Northern Territory Ambient Air Quality Monitoring Report 2022

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
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
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/m³	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

This report presents Northern Territory air quality monitoring data for the 2022 calendar year and assesses them against the requirements for *National Environment Protection (Ambient Air Quality) Measure* (AAQ NEPM).

During 2022, 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.

Assessment of goal compliance: During 2022, none of the designated ambient air quality monitoring stations in the Darwin region recorded any exceedances of the AAQ NEPM standards for NO_2, SO_2, O_3 and CO; sufficient data was collected to demonstrate compliance of the stations with the AAQ NEPM goal for these air pollutants. Several exceedances of the short-term standards were recorded for PM_{10} and $PM_{2.5}$ in Darwin and Katherine, but these exceedances were directly associated with exceptional events such as bushfire smoke. All the stations, except Stokes Hill, recorded exceedances of the 1-year average $PM_{2.5}$ standard, but none recorded any exceedances of the 1-year average PM_{10} standard.

Carbon monoxide: During 2022, 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: There were no exceedances of the 1-hour or 1-year NO_2 standards at the stations during 2022. All the stations demonstrated compliance with the AAQ NEPM goal for NO_2.

Ozone: During 2022, 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 2022.

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. Katherine recorded 10

exceedances, Palmerston recorded 2 exceedances, Stokes Hill recorded 5 exceedances, and Winnellie recorded 4 exceedances of the 1-day standard, but these exceedances were linked to smoke from bushfires, which are exceptional events. The PM_{10} 1-year averages of 22.2, 13.1, 17.0 and 15.7 $\mu g/m^3$ at Katherine, Palmerston, Stokes Hill and Winnellie, respectively, were below the AAQ NEPM standard of 25 $\mu g/m^3$. Thus during 2022, all the stations 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 2022, all exceedances of the $PM_{2.5}$ 1-day standard (19 at Katherine, 12 at Palmerston, 5 at Stokes Hill and 19 at Winnellie) were linked to smoke from bushfires, which are classified as exceptional events. The $PM_{2.5}$ 1-year averages of 11.8, 8.6 and 10.3 $\mu g/m^3$ at Katherine, Palmerston, and Winnellie respectively, were above the AAQ NEPM standard of 8 $\mu g/m^3$; as such, these stations did not comply with the AAQ NEPM goal for $PM_{2.5}$. Stokes Hill's annual average of 5.8 $\mu g/m^3$ was below the standard, so this station met the AAQ NEPM goals for $PM_{2.5}$.

It is now a requirement by the AAQ NEPM that jurisdictions should report population exposure for particles as $PM_{2.5}$ as well as for NO_2 and O_3. Using a simplified approach, a population-weighted annual average concentration of 9.0 $\mu g/m^3$ was estimated for $PM_{2.5}$: 0.0022 ppm for NO_2; and 0.015 ppm for O_3 in the Greater Darwin Region in 2022.

2 Background

The Department of Environment, Parks and Water Security (DEPWS) 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).

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

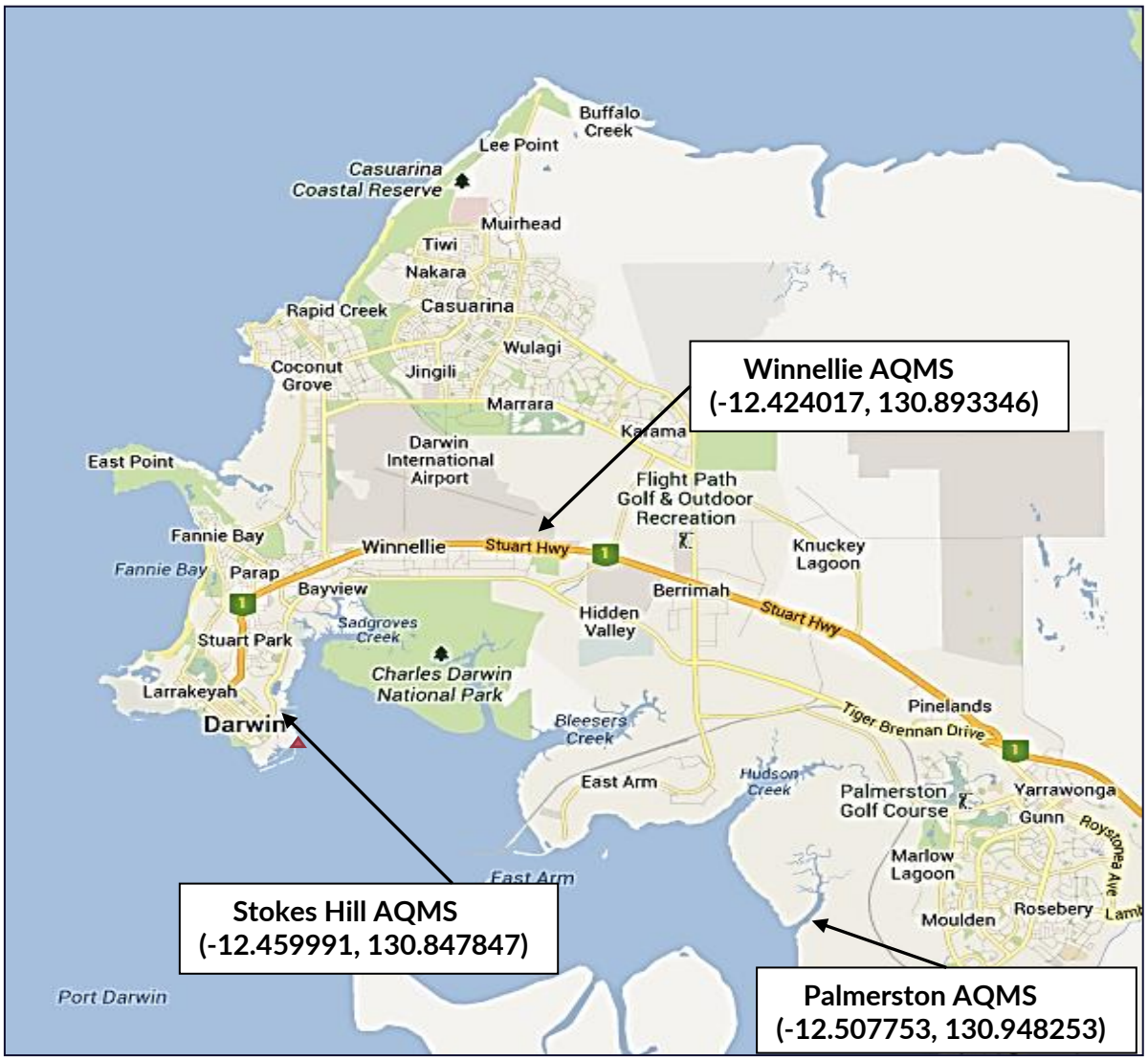

Figure 1a: Locations of Palmerston, Winnellie and Stokes Hill Air Quality Monitoring Stations (AQMS) in the Greater Darwin Region (Stokes Hill AQMS was previously located at -12.466983, 130.850584▲)

Consistent with the reporting period defined in the AAQ NEPM, this report covers the calendar year ending on 31 December 2022 for data collected from the NT EPA monitoring stations located at Palmerston, Winnellie and Stokes Hill (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 AAQ NEPM.

This technical report, *Northern Territory Ambient Air Quality Monitoring Report 2022 - 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.

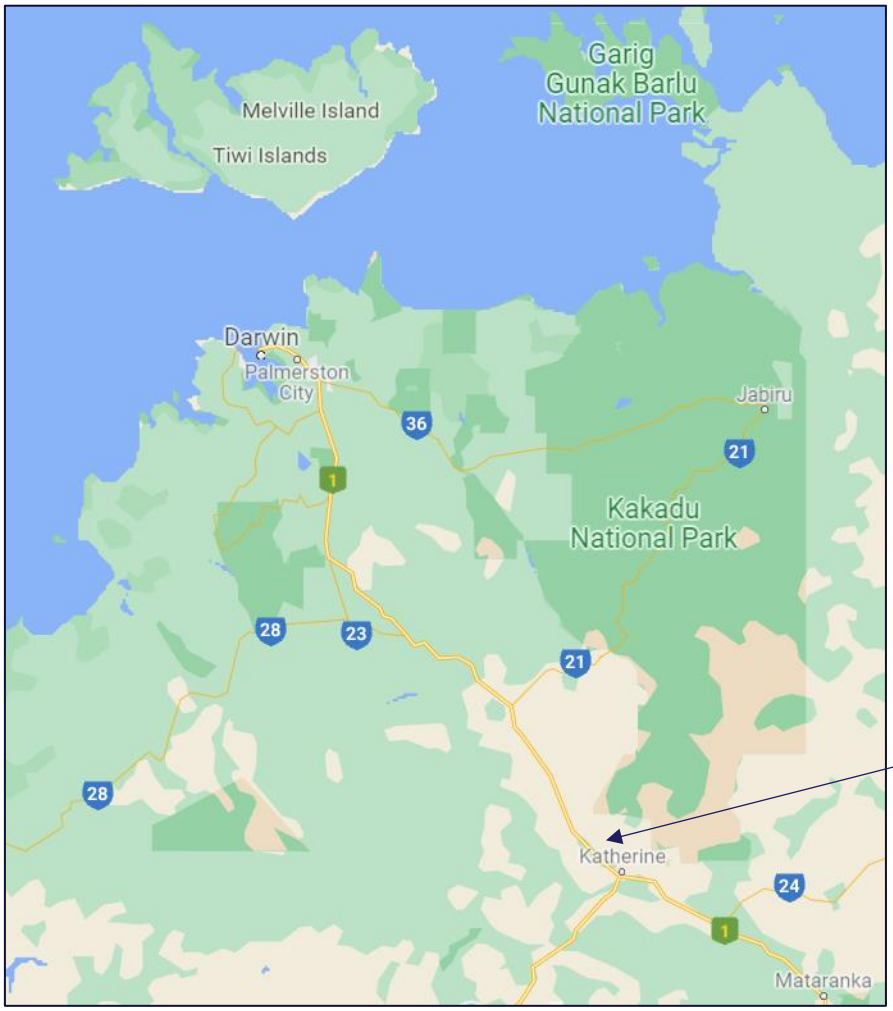

Figure 1b. Katherine AQMS - operated by Katherine Town Council

3 Overview of the 2022 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 unleaded 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 samplers. 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 4km 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 in 2017; it was relocated to a site about 600m east of the CDB (~800m north of original site) 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 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 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 2022 data: $PM_{2.5}$ annual average levels were 8.6, 10.3 and 5.8 $\mu g/m^3$ at Palmerston, Winnellie and Stokes Hill 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 3580.1.1:2007 (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.

