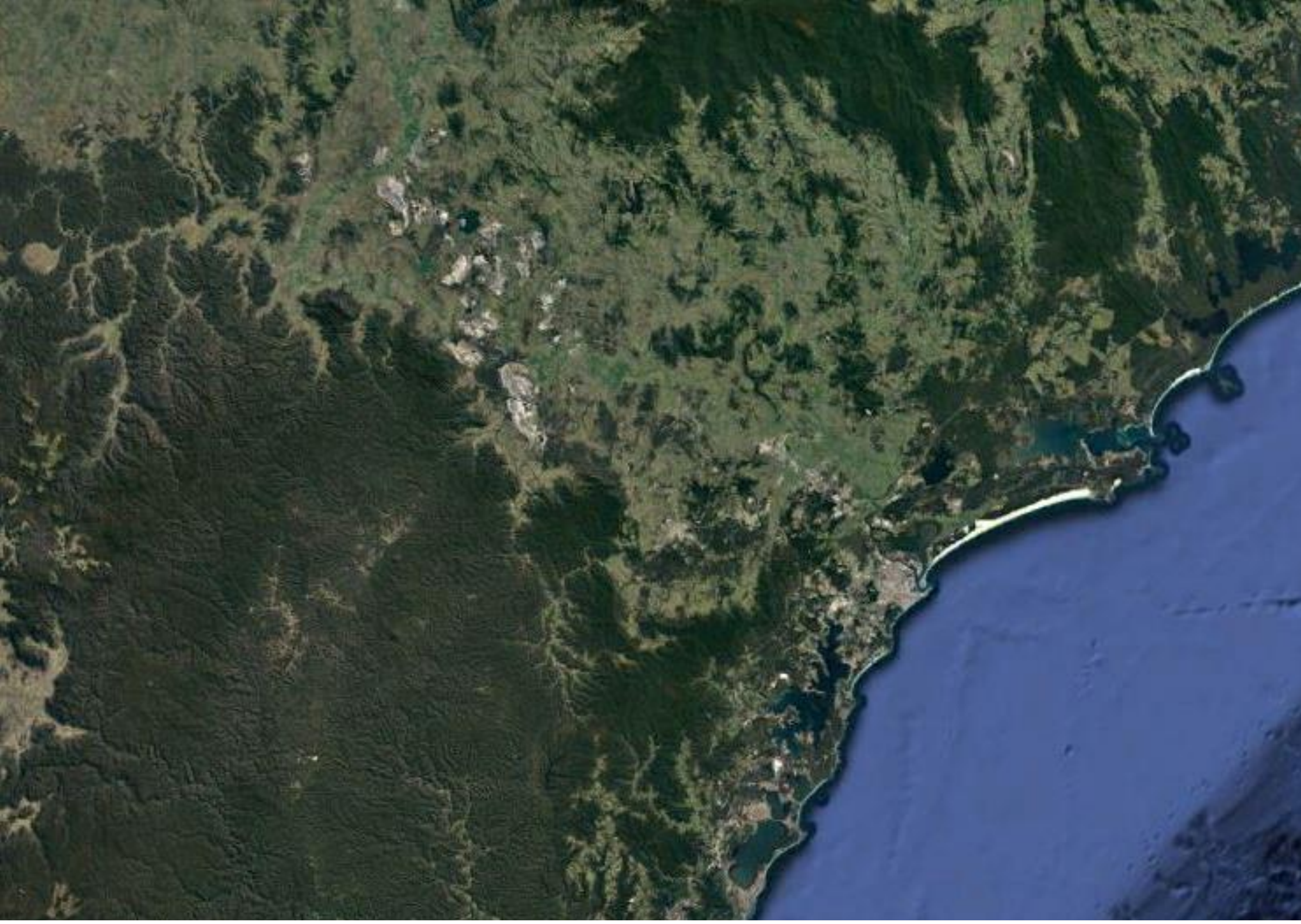

Upper Hunter Mining Dialogue

Air Quality Monitoring Data Analysis Project

16 November 2020

Project No.: 0526661

The business of sustainability

ERM

Document details

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16 November 2020

Upper Hunter Mining Dialogue

Air Quality Monitoring Data Analysis Project

James Grieve
Senior Consultant

Damon Roddis
Partner

ERM Australia Pacific P/L

Level 15, 309 Kent Street

Sydney NSW 2000

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Acronyms and Abbreviations

Name	Description
AAQS	Ambient Air Quality Standard
AQMS	Air Quality Monitoring Station
DPIE	Department of Planning, Industry and the Environment
LGA	Local Government Area
NEPC	National Environment Protection Council
NPI	National Pollutant Inventory
NSWMC	New South Wales Minerals Council
NSWEPA	New South Wales Environment Protection Authority
OEH	Office of Environment and Heritage (superseded by DPIE)
$PM_{2.5}$	Particulate Matter less than 2.5 microns in aerodynamic diameter
PM_{10}	Particulate Matter less than 10 microns in aerodynamic diameter
UHAQAC	Upper Hunter Air Quality Advisory Committee
UHAQMN	Upper Hunter Air Quality Monitoring Network
TSP	Total Suspended Particulate
WHO	World Health Organisation

EXECUTIVE SUMMARY

ERM has been commissioned by the NSW Minerals Council to undertake a review of ambient air quality monitoring data collected across the NSW Department of Planning, Industry and Environment (DPIE) air quality network, inclusive of the Upper Hunter Air Quality Monitoring Network (UHAQMN).

The objective of this analysis is to address the following two questions:

1. *Has the air quality in the Upper Hunter Valley changed since monitoring began?; and*
2. *Is the air quality in the Upper Hunter Valley measured at the monitoring stations different from air quality measured at other locations in NSW?*

Based on this analysis, the following findings are made:

- Annual average PM_{10} concentrations within the Upper Hunter are broadly consistent with Lower Hunter, but also higher than a range of other regions within NSW. The difference between the Upper Hunter and average concentrations in NSW is small relative to the variability observed between years.
- Across the UHAQMN, the difference between Background, Diagnostic and population-based station groups is indicative of an influence from mining as well as other anthropogenic sources. Lower concentrations are observed at Background stations, and higher concentrations are observed at Diagnostic stations. Concentrations observed at population-based stations fall between these two monitor groups.
- A further analysis of the trends in station group values was conducted for the review period. This analysis showed a consistent difference between station groups (within each year), indicating that changes in Upper Hunter PM_{10} concentrations over time are associated with regional conditions such as rainfall and are indicative of a minimal change in the contribution from local emission sources inclusive of mining
- Significant increases were observed in annual average UHAQMN PM_{10} concentrations between 2017 and 2019. These increases were found to be generally consistent with trends observed across the remainder of NSW, which showed a correlation with the progressive decrease in annual rainfall and increased prevalence of drought conditions.
- A review of trends in mining operations did not find a correlation between ambient PM_{10} concentrations and coal production, or ambient PM_{10} concentrations and NPI reported PM_{10} emissions.
- A review of NSW/ACT average rainfall showed a correlation between below average rainfall and above average UHAQMN PM_{10} concentrations.
- As consistent with PM_{10} monitoring results, $PM_{2.5}$ concentrations are elevated across 2018 and 2019, with highest concentrations measured at the UHAQMN Larger Populations station group. These data likely contain a significant influence from wood smoke (CSIRO, 2013). Trends in annual average concentrations were also found to be consistent with the remainder of NSW.

