**70.1**
1-Nov	12.9	24.7	13.4	23.1	15.3	28.8	14.3	**51.1**
2-Nov	15.8	27.0	13.6	21.4	16.6	28.0	18.8	**64.8**
5-Nov	**34.2**	41.2	18.9	24.7	20.6	26.2	17.0	23.0
7-Nov	**26.1**	33.4	17.4	22.9	14.6	21.7	17.0	34.0
19-Nov	**29.5**	34.3	15.0	19.2	16.2	18.8	n/a	n/a
Exceedances	**16**	**7**	**34**	**5**	**3**	**3**	**67**	**35**

n/a – data not available

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).

Appendix B: Inferred causes of exceedances in 2023

Table 26: 2023 PM_{10} exceedances of 24-hour AAQ NEPM standard at Katherine AQMS

Date	PM_{10} (µg/m^3)	Inferred Cause
9-May	87.4	smoke
18-May	73.1	smoke
23-May	82.0	smoke
24-May	51.8	smoke
25-May	96.3	smoke
29-Aug	74.5	smoke
28-Oct	60.4	smoke

Table 27: 2023 PM_{10} exceedances of 24-hour AAQ NEPM standard at Palmerston AQMS

Date	PM_{10} (µg/m^3)	Inferred Cause
3-Jul	55.4	smoke
11-Aug	120.1	smoke
12-Aug	54.3	smoke
13-Aug	164.0	smoke
28-Aug	50.3	smoke

Table 28: 2023 PM_{10} exceedances of 24-hour AAQ NEPM standard at Stokes Hill AQMS

Date	PM_{10} (µg/m^3)	Inferred Cause
22-May	51.7	smoke
3-Jul	52.9	smoke
24-Jul	100.4	smoke

Table 29: 2023 PM_{10} exceedances of 24-hour AAQ NEPM standard at Winnellie AQMS

Date	PM_{10} (µg/m^3)	Inferred Cause
13-May	51.1	smoke
22-May	51.9	smoke
23-May	53.4	smoke
29-May	64.2	smoke
30-May	53.7	smoke
19-Jun	51.3	smoke
22-Jun	57.7	smoke
26-Jul	50.8	smoke
27-Jul	54.3	smoke
1-Aug	53.4	smoke
5-Aug	51.8	smoke

Date	PM_{10} (µg/m^3)	Inferred Cause
6-Aug	51.3	smoke
7-Aug	50.8	smoke
8-Aug	53.7	smoke
9-Aug	55.1	smoke
10-Aug	57.3	smoke
19-Aug	59.5	smoke
22-Aug	56.6	smoke
23-Aug	52.5	smoke
9-Oct	103.5	smoke
10-Oct	82.0	smoke
11-Oct	70.9	smoke
12-Oct	59.6	smoke
13-Oct	60.2	smoke
17-Oct	55.8	smoke
19-Oct	62.0	smoke
20-Oct	63.5	smoke
23-Oct	59.7	smoke
24-Oct	61.9	smoke
25-Oct	61.7	smoke
26-Oct	51.7	smoke
30-Oct	52.8	smoke
31-Oct	70.1	smoke
1-Nov	51.1	smoke
2-Nov	64.8	smoke

Table 30: 2023 $PM_{2.5}$ exceedances of 24-hour AAQ NEPM standard at Katherine AQMS

Date	PM2.5 (µg/m^3)	Inferred Cause
8-May	27.0	smoke
18-May	64.4	smoke
19-May	28.6	smoke
23-May	64.3	smoke
24-May	35.6	smoke
25-May	75.2	smoke
10-Sep	30.9	smoke
13-Sep	38.6	smoke
7-Oct	25.7	smoke
19-Oct	29.3	smoke
25-Oct	30.5	smoke
28-Oct	40.3	smoke
29-Oct	26.1	smoke
5-Nov	34.2	smoke
7-Nov	26.1	smoke
19-Nov	29.5	smoke

Table 31: 2023 $PM_{2.5}$ exceedances of 24-hour AAQ NEPM reporting level at Palmerston AQMS

