

# Northern Territory Ambient Air Quality Monitoring Report 2021

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

<b>Document title</b>	Northern Territory Ambient Air Quality Monitoring Report 2021
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<b>Approved by</b>	Director Environmental Operations
<b>Date approved</b>	November 2023
<b>TRM number</b>	NTEPA2018/0076-032~0001

Version	Date	Author	Changes made
1.0	August 2023	Environmental Operations	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
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 <sub>2</sub> / NO <sub>x</sub>	Nitric oxide/ Nitrogen dioxide/ Oxides of nitrogen
NT EPA	Northern Territory Environment Protection Authority
O <sub>3</sub>	Ozone
PM <sub>10</sub>	Particulate matter with aerodynamic diameter less than or equal to 10 µm
PM <sub>2.5</sub>	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 <sub>2</sub>	Sulfur dioxide
TEOM	Tapered element oscillating microbalance
µg/m <sup>3</sup>	Micrograms per cubic metre referenced to a temperature of 0 degrees Celsius and an absolute pressure of 101.325 kilopascals
µm	Micrometres (10 <sup>-6</sup> metres)
WMPC Act	Waste Management and Pollution Control Act 1998

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## 1 Summary

This report presents Northern Territory air quality monitoring data for the 2021 calendar year and assesses them against the requirements for *National Environment Protection (Ambient Air Quality) Measure* (AAQ NEPM).

During 2021, the Northern Territory Environment Protection Authority (NT EPA) operated three designated ambient air quality monitoring stations (AQMS) in the Darwin region. These stations, located at Palmerston, Winnellie and Stokes Hill measure and report real-time data on the concentrations of six AAQ NEPM air pollutants: sulfur dioxide (SO<sub>2</sub>), nitrogen dioxide (NO<sub>2</sub>), carbon monoxide (CO), photochemical oxidants as ozone (O<sub>3</sub>), and particulate matter with sizes of 10 micrometres or less (PM<sub>10</sub>) and 2.5 micrometres or less (PM<sub>2.5</sub>). Katherine Town Council operates an air quality monitoring station at Katherine under a performance agreement with the NT EPA: this station monitors PM<sub>10</sub> and PM<sub>2.5</sub> only. Meteorological instruments for measuring parameters such as wind speed and direction, ambient temperature, relative humidity and atmospheric pressure are located at the sites.

In May 2021, Stokes Hill AQMS was relocated to another coastal site about 800m north of the original site. The name of the station and the database were not changed; however, the move resulted in the loss of over 50% of the station's data for the second quarter of that year.

**Assessment of goal compliance:** Compliance was assessed against the amended AAQ NEPM, which came into force on 18 May 2021. Between 1 January and 31 December 2021, none of the designated ambient air quality monitoring stations in the Darwin region recorded any exceedances of the AAQ NEPM standards for NO<sub>2</sub>, SO<sub>2</sub>, O<sub>3</sub> and CO; however, performance against the goals could not be determined for some air pollutants since insufficient data was collected. Several exceedances of the short-term standards were recorded for PM<sub>10</sub> and PM<sub>2.5</sub> 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<sub>2.5</sub> standard, but none recorded any exceedances of the 1-year average PM<sub>10</sub> standard.

**Carbon monoxide:** During 2021, although no exceedances of the 8-hour rolling average standard for CO were recorded at any of the stations, compliance with the AAQ NEPM was not demonstrated at Stokes Hill station due to low data recovery rates (less than 75% in the 2nd quarter), caused by data loss during relocation of the station. The AAQ NEPM goal for CO was met at Palmerston and Winnellie.

**Nitrogen dioxide:** There were no exceedances of the 1-hour or 1-year NO<sub>2</sub> standards at the stations. All the stations demonstrated compliance with the 1-year standard for NO<sub>2</sub>, but only Winnellie demonstrated compliance with the short-term standard due to loss of data at the other two stations.

**Ozone:** During 2021, no exceedances of the 8-hour rolling average O<sub>3</sub> standard were recorded at any of the stations – all the stations except Stokes Hill demonstrated compliance with the AAQ NEPM goal for ozone. There was insufficient data at Stokes Hill to demonstrate compliance.

**Sulfur dioxide:** There were no recorded exceedances of the SO<sub>2</sub> 1-hour and 1-day standards at any of the stations. Compliance with the AAQ NEPM goal for SO<sub>2</sub> was only demonstrated at Winnellie.

**PM<sub>10</sub>:** To comply with the AAQ NEPM 1-day standard for particles as PM<sub>10</sub>, no exceedance of the 1-day average standard of 50 µg/m<sup>3</sup> is allowed, unless determined as an exceptional event. Katherine recorded 6 exceedances, Palmerston recorded 3 exceedances, Stokes Hill recorded 4 exceedances, and Winnellie recorded 2 exceedances of the 1-day standard, but these exceedances were linked to smoke from bushfires, which are exceptional events. The PM<sub>10</sub> 1-year averages of 20.3, 15.1, 18.2 and 19.6 µg/m<sup>3</sup> at Katherine, Palmerston, Stokes Hill and Winnellie, respectively, were below the AAQ NEPM standard of 25 µg/m<sup>3</sup>. Winnellie and Stokes Hill did not achieve the required 75% data capture rates in the first and second quarters respectively, and so only Katherine and Palmerston demonstrated compliance with the AAQ NEPM goal for PM<sub>10</sub>.

**PM<sub>2.5</sub>:** To comply with the AAQ NEPM 1-day standard for particles as PM<sub>2.5</sub>, no exceedances of the 1-day average standard of 25 µg/m<sup>3</sup> is allowed, unless determined as an exceptional event. During 2021, all exceedances of the PM<sub>2.5</sub> 1-day standard (15 at Katherine, 12 at Palmerston, 4 at Stokes Hill and 27 at Winnellie) were linked to smoke from bushfires, which are classified as exceptional events. The PM<sub>2.5</sub> 1-year averages of 9.8, 8.8 and 11.6 µg/m<sup>3</sup> at Katherine, Palmerston, and Winnellie, respectively, were above the AAQ NEPM standard of 8 µg/m<sup>3</sup>; as such, these stations did not comply with the AAQ NEPM goal for PM<sub>2.5</sub>. Stokes Hill's annual average of 6.3 µg/m<sup>3</sup> was below the standard, but compliance with the goal was not demonstrated at that site as there was insufficient data collected during the second quarter of the year.

It is now a requirement by the AAQ NEPM that jurisdictions should report population exposure for particles as PM<sub>2.5</sub> as well as for NO<sub>2</sub> and O<sub>3</sub>. Using a simplified approach, a population-weighted annual average concentration of 9.7 µg/m<sup>3</sup> was estimated for PM<sub>2.5</sub>; 0.0040 ppm for NO<sub>2</sub>; and 0.016 ppm for O<sub>3</sub> in the Greater Darwin Region in 2021.

## 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.

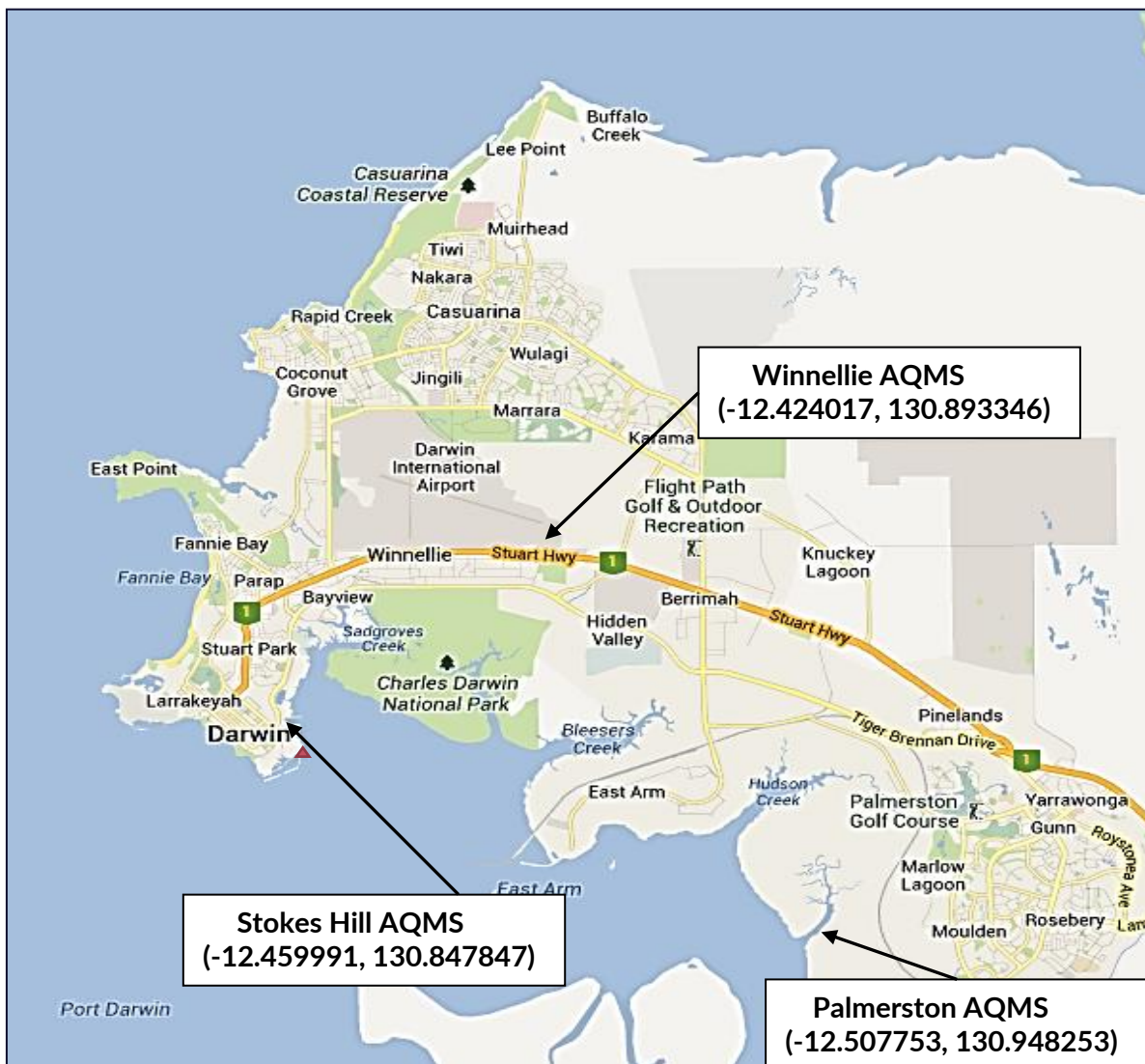


Figure 1a: Locations of Palmerston, Winnellie and Stokes Hill Air Quality Monitoring Stations (AQMS) in the Greater Darwin Region (Stokes Hill AQMS was previously located at -12.466983, 130.850584▲)

Consistent with the reporting period defined in the AAQ NEPM, this report covers the calendar year ending on 31 December 2021 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 2021 - 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>.