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 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. With the exception of Stokes Hill AQMS, 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. The TEOM at Stokes Hill AQMS does not operate with an FDMS unit.

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 1405D 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 1405D 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*

3.4 Monitoring during the reporting period

Palmerston, Winnellie and Stokes Hill stations monitor the same suite of air pollutants; Katherine only monitors particulates. During 2022, 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 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 was at least 75% for each quarter of the year.

Performance is assessed as not meeting standards and goal of the AAAQ 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 (less than 75% availability in any quarter of the year), then performance is assessed as not demonstrated (ND), even if there were no exceedances recorded.

4.1 Carbon monoxide compliance

Table 5: 2022 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	100	99	98	0	Met
Stokes Hill	96	100	99	99	98	0	Met
Winnellie	99	100	100	92	97	0	Met

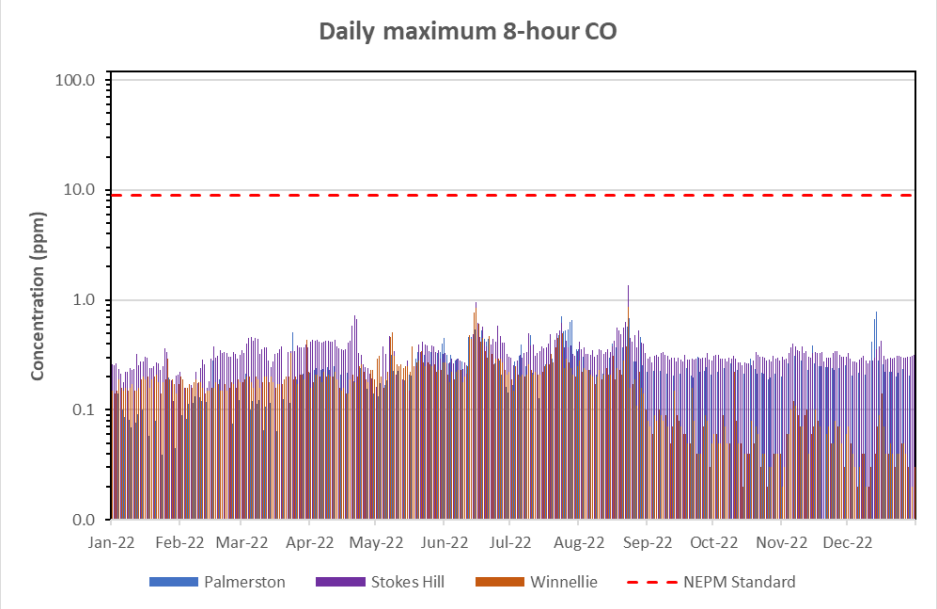

Figure 2: Daily maximum Carbon Monoxide 8-hour averages for Palmerston, Stokes Hill and Winnellie in 2022

During 2022, 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: 2022 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	88	91	91	91	90	0	0.0017	Met	Met
Stokes Hill	92	96	90	95	93	0	0.0043	Met	Met
Winnellie	94	75	95	83	85	0	0.0021	Met	Met

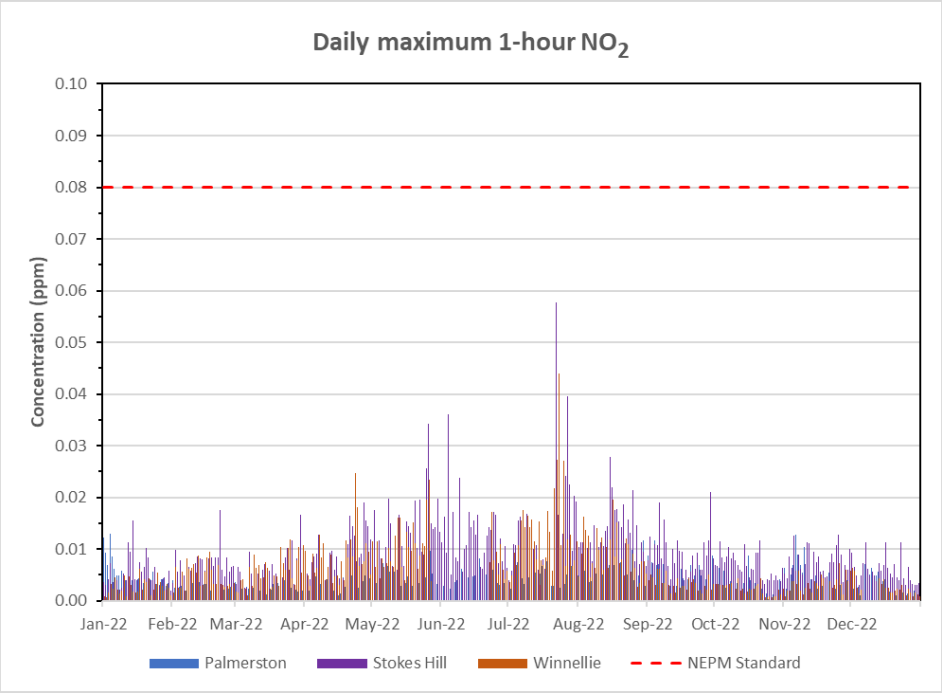

Figure 3: Daily maximum Nitrogen Dioxide 1-hour averages for Palmerston, Stokes Hill and Winnellie in 2022

In 2022, 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: 2022 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	95	99	99	99	98	0	Met
Stokes Hill	96	99	100	100	99	0	Met
Winnellie	98	99	100	92	97	0	Met

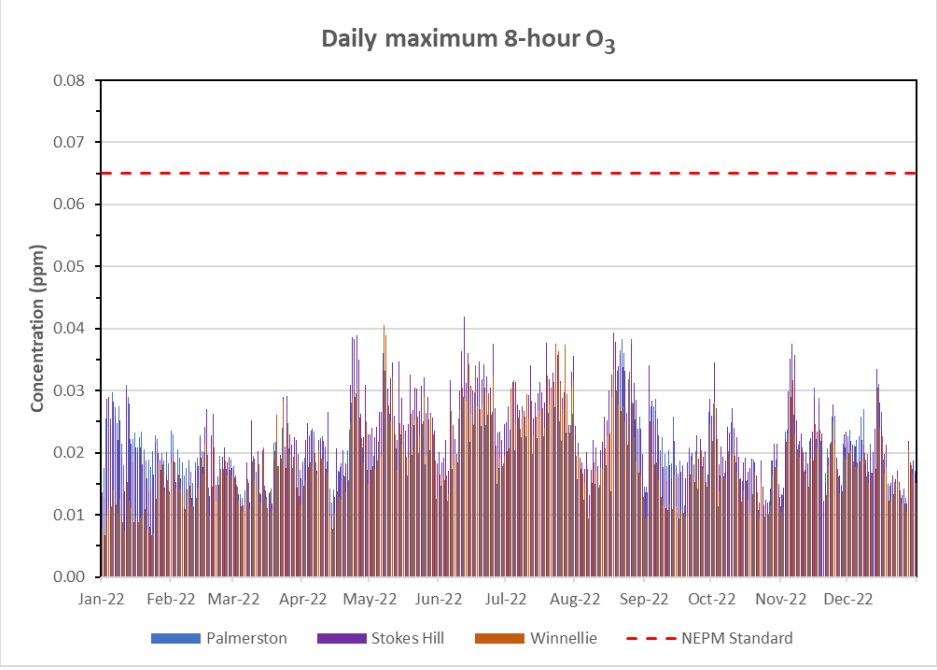

Figure 4: Daily maximum Ozone 8-hour averages for Palmerston, Stokes Hill and Winnellie in 2022

During 2022, 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.