Date	$PM_{2.5}$ (µg/m^3)	Inferred Cause
10-May	31.5	smoke
12-May	28.1	smoke
13-May	35.7	smoke
14-May	26.2	smoke
18-May	26.7	smoke
19-May	28.4	smoke
20-May	27.0	smoke
21-May	29.1	smoke
22-May	33.0	smoke
23-May	29.2	smoke
24-May	26.1	smoke
29-May	42.3	smoke
30-May	38.8	smoke
8-Jun	31.8	smoke
9-Jun	26.4	smoke
10-Jun	30.7	smoke
14-Jun	26.5	smoke
18-Jun	33.0	smoke
19-Jun	40.1	smoke
20-Jun	28.4	smoke
21-Jun	32.3	smoke
22-Jun	32.1	smoke
23-Jun	26.6	smoke
3-Jul	49.9	smoke
4-Jul	30.6	smoke
11-Aug	109.6	smoke
12-Aug	43.2	smoke
13-Aug	130.1	smoke
14-Aug	26.6	smoke
27-Aug	33.2	smoke
28-Aug	38.2	smoke
2-Sep	25.5	smoke
8-Oct	27.0	smoke
29-Oct	26.0	smoke

Table 32: 2023 $PM_{2.5}$ exceedances of 24-hour AAQ NEPM reporting level at Stokes Hill AQMS

Date	$PM_{2.5}$ (µg/m^3)	Inferred Cause
22-May	35.1	smoke
3-Jul	28.7	smoke
29-Oct	31.0	smoke

Table 33: 2023 $PM_{2.5}$ exceedances of 24-hour AAQ NEPM reporting level at Winnellie AQMS

Date	$PM_{2.5}$ (µg/m^3)	Inferred Cause
10-May	25.1	smoke
11-May	26.2	smoke
12-May	38.0	smoke
13-May	44.5	smoke
14-May	33.4	smoke
18-May	31.8	smoke
21-May	32.3	smoke
22-May	42.9	smoke
23-May	37.7	smoke
29-May	53.3	smoke
30-May	43.5	smoke
1-Jun	25.8	smoke
9-Jun	26.7	smoke
10-Jun	31.6	smoke
11-Jun	28.9	smoke
13-Jun	27.5	smoke
14-Jun	30.8	smoke
15-Jun	36.2	smoke
16-Jun	31.6	smoke
17-Jun	33.5	smoke
18-Jun	38.1	smoke
19-Jun	41.2	smoke
20-Jun	30.5	smoke
21-Jun	35.2	smoke
22-Jun	37.4	smoke
23-Jun	28.3	smoke
24-Jun	26.9	smoke
2-Jul	28.4	smoke
3-Jul	25.1	smoke
4-Jul	35.7	smoke
11-Jul	25.4	smoke
12-Jul	26.3	smoke
13-Jul	31.4	smoke
14-Jul	25.9	smoke
20-Jul	28.5	smoke

Date	$PM_{2.5}$ (µg/m^3)	Inferred Cause
21-Jul	35.1	smoke
22-Jul	34.0	smoke
23-Jul	28.3	smoke
26-Jul	42.0	smoke
27-Jul	37.8	smoke
28-Jul	34.0	smoke
29-Jul	28.1	smoke
30-Jul	33.0	smoke
31-Jul	36.1	smoke
1-Aug	42.1	smoke
2-Aug	40.1	smoke
3-Aug	37.1	smoke
4-Aug	37.3	smoke
5-Aug	43.9	smoke
6-Aug	45.4	smoke
7-Aug	43.5	smoke
8-Aug	47.4	smoke
9-Aug	48.7	smoke
10-Aug	48.5	smoke
11-Aug	34.9	smoke
13-Aug	30.0	smoke
14-Aug	28.7	smoke
15-Aug	26.4	smoke
16-Aug	29.1	smoke
17-Aug	32.4	smoke
18-Aug	34.0	smoke
19-Aug	51.8	smoke
20-Aug	35.8	smoke
21-Aug	29.1	smoke
22-Aug	34.4	smoke
23-Aug	37.4	smoke
29-Oct	30.0	smoke

Appendix C: Population-weighted exposure

A simplified approach was used to calculate population-weighted annual averages for particles as $PM_{2.5}$, nitrogen dioxide (NO_2) and ozone (O_3) concentrations for the Greater Darwin Region.