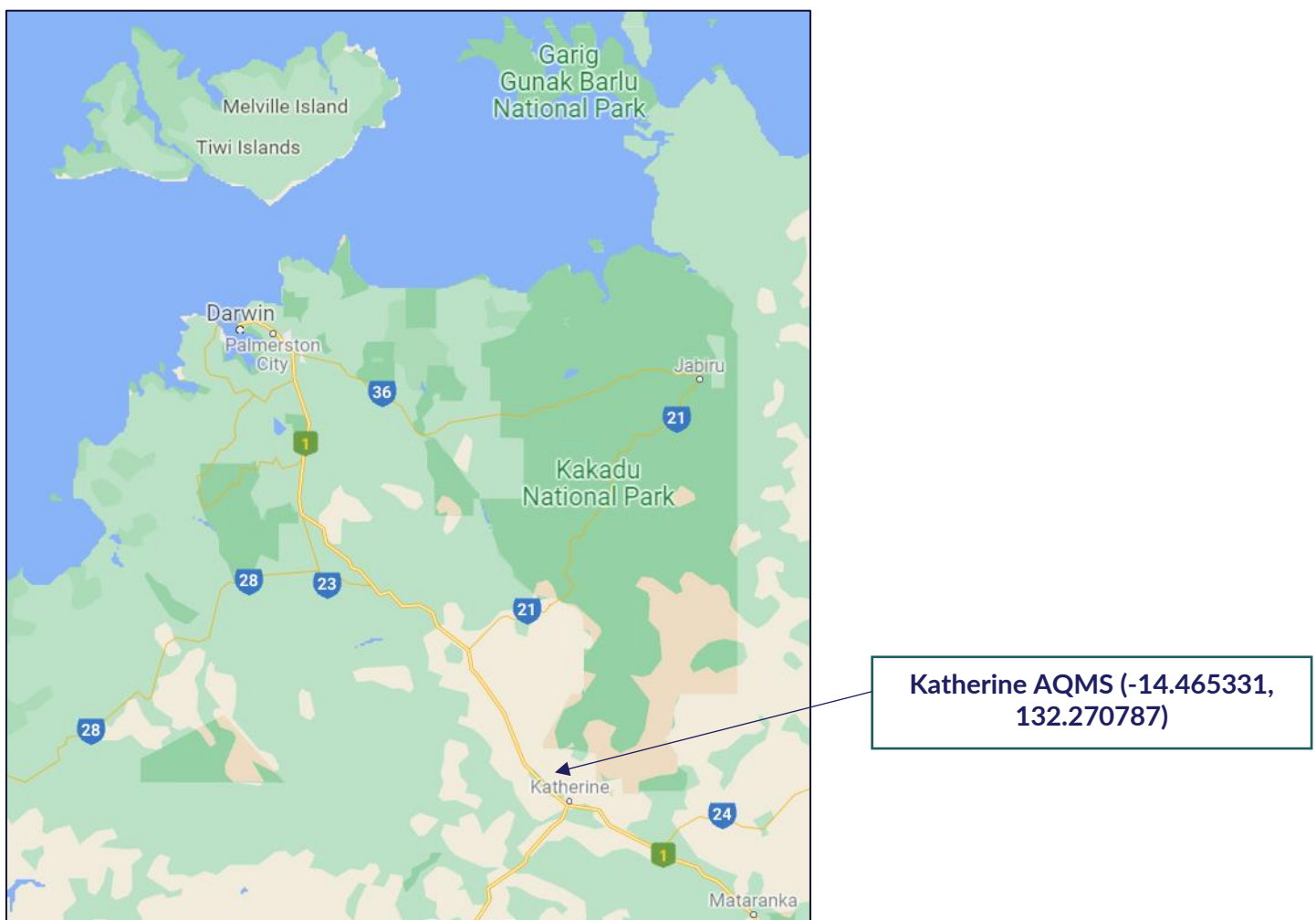


Figure 1b. Katherine AQMS - operated by Katherine Town Council

## 3 Overview of the 2021 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, 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<sub>3</sub>), sulphur dioxide (SO<sub>2</sub>), carbon monoxide (CO) and oxides of nitrogen (NO<sub>x</sub>) concentrations by various instruments connected to a single gas-sampling manifold protruding through the station roof. NO<sub>x</sub> represents the sum of nitrogen dioxide (NO<sub>2</sub>) and nitric oxide (NO) concentrations. A separate mast protruding through the station roof serves as a conduit for drawing air into the particulate samplers. The

mast is fitted with appropriate size selection inlets to sample specific particle size ranges (i.e., PM<sub>10</sub> which are particles with aerodynamic diameters of 10 µm or less and PM<sub>2.5</sub> 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<sub>10</sub> and PM<sub>2.5</sub> 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 CBD (~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<sub>10</sub> and PM<sub>2.5</sub> 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 2021 data: PM<sub>2.5</sub> annual average levels were 8.8, 11.6 and 6.3 µg/m<sup>3</sup> 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<sub>2</sub>, SO<sub>2</sub>, O<sub>3</sub> 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<sub>10</sub> and PM<sub>2.5</sub>. 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 <sub>10</sub>	01/01/11 (Palmerston) 18/07/12 (Winnellie) 03/07/17 (Stokes Hill) 02/09/20 (Katherine)	present	TEOM 1405DF <sup>1</sup> TEOM 1405DF <sup>2</sup> TEOM 1405D TEOM 1405DF	continuous
PM <sub>2.5</sub>	01/01/11 (Palmerston) 18/07/12 (Winnellie) 03/07/17 (Stokes Hill) 02/09/20 (Katherine)	present	TEOM 1405DF <sup>1</sup> TEOM 1405DF <sup>2</sup> TEOM 1405D TEOM 1405DF	continuous
SO <sub>2</sub>	01/01/11 (Palmerston) 18/07/12 (Winnellie) 05/05/17 (Stokes Hill)	present	Thermo Model 43i	continuous
NO <sub>x</sub> , NO, NO <sub>2</sub>	01/01/11 (Palmerston) 18/07/12 (Winnellie) 05/05/17 (Stokes Hill)	present	Thermo Model 42i	continuous
O <sub>3</sub>	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

<sup>1</sup>TEOM at Palmerston AQMS upgraded from 1405D to 1405DF on 18/02/2021

<sup>2</sup>TEOM at Winnellie AQMS 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 2021, data was lost because of the relocation of the Stokes Hill station; upgrading the TEOMs at Palmerston and Winnellie stations; and loss of air conditioning at Palmerston AQMS. However, most 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.

The TEOM at Winnellie AQMS was upgraded to an FDMS model on 21/01/2021 and the TEOM at Palmerston AQMS was upgraded to an FDMS model on 19/02/2021.

In May 2021, Stokes Hill AQMS site on Stokes Hill Road was decommissioned and the station moved to Hornibrooks Wharf, off Frances Bay Drive, Darwin. The station resumed operations at the new site in June 2021, retaining the original name and database.

### 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 <sub>10</sub>	AS 3580.9.8	Determination of Suspended Particulate Matter – PM <sub>10</sub> continuous direct mass method using tapered element oscillating microbalance analyser	Tapered element oscillating microbalance (TEOM) dichotomous air monitor
	AS/NZS 3580.9.16:2016	Determination of suspended particulate matter – PM <sub>10</sub> 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 with FDMS
Particles as PM <sub>2.5</sub>	AS/NZS 3580.9.13:2013	Determination of Suspended Particulate Matter – PM <sub>2.5</sub> 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 <sub>10</sub>	1 day	50 µg/m <sup>3</sup>	*None
	1 year	25 µg/m <sup>3</sup>	None
Particles as PM <sub>2.5</sub>	1 day	25 µg/m <sup>3</sup>	*None
	1 year	8 µg/m <sup>3</sup>	None

*\*For the purpose of reporting compliance against PM<sub>10</sub> and PM<sub>2.5</sub> 1-day average and O<sub>3</sub> 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: 2021 compliance summary for CO in the Northern Territory

Region/ Performance monitoring station	Data Availability Rates (% of Days)					Number of exceedances (days)	AAQ NEPM Standard
	Q1	Q2	Q3	Q4	Annual		9.0 ppm (8-hour average)
Palmerston	95	75	100	99	92	0	Met
Stokes Hill	96	44	98	92	82	0	ND
Winnellie	92	97	95	89	93	0	Met

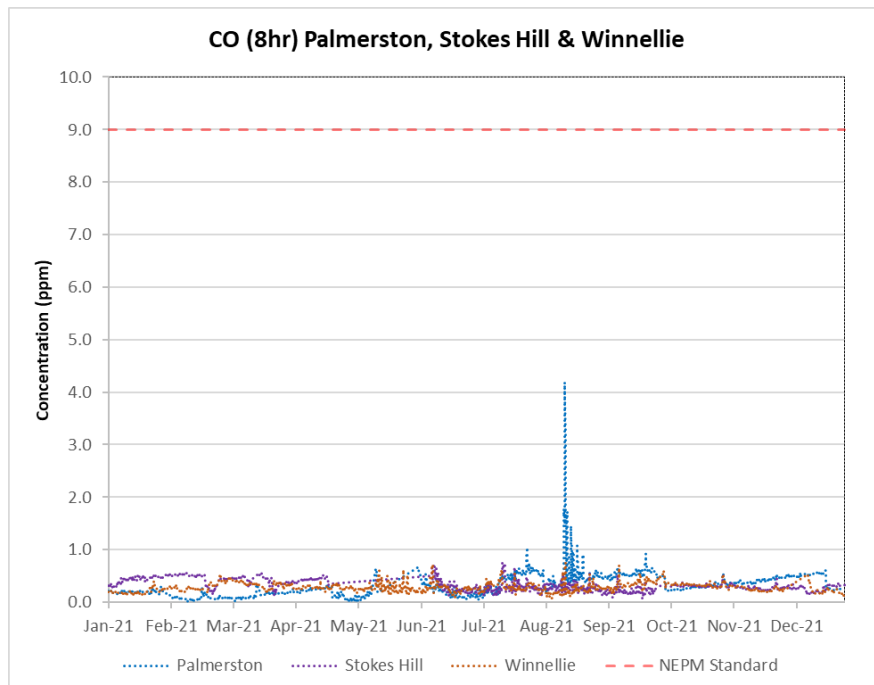


Figure 2: Carbon monoxide 8-hour averages 2021

During 2021, none of the stations recorded any exceedance of the carbon monoxide (CO) standard. However, Stokes Hill AQMS did not demonstrate compliance with the AAQ NEPM goal for CO since data capture at the station was less than 75% during the second quarter of the year.

## 4.2 Nitrogen dioxide compliance

Table 6: 2021 compliance summary for NO<sub>2</sub> 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	89	68	91	91	85	0	0.0059	ND	ND
Stokes Hill	93	33	96	95	79	0	0.0031	ND	ND
Winnellie	92	93	91	85	90	0	0.0026	Met	Met

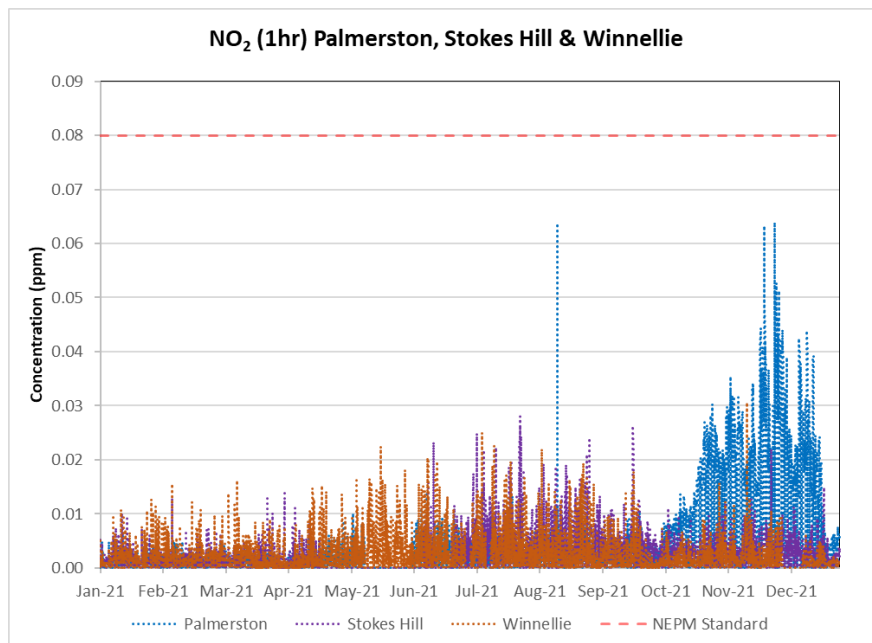


Figure 3: Nitrogen dioxide 1-hour averages 2021

In 2021, none of the stations recorded any exceedance of the nitrogen dioxide (NO<sub>2</sub>) 1-hour and 1-year standards. Compliance with the AAQ NEPM goal for NO<sub>2</sub> was met only at Winnellie AQMS, since Palmerston and Stokes Hill stations did not capture sufficient data.