In the context of the objectives of this analysis:

1. ***Has the air quality in the Upper Hunter Valley changed since monitoring began?***

   Yes, concentrations have varied significantly over the period reviewed, but in a manner that is generally consistent with monitoring data collected at DPIE stations across the remainder of NSW.

   While correlations with mining emissions and coal production were not identified, a correlation with regional average rainfall was observed. Lower than average rainfall is associated with above average particulate matter concentrations. The mechanisms for this are associated with progression of drought conditions, including increased prevalence of wind erosion/dust storms and bushfire activity.

An increase in the contribution from mining operations would be expected to produce an increasing difference between the concentrations measured at Diagnostic stations and those measured at Background stations. Such a trend was not observed, with the differences between PM_{10} concentrations at Background stations and Diagnostic stations found to be near identical across 2013-2019 (i.e. up to 2 µg/m³ variability). The range in annual average concentrations across this period is of the order of 15 µg/m³. In this respect, the trends in Upper Hunter PM_{10} concentrations are not considered indicative of an increased contribution from mining operations.

2. ***Is the air quality in the Upper Hunter Valley measured at the monitoring stations different from air quality measured at other locations in NSW?***

Yes, the UHAQMN data does feature higher PM_{10} concentrations than a range of regions across NSW but is also broadly consistent with concentrations measured within the Lower Hunter and Central Coast. In addition, the difference between the Upper Hunter and the remainder of NSW is small in scale relative to the variability in concentrations across NSW. $PM_{2.5}$ concentrations are higher than elsewhere in NSW, and are likely to be influenced by wood smoke, as identified in CSIRO (2013).

1. INTRODUCTION

ERM Australia Pacific P/L (ERM) has been commissioned by the NSW Minerals Council (NSWMC) to undertake a review of ambient air quality monitoring data collected across the NSW Department of Planning, Industry and Environment (DPIE) air quality network, inclusive of the Upper Hunter Air Quality Monitoring Network (UHAQMN).

The Upper Hunter Mining Dialogue (‘the Dialogue) hosted their annual forum event in November 2018, seeking feedback from stakeholders on potential environment-focused projects that the Dialogue could explore in future years. A common theme of the feedback received was for the Dialogue to provide guidance to the Upper Hunter community on how to better understand and interpret air quality data.

The Dialogue's Joint Environment Working Group and Joint Advisory Steering Committee discussed various project ideas under the Air Quality theme, and supported the Dialogue to conduct an analysis of publicly available long-term air quality monitoring data to determine whether this had changed over time and how it compared with other regions.

The Dialogue regularly receives community stakeholder feedback regarding the impacts of mining activity on air quality in the Upper Hunter, including concerns that:

- the air quality in the Upper Hunter is worsening; and
- the air quality is poorer in the Upper Hunter than in other regions.

The Dialogue’s Steering Committee recently endorsed a project seeking to analyse available long-term air quality data gathered via the Upper Hunter Air Quality Monitoring Network data to provide an assessment of long-term trends of air quality in the Upper Hunter.

The development of the project, including governance arrangements and objectives, was undertaken in consultation with members from the Dialogue’s Joint Working Group and Steering Committees, which consist of community, business, government, research and industry representatives.

Under this project, the Dialogue is seeking an analysis and interpretation of existing air quality monitoring network data and other contextual information in order answer the following questions:

1. *Has the air quality in the Upper Hunter Valley changed since monitoring began?; and*
2. *Is the air quality in the Upper Hunter Valley measured at the monitoring stations different from air quality measured at other locations in NSW?*

The intent of this project is to provide:

- accurate information to Upper Hunter stakeholders about the air quality they are experiencing in easily understood terms; and
- clarity and certainty to the Upper Hunter air quality debate through an assessment and comparison of air quality measured at the Upper Hunter monitoring network to the air quality measured at other NSW regions, with analysis supported by data from independent organisations.

This project was designed to address two specific air quality questions, and is not intended to be a comprehensive assessment of all air quality issues experienced in the Upper Hunter. The Dialogue will continue to work with key stakeholders on air quality issues which may result in the need to undertake further investigations or analysis projects under this theme.

2. PARTICULATE MATTER OVERVIEW

Particulate matter has the capacity to affect health and to cause nuisance effects, and is categorised by size and/or by chemical composition. The potential for harmful effects depends on both. The particulate size ranges are commonly described as:

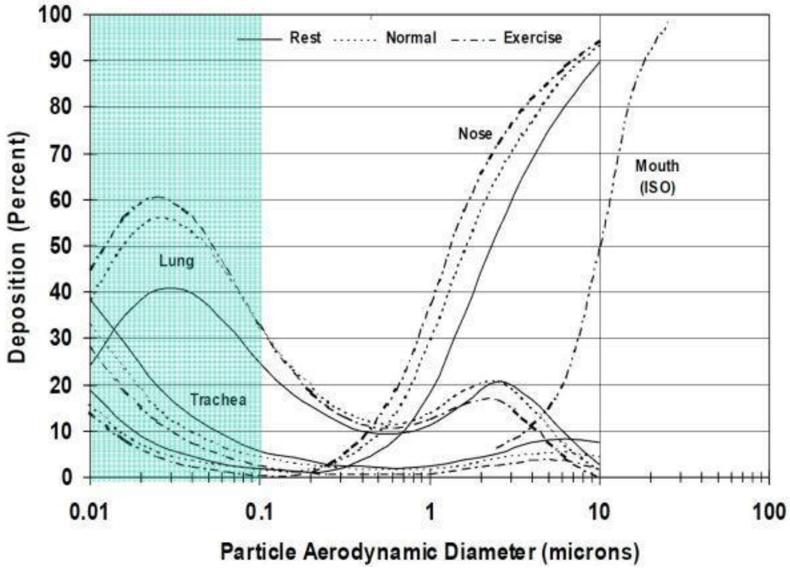
- TSP – refers to all suspended particles in the air. In practice, the upper size range is typically 30 µm.
- PM_{10} – refers to all particles with equivalent aerodynamic diameters of less than 10 µm, that is, all particles that behave aerodynamically in the same way as spherical particles with diameters less than 10 µm and with a unit density. PM_{10} is a sub-component of TSP.
- $PM_{2.5}$ – refers to all particles with equivalent aerodynamic diameters of less than 2.5 µm diameter. These are often referred to as the fine particles and are a sub-component of PM_{10}.