Table 34: Calculation of population-weighted exposures for 2023

SA2[1]	Population[2] *(P_i)*	$PM_{2.5}$ (µg/m^3) *(P_i x C_i)*	NO_2 (ppm) *(P_i x C_i)*	O_3 (ppm) *(P_i x C_i)*
Darwin City	7671	70573.2	30.684	144.52164
Fannie Bay - The Gardens	3829	35226.8	15.316	72.13836
Larrakeyah	4295	39514	17.18	80.9178
Stuart Park	4355	40066	17.42	82.0482
Darwin Airport	20	340	0.042	0.2888
East Point	0	0	0	0
Ludmilla - The Narrows	2753	46801	5.7813	39.75332
Parap	2919	49623	6.1299	42.15036
Woolner - Bayview - Winnellie	2893	49181	6.0753	41.77492
Alawa	2187	37179	4.5927	31.58028
Anula	2499	42483	5.2479	36.08556
Berrimah	2125	36125	4.4625	30.685
Brinkin - Nakara	3487	59279	7.3227	50.35228
Buffalo Creek	0	0	0	0
Charles Darwin	3	51	0.0063	0.04332
Coconut Grove	3034	51578	6.3714	43.81096
East Arm	23	391	0.0483	0.33212
Jingili	1924	32708	4.0404	27.78256
Karama	5058	85986	10.6218	73.03752
Leanyer	4935	83895	10.3635	71.2614
Lyons (NT)	6759	114903	14.1939	97.59996
Malak - Marrara	4645	78965	9.7545	67.0738
Millner	2642	44914	5.5482	38.15048
Moil	2104	35768	4.4184	30.38176
Nightcliff	4076	69292	8.5596	58.85744
Rapid Creek	3359	57103	7.0539	48.50396
Tiwi	2590	44030	5.439	37.3996
Wagaman	2069	35173	4.3449	29.87636
Wanguri	1899	32283	3.9879	27.42156
Wulagi	2702	45934	5.6742	39.01688
Howard Springs	5711	69674.2	9.7087	71.55883
Humpty Doo	9110	111142	15.487	114.1483
Koolpinyah	14	170.8	0.0238	0.17542
Virginia	3480	42456	5.916	43.6044
Weddell	4610	56242	7.837	57.7633
Bakewell	3314	40430.8	5.6338	41.52442
Driver	2863	34928.6	4.8671	35.87339

SA2[1]	Population[2] (P_i)	$PM_{2.5}$ (µg/m^3) (P_i x C_i)	NO_2 (ppm) (P_i x C_i)	O_3 (ppm) (P_i x C_i)
Durack - Marlow Lagoon	4859	59279.8	8.2603	60.88327
Gray	3410	41602	5.797	42.7273
Moulden	3278	39991.6	5.5726	41.07334
Palmerston - North	4761	58084.2	8.0937	59.65533
Palmerston - South	8138	99283.6	13.8346	101.96914
Rosebery - Bellamack	6932	84570.4	11.7844	86.85796
Woodroffe	3401	41492.2	5.7817	42.61453
Population Weighted Exposure	**Population**	**$PM_{2.5}$ (µg/m^3)**	**NO_2 (ppm)**	**O_3 (ppm)**
Greater Darwin Region	150736	13.92	0.00218	0.0142

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

[2]Population from ABS 2023 census for the SA2 area

$$\textbf{\textit{Population weighted exposure}} = \sum_i \frac{C_i \times P_i}{P_T}$$

C_i = annual average pollutant concentration at each suburb

P_i = population at each suburb

P_T = total population in Greater Darwin Region

Table 35: Annual average pollutants concentrations (C_i) used to determine population weighted exposure

	$PM_{2.5}$ (µg/m^3)	NO_2 (ppm)	O_3 (ppm)
Palmerston	12.2	0.0017	0.01253
Stokes Hill	9.2	0.004	0.01884
Winnellie	17.0	0.0021	0.01444