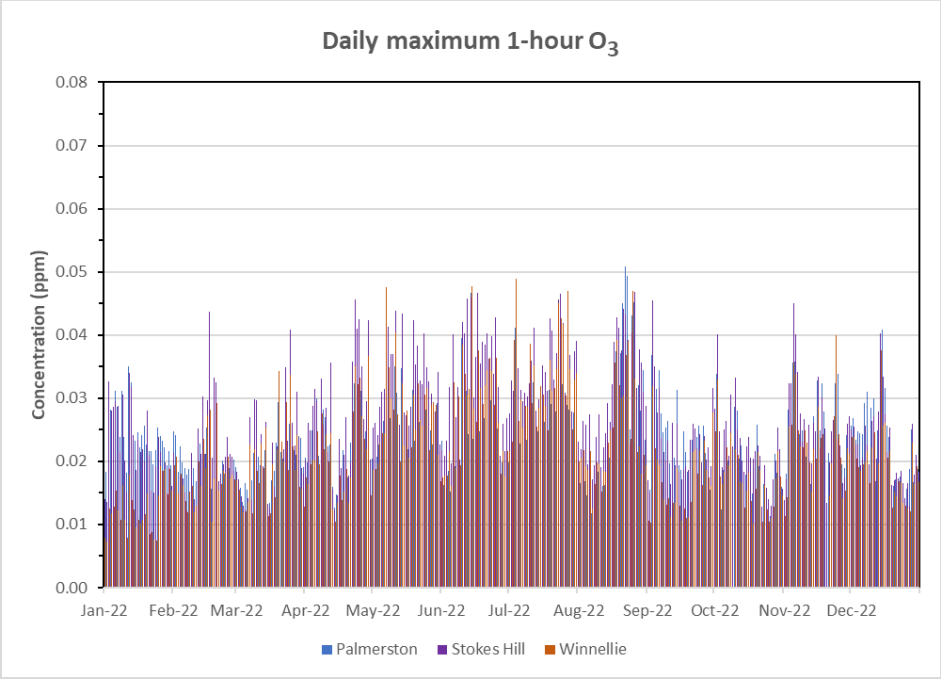

Figure 5: Daily maximum Ozone 1-hour averages for Palmerston, Stokes Hill and Winnellie in 2022

4.4 Sulfur dioxide compliance

Table 8: 2022 compliance summary for SO_2 in the Northern Territory

AAQ NEPM Standard

0.10 ppm (1-hour average)

0.02 ppm (1-day 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	24h	1h	24h
Palmerston	88	89	91	91	90	0	0	Met	Met
Stokes Hill	92	92	77	95	89	0	0	Met	Met
Winnellie	94	95	95	89	93	0	0	Met	Met

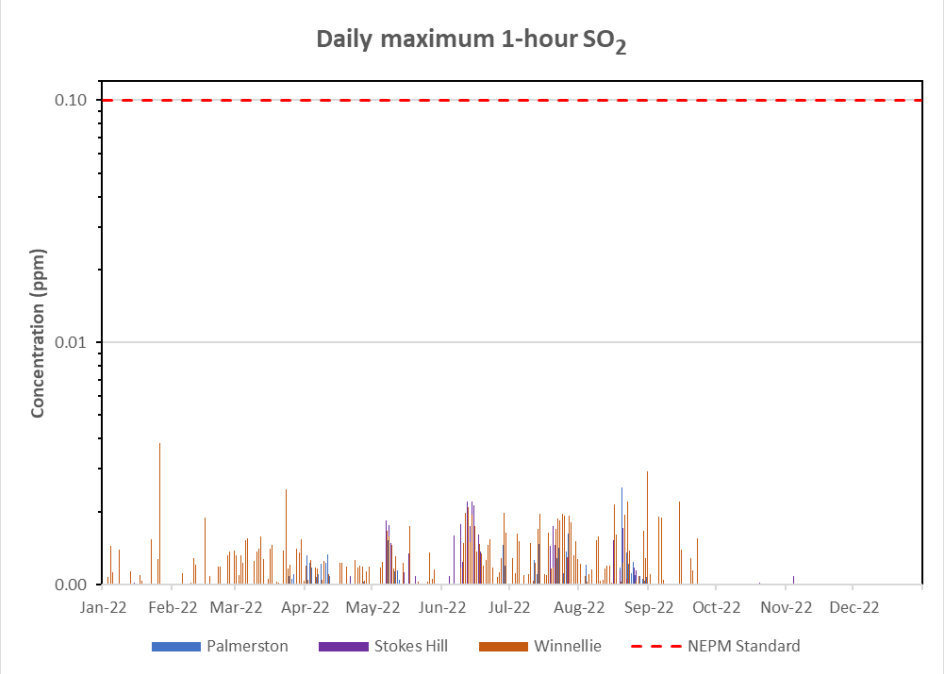

Figure 6: Daily maximum Sulfur Dioxide 1-hour averages for Palmerston, Stokes Hill and Winnellie in 2022

During 2022, 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.

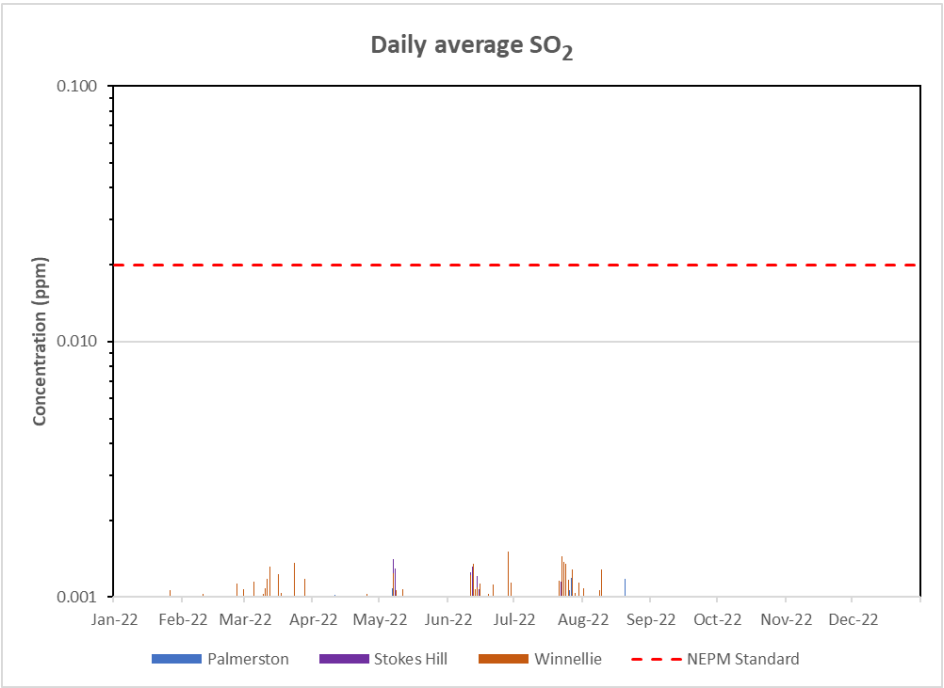

Figure 7: Sulfur Dioxide 1-day averages for Palmerston, Stokes Hill and Winnellie in 2022

4.5 Particulates (PM_{10}) compliance

Table 9: 2022 compliance summary for PM_{10} in the Northern Territory

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
								AAQ NEPM Standard	
								50 µg/m³ (1-day average)	
								25 µg/m³ (1-year average)	
Katherine:									
Katherine	75	89	96	87	85	10	22.2	Met	Met
Darwin:									
Palmerston	77	78	84	92	83	2	13.1	Met	Met
Stokes Hill	79	100	100	100	95	5	17.0	Met	Met
Winnellie	96	100	100	75	93	4	15.7	Met	Met

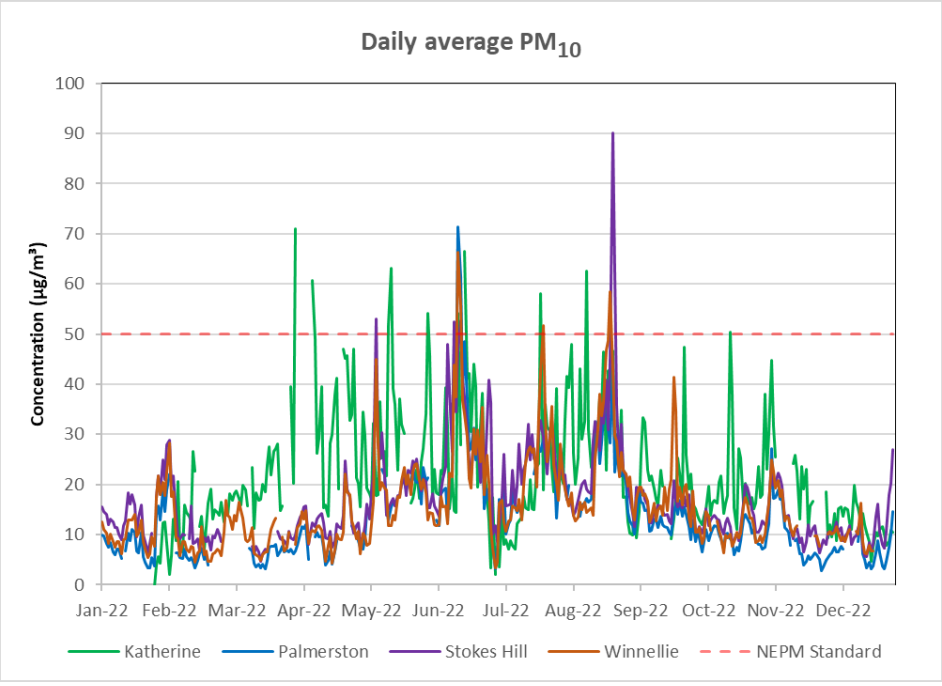

Figure 8: PM_{10} 1-day averages for Katherine, Palmerston, Stokes Hill and Winnellie in 2022

During 2022, 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 averages for all the stations were below the 1-year standard. Sufficient data was collected at all the stations to demonstrate compliance with the AAQ NEPM goal for PM_{10} at each station.

4.6 Particulates ($PM_{2.5}$) compliance

Table 10: 2022 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	75	89	96	87	85	19	11.8	Met	Not met
Darwin:									
Palmerston	77	78	84	92	83	12	8.6	Met	Not met
Stokes Hill	79	100	100	100	95	5	5.8	Met	Met
Winnellie	96	100	100	78	93	19	10.3	Met	Not met

During 2022, 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.

Katherine, Palmerston and Winnellie did not meet the NEPM $PM_{2.5}$ goal, as their 1-year averages were all above the AAQ NEPM standard. The 1-year average for Stokes Hill was below the 1-year average standard of 8 µg/m³, and sufficient data was collected there to demonstrate compliance with the goal.