### 4.3 Ozone compliance

Table 7: 2021 compliance summary for O<sub>3</sub> 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	90	75	99	100	91	0	Met
Stokes Hill	96	45	100	99	85	0	ND
Winnellie	96	82	95	85	89	0	Met

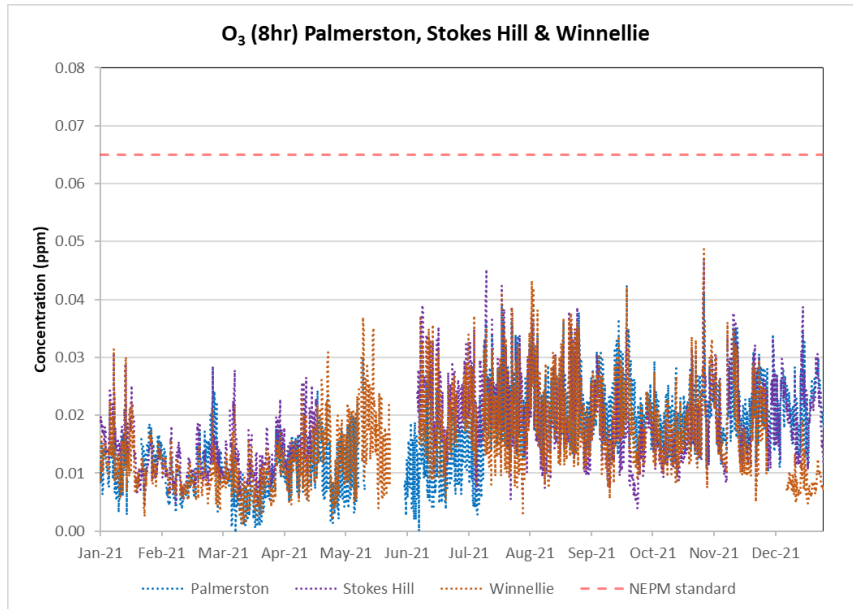


Figure 4: Ozone 8-hour averages 2021

During 2021, none of the monitoring stations recorded any exceedance of the ozone (O<sub>3</sub>) 8-hour rolling average standard. Compliance with the AAQ NEPM O<sub>3</sub> goal was demonstrated at Palmerston and Winnellie:

Stokes Hill AQMS did not collect sufficient data to demonstrate compliance. There is no 1-hour average standard for ozone.

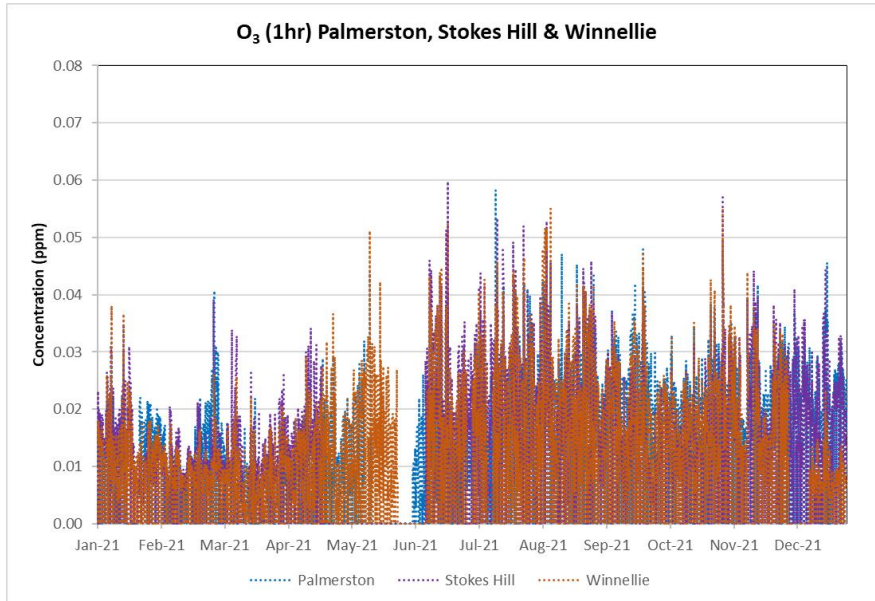


Figure 5: Ozone 1-hour averages 2021

#### 4.4 Sulfur dioxide compliance

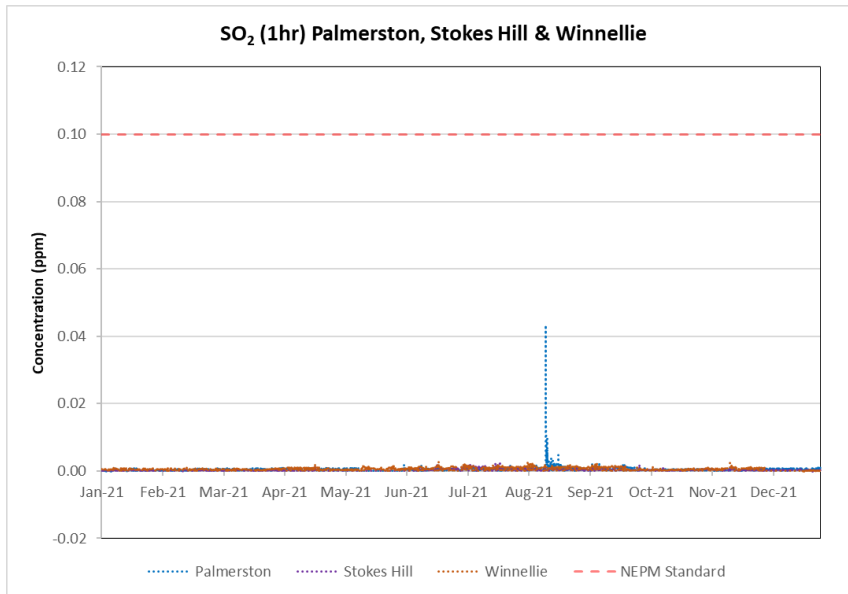
Table 8: 2021 compliance summary for SO<sub>2</sub> in the Northern Territory

AAQ NEPM Standard

0.10 ppm (1-hour average)

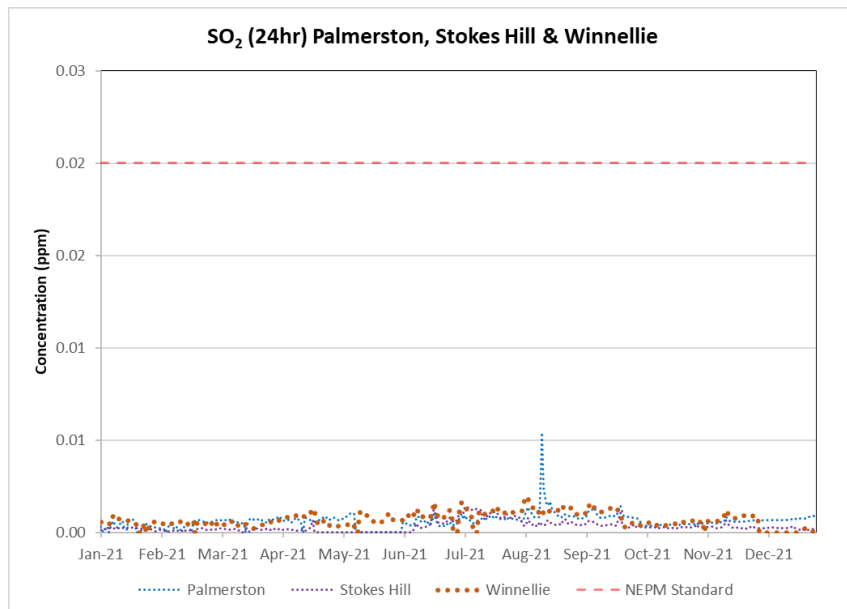
0.02 ppm (1-day average)

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	68	91	91	85	0	0	ND	ND
Stokes Hill	93	42	96	95	81	0	0	ND	ND
Winnellie	91	93	91	76	88	0	0	Met	Met



**Figure 6: Sulfur dioxide 1-hour averages 2021**

During 2021, none of the stations recorded any exceedance of the sulfur dioxide (SO<sub>2</sub>) 1-hour or 1-day standards. Compliance with the AAQ NEPM goal for SO<sub>2</sub> was only demonstrated Winnellie.



**Figure 7: SO<sub>2</sub> 1-day averages 2021**

## 4.5 Particulates (PM<sub>10</sub>) compliance

Table 9: 2021 compliance summary for PM<sub>10</sub> in the Northern Territory

AAQ NEPM Standard

50 µg/m<sup>3</sup> (1-day average)

25 µg/m<sup>3</sup> (1-year average)

Region/ Performance monitoring station	Data Availability Rates (%)					Number of exceedances (days)	Annual average (µg/m <sup>3</sup> )	Performance against the standard and goal	
	Q1	Q2	Q3	Q4	Annual			24h	1y
<b>Katherine:</b>									
Katherine	75	78	96	87	84	6	20.3	Met	Met
<b>Darwin:</b>									
Palmerston	78	75	95	98	85	3	15.1	Met	Met
Stokes Hill	94	44	91	100	82	4	18.2	ND	ND
Winnellie	50	75	83	83	75	2	19.6	ND	ND

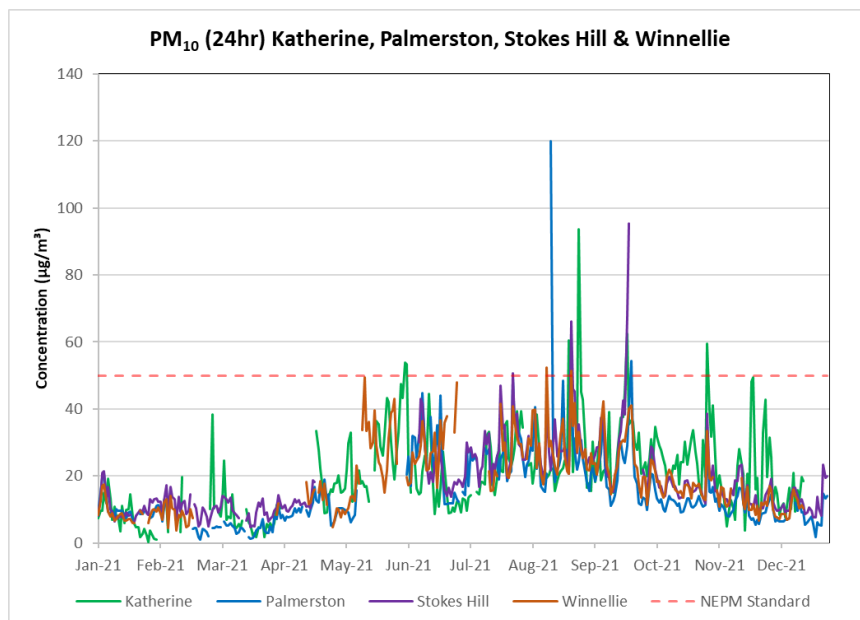


Figure 8: PM<sub>10</sub> 1-day averages 2021

During 2021, the stations recorded several exceedances of the PM<sub>10</sub> 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<sub>10</sub> and PM<sub>2.5</sub> 1-day average standards. Although all the annual averages were below the 1-year standard, compliance with the AAQ NEPM goal for PM<sub>10</sub> was only demonstrated at Katherine and Palmerston: the other stations did not have sufficient data to demonstrate compliance with the AAQ NEPM.