Evidence suggests that health effects from exposure to airborne particulate matter are predominantly related to the respiratory and cardiovascular systems (WHO, 2011). The human respiratory system has in-built defensive systems that prevent larger particles from reaching the more sensitive parts of the respiratory system. Particles larger than 10 µm, while not able to affect health, can stain materials and generally degrade aesthetic elements of the environment. For this reason, air quality goals make reference to measures of the total mass of all particles suspended in the air, referred to as TSP. In practice, particles larger than 30 to 50 µm settle out of the atmosphere too quickly to be regarded as air pollutants. The upper size range for TSP is usually taken to be 30 µm.

Both natural and anthropogenic processes contribute to the atmospheric load of particulate matter. Coarse particles ($PM_{2.5-10}$) are derived primarily from mechanical processes resulting in the suspension of dust, soil, or other crustal materials from roads, farming, mining and dust storms. Coarse particles also include sea salts, pollen, mould, spores, and other plant parts. Mining dust is likely to be composed of predominantly coarse particulate matter (and larger).

Fine particles or $PM_{2.5}$ are derived primarily from combustion processes, such as vehicle emissions, wood burning, coal burning for power generation and natural processes such as bush fires. Fine particles also consist of transformation products, including sulphate and nitrate particles, and secondary organic aerosol from volatile organic compound emissions. $PM_{2.5}$ may penetrate beyond the larynx and into the thoracic respiratory tract and evidence suggests that particles in this size range are more harmful than the coarser component of PM_{10}.

The size of particles determine their behaviour in the respiratory system, including how far the particles are able to penetrate, where they deposit, and how effective the body's clearance mechanisms are in removing them. This is demonstrated in Figure 3.1, which shows the relative deposition by particle size within various regions of the respiratory tract. Additionally, particle size is an important parameter in determining the residence time and spatial distribution of particles in ambient air and is a key consideration in assessing exposure.



Source: *(Phalen et.al, 1991)*

Figure 2.1: Particle deposition within the respiratory tract

The health-based assessment criteria used by NSW EPA have, to a large extent, been developed by reference to epidemiological studies undertaken in urban areas with large populations where the primary pollutants are the products of combustion (National Environment Protection Council [NEPC], 1998a; NEPC, 1998b).

Table 2.1 presents the ambient air quality standards (AAQS) for particulate matter as applied within NSW (NSW EPA, 2016) and NEPM compliance frameworks (NEPC, 1998a, 2015).

Table 2.1: NSW ambient air quality standards for particulate matter

Pollutant	Averaging Period	Concentration (µg/m³)
PM_{10}	24-hour	50
	Annual mean	25
$PM_{2.5}$	24-hour	25
	Annual mean	8

The current PM_{10} and $PM_{2.5}$ AAQS provided in EPA (2016) are consistent with the national standards provided in the amended National Environment Protection (Ambient Air Quality) Measure (AG, 2015). It is noted that an annual average PM_{10} standard was introduced in the NEPM at this time, while the Approved Methods annual average PM_{10} standard was changed from 30 µg/m³ to 25 µg/m³ in 2017 to be consistent with the recently introduced NEPM value.

3. UPPER HUNTER AIR QUALITY MONITORING NETWORK (UHAQMN)

The UHAQMN was established between 2010 and 2012 and comprises 14 air quality monitoring stations (AQMS) in total. The UHAQMN is a partnership between the NSW Government and the Upper Hunter coal and power industries. The sites are operated and maintained by Department of Planning Industry and Environment (DPIE) staff using funds contributed by industry under Chapter 5A of the Protection of the Environment (General) Regulation 2009.

The Upper Hunter Air Quality Advisory Committee (UHAQAC) advises the NSW Environment Protection Authority (EPA) and DPIE on matters specifically related to the design and operation of the network. The UHAQAC currently has 14 members representing the community, the coal and power generation industries, local government and NSW government agencies. More information about the about the UHAQMN is available at the DPIE website[1] (DPIE, 2020a)

The data are collected on a continuous basis and are reported on the DPIE website (DPIE, 2020b). The measured parameters include PM_{10}, wind speed, wind direction, temperature and relative humidity, as well as $PM_{2.5}$ at Singleton, Muswellbrook and Camberwell.

Table 3.1 presents a summary of stations and purpose of stations within the UHAQMN, while Figure 4.1 shows the location of these stations within and around the Hunter Valley.

Table 3.1: Summary of Stations / purpose within the UHAQMN

Station type	Purpose	Stations
Larger Populations	Monitoring air quality in the larger population centres	- Muswellbrook - Singleton - Aberdeen
Smaller communities	Monitoring air quality in the smaller communities	- Bulga - Camberwell - Jerrys Plains - Maison Dieu - Warkworth - Wybong
Diagnostic	Providing data that can help to diagnose the likely sources and movement of particles across the region as a whole; they do not provide information about air quality at population centres.	- Mount Thorley - Muswellbrook NW - Singleton NW
Background	Provide background data; located at both ends of the valley they measure the quality of air entering and leaving the Upper Hunter Valley under predominant winds (south-easterlies and north-westerlies).	- Merriwa - Singleton South

[1] https://www.environment.nsw.gov.au/topics/air/monitoring-air-quality/upper-hunter/upper-hunter-air-quality-reports