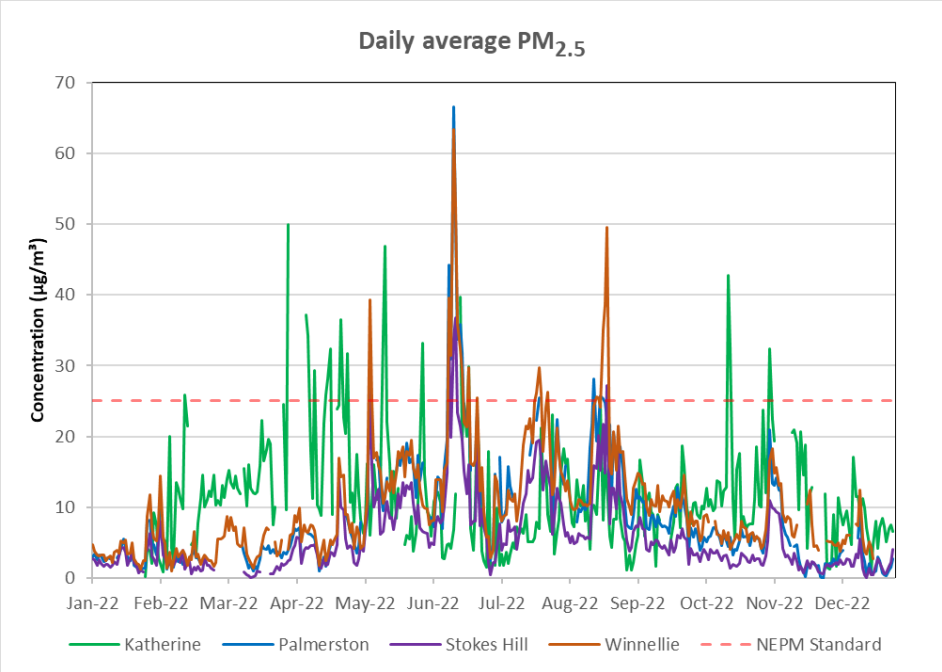

Figure 9: $PM_{2.5}$ 1-day averages for Katherine, Palmerston, Stokes Hill and Winnellie in 2022

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."

5 Analysis of air quality data

This section presents summary statistics of pollutants concentrations recorded in 2022. 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 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: 2022 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	358	0.78	14/12/2022 10:00	0.71	24/07/2022 08:00
Stokes Hill	357	1.35	23/08/2022 08:00	0.96	15/06/2022 08:00
Winnellie	352	0.88	23/08/2022 08:00	0.87	15/06/2022 08:00

CO levels at all the stations were well below the CO 8-hour rolling average standard during the year. The highest event, recorded at Stokes Hill (1.35 ppm, 8am on 23 August 2022) was about 15% of the AAQ NEPM standard. The next highest peak also occurred at Stokes Hill (0.96 ppm, 8am on 15 June 2022). Winnellie recorded its highest and second highest peaks on those days respectively.

5.2 Nitrogen dioxide statistics

Table 12: 2022 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	359	0.013	04/01/2022 19:00	0.013	06/11/2022 23:00
Stokes Hill	351	0.058	22/07/2022 21:00	0.040	27/07/2022 20:00
Winnellie	320	0.044	23/07/2022 22:00	0.027	22/07/2022 22:00

NO_2 levels were below the new AAQ NEPM 1-hour NO_2 standard of 0.08 ppm. The highest recorded reading (0.058 ppm) was recorded at Stokes Hill at 9 pm on 22 July 2022; the second highest peak was recorded at Winnellie (0.044 ppm). Both concentrations were much greater than the highest peaks recorded at Palmerston and were greater than 50% of the NEPM standard.

5.3 Ozone statistics

Table 13: 2022 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	358	0.038	26/08/2022 18:00	0.038	22/08/2022 18:00
Stokes Hill	359	0.042	12/06/2022 17:00	0.039	18/08/2022 17:00
Winnellie	350	0.041	07/05/2022 23:00	0.038	23/07/2022 20:00

There were no exceedances of the 8-hour O_3 standard at any of the monitoring sites. The highest peak of 0.042 ppm, recorded at Stokes Hill on June 12, is about 65% of the standard; the other stations also recorded

elevated ozone levels on that day. This event day was characterised by high temperatures (~30 °C, maximum) and high solar radiation (~850 W/m^2, maximum). All the stations recorded high particulate levels from bushfire smoke on June 12, when the highest O_3 was recorded.

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

Table 14: 2022 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	358	0.051	22/08/2022 16:00	0.049	23/08/2022 16:00
Stokes Hill	359	0.047	26/08/2022 15:00	0.047	17/06/2022 18:00
Winnellie	350	0.049	04/07/2022 15:00	0.048	14/06/2022 18:00

5.4 Sulfur dioxide statistics

Table 15: 2022 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	0.0025	20/08/2022 20:00	0.0016	27/07/2022 15:00
Stokes Hill	337	0.0022	12/06/2022 08:00	0.0022	14/06/2022 03:00
Winnellie	352	0.0038	26/01/2022 08:00	0.0029	31/08/2022 14:00

SO_2 levels in the Darwin region were substantially below the AAQ NEPM 1-hour and 1-day SO_2 standards. The highest recorded 1-hour reading was at Winnellie (0.0038 ppm) at 8am on 26 January. Winnellie also

recorded the highest daily average SO_2 concentration (0.0015 ppm) on 28 June. These values are comparable to peak concentrations recorded at the other stations.

Table 16: 2022 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	356	0.0012	27/07/2022	0.0012	20/08/2022
Stokes Hill	337	0.0014	07/05/2022	0.0013	12/06/2022
Winnellie	352	0.0015	28/06/2022	0.0014	22/07/2022

5.5 Particulates statistics

Stokes Hill recorded the highest PM_{10} event (90.1 μg/m³) on 24 August 2022 (Table 17); the other Darwin stations recorded high PM_{10} levels on this day but did not exceed the NEPM standard. This plume did not have elevated levels of combustion products $PM_{2.5}$, O_3, CO and NOx, which suggests dust as the source.

Palmerston recorded the next highest PM_{10} event (71.3 μg/m³) on 14 June 2022; the plume was associated with a smoke event as it had substantial levels of $PM_{2.5}$ (see also Appendix A: Particulates Events for 2022). The highest peak recorded at Katherine AQMS was 71.0 μg/m³ (31 March 2022). 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.

The highest $PM_{2.5}$ concentration (66.6 μg/m³) was recorded at Palmerston on 14 June 2022, and the next highest (63.3 μg/m³) was recorded at Winnellie, also on the same day; 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 17: 2022 summary statistics for 24-hour PM_{10} in the Northern Territory

AAQ NEPM Standard

50 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)
Katherine	309	71.0	31/03/2022	66.5	17/06/2022
Palmerston	302	71.3	14/06/2022	61.5	15/06/2022
Stokes Hill	344	90.1	24/08/2022	62.3	25/08/2022
Winnellie	337	66.4	14/06/2022	58.5	23/08/2022

Table 18: 2022 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)
Katherine	309	50.0	31/03/2022	46.9	14/05/2022
Palmerston	302	66.6	14/06/2022	50.6	15/06/2022
Stokes Hill	344	36.7	15/06/2022	34.4	12/06/2022
Winnellie	340	63.3	14/06/2022	52.4	15/06/2022

6 Analysis of exceedances and population exposure

This section will analyse exceedance events that occurred during 2022 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-October) and the Wet (November-April). In general, air quality was excellent during the Wet, but poor during the Dry of 2022. Averaged daily levels of $PM_{2.5}$ across all the Darwin stations over the six months of the Dry was 12 $\mu g/m^3$; compared to 4 $\mu g/m^3$ during the Wet. 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 2022 was 8 $\mu g/m^3$, which is not greater than the AAQ NEPM standard. The $PM_{2.5}$ annual average across all Darwin stations for 2021 was 9 $\mu g/m^3$. These averages are different from population-weighted averages discussed in the next subsection.

The 1-day standard for $PM_{2.5}$ had multiple exceedances in 2022 (Figure 9). There were 12 exceedances of the 1-day standard at Palmerston station and the annual limit was exceeded. Winnellie station recorded 19 exceedances of the 1-day standard and exceeded the annual limit. Katherine recorded 19 exceedances of the 1-day standard and exceeded the annual limit. Stokes Hill station recorded only five exceedances of the 1-day standard and did not exceed the annual limit. 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 2022).

The AAQ NEPM 1-day standard for PM_{10} was exceeded on several days: Katherine recorded 10; Palmerston recorded two; Stokes Hill recorded five and Winnellie recoded four. None of the stations exceeded the annual PM_{10} limit. 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.

Tables 19 - 26 show dates and inferred causes of particulate exceedances for all stations.