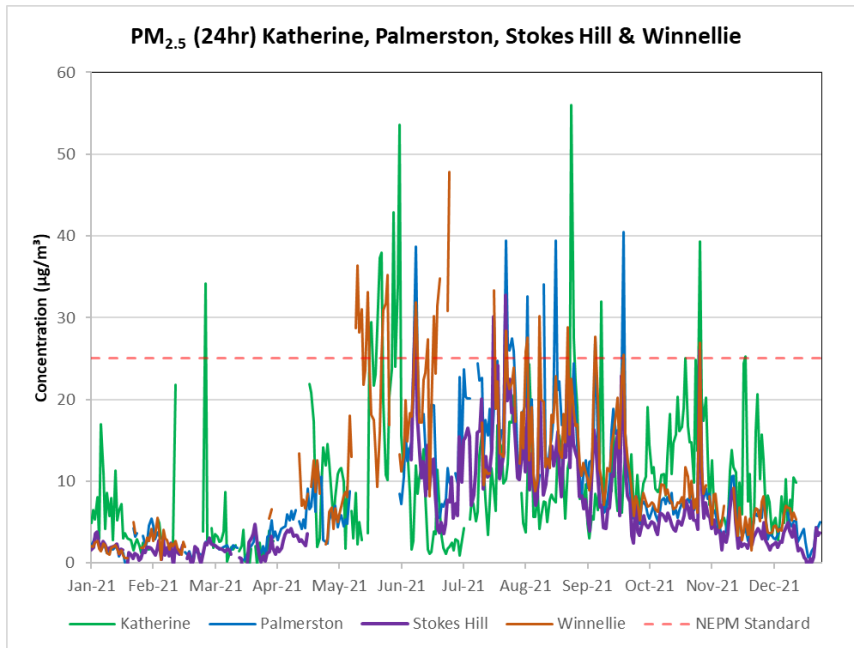
## 4.6 Particulates (PM<sub>2.5</sub>) compliance

**Table 10: 2021 compliance summary for PM<sub>2.5</sub> in the Northern Territory**

Region/ Performance monitoring station	Data Availability Rates (%)					Number of exceedances (days)	Annual average µg/m <sup>3</sup>	AAQ NEPM Standard	
	Q1	Q2	Q3	Q4	Annual			25 µg/m <sup>3</sup> (1-day average)	8 µg/m <sup>3</sup> (1-year average)
								24h	1y
<b>Katherine:</b>									
<b>Katherine</b>	75	77	96	87	83	15	9.8	ND	Not met
<b>Darwin:</b>									
<b>Palmerston</b>	78	75	95	98	85	12	8.8	Met	Not met
<b>Stokes Hill</b>	94	44	100	100	85	4	6.3	ND	ND
<b>Winnellie</b>	50	75	83	83	75	27	11.6	ND	Not met

During 2021, the Darwin region and Katherine recorded several exceedances of the PM<sub>2.5</sub> 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<sub>2.5</sub> 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/m<sup>3</sup>, but insufficient data was collected there to demonstrate compliance with the goal.



**Figure 9: PM<sub>2.5</sub> 1-day averages 2021**

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<sub>10</sub>;*
- (ii) 1 day average standard for particles as PM<sub>2.5</sub>;*
- (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 2021. 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<sub>10</sub>, PM<sub>2.5</sub> and O<sub>3</sub> standards caused by exceptional events such as bushfires. Data presented in the previous section show that levels of CO and SO<sub>2</sub> were significantly below the AAQ NEPM standards and there were no exceedances recorded for CO, NO<sub>2</sub>, O<sub>3</sub> and SO<sub>2</sub>.

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: 2021 summary statistics for daily peak 8 hour CO**

Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date/hour)	AAQ NEPM Standard	
				2 <sup>nd</sup> highest (ppm)	2 <sup>nd</sup> Highest (date/hour)
Palmerston	333	4.20	15/08/2021 05:00	2.56	14/08/2021 23:00
Stokes Hill	298	0.76	15/07/2021 08:00	0.74	16/07/2021 07:00
Winnellie	337	0.75	15/08/2021 08:00	0.72	10/06/2021 12:00

CO levels at all the stations were well below the CO 8-hour rolling average standard for most of the year. The highest event, recorded at Palmerston (4.20 ppm, 5am on 15 August 2021) was about 50% of the AAQ NEPM standard. It was inferred that this was associated with a bushfire since the highest PM<sub>10</sub> level recorded in 2021, peaked at 02:00 hrs on that day.

## 5.2 Nitrogen dioxide statistics

**Table 12: 2021 summary statistics for daily peak 1 hour NO<sub>2</sub> in the Northern Territory**

AAQ NEPM Standard

0.08 ppm (1-hour average)

Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date/hour)	2 <sup>nd</sup> highest (ppm)	2 <sup>nd</sup> Highest (date/hour)
Palmerston	335	0.064	29/11/2021 19:00	0.064	14/08/2021 12:00
Stokes Hill	298	0.028	27/07/2021 00:00	0.026	20/09/2021 21:00
Winnellie	339	0.031	16/11/2021 00:00	0.025	08/07/2021 07:00

NO<sub>2</sub> levels were below the new AAQ NEPM 1-hour NO<sub>2</sub> standard of 0.08 ppm. The highest recorded reading (0.064 ppm) was recorded at Palmerston at 7 pm on 29 November 2021; the second highest peak was also recorded at Palmerston. Both concentrations were much higher than the highest peaks recorded at the other two stations. From October to December, daily peak 1-hour NO<sub>2</sub> recorded at Palmerston ranged from ~30% to ~75% of the NEPM standard.

## 5.3 Ozone statistics

**Table 13: 2021 summary statistics for daily peak 8 hour O<sub>3</sub> in the Northern Territory**

AAQ NEPM Standard

0.065 ppm (8-hour average)

Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date/hour)	2 <sup>nd</sup> highest (ppm)	2 <sup>nd</sup> Highest (date/hour)
Palmerston	330	0.042	23/09/2021 19:00	0.041	01/11/2021 17:00
Stokes Hill	307	0.047	01/11/2021 17:00	0.047	10/06/2021 00:00
Winnellie	319	0.049	01/11/2021 17:00	0.043	06/08/2021 19:00

There were no exceedances of the new 8-hour O<sub>3</sub> standard at any of the monitoring sites. The highest peak of 0.049 ppm recorded at Winnellie on Nov 1, is about 70% of the standard; the other stations also recorded high ozone levels on that day. This event day was characterised by high temperatures (~39 °C, maximum), low wind speeds (1.5 – 2.5 m/s) and high solar radiation (~1000 W/m<sup>2</sup>, maximum). All the stations (including Katherine) also recorded high particulate levels from bushfire smoke on Nov 1 2021.

There is no 1-hour AAQ NEPM standard for O<sub>3</sub>; summary statistics provided below is for information only.

**Table 14: 2021 summary statistics for daily peak 1 hour O<sub>3</sub> in the Northern Territory**

No AAQ NEPM Standard

Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date/hour)	2 <sup>nd</sup> highest (ppm)	2 <sup>nd</sup> Highest (date/hour)
Palmerston	330	0.058	13/07/2021 18:00	0.048	07/08/2021 15:00
Stokes Hill	307	0.060	20/06/2021 14:00	0.057	01/11/2021 13:00
Winnellie	319	0.055	01/11/2021 13:00	0.055	09/08/2021 14:00

## 5.4 Sulfur dioxide statistics

**Table 15: 2021 summary statistics for daily peak 1 hour SO<sub>2</sub> in the Northern Territory**

AAQ NEPM Standard

0.10 ppm (1-hour average)

Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date/hour)	2 <sup>nd</sup> highest (ppm)	2 <sup>nd</sup> Highest (date/hour)
Palmerston	335	0.0433	14/08/2021 12:00	0.0061	15/08/2021 05:00
Stokes Hill	307	0.0029	22/07/2021 00:00	0.0025	19/07/2021 23:00
Winnellie	331	0.0027	09/09/2021 03:00	0.0026	20/06/2021 21:00

SO<sub>2</sub> levels in the Darwin region were substantially below the AAQ NEPM 1-hour and 1-day SO<sub>2</sub> standards. The highest recorded 1-hour reading was at Palmerston (0.0433 ppm) at 12pm on 14 August. Palmerston also recorded the highest daily average SO<sub>2</sub> concentration (0.0054 ppm) on the same day. These values were much higher than peak concentrations recorded at the other stations.

**Table 16: 2021 summary statistics for 24 hour SO<sub>2</sub> in the Northern Territory**

Performance monitoring station	Number of valid days	Highest (ppm)	Highest (date)	AAQ NEPM Standard	
				0.02 ppm (1-day average)	
				2 <sup>nd</sup> highest (ppm)	2 <sup>nd</sup> Highest (date)
Palmerston	335	0.0054	14/08/2021	0.0024	15/08/2021
Stokes Hill	307	0.0014	6/07/2021	0.0014	20/06/2021
Winnellie	331	0.0020	6/07/2021	0.0019	7/08/2021

## 5.5 Particulates statistics

Palmerston recorded the highest PM<sub>10</sub> event (119.9 µg/m<sup>3</sup>) on 15 August 2021 (Table 17); the other Darwin stations did not record high PM<sub>10</sub> levels on this day, suggesting that the plume was from a local bushfire event. This plume had elevated levels of PM<sub>2.5</sub>, O<sub>3</sub> and combustion products such as CO and NO<sub>x</sub>, which confirms a bushfire as the source; unfortunately, the station did not capture peak values for these other pollutants due to instrument failure and automated zero-span checks that occurred at that time.

Stokes Hill recorded the next highest PM<sub>10</sub> event (95.3 µg/m<sup>3</sup>) on 23 September 2021; the plume was associated with a smoke event as it had substantial levels of PM<sub>2.5</sub> (see also Appendix A: Particulates Events for 2021). The highest peak recorded at Katherine AQMS was 93.6 µg/m<sup>3</sup> (29 August 2021). Although these PM<sub>10</sub> events exceeded the AAQ standard, they are considered as exceptional events since they are associated with natural events such as smoke from bushfires.