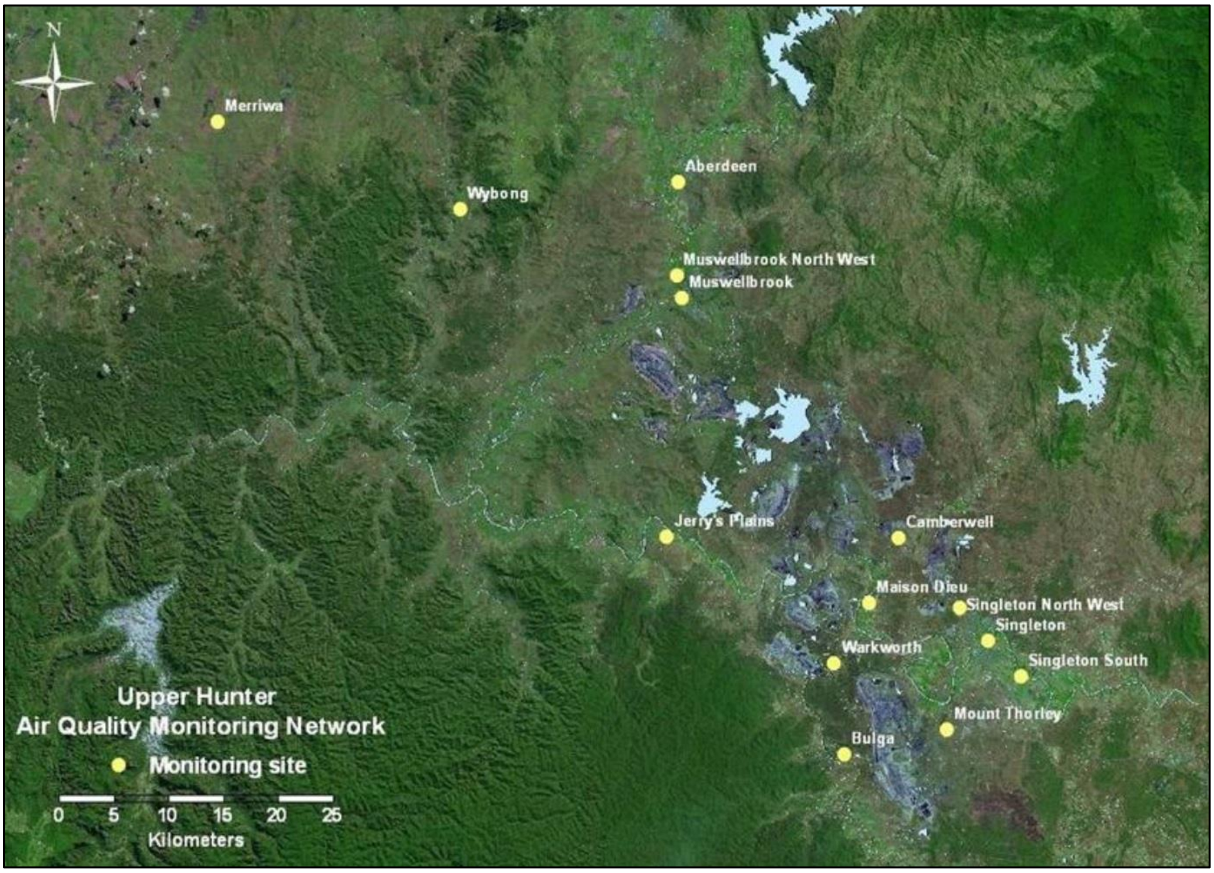


Image source: OEH (2016)

Figure 3.1: Aerial image showing UHAQMN locations within and around the Hunter Valley.

4. MONITORING DATA

This section provides a summary of monitoring data collected between 2013 and 2019 by DPIE monitoring stations. This is inclusive of the 14 UHAQMN AQMS, and the broader DPIE air quality monitoring network, which comprises an additional 45 AQMS across NSW.

These seven years of data have been presented for both PM_{10} and $PM_{2.5}$ as the following:

- Period (2013-2019) average concentration by monitoring station;
- Annual average concentration by region;
- Period (2013-2019) average exceedances by station; and
- Annual exceedances by region.

Monitoring data has been sourced from the DPIE website and presented in both tabulated and graphical formats. Results have been shaded using a green to red colour relative gradient scheme with lowest values shown in green, and highest values shown in red, with the median value shown in yellow. It is noted that this colour gradient scheme is focused on aiding interpretation of the data, and does not follow the Air Quality Index (AQI) colour coding scheme applied on the DPIE website[2]. This gradient scheme has been applied to the annual data and 'all years' result groups separately.

Stations with three or more years of missing data have been excluded from this analysis. These comprise newly introduced stations, as well as several stations that were decommissioned during the study period.

Table 4.1: List of DPIE stations excluded from analysis

PM_{10}	$PM_{2.5}$
Albion Park	Rozelle
Albion Park Rail	Bringelly
Warrawong	Kembla Grange
Armidale	Bargo
Gunnedah	Albury
Goulburn	St Marys
Narrabri	Bathurst
Orange	Oakdale
Wagga Wagga	Campbelltown West
Blacktown	Tamworth
Campbelltown	
Cook and Phillip	
Lidcombe	
Macarthur	
Macquarie Park	
Parramatta North	
Rouse Hill	

Further detail is provided in the following sections.

Exceedances have been based on performance against the ambient air quality standards presented in Section 2.

[2] https://www.dpie.nsw.gov.au/air-quality/current-air-quality

4.1 PM_{10} Monitoring Results

Table 4.2 presents a summary of PM_{10} monitoring results for each DPIE station between 2013 and 2019. Averages across this period are shown in the right hand column.

Table 4.2: Annual and period average PM_{10} concentrations by station (µg/m³)

Region / Group	Station	Year							All Years
		2013	2014	2015	2016	2017	2018	2019	
Central Tablelands	Bathurst	15.1	14.6	13.4	13.3	14.1	18.8	27.4	16.7
Illawarra	Wollongong	17.6	17.7	16.9	17.3	18.1	19.8	22.6	18.6
	Kembla Grange	18.5	17.3	17.8	20	20.5	22.7	25.5	20.3
	Albion Park South	14.7	16.2	14	14.9	15.3	17.8	19.5	16.1
Lower Hunter & Central Coast	Wyong	16.6	15.1	14.9	15.2	16.1	18	21.1	16.7
	Wallsend	-	16.9	16.7	16.6	17.4	19.4	22.9	18.3
	Carrington	-	-	22.8	23.6	24.4	27.3	31	25.8
	Stockton	-	-	35.8	35.1	36.4	38.7	43.6	37.9
	Newcastle	22.7	21.4	21.4	21.6	22.4	24.5	28.4	23.2
	Mayfield	-	-	21.7	22.6	24.2	26.9	30.8	25.2
	Beresfield	21.4	19.4	18.8	19.1	19.6	21.6	25.9	20.8
North West Slopes	Tamworth	16.6	15.8	14.1	15.3	15.3	20.1	33.7	18.7
South West Slopes	Albury	15.8	15.9	14.6	15.1	15.8	19.8	23.4	17.2
	Wagga Wagga North	22.1	20.7	19.9	20.6	20.6	27.4	35.3	23.8
Sydney East	Randwick	18.8	18.1	18.6	18	19.2	21.2	24.1	19.7
	Rozelle	18.3	17.9	16.7	16.8	18.1	-	22.7	18.4
	Lindfield	14.4	14.1	14	15.4	16	18	-	15.3
	Chullora	18.3	18.1	17.5	18.1	20.1	21.9	24.6	19.8
	Earlwood	19.9	18.3	17.2	17.6	18	19.8	23	19.1
Sydney North West	Richmond	17.3	15.4	12.8	16	16	18.7	24.2	17.2
	St Marys	16	16.7	15	16.1	16.2	-	24.6	17.4
	Prospect	19.2	17.6	17.6	18.9	18.9	21.9	26	20.0
Sydney South West	Liverpool	21	19.1	18.5	19.6	20.6	24.2	27.7	21.5
	Bringelly	17	16.6	15.8	16.9	19.8	21.3	23.6	18.7
	Bargo	15.3	14.3	13.4	14.4	13.9	16.9	21.2	15.6
	Oakdale	13.6	13.1	11.4	12.2	12.1	15.4	22.4	14.3
	Campbelltown West	15.5	17	15.6	16.1	15.7	17.9	22.3	17.2
	Camden	15.4	15.6	13.8	14.4	14.7	17.5	22.5	16.3
UHAQMN - BG	Singleton South	20.2	18.3	16.9	18	19.4	23	30.7	20.9
	Merriwa	14.9	15.2	13.2	13.5	14.2	19.2	27.9	16.9
UHAQMN - DG	Singleton NW	25.9	22.7	20.9	21.9	22.7	26.9	34.6	25.1
	Mount Thorley	24.7	21.5	19.8	22.8	25.4	29.1	36.4	25.7
	Muswellbrook NW	18.9	19.2	16.7	16.6	18.5	25	33.7	21.2
UHAQMN - LP	Muswellbrook	22.6	21.4	19.1	19.2	21.7	27.2	34.4	23.7
	Singleton	23.3	21	19.3	19.3	20.8	24	30.1	22.5
	Aberdeen	17.3	17.9	15.2	15.6	17.6	22.3	29.5	19.3
UHAQMN - SC	Maison Dieu	25.8	22.7	20.4	20.4	23.1	27.9	38	25.5
	Camberwell	27.8	24.6	22	24.5	27.4	31.1	39.9	28.2
	Bulga	19.2	17.7	15	16.1	17.2	21.3	28.6	19.3
	Wybong	15.5	16.9	14.8	15.3	16.6	21.6	28.5	18.5
	Jerrys Plains	18.6	18.2	15.5	16.8	18	24.3	32.1	20.5
	Warkworth	21.4	20.6	18.2	18.6	21.8	26.4	33.4	22.9