Table 19: 2022 PM_{10} exceedances of 24-hour AAQ NEPM standard at Katherine AQMS

Date	PM_{10} (µg/m^3)	Inferred Cause
31-Mar	71.0	smoke
8-Apr	60.6	smoke
13-May	51.8	smoke
14-May	63.1	smoke
31-May	54.2	smoke
14-Jun	54.2	smoke
17-Jun	66.5	smoke
22-Jul	58.1	smoke
12-Aug	62.6	smoke
17-Oct	50.3	smoke

Table 20: 2022 PM_{10} exceedances of 24-hour AAQ NEPM standard at Palmerston AQMS

Date	PM_{10} (µg/m^3)	Inferred Cause
14-Jun	71.3	smoke
15-Jun	61.5	smoke

Table 21: 2022 PM_{10} exceedances of 24-hour AAQ NEPM standard at Stokes Hill AQMS

Date	PM_{10} (µg/m^3)	Inferred Cause
7-May	53.0	smoke
12-Jun	52.5	smoke
15-Jun	52.6	smoke
24-Aug	90.1	dust
25-Aug	62.3	dust

Table 22: 2022 PM_{10} exceedances of 24-hour AAQ NEPM standard at Winnellie AQMS

Date	PM_{10} (µg/m^3)	Inferred Cause
14-Jun	66.4	smoke
15-Jun	55.7	smoke
23-Jul	51.6	smoke
23-Aug	58.5	smoke

Table 23: 2022 $PM_{2.5}$ exceedances of 24-hour AAQ NEPM standard at Katherine AQMS

Date	$PM_{2.5}$ (µg/m^3)	Inferred Cause
12-Feb	25.8	smoke
31-Mar	50.0	smoke
6-Apr	34.0	smoke
8-Apr	37.1	smoke
9-Apr	34.3	smoke
12-Apr	29.4	smoke
17-Apr	25.9	smoke
18-Apr	28.1	smoke
19-Apr	32.3	smoke
24-Apr	36.5	smoke
27-Apr	31.7	smoke
13-May	34.2	smoke
14-May	46.9	smoke
31-May	33.2	smoke
17-Jun	39.7	smoke
21-Jun	29.8	smoke
17-Oct	42.7	smoke
18-Oct	32.7	smoke
5-Nov	32.4	smoke

Table 24: 2022 $PM_{2.5}$ exceedances of 24-hour AAQ NEPM reporting level at Palmerston AQMS

Date	$PM_{2.5}$ (µg/m^3)	Inferred Cause
12-Jun	44.2	smoke
13-Jun	30.9	smoke
14-Jun	66.6	smoke
15-Jun	50.6	smoke
16-Jun	33.8	smoke
17-Jun	35.8	smoke
18-Jun	31.8	smoke
21-Jun	25.7	smoke
23-Jul	25.5	smoke
17-Aug	28.2	smoke
20-Aug	25.7	smoke
21-Aug	25.3	smoke

Table 25: 2022 $PM_{2.5}$ exceedances of 24-hour AAQ NEPM reporting level at Stokes Hill AQMS

Date	$PM_{2.5}$ (µg/m^3)	Inferred Cause
7-May	27.5	smoke
12-Jun	34.4	smoke
14-Jun	33.9	smoke
15-Jun	36.7	smoke
23-Aug	27.3	smoke

Table 26: 2022 $PM_{2.5}$ exceedances of 24-hour AAQ NEPM reporting level at Winnellie AQMS

Date	$PM_{2.5}$ (µg/m^3)	Inferred Cause
7-May	39.3	smoke
12-Jun	39.6	smoke
13-Jun	31.4	smoke
14-Jun	63.3	smoke
15-Jun	52.4	smoke

Date	$PM_{2.5}$ (µg/m³)	Inferred Cause
16-Jun	36.0	smoke
17-Jun	32.3	smoke
18-Jun	29.2	smoke
21-Jun	29.8	smoke
25-Jun	25.5	smoke
22-Jul	26.2	smoke
23-Jul	29.7	smoke
24-Jul	26.2	smoke
27-Jul	26.3	smoke
18-Aug	25.6	smoke
19-Aug	25.5	smoke
21-Aug	35.1	smoke
22-Aug	38.6	smoke
23-Aug	49.6	smoke

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.

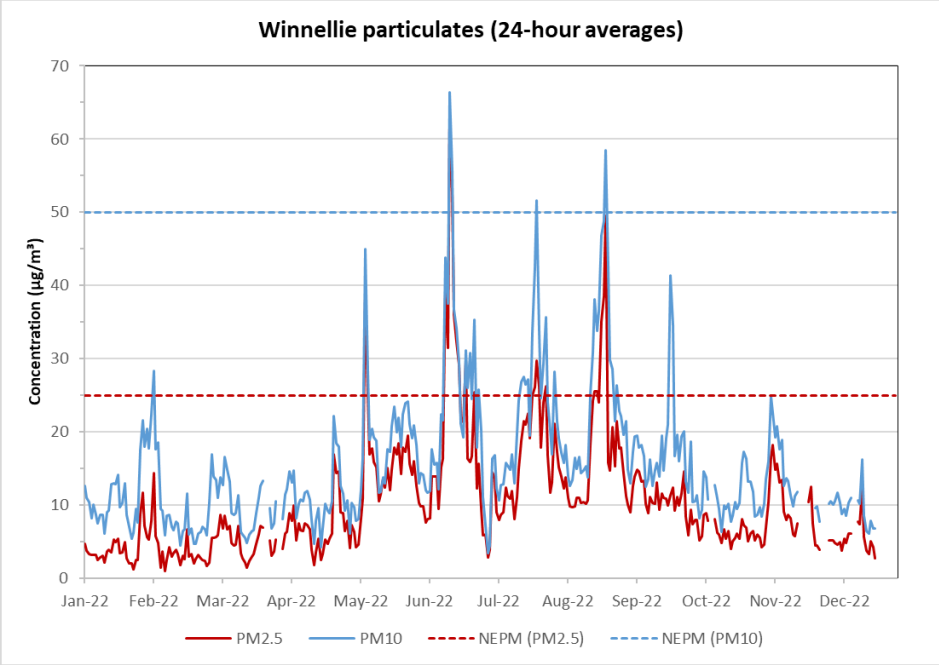

Figure 10: Particulate Matter concentration at Winnellie AQMS during 2022

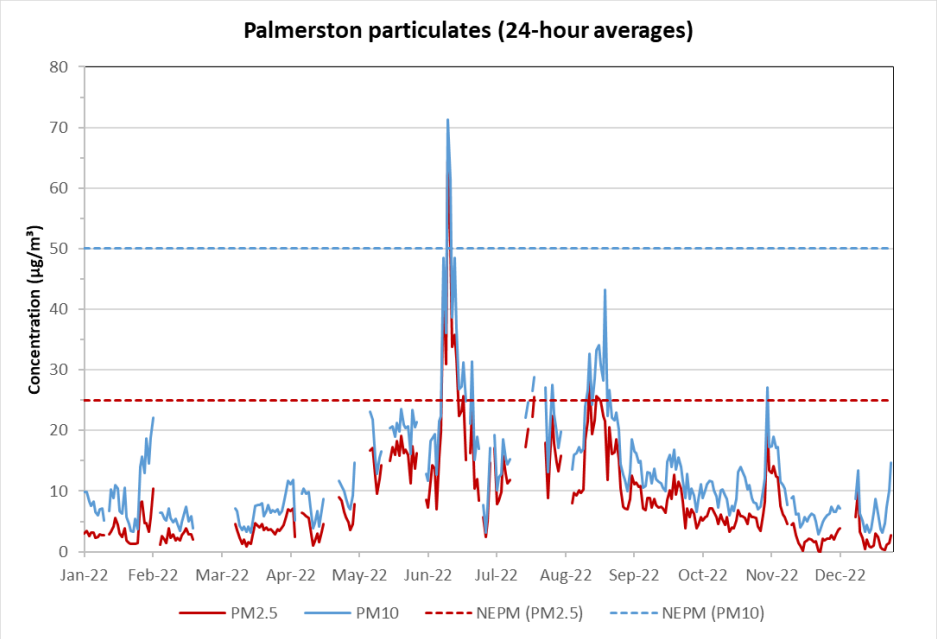

Figure 11: Particulate Matter concentration at Palmerston AQMS during 2022

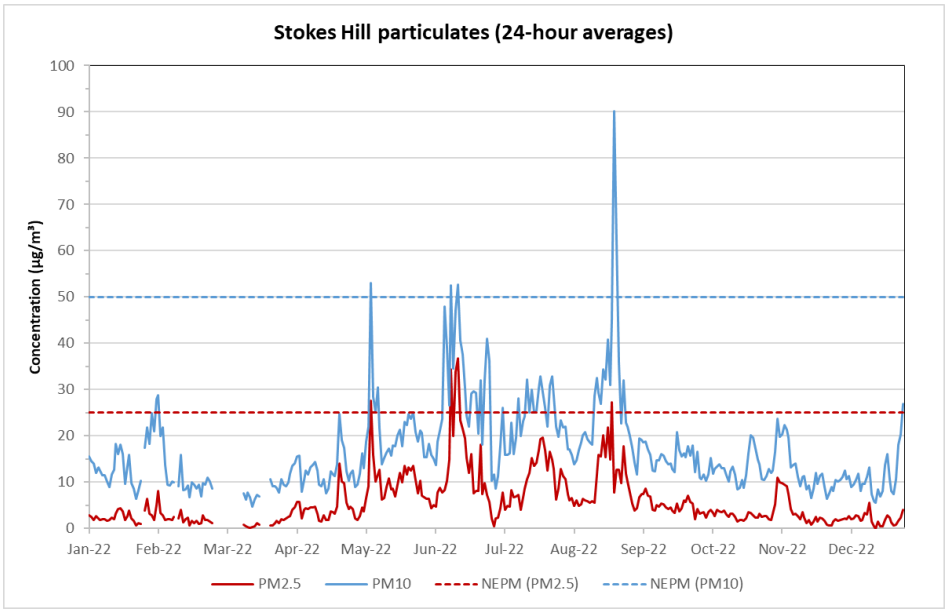

Figure 12: Particulate Matter concentration at Stokes Hill AQMS during 2022

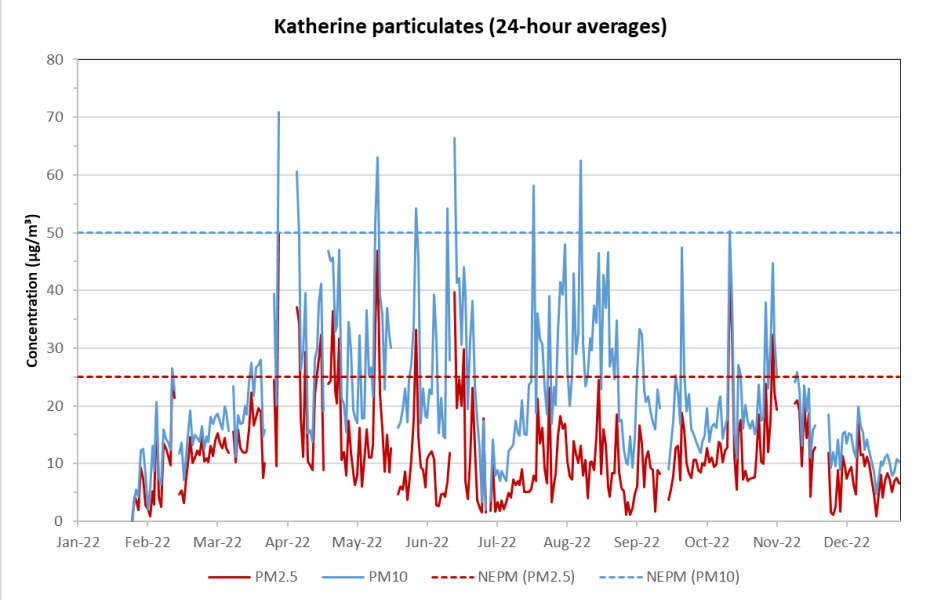

Figure 13: Particulate Matter concentration at Katherine AQMS during 2022

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.