The highest PM<sub>2.5</sub> concentration (56.0 µg/m<sup>3</sup>) was recorded at Katherine on 29 August 2021, and the next highest (53.6 µg/m<sup>3</sup>) was also recorded at Katherine; these and the other events for the Darwin 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: 2021 summary statistics for 24 hour PM<sub>10</sub> in the Northern Territory**

AAQ NEPM Standard

50 µg/m<sup>3</sup> (1-day average)

Region/Performance monitoring station	Number of valid days	Highest (µg/m <sup>3</sup> )	Highest (date)	2 <sup>nd</sup> highest (µg/m <sup>3</sup> )	2 <sup>nd</sup> Highest (date)
Katherine	305	93.6	29/08/2021	62.4	22/09/2021
Palmerston	312	119.9	15/08/2021	54.2	24/09/2021
Stokes Hill	301	95.3	23/09/2021	67.6	22/09/2021
Winnellie	264	52.3	13/08/2021	51.3	25/08/2021

**Table 18: 2021 summary statistics for 24 hour PM<sub>2.5</sub> in the Northern Territory**

AAQ NEPM Standard

25 µg/m<sup>3</sup> (1-day average)

Region/Performance monitoring station	Number of valid days	Highest (µg/m <sup>3</sup> )	Highest (date)	2 <sup>nd</sup> highest (µg/m <sup>3</sup> )	2 <sup>nd</sup> Highest (date)
Katherine	304	56.0	29/08/2021	53.6	4/06/2021
Palmerston	312	40.5	24/09/2021	39.5	27/07/2021
Stokes Hill	309	32.8	27/07/2021	30.2	21/07/2021
Winnellie	264	47.8	29/06/2021	36.4	14/05/2021

## 6 Analysis of exceedances and population exposure

This section will analyse exceedance events that occurred during 2021 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 2021. Averaged daily levels of PM<sub>2.5</sub> across all the Darwin stations over the six months of the Dry was 14 µg/m<sup>3</sup>; compared to 4 µg/m<sup>3</sup> during the Wet. The elevated PM<sub>2.5</sub> levels during the Dry are unavoidable and people with respiratory or cardiopulmonary issues may be impacted. PM<sub>2.5</sub> annual average concentration across all Darwin stations for 2021 was 9 µg/m<sup>3</sup>, which is greater than the AAQ NEPM standard of 8 µg/m<sup>3</sup>. The PM<sub>2.5</sub> annual average across all Darwin stations for 2020 was 7 µg/m<sup>3</sup>. These averages are different from population-weighted averages discussed in the next subsection.

The 1-day standard for PM<sub>2.5</sub> had multiple exceedances in 2021 (Figure 9). There were 12 exceedances of the 1-day standard at Palmerston station and the annual limit was exceeded. Winnellie station recorded 27 exceedances of the 1-day standard and exceeded the annual limit. Katherine recorded 15 exceedances of the 1-day standard and exceeded the annual limit. Stokes Hill station recorded only 4 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, 13 to 16 May at Winnellie; 24 to 26 May at Katherine; and 27 to 31 July at Palmerston (see Appendix A: Particulates events for 2021).

The AAQ NEPM 1-day standard for PM<sub>10</sub> was exceeded on several days: Katherine recorded six, Palmerston recorded three; Stokes Hill recorded four and Winnellie recorded two. None of the stations exceeded the annual PM<sub>10</sub> limit. As explained in previous sections of this report, since natural events such as bushfire activity caused the PM<sub>2.5</sub> and PM<sub>10</sub> exceedances, the exceedances are exceptional events under the AAQ NEPM.

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

Table 19: 2021 PM<sub>10</sub> exceedances of 24-hour AAQ NEPM standard at Katherine AQMS

Date	PM <sub>10</sub> (µg/m <sup>3</sup> )	Inferred Cause
3-Jun	53.84	smoke
4-Jun	53.43	smoke
24-Aug	60.41	smoke
29-Aug	93.58	smoke
22-Sep	62.43	smoke
1-Nov	59.52	smoke

Table 20: 2021 PM<sub>10</sub> exceedances of 24-hour AAQ NEPM standard at Palmerston AQMS

Date	PM <sub>10</sub> (µg/m <sup>3</sup> )	Inferred Cause
15-Aug	119.9	smoke
25-Aug	51.84	smoke
24-Sep	54.21	smoke

Table 21: 2021 PM<sub>10</sub> exceedances of 24-hour AAQ NEPM standard at Stokes Hill AQMS

Date	PM <sub>10</sub> (µg/m <sup>3</sup> )	Inferred Cause
27-Jul	50.7	smoke
25-Aug	66.0	smoke
22-Sep	67.6	smoke
24-Sep	95.3	smoke

Table 22: 2021 PM<sub>10</sub> exceedances of 24-hour AAQ NEPM standard at Winnellie AQMS

Date	PM <sub>10</sub> (µg/m <sup>3</sup> )	Inferred Cause
13-Aug	52.29	smoke
25-Aug	51.32	smoke

Table 23: 2021 PM<sub>2.5</sub> exceedances of 24-hour AAQ NEPM standard at Katherine AQMS

Date	PM <sub>2.5</sub> (µg/m <sup>3</sup> )	Inferred Cause
27-Feb	34.19	smoke
20-May	27.9	smoke
21-May	29.45	smoke
24-May	28.57	smoke
25-May	37.37	smoke
26-May	37.97	smoke
1-Jun	42.89	smoke
3-Jun	33.94	smoke
4-Jun	53.62	smoke
29-Aug	56.0	smoke
30-Aug	27.49	smoke
13-Sep	31.95	smoke
25-Oct	25.04	smoke
1-Nov	39.34	smoke
24-Nov	25.26	smoke

Table 24: 2021 PM<sub>2.5</sub> exceedances of 24-hour AAQ NEPM reporting level at Palmerston AQMS

Date	PM <sub>2.5</sub> (µg/m <sup>3</sup> )	Inferred Cause
12-Jun	38.7	smoke
27-Jul	39.5	smoke
28-Jul	26.8	smoke
29-Jul	26.0	smoke
30-Jul	27.4	smoke
31-Jul	25.9	smoke
7-Aug	32.6	smoke
15-Aug	34.1	smoke
21-Aug	39.4	smoke
10-Sep	27.6	smoke
24-Sep	40.5	smoke
1-Nov	26.8	smoke

Table 25: 2021 PM<sub>2.5</sub> exceedances of 24-hour AAQ NEPM reporting level at Stokes Hill AQMS

Date	PM <sub>2.5</sub> (µg/m <sup>3</sup> )	Inferred Cause
12-Jun	30.1	smoke
21-Jul	30.2	smoke
27-Jul	32.8	smoke
1-Nov	26.1	smoke

Table 26: 2021 PM<sub>2.5</sub> exceedances of 24-hour AAQ NEPM reporting level at Winnellie AQMS

Date	PM <sub>2.5</sub> (µg/m <sup>3</sup> )	Inferred Cause
13-May	28.7	smoke
14-May	36.4	smoke
15-May	28.24	smoke
16-May	31.04	smoke
19-May	33.2	smoke
26-May	25.31	smoke
27-May	30.98	smoke
28-May	31.7	smoke
29-May	35.3	smoke
12-Jun	31.9	smoke
13-Jun	25.67	smoke
18-Jun	27.4	smoke
21-Jun	30.24	smoke
23-Jun	31.5	smoke
24-Jun	34.8	smoke
26-Jun	30.14	smoke
28-Jun	30.8	smoke
29-Jun	47.8	smoke
21-Jul	33.4	smoke
27-Jul	28.44	smoke
6-Aug	25.94	smoke
7-Aug	27.59	smoke

Date	PM <sub>2.5</sub> (µg/m <sup>3</sup> )	Inferred Cause
13-Aug	30.21	smoke
27-Aug	28.87	smoke
10-Sep	27.66	smoke
24-Sep	25.42	smoke
1-Nov	26.93	smoke

Smoke from burning vegetation contains PM<sub>10</sub> and PM<sub>2.5</sub>, Figures 10 - 13 show the close relationship between these parameters at the all stations, especially during the Dry Season.