Colour Coding by Percentile (scheme applied independently to annual data and 'all years')

0% (Minimum)	10%	20%	30%	40%	50% (Median)	60%	70%	80%	90%	100% (Maximum)

Notes: BG – Background, DG – Diagnostic, LP – Larger Populations, SC – Smaller Communities.

As shown in Table 4.2, PM_{10} concentrations are highest in 2019, with Stockton showing the highest results across all stations. Stockton particle levels are influenced by sea salt spray transported by onshore winds, which are dominant during the summer months (OEH, 2018). The second highest concentrations are measured at Camberwell, where PM_{10} concentrations have been associated with mining emissions and other sources such as wood smoke, as identified within UHAQMN reporting (OEH, 2016).

Table 4.3 presents a summary of annual and period average PM_{10} monitoring results that have been averaged into each region/group. The Lower Hunter and Central Coast average has been shown both with and without Stockton data, as noted within the Table 5.3.

Table 4.3: Annual and period average PM_{10} concentrations by region/group and year (µg/m³)

Region / Group	Year							All Years
	2013	2014	2015	2016	2017	2018	2019	
Central Tablelands	15.1	14.6	13.4	13.3	14.1	18.8	27.4	16.7
Illawarra	16.9	17.1	16.2	17.4	18.0	20.1	22.5	18.3
Lower Hunter & Central Coast	20.2	18.2	21.7	22.0	22.9	25.2	29.1	22.8 *(21.1)*
North West Slopes	16.6	15.8	14.1	15.3	15.3	20.1	33.7	18.7
South West Slopes	19.0	18.3	17.3	17.9	18.2	23.6	29.4	20.5
Sydney East	17.9	17.3	16.8	17.2	18.3	20.2	23.6	18.8
Sydney North West	17.5	16.6	15.1	17.0	17.0	20.3	24.9	18.4
Sydney South West	16.3	16.0	14.8	15.6	16.1	18.9	23.3	17.3
UHAQMN								
Background	17.6	16.8	15.1	15.8	16.8	21.1	29.3	18.9
Diagnostic	23.2	21.1	19.1	20.4	22.2	27.0	34.9	24.0
Larger Populations	21.1	20.1	17.9	18.0	20.0	24.5	31.3	21.8
Smaller Communities	21.4	20.1	17.7	18.6	20.7	25.4	33.4	22.5

Colour Coding by Percentile (scheme applied independently to annual data and 'all years')

0% (Minimum)	10%	20%	30%	40%	50% (Median)	60%	70%	80%	90%	100% (Maximum)

Note: Regional average excluding Stockton shown in brackets.

As shown in Table 4.3, PM_{10} concentrations vary on both an annual and regional basis, with variability also present within the UHAQMN station groups. Across NSW, the UHAQMN Diagnostic stations show the highest average (24 µg/m³) across all years, while the central tablelands feature the lowest average (17 µg/m³), representing a range of approximately 7 µg/m³. Concentrations measured at Larger Populations and Smaller Communities are broadly consistent with those measured in the Lower Hunter and Central Coast region. It should be noted that unlike other stations featured in this analysis, the Diagnostic stations are not sited with a focus on population exposure.

In terms of interannual variability within each region, the North West Slopes experienced the greatest range in annual average concentrations (20 µg/m³), while the Illawarra experienced the lowest range (6 µg/m³). This difference is expected to be primarily due to the varied regional influences of bushfire and dry conditions (inclusive of dust storms) in late-2019. Excluding 2019, the ranges are lower and more regionally consistent (3 to 7 µg/m³).

Table 5.4 provides a summary of average PM_{10} concentrations averaged across all regions. While these data are not weighted spatially or by population, they are still useful in considering interannual variability at a broad scale. As shown in Table 4.4, average concentrations across the regions were 72% higher in 2019 (the maximum year) than in 2015 (the minimum year). Also evident is the progressive increase in average concentrations between 2015 and 2019, as consistent with progressive onset of drought conditions[3] evident in 2017 and 2018, as discussed in Section 5.4.

[3] https://www.dpi.nsw.gov.au/climate-and-emergencies/seasonal-conditions/ssu/nsw-state-seasonal-update-september-2019

Table 4.4: Annual statistics across all regions

Parameter	Year							Range
	2013	2014	2015	2016	2017	2018	2019	
Average – All Regions (µg/m³)	18.6	17.7	16.6	17.4	18.3	22.1	28.6	12.0
Average (% minimum year)	112%	106%	100%	105%	110%	133%	172%	72%
Range (µg/m³)	8.1	6.5	8.3	8.7	8.8	8.2	12.4	-

Colour Coding by Percentile (scheme applied independently to each row)

0% (Minimum)	10%	20%	30%	40%	50% (Median)	60%	70%	80%	90%	100% (Maximum)

Table 4.5 presents a summary of the number of times which the NSW 24-hour PM_{10} standard is exceeded by station and year, while Table 5.6 presents a summary of total 24-hour PM_{10} exceedances by region and year.

(accessed August 2020).

Table 4.5: Exceedances of the 24 hour (short-term) PM_{10} standard by station and year