The population-weighted annual average $PM_{2.5}$, NO_2 and O_3 concentrations for the Greater Darwin Region were determined using a simplified approach that outputs a single value for each pollutant (EWG 2017).

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 2021 (ABS 2021). 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 9.0 $\mu g/m^3$ was estimated for $PM_{2.5}$; 0.0022 ppm for NO_2; and 0.015 ppm for O_3 in the Greater Darwin Region in 2022 (see Appendix B for details of the calculations). Population-weighted exposure data for 2022 are compared to data from previous years in Table 27.

Table 27: Historical population-weighted annual concentrations for Greater Darwin

Region	$PM_{2.5}$ ($\mu g/m^3$)	NO_2 (ppm)	O_3 (ppm)
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 28 to 31 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).
- 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.

During the Wet of 2013, the Palmerston TEOM was offline for several 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 28: 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 29: 24-hour PM_{10} Trends (2011-2022)

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	-	-	-	-	-	-
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

Table 30: 24-hour $PM_{2.5}$ Trends (2011-2022)

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	-	-	-	-	-	-
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
2022	83	12	67	93	19	63	95	5	37	85	19	50

Table 31: Averaged Particulates Key Metrics 2004-2022 (across all historical & current monitoring locations)

	Data Availability (%)	Number of Exceedances	Maximum Concentration (µg/m^3)
PM_{10}	86	4	70
$PM_{2.5}$	84	11	47

Historical data for the 2004 to 2022 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 all the stations in 2022 compared to 2021; but a general downward trend exists across most years.

The population of the Greater Darwin region has increased from approximately 105,000 in 2004 to ~140,000 in 2022 showing a clear upward trend in population. 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.