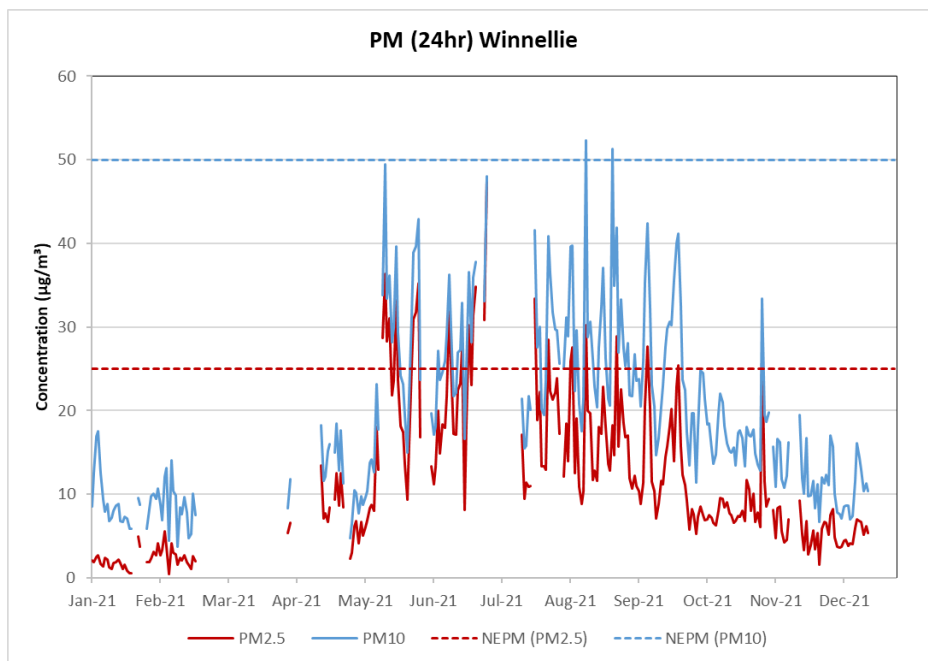


Figure 10: Particulates concentration at Winnellie AQMS 2021

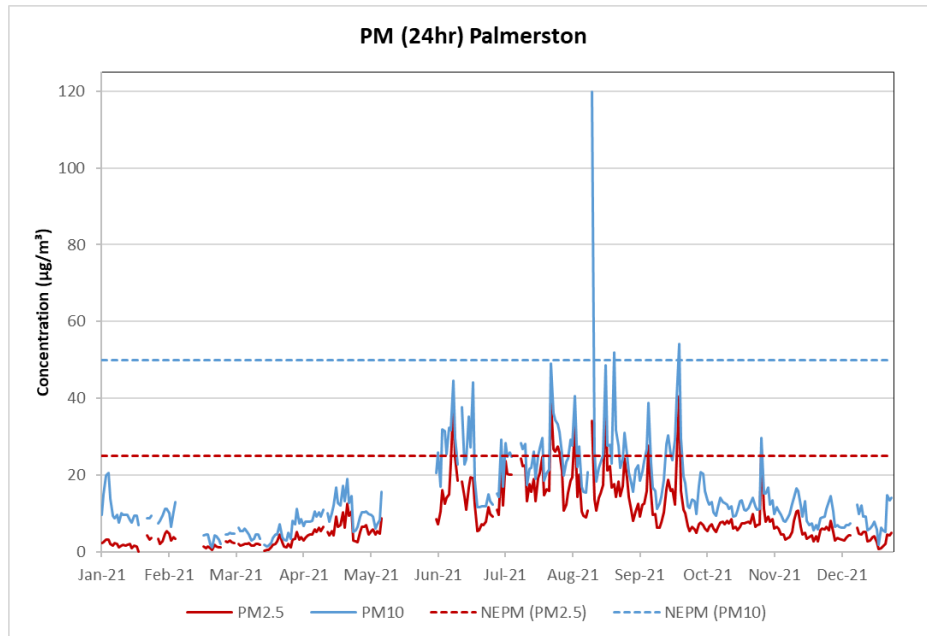


Figure 11: Particulates concentration at Palmerston AQMS 2021

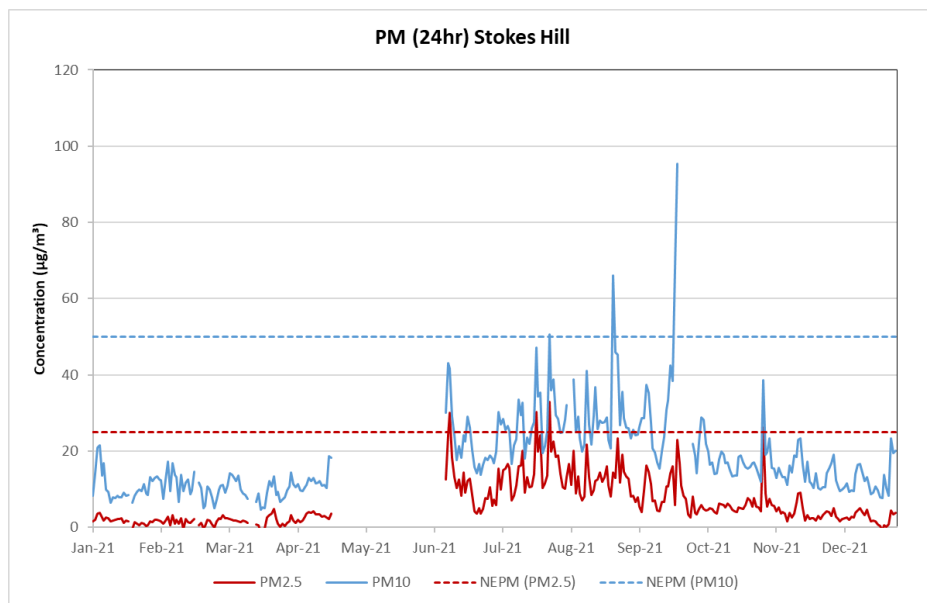
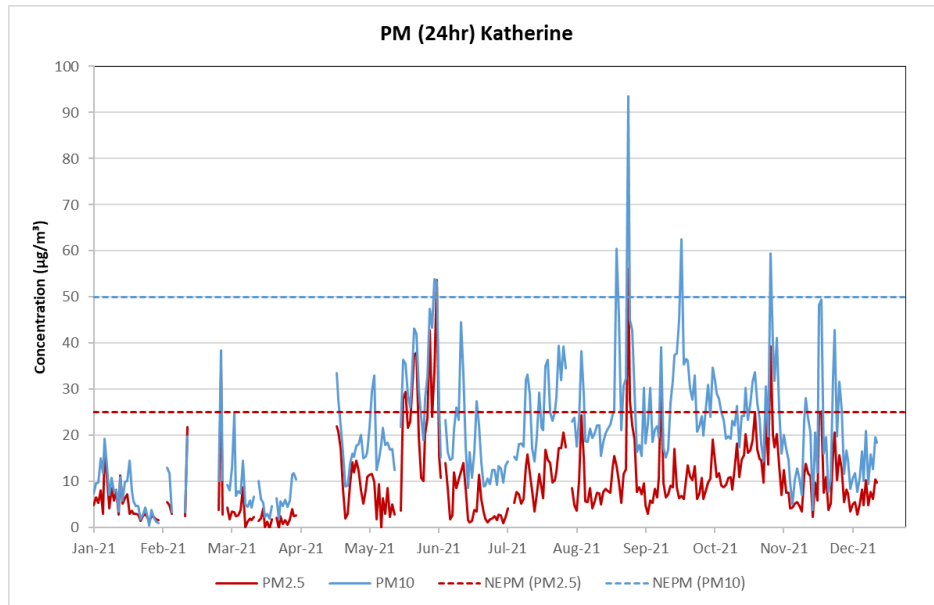


Figure 12: Particulates concentration at Stokes Hill AQMS 2021



**Figure 13: Particulates concentration at Katherine AQMS 2021**

## 6.2 Population exposure to PM<sub>2.5</sub>, NO<sub>2</sub> and O<sub>3</sub>

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

- (a) particles as PM<sub>2.5</sub> from June 2018; and
- (b) NO<sub>2</sub> and O<sub>3</sub> from June 2021.

The population-weighted annual average PM<sub>2.5</sub>, NO<sub>2</sub> and O<sub>3</sub> 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<sub>2.5</sub>, NO<sub>2</sub> and O<sub>3</sub> 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:

- people living in the SA2 areas of Darwin City, Fannie Bay - The Gardens, Larrakeyah and Stuart Park would be exposed to PM<sub>2.5</sub>, NO<sub>2</sub> and O<sub>3</sub> levels represented by concentrations measured at Stokes Hill AQMS;
- all other Darwin SA2 areas would be exposed to PM<sub>2.5</sub>, NO<sub>2</sub> and O<sub>3</sub> levels measured at Winnellie AQMS; and
- people living in SA2 areas in Palmerston would be exposed to PM<sub>2.5</sub>, NO<sub>2</sub> and O<sub>3</sub> 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 9.7 µg/m<sup>3</sup> was estimated for PM<sub>2.5</sub>; 0.0040 ppm for NO<sub>2</sub>; and 0.016 ppm for O<sub>3</sub> in the Greater Darwin Region in 2021 (see Appendix B for details of the calculations).

**Table 27: 2021 Population-weighted annual concentrations**

Region	PM <sub>2.5</sub> (µg/m <sup>3</sup> )	NO <sub>2</sub> (ppm)	O <sub>3</sub> (ppm)
Greater Darwin	9.7	0.0040	0.016

## 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<sub>10</sub> and PM<sub>2.5</sub> was normally operating at Charles Darwin University in Casuarina and was collocated with a TEOM, which measured PM<sub>10</sub>.

### 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<sub>10</sub> & PM<sub>2.5</sub> now measured with a dichotomous TEOM).
- 2012 – Winnellie AQMS started operating on 18 July (PM<sub>10</sub> & PM<sub>2.5</sub> 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 a number of months resulting in inadequate data collection for NEPC reporting. As the TEOM was operational for most of the Dry, when particulates are an issue, 2013 data from Palmerston is still useful when considering longer term trends in particulates.

Table 28: Casuarina 24-hour PM<sub>10</sub> & PM<sub>2.5</sub> Trends (2004 -2010)

Year	*PM <sub>10</sub>			**PM <sub>2.5</sub>		
	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m <sup>3</sup> )	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m <sup>3</sup> )
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<sub>10</sub> data used for 2006)

\*\*PM<sub>2.5</sub> data from Partisol dichotomous sampler

Table 29: 24-hour PM<sub>10</sub> Trends (2011-2021)

Year	Palmerston			Winnellie			Stokes Hill			Katherine		
	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m <sup>3</sup> )	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m <sup>3</sup> )	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m <sup>3</sup> )	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m <sup>3</sup> )
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

Table 30: 24-hour PM<sub>2.5</sub> Trends (2011-2021)

Year	Palmerston			Winnellie			Stokes Hill			Katherine		
	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m <sup>3</sup> )	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m <sup>3</sup> )	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m <sup>3</sup> )	Data Availability (%)	Number of Exceedances	Max Concentration (µg/m <sup>3</sup> )
2011	2696	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

Table 31: Averaged Particulates Key Metrics 2004-2021 (across all historic &amp; current monitoring locations)

	Data Availability (%)	Number of Exceedances	Maximum Concentration (µg/m <sup>3</sup> )
PM <sub>10</sub>	86	4	70
PM <sub>2.5</sub>	84	10	46

Historical data for the 2004 to 2021 period, presented in Figures 14 to 19, show that there is no clear trend in PM<sub>2.5</sub> or PM<sub>10</sub> 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 2021 compared to 2020; 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 2021 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.