Region / Group	Station	Year							Average All Years
		2013	2014	2015	2016	2017	2018	2019	
Central Tablelands	Bathurst	3	0	2	0	0	8	40	8
Illawarra	Wollongong	7	0	0	2	1		17	5
	Kembla Grange	4	1	1	4	4	10	21	6
	Albion Park South	2	0	0	0	0	2	14	3
Lower Hunter & Central Coast	Wyong	1	0	1	0	1	6	19	4
	Wallsend		0	1	1	0		21	5
	Carrington			4	2	10	12	33	12
	Stockton			67	60	60	65	102	71
	Newcastle	4	2	3	1	1	8	29	7
	Mayfield			4	1	3	11	36	11
	Beresfield	5	0	2	0	0		30	6
North West Slopes	Tamworth	0	1	1	1	2	9	52	9
South West Slopes	Albury	2	5	2	1	0	7	25	6
	Wagga Wagga North	15	14	7	16	10	34	63	23
Sydney East	Randwick	3	0	1	0	1	5	19	4
	Rozelle	3	0	1	1	1		18	4
	Lindfield	1	0	1	1	0	4		1
	Chullora	4	0	1	1	4	7	20	5
	Earlwood	5	0	1	0	1		17	4
Sydney North West	Richmond	5	0	0	2	1		28	6
	St Marys	2	0	1	3	0		26	5
	Prospect	4	0	1	4	1	8	25	6
Sydney South West	Liverpool	3	0	1	3	2	13	28	7
	Bringelly	3	0	1	3	6		24	6
	Bargo	2	1	2	3	1	4	21	5
	Oakdale	4	1	1	5	0	5	28	6
	Campbelltown West	1	0	1	1	1	3	24	4
	Camden	2	0	1	0	0	6	27	5
UHAQMN - BG	Singleton South	5	0	2	0	2	9	44	9
	Merriwa	0	3	1	0	0	6	48	8
UHAQMN - DG	Singleton NW	28	6	4	4	12	22	62	20
	Mount Thorley	26	3	7	6	21	34	69	24
	Muswellbrook NW	1	1	2	0	1	10	57	10
UHAQMN - LP	Muswellbrook	3	1	2	0	2	13	58	11
	Singleton	12	1	3	1	5	10	41	10
	Aberdeen	0	2	1	0	2	7	51	9
UHAQMN - SC	Maison Dieu	28	6	5	0	9	25	66	20
	Camberwell	36	12	11	11	33	44	87	33
	Bulga	7	3	2	0	0	8	46	9
	Wybong	2	3	1	1	3	9	48	10
	Jerrys Plains	6	6	1	0	1	11	54	11
	Warkworth	8	3	3	0	1	16	59	13

Colour Coding by Percentile (scheme applied independently to annual data and 'average all years')

0% (Minimum)	10%	20%	30%	40%	50% (Median)	60%	70%	80%	90%	100% (Maximum)

Notes: BG – Background, DG – Diagnostic, LP – Larger Populations, SC – Smaller Communities.

Table 4.6: Exceedances of the 24 hour (short-term) PM_{10} standard by region/group and year

Region / Group	Year							Average All Years
	2013	2014	2015	2016	2017	2018	2019	
Central Tablelands	3	0	2	0	0	8	40	8
Illawarra	4	0	0	2	2	6	17	5
Lower Hunter & Central Coast	3	1	12	9	11	20	39	14
North West Slopes	0	1	1	1	2	9	52	9
South West Slopes	9	10	5	9	5	21	44	14
Sydney East	3	0	1	1	1	5	19	4
Sydney North West	4	0	1	3	1	8	26	6
Sydney South West	3	0	1	3	2	6	25	6
UHAQMN								
Background	3	2	2	0	1	8	46	9
Diagnostic	18	3	4	3	11	22	63	18
Larger Populations	5	1	2	0	3	10	50	10
Smaller Communities	15	6	4	2	8	19	60	16

Colour Coding by Percentile (scheme applied independently to annual data and 'average all years')

0% (Minimum)	10%	20%	30%	40%	50% (Median)	60%	70%	80%	90%	100% (Maximum)

Note: Regional average excluding Stockton shown in brackets.

Figure 5.1 and Figure 5.2 present PM_{10} concentrations across DPIE air quality monitoring by station and region/group (respectively), while Figure 5.3 and Figure 5.4 provide average days per year that the short term PM_{10} standard is exceeded by station and region/group (respectively).

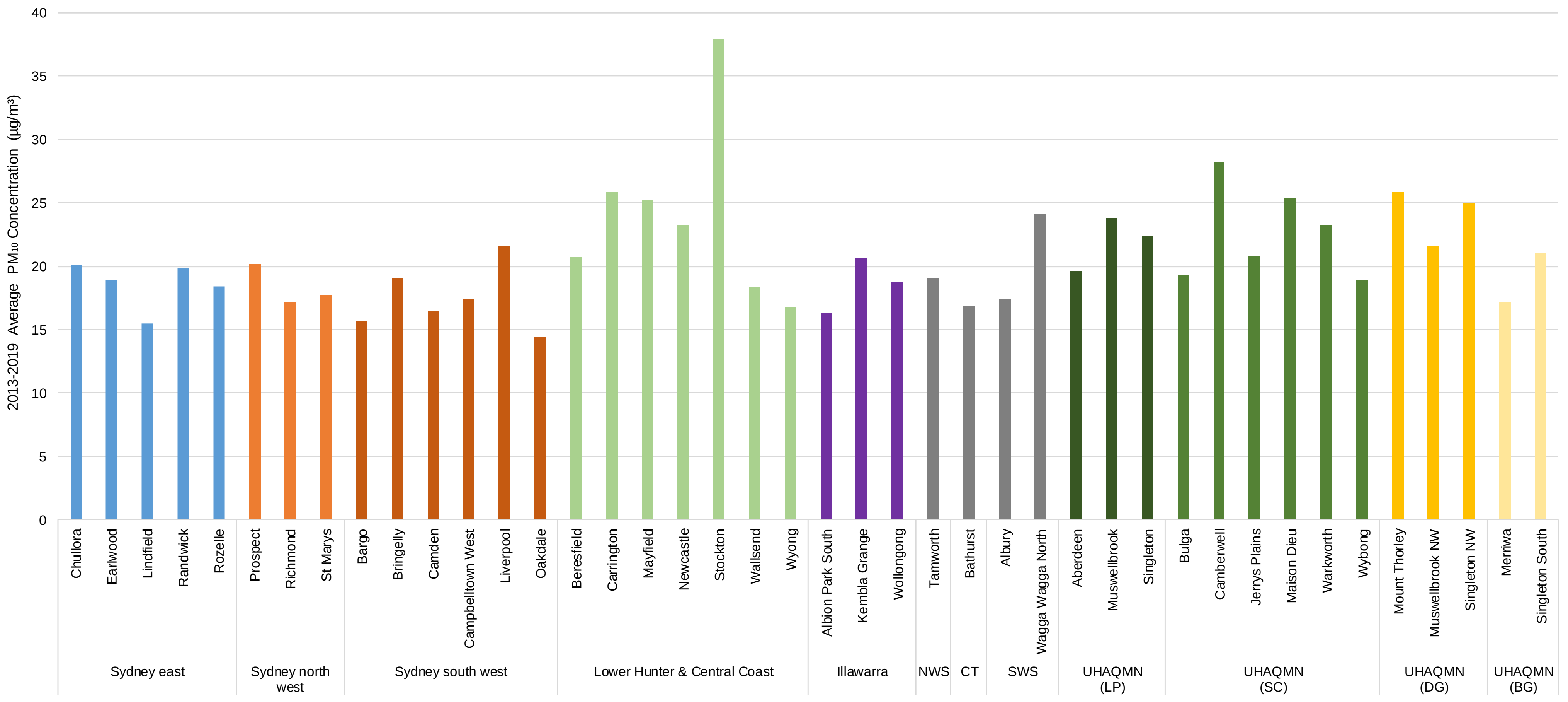


Figure 4.1: 2013–2019 average PM_{10} concentration across DPIE AQMS

Notes: NWS – North West Slopes, CT, Central Tablelands, SWS – South West Slopes, LP – Larger Populations, SC – Smaller Communities, DG – Diagnostic, BG – Background