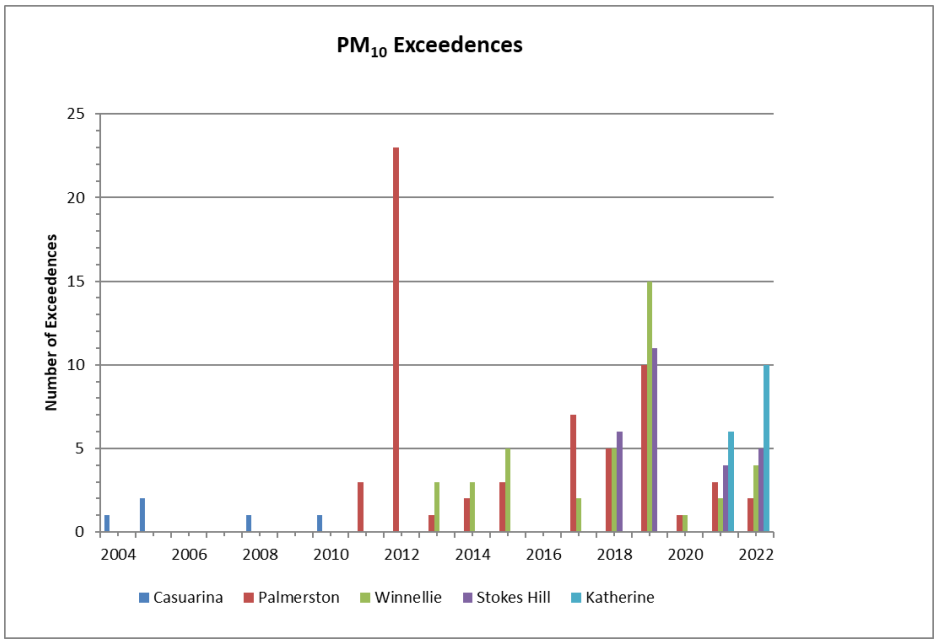

Figure 14: Historical PM_{10} exceedances of 24-hour AAQ NEPM

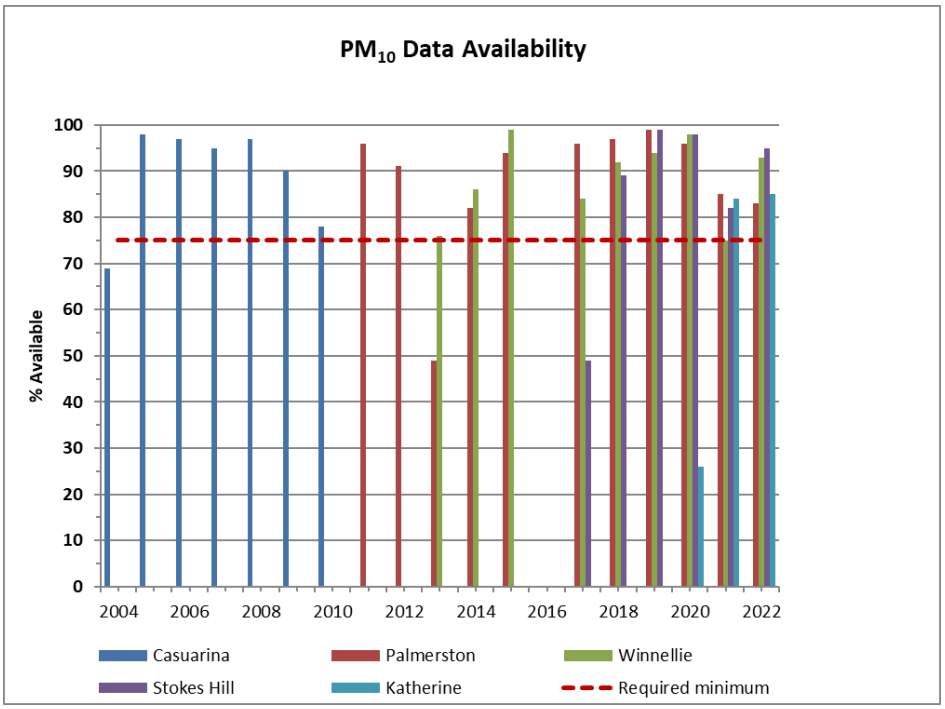

Figure 15: Historical PM_{10} data availability

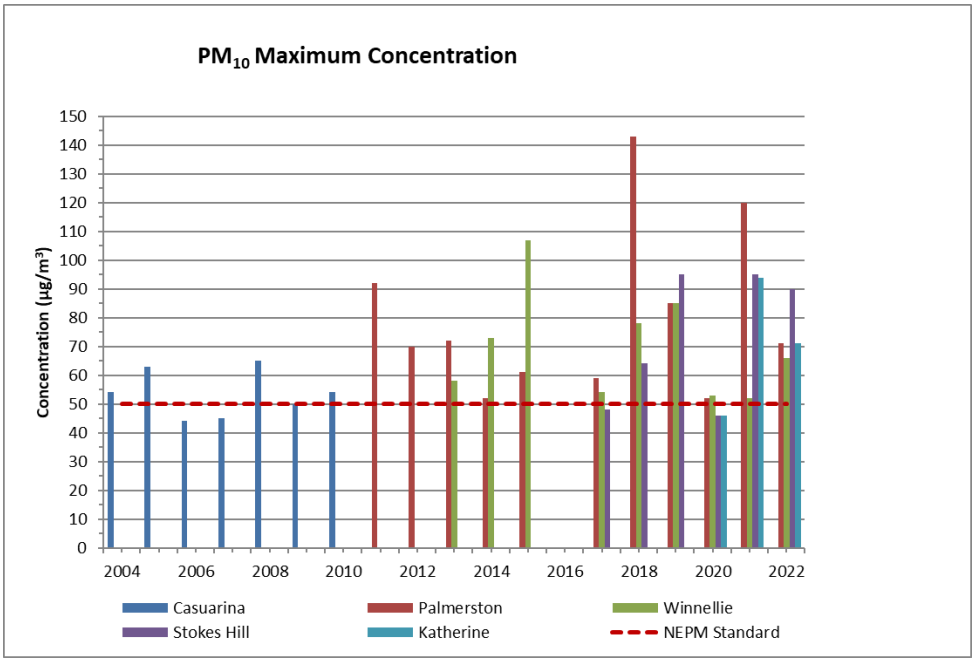

Figure 16: Historical maximum 24-hour PM_{10} concentrations

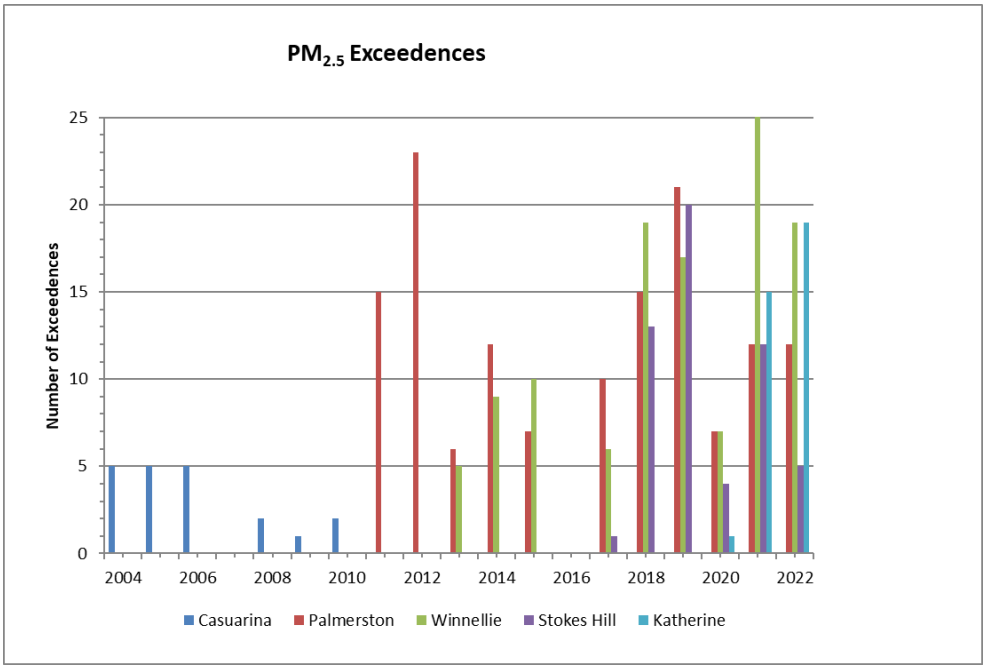

Figure 17: Historical $PM_{2.5}$ exceedances of 24-hour AAQ NEPM

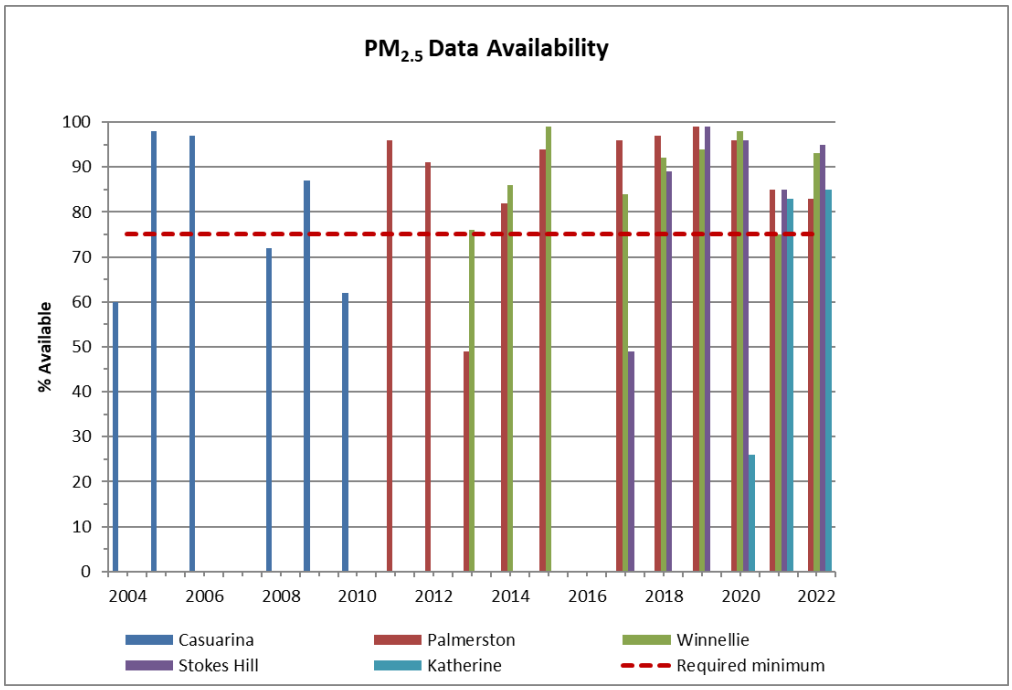

Figure 18: Historical $PM_{2.5}$ data availability

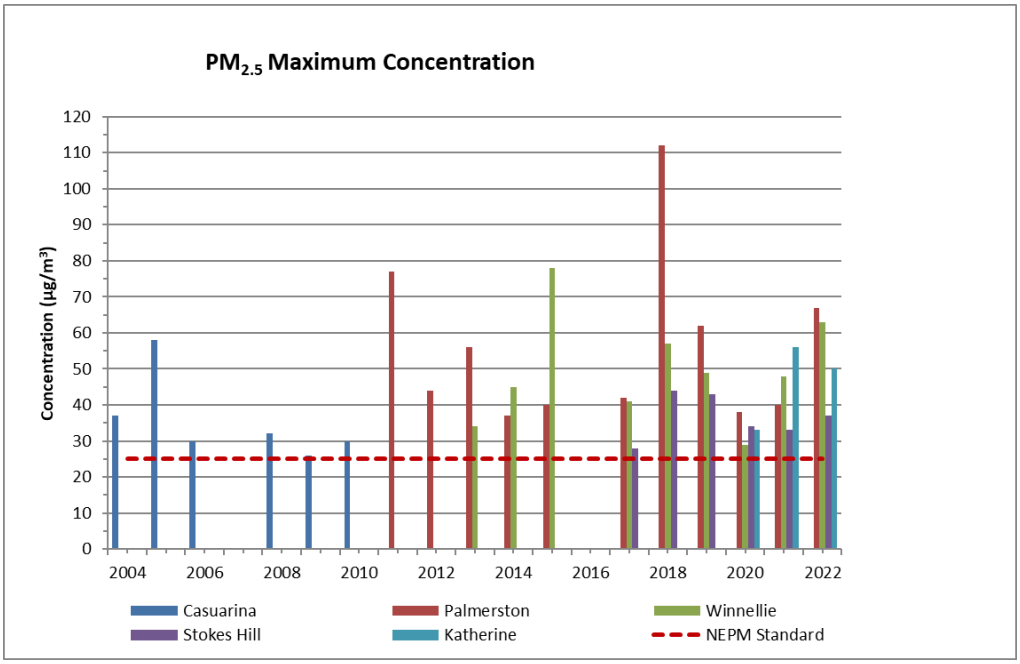

Figure 19: Historical $PM_{2.5}$ 24-hour maximum concentrations

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 2022) 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 2022. 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 in June for all the stations (12 - 22 $\mu g/m^3$), with area burnt (1150 sq km). A second peak occurred in August for all the stations as well as area burnt. There was a general decline in both parameters after August.

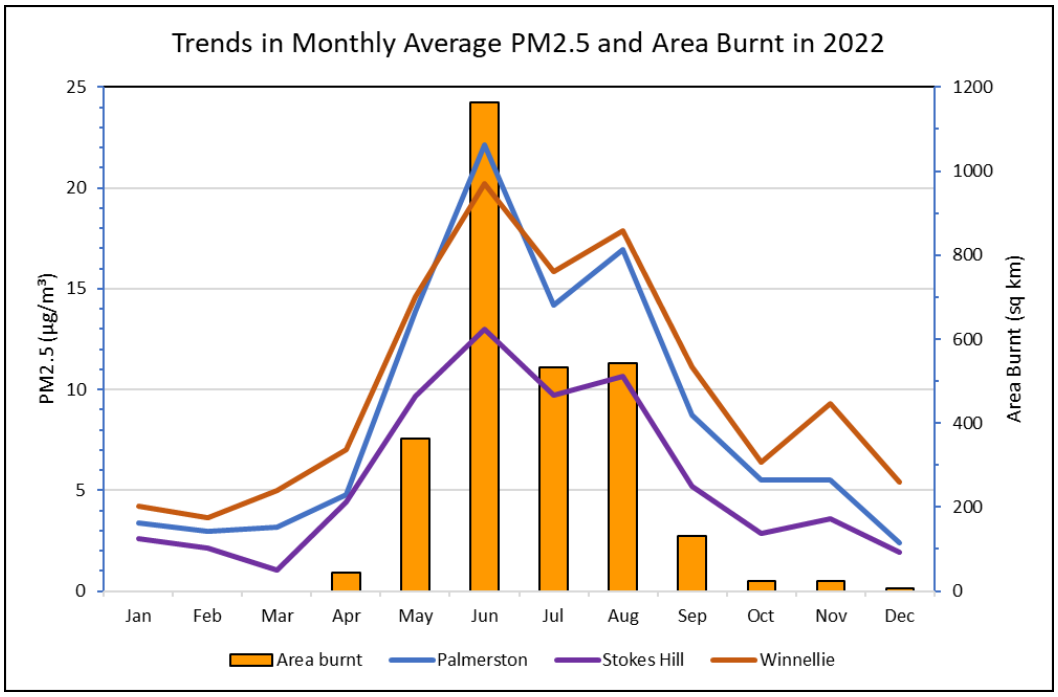

Figure 20: Comparison of $PM_{2.5}$ levels with Area Burnt (50 km radius from McMinns Lagoon)

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. The picture in Figure 21 shows that smoke from fires burning in areas in Marrakai (about 80 km southeast of Darwin and 35 km east of Batchelor), on 12 June 2022, could have affected air quality in the Darwin region. Palmerston and Winnellie stations both recorded $PM_{2.5}$ levels above the AAQ NEPM standard on seven consecutive days (12 to 18 June 2022); Stokes Hill recorded $PM_{2.5}$ exceedances on three days during that period (see Appendix A).