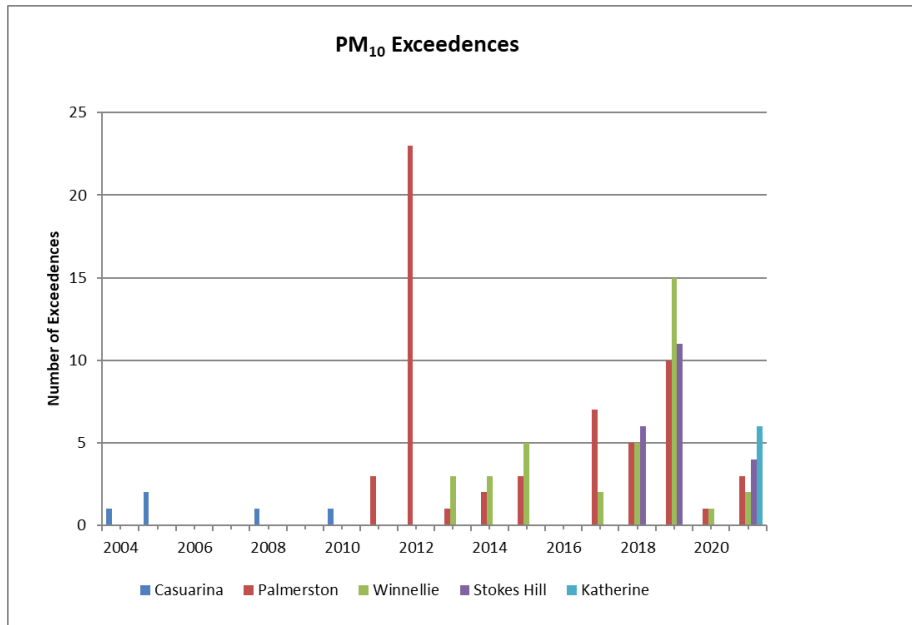


Figure 14: Historical PM<sub>10</sub> exceedences of 24-hour AAQ NEPM

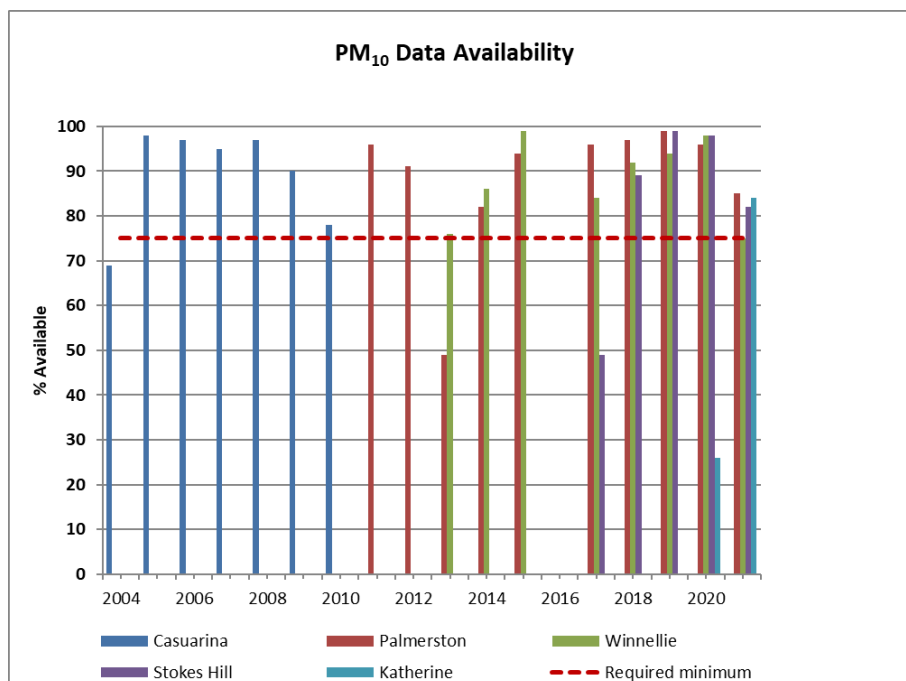


Figure 15: Historical PM<sub>10</sub> data availability

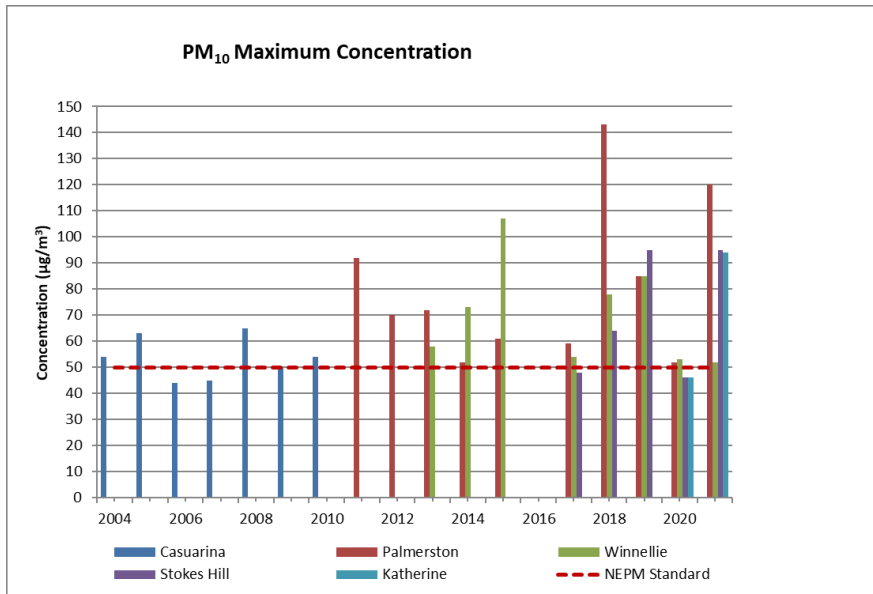


Figure 16: Historical maximum 24-hour PM<sub>10</sub> concentrations

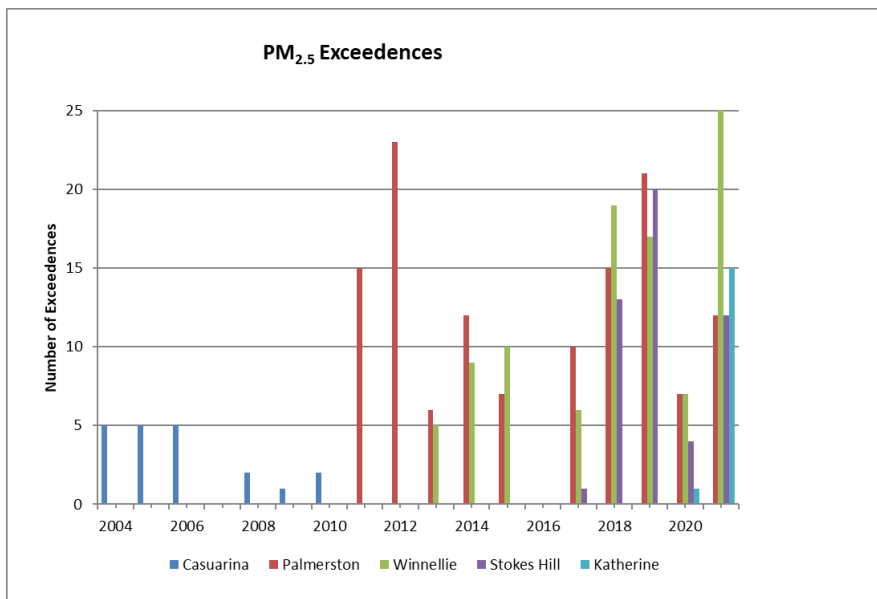


Figure 17: Historical PM<sub>2.5</sub> exceedences of 24 hour AAQ NEPM

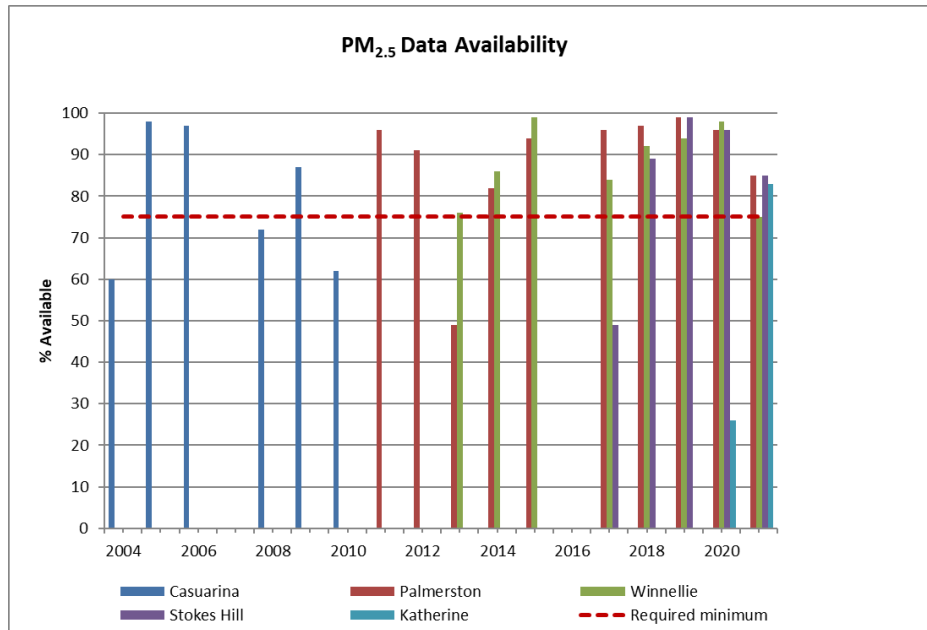


Figure 18: Historical PM<sub>2.5</sub> data availability

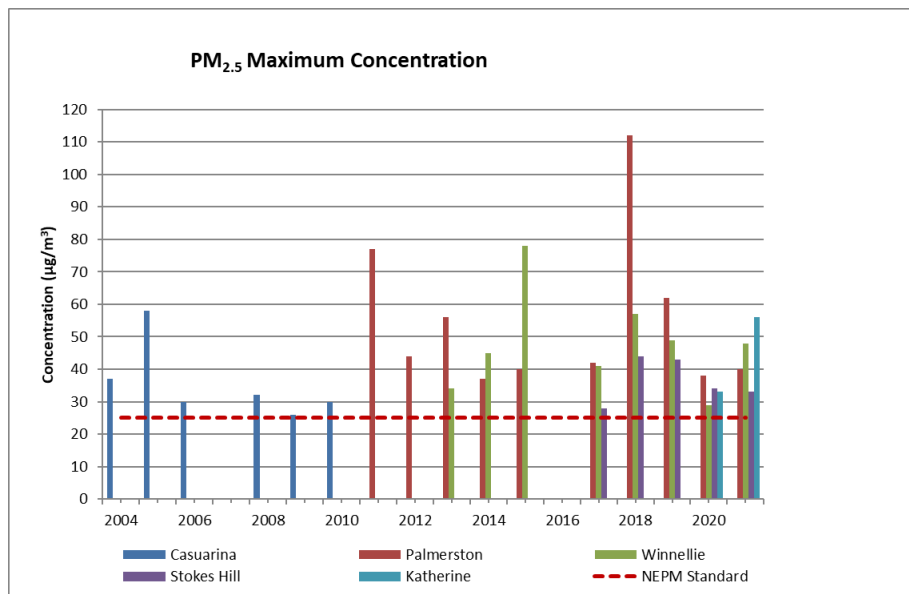


Figure 19: Historical PM<sub>2.5</sub> 24-hour maximum concentrations

## 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 2021) 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 2021. A relationship was observed between the monthly area burnt and the monthly averaged PM<sub>2.5</sub> concentrations measured at the stations. Figure 20 shows that the monthly PM<sub>2.5</sub> concentrations increased sharply with area burnt in May. Although PM<sub>2.5</sub> levels peaked in June - July at all the stations (15 -23 µg/m<sup>3</sup>), and the area burnt peaked in June (780 sq km), there was a general decline in both parameters after July.

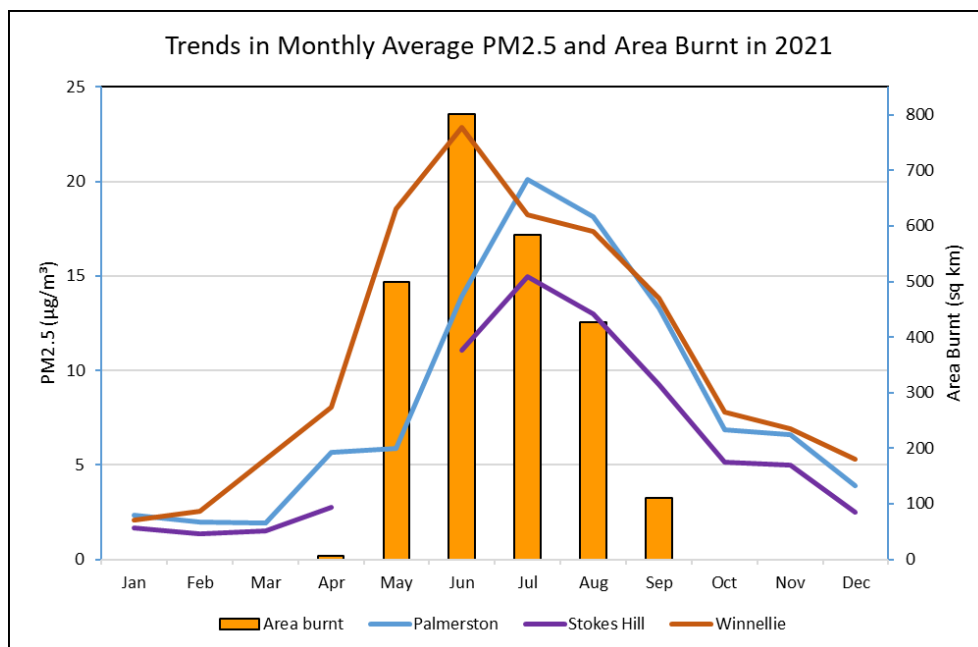
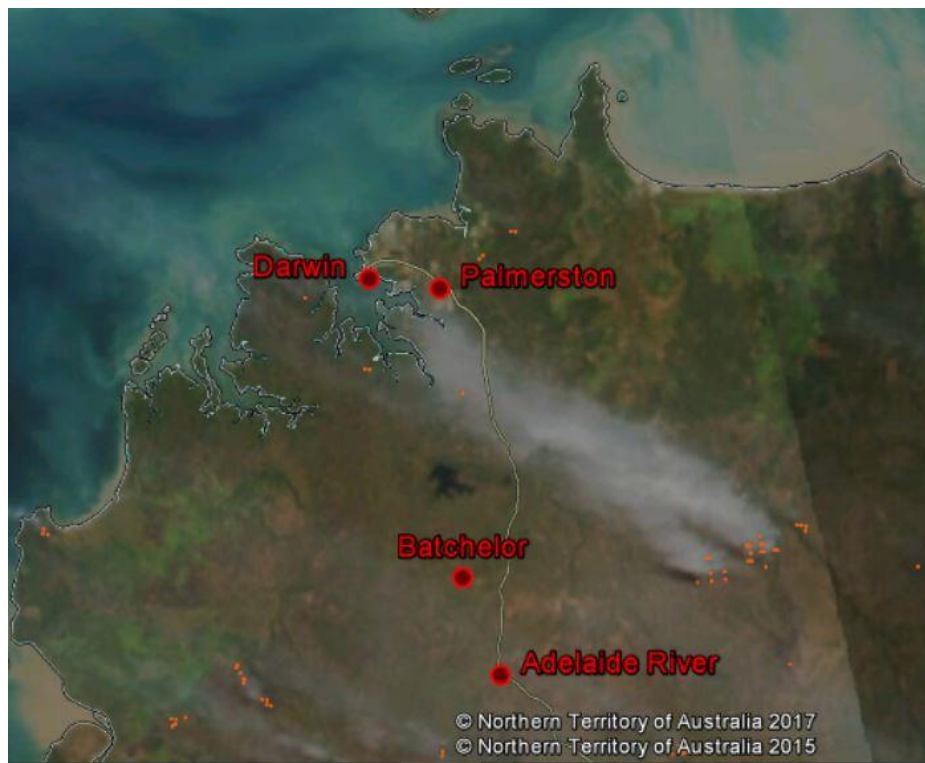


Figure 20: Comparison of PM<sub>2.5</sub> levels with Area Burnt (50 km radius from McMinns Lagoon)

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 Mount Bunday, about 100 km southeast of Darwin, on 28 May 2021, could have affected air quality in the Darwin region. Winnellie AQMS recorded PM<sub>2.5</sub> levels above the AAQ NEPM standard from 26 to 29 May 2021; particulates instruments at the other Darwin stations were offline during these days (see Appendix A).