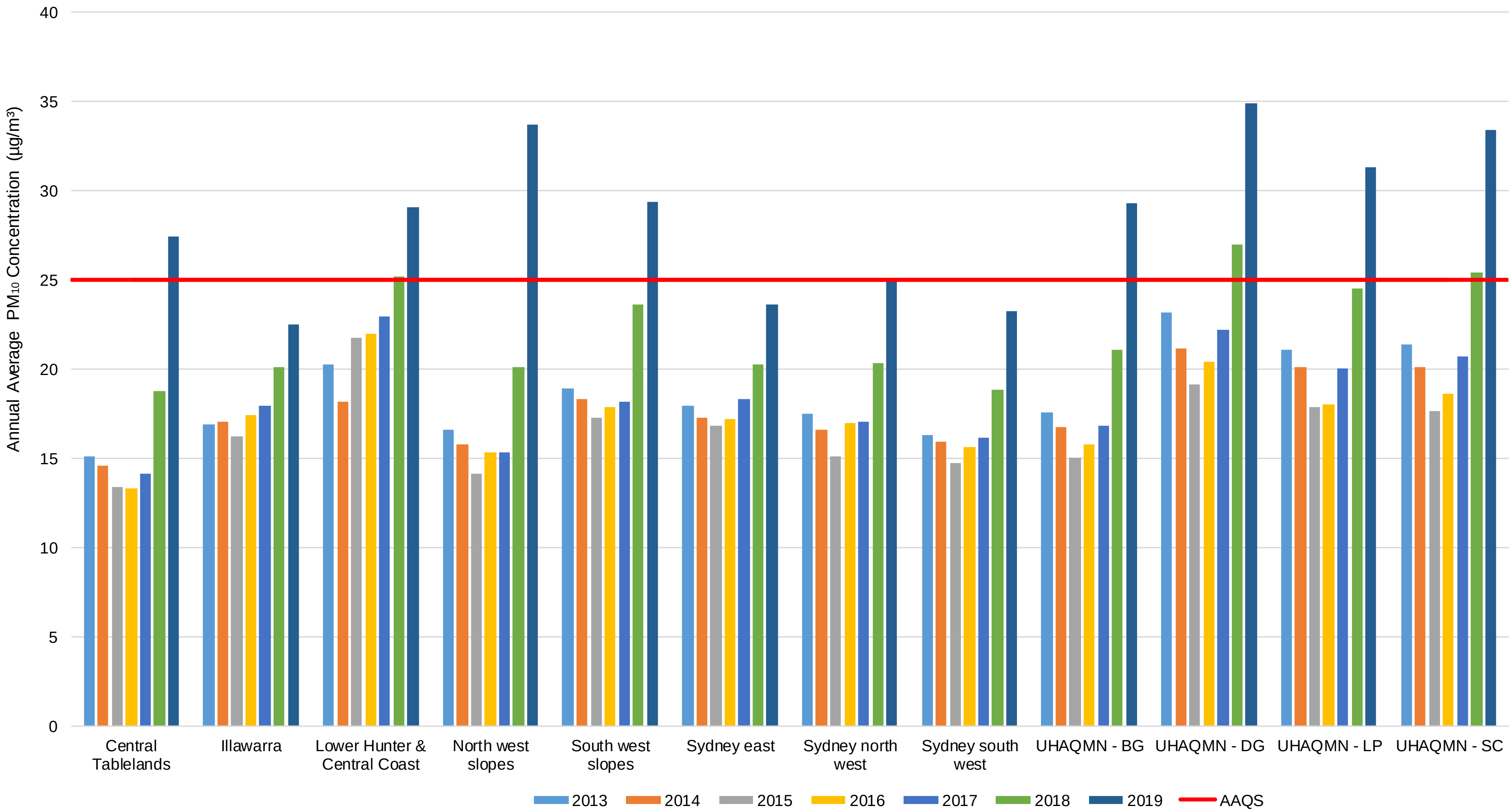


Figure 4.2: Annual average PM_{10} concentration by region/group and year

Notes: AAQS: Current NSW Ambient Air Quality Standard. AAQS apply at sensitive receptors, hence are not intended to apply to Diagnostic (DG) monitoring locations.
NWS – North West Slopes, CT - Central Tablelands, SWS – South West Slopes, LP – Larger Populations, SC – Smaller Communities, DG – Diagnostic, BG – Background,

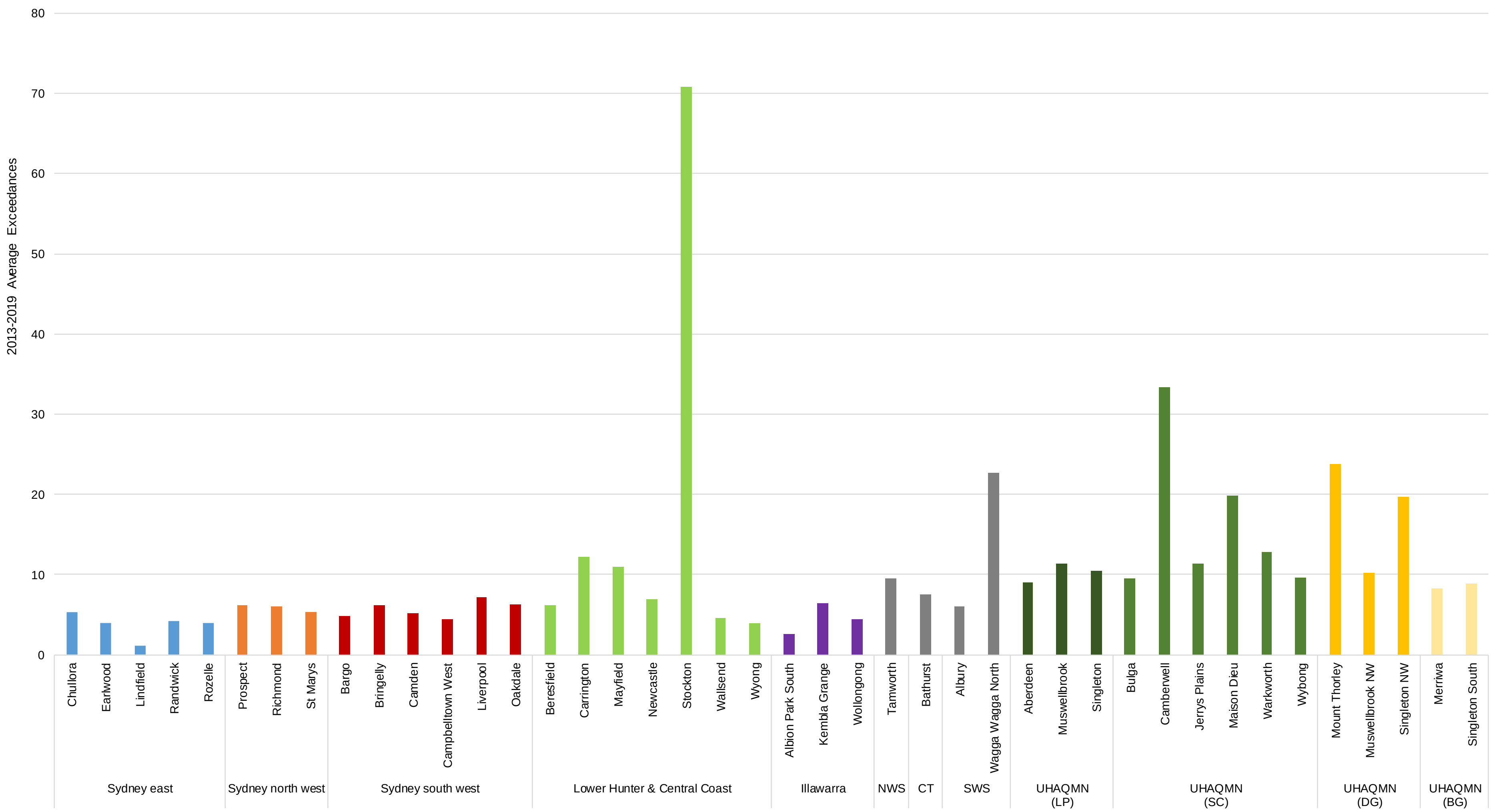


Figure 4.3: Average days per year that the short term PM_{10} standard is exceeded (2013-2019) – by station

Notes: Exceedances apply at sensitive receptors, hence are not intended to apply to Diagnostic (DG) monitoring locations.
NWS – North West Slopes, CT - Central Tablelands, SWS – South West Slopes, LP – Larger Populations, SC – Smaller Communities, DG – Diagnostic, BG – Background, AAQS – Ambient Air Quality Standard

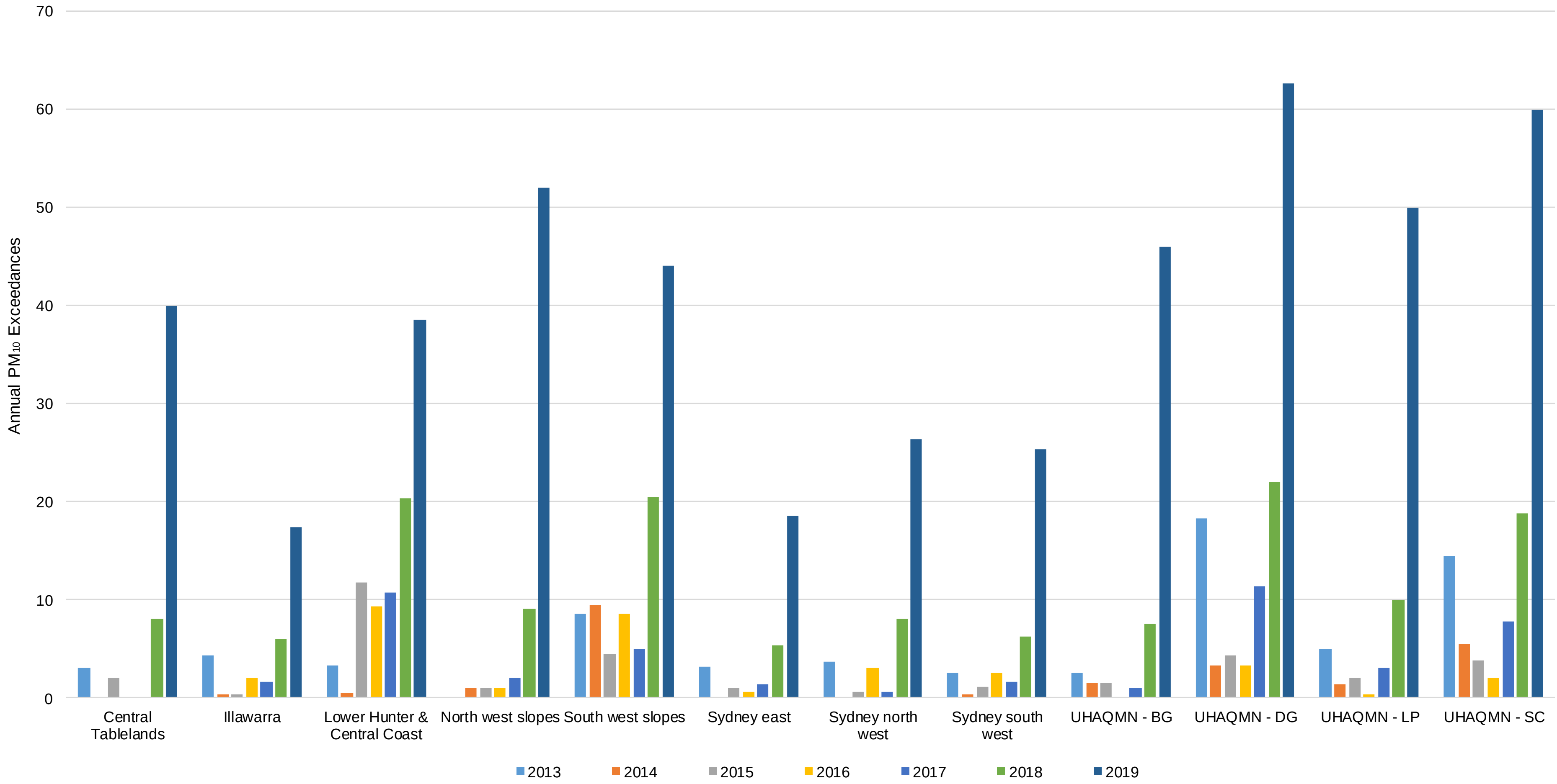


Figure 4.4: Average days per year that the short term PM_{10} standard is exceeded (2013-2019) – by region

Notes: AAQS – Ambient Air Quality Standard. AAQS apply at sensitive receptors, hence are not intended to apply to Diagnostic (DG) monitoring locations.
NWS – North West Slopes, CT - Central Tablelands, SWS – South West Slopes, LP – Larger Populations, SC – Smaller Communities, DG – Diagnostic, BG – Background.

4.2 $PM_{2.5}$ Monitoring Results

Table 4.7 presents a summary of $PM_{2.5}$ concentrations by station and region/group, while Table 4.8 presents a summary of annual and period average $PM_{2.5}$ monitoring results that have been averaged into each region/group.

Table 4.7: Annual and period average $PM_{2.5}$ concentrations by station and year (µg/m³)

Region/Group	Station	Year							All Years
		2013	2014	2015	2016	2017	2018	2019	
Illawarra	Wollongong	7.7	7	7.6	7.4	7.1	7.3	9	7.6
	Albion Park South	-	-	6.4	7.2	6.6	6.8	8.6	7.1
Lower Hunter & Central Coast	Wyong	6.7	5.5	5.2	5.7	5.8	6.8	10.5	6.6
	Wallsend