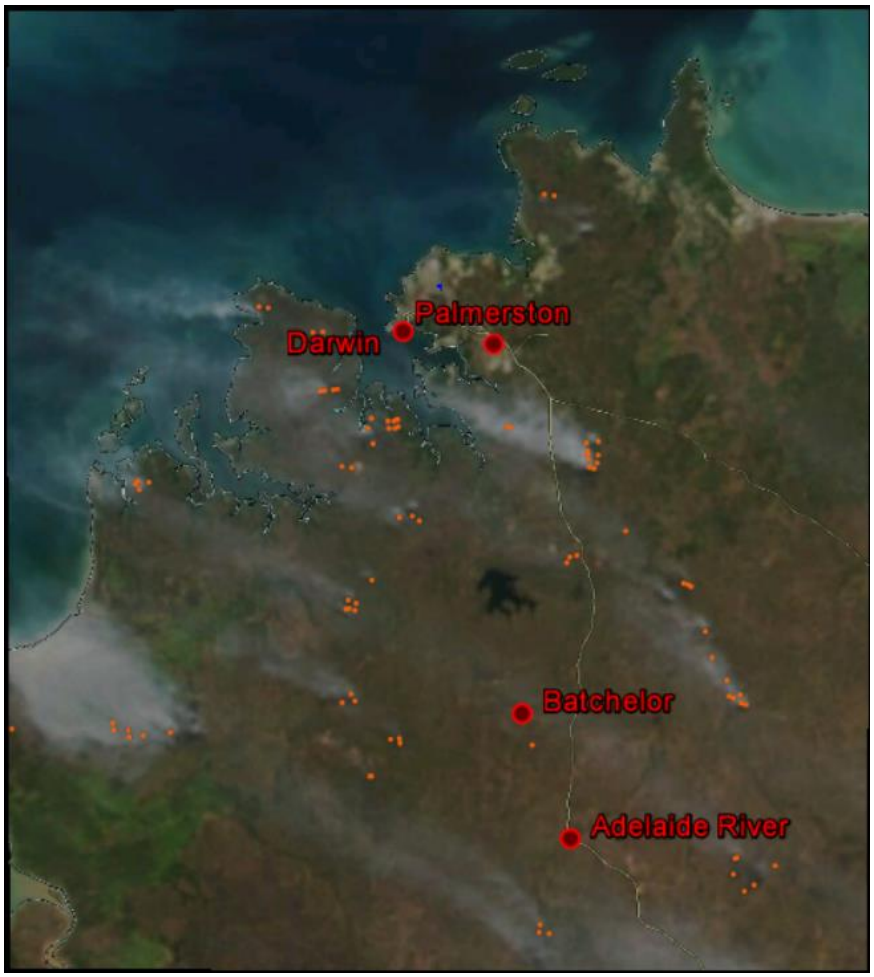

Figure 21: Large-scale fire events impacting the Top End on 12 June 2022 (Source: NASA Worldview)

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.

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Appendix A: Particulates events for 2022

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)

	Particulates Concentration (µg/m³)							
	Katherine		Palmerston		Stokes Hill		Winnellie	
Date	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10
12-Feb	25.8	26.5	2.3	4.6	1.2	8.2	3.3	7.6
31-Mar	50.0	71.0	3.9	6.7	2.5	9.9	4.0	8.1
6-Apr	34.0	38.8	2.5	5.1	2.1	8.0	5.1	8.1
8-Apr	37.1	60.6	n/a	n/a	4.3	12.4	6.6	10.8
9-Apr	34.3	49.0	6.4	9.5	4.1	11.7	6.5	10.5
12-Apr	29.4	39.6	5.6	9.8	4.7	14.3	6.7	10.8
17-Apr	25.9	30.0	1.6	4.2	1.8	7.5	2.5	4.2
18-Apr	28.1	37.8	3.3	6.8	1.9	8.6	3.3	6.8
19-Apr	32.3	41.2	4.6	8.8	3.7	12.2	5.3	10.2
24-Apr	36.5	45.6	n/a	n/a	10.1	19.1	14.3	18.5
27-Apr	31.7	47.0	8.4	10.9	4.2	10.3	8.9	11.5
7-May	6.0	17.8	n/a	n/a	27.5	53.0	39.3	45.0
13-May	34.2	51.8	9.5	12.9	6.5	15.1	10.5	11.7
14-May	46.9	63.1	12.0	15.6	8.9	16.4	11.5	11.8
31-May	33.2	54.2	16.3	21.4	6.6	15.3	10.3	13.0
12-Jun	4.8	14.7	44.2	48.5	34.4	52.5	39.6	43.9
13-Jun	4.2	14.4	30.9	36.2	19.9	34.5	31.4	37.5
14-Jun	6.8	54.2	66.6	71.3	33.9	47.0	63.3	66.4
15-Jun	11.9	27.9	50.6	61.5	36.7	52.6	52.4	55.7
16-Jun	n/a	n/a	33.8	38.6	23.3	40.6	36.0	36.8
17-Jun	39.7	66.5	35.8	48.5	21.4	37.5	32.3	34.1
18-Jun	19.6	41.3	31.8	36.8	19.4	30.2	29.2	29.4
21-Jun	29.8	44.1	25.7	31.2	16.0	29.1	29.8	31.1
25-Jun	23.1	38.2	23.4	31.4	18.1	32.0	25.5	35.3
22-Jul	8.0	58.1	22.3	26.5	19.3	32.8	26.2	42.4
23-Jul	7.0	18.8	25.5	28.8	19.5	29.4	29.7	51.6
24-Jul	21.2	36.0	n/a	n/a	16.9	26.0	26.2	33.9
27-Jul	9.0	23.2	n/a	n/a	14.8	32.8	26.3	35.6
12-Aug	13.1	62.6	10.2	17.2	5.9	19.2	10.2	14.4
17-Aug	10.3	29.6	28.2	32.6	15.8	29.3	24.2	30.9
18-Aug	8.9	37.4	19.4	24.2	15.5	26.9	25.6	38.1
19-Aug	14.8	34.4	21.7	28.5	20.1	34.4	25.5	33.8
20-Aug	24.5	46.5	25.7	33.3	15.3	32.2	24.1	36.5
21-Aug	8.2	22.9	25.3	34.0	21.8	40.8	35.1	46.9
22-Aug	16.0	42.6	24.8	30.9	14.8	30.9	38.6	48.8
23-Aug	13.2	36.9	22.4	28.3	27.3	45.0	49.6	58.5
24-Aug	5.9	46.6	21.6	43.3	7.6	90.1	15.7	42.7
25-Aug	4.3	26.8	11.8	22.5	12.6	62.3	14.7	29.9
17-Oct	42.7	50.3	4.5	9.2	2.4	11.6	6.5	10.1

	Particulates Concentration (µg/m^3)							
	Katherine		Palmerston		Stokes Hill		Winnellie	
Date	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10
18-Oct	32.7	38.1	5.8	8.7	1.4	8.4	4.0	7.7
5-Nov	32.4	44.8	20.9	27.1	10.9	23.6	16.6	24.9
Exceedances	**19**	**10**	**12**	**2**	**5**	**5**	**19**	**4**

n/a – data not available

Appendix B: 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.

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 Airport	18	185.94	0.0378	0.24948
East Point	14	144.62	0.0294	0.19404
Ludmilla - The Narrows	2545	26289.85	5.3445	35.2737
Parap	2747	28376.51	5.7687	38.07342
Woolner - Bayview - Winnellie	2821	29140.93	5.9241	39.09906
Alawa	2127	21971.91	4.4667	29.48022
Anula	2369	24471.77	4.9749	32.83434
Berrimah	1277	13191.41	2.6817	17.69922
Brinkin - Nakara	3581	36991.73	7.5201	49.63266
Buffalo Creek	0	0	0	0
Charles Darwin	0	0	0	0
Coconut Grove	3050	31506.5	6.405	42.273
East Arm	13	134.29	0.0273	0.18018
Jingili	1757	18149.81	3.6897	24.35202
Karama	4944	51071.52	10.3824	68.52384
Leanyer	4578	47290.74	9.6138	63.45108
Lyons (NT)	4799	49573.67	10.0779	66.51414
Malak - Marrara	4549	46991.17	9.5529	63.04914
Millner	2548	26320.84	5.3508	35.31528
Moil	2000	20660	4.2	27.72
Nightcliff	3853	39801.49	8.0913	53.40258
Rapid Creek	3282	33903.06	6.8922	45.48852
Tiwi	2562	26465.46	5.3802	35.50932
Wagaman	2162	22333.46	4.5402	29.96532
Wanguri	1876	19379.08	3.9396	26.00136
Wulagi	2435	25153.55	5.1135	33.7491
Darwin City	6464	37555.84	27.7952	116.61056
Fannie Bay - The Gardens	3351	19469.31	14.4093	60.45204
Larrakeyah	3729	21665.49	16.0347	67.27116
Stuart Park	4149	24105.69	17.8407	74.84796
Howard Springs	6981	59966.79	11.8677	105.13386
Humpty Doo	8711	74827.49	14.8087	131.18766
Koolpinyah	25	214.75	0.0425	0.3765
Virginia	3292	28278.28	5.5964	49.57752
Weddell	4527	38886.93	7.6959	68.17662
Bakewell	3069	26362.71	5.2173	46.21914
Driver	2884	24773.56	4.9028	43.43304
Durack - Marlow Lagoon	4287	36825.33	7.2879	64.56222
Gray	3288	28243.92	5.5896	49.51728

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)
Moulden	2959	25417.81	5.0303	44.56254
Palmerston - North	4231	36344.29	7.1927	63.71886
Palmerston - South	3069	26362.71	5.2173	46.21914
Rosebery - Bellamack	6678	57364.02	11.3526	100.57068
Woodroffe	3233	27771.47	5.4961	48.68898
Population Weighted Exposure	**Population**	**$PM_{2.5}$ (µg/m^3)**	**NO_2 (ppm)**	**O_3 (ppm)**
Greater Darwin Region	**136834**	**9.02**	**0.00222**	**0.0149**

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

[2]Population from ABS 2016 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

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	8.59	0.0017	0.01506
Stokes Hill	5.81	0.0043	0.01804
Winnellie	10.33	0.0021	0.01386