**Figure 21: Large-scale fire events impacting the Top End on 28 May 2021 (Source: NASA Worldview)**

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

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 2021

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/m<sup>3</sup> for PM<sub>2.5</sub> and 50 µg/m<sup>3</sup> for PM<sub>10</sub>. (**Red** – PM<sub>2.5</sub> exceedances; **Blue** – PM<sub>10</sub> exceedances)

Date	Particulates Concentration (µg/m <sup>3</sup> )							
	Katherine		Palmerston		Stokes Hill		Winnellie	
	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10
27-Feb	<b>34.2</b>	38.5	2.6	4.5	2.4	9.9	n/a	n/a
13-May	8.6	18.5	n/a	n/a	n/a	n/a	<b>28.7</b>	33.8
14-May	2.3	16.8	n/a	n/a	n/a	n/a	<b>36.4</b>	49.5
15-May	5.0	17.1	n/a	n/a	n/a	n/a	<b>28.2</b>	33.4
16-May	2.8	12.5	n/a	n/a	n/a	n/a	<b>31.0</b>	36.2
19-May	3.6	21.7	n/a	n/a	n/a	n/a	<b>33.2</b>	39.6
20-May	<b>27.9</b>	36.4	n/a	n/a	n/a	n/a	23.6	29.3
21-May	<b>29.5</b>	35.5	n/a	n/a	n/a	n/a	18.1	24.2
24-May	<b>28.6</b>	32.3	n/a	n/a	n/a	n/a	9.3	14.9
25-May	<b>37.4</b>	43.3	n/a	n/a	n/a	n/a	16.0	21.6
26-May	<b>38.0</b>	42.1	n/a	n/a	n/a	n/a	<b>25.3</b>	31.2
27-May	19.7	29.9	n/a	n/a	n/a	n/a	<b>31.0</b>	38.9
28-May	10.8	23.8	n/a	n/a	n/a	n/a	<b>31.7</b>	39.7
29-May	10.1	18.9	n/a	n/a	n/a	n/a	<b>35.3</b>	43.0
1-Jun	<b>42.9</b>	47.4	n/a	n/a	n/a	n/a	n/a	n/a
3-Jun	<b>33.9</b>	<b>53.8</b>	n/a	n/a	n/a	n/a	n/a	n/a
4-Jun	<b>53.6</b>	<b>53.4</b>	8.4	20.4	n/a	n/a	13.3	19.7
12-Jun	11.9	21.3	<b>38.7</b>	44.7	<b>30.1</b>	41.7	<b>31.9</b>	36.3
13-Jun	8.5	26.1	24.6	29.6	18.2	29.1	<b>25.7</b>	29.9
18-Jun	1.7	8.6	11.0	24.2	14.4	24.1	<b>27.4</b>	32.9
21-Jun	3.9	16.4	19.2	44.1	12.7	26.2	<b>30.2</b>	36.6
23-Jun	11.4	22.1	5.4	11.6	4.2	15.8	<b>31.5</b>	36.0
24-Jun	6.1	14.0	5.6	11.5	3.7	14.1	<b>34.8</b>	37.8
26-Jun	1.9	9.2	6.9	11.9	3.6	13.8	<b>30.1</b>	33.5
28-Jun	1.7	9.4	11.7	15.0	7.7	18.2	<b>30.8</b>	33.1
29-Jun	1.9	12.4	9.9	13.1	7.5	17.5	<b>47.8</b>	48.1
21-Jul	8.6	21.6	19.2	25.0	<b>30.2</b>	47.1	<b>33.4</b>	41.6
27-Jul	10.3	25.0	<b>39.5</b>	49.0	<b>32.8</b>	<b>50.7</b>	<b>28.4</b>	40.9
28-Jul	12.1	28.2	<b>26.8</b>	36.2	19.9	36.0	22.3	36.4
29-Jul	17.3	39.4	<b>26.0</b>	34.3	22.5	38.7	21.3	31.7
30-Jul	17.2	32.0	<b>27.4</b>	33.3	18.4	29.5	22.1	29.7
31-Jul	20.6	39.2	<b>25.9</b>	31.1	18.9	28.5	23.9	29.6
6-Aug	3.7	17.6	19.5	27.6	11.2	n/a	<b>25.9</b>	39.6
7-Aug	10.1	23.4	<b>32.6</b>	40.7	20.1	38.9	<b>27.6</b>	39.8
13-Aug	4.1	19.5	10.8	20.8	21.8	41.1	<b>30.2</b>	<b>52.3</b>
15-Aug	7.5	22.1	<b>34.1</b>	<b>119.9</b>	8.4	21.7	19.7	30.6
21-Aug	7.5	22.3	<b>39.4</b>	48.6	13.1	27.6	22.8	37.1
24-Aug	13.4	<b>60.4</b>	16.8	23.0	8.1	20.6	12.9	20.6
25-Aug	9.9	45.7	17.7	<b>51.8</b>	14.4	<b>66.0</b>	18.2	<b>51.3</b>
27-Aug	11.6	30.7	18.2	27.7	23.2	45.2	<b>28.9</b>	41.9

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Date	Particulates Concentration ( $\mu\text{g}/\text{m}^3$ )							
	Katherine		Palmerston		Stokes Hill		Winnellie	
	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10
29-Aug	<b>56.0</b>	<b>93.6</b>	17.3	24.1	19.1	35.5	22.5	33.3
30-Aug	<b>27.5</b>	45.0	24.4	30.9	14.6	28.6	18.4	27.5
10-Sep	8.4	21.3	<b>27.6</b>	38.8	14.6	35.4	<b>27.7</b>	42.4
13-Sep	<b>32.0</b>	39.2	9.9	15.9	7.0	19.6	10.4	20.5
22-Sep	6.9	<b>62.4</b>	12.3	29.1	5.8	<b>67.6</b>	14.0	35.7
23-Sep	6.1	35.3	24.4	39.9	22.9	<b>95.3</b>	22.9	40.1
24-Sep	10.7	36.6	<b>40.5</b>	<b>54.2</b>	16.7	n/a	<b>25.4</b>	41.2
25-Oct	<b>25.0</b>	33.7	7.6	10.7	7.6	15.4	11.7	18.0
1-Nov	<b>39.3</b>	<b>59.5</b>	<b>26.8</b>	29.7	<b>26.1</b>	38.6	<b>26.9</b>	33.4
24-Nov	<b>25.3</b>	49.5	4.3	7.5	2.3	10.4	5.6	11.6
<b>Exceedances</b>	<b>15</b>	<b>6</b>	<b>12</b>	<b>3</b>	<b>4</b>	<b>4</b>	<b>27</b>	<b>2</b>

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<sub>2.5</sub>, nitrogen dioxide (NO<sub>2</sub>) and ozone (O<sub>3</sub>) concentrations for the Greater Darwin Region.

SA2 <sup>1</sup>	Population <sup>2</sup> (P <sub>i</sub> )	PM <sub>2.5</sub> (µg/m <sup>3</sup> ) (P <sub>i</sub> × C <sub>i</sub> )	NO <sub>2</sub> (ppm) (P <sub>i</sub> × C <sub>i</sub> )	O <sub>3</sub> (ppm) (P <sub>i</sub> × C <sub>i</sub> )
Darwin Airport	18	208.8	0.0468	0.288
East Point	14	162.4	0.0364	0.224
Ludmilla - The Narrows	2545	29522	6.617	40.72
Parap	2747	31865.2	7.1422	43.952
Woolner - Bayview - Winnellie	2821	32723.6	7.3346	45.136
Alawa	2127	24673.2	5.5302	34.032
Anula	2369	27480.4	6.1594	37.904
Berrimah	1277	14813.2	3.3202	20.432
Brinkin - Nakara	3581	41539.6	9.3106	57.296
Buffalo Creek	0	0	0	0
Charles Darwin	0	0	0	0
Coconut Grove	3050	35380	7.93	48.8
East Arm	13	150.8	0.0338	0.208
Jingili	1757	20381.2	4.5682	28.112
Karama	4944	57350.4	12.8544	79.104
Leanyer	4578	53104.8	11.9028	73.248
Lyons (NT)	4799	55668.4	12.4774	76.784
Malak - Marrara	4549	52768.4	11.8274	72.784
Millner	2548	29556.8	6.6248	40.768
Moil	2000	23200	5.2	32
Nightcliff	3853	44694.8	10.0178	61.648
Rapid Creek	3282	38071.2	8.5332	52.512
Tiwi	2562	29719.2	6.6612	40.992
Wagaman	2162	25079.2	5.6212	34.592
Wanguri	1876	21761.6	4.8776	30.016
Wulagi	2435	28246	6.331	38.96
Darwin City	6464	40723.2	20.0384	116.352
Fannie Bay - The Gardens	3351	21111.3	10.3881	60.318
Larrakeyah	3729	23492.7	11.5599	67.122
Stuart Park	4149	26138.7	12.8619	74.682
Howard Springs	6981	61432.8	41.1879	111.696
Humpty Doo	8711	76656.8	51.3949	139.376
Koolpinyah	25	220	0.1475	0.4
Virginia	3292	28969.6	19.4228	52.672
Weddell	4527	39837.6	26.7093	72.432
Bakewell	3069	27007.2	18.1071	49.104
Driver	2884	25379.2	17.0156	46.144
Durack - Marlow Lagoon	4287	37725.6	25.2933	68.592
Gray	3288	28934.4	19.3992	52.608

SA2 <sup>1</sup>	Population <sup>2</sup> (P <sub>i</sub> )	PM <sub>2.5</sub> (µg/m <sup>3</sup> ) (P <sub>i</sub> × C <sub>i</sub> )	NO <sub>2</sub> (ppm) (P <sub>i</sub> × C <sub>i</sub> )	O <sub>3</sub> (ppm) (P <sub>i</sub> × C <sub>i</sub> )
Moulden	2959	26039.2	17.4581	47.344
Palmerston - North	4231	37232.8	24.9629	67.696
Palmerston - South	3069	27007.2	18.1071	49.104
Rosebery - Bellamack	6678	58766.4	39.4002	106.848
Woodroffe	3233	28450.4	19.0747	51.728
<b>Population Weighted Exposure</b>	<b>Population</b>	<b>PM<sub>2.5</sub> (µg/m<sup>3</sup>)</b>	<b>NO<sub>2</sub> (ppm)</b>	<b>O<sub>3</sub> (ppm)</b>
<b>Greater Darwin Region</b>	<b>136834</b>	<b>9.74</b>	<b>0.00404</b>	<b>0.0163</b>

<sup>1</sup>SA2 – ABS Statistical Areas Level 2 are normally designed around whole gazetted suburbs

<sup>2</sup>Population from ABS 2016 census for the SA2 area

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

*C<sub>i</sub>* = annual average pollutant concentration at each suburb

*P<sub>i</sub>* = population at each suburb

*P<sub>T</sub>* = total population in Greater Darwin Region

Annual average pollutants concentrations (C<sub>i</sub>) used to determine population weighted exposure

	PM <sub>2.5</sub> (µg/m <sup>3</sup> )	NO <sub>2</sub> (ppm)	O <sub>3</sub> (ppm)
Palmerston	8.8	0.0059	0.016
Stokes Hill	6.3	0.0031	0.018
Winnellie	11.6	0.0026	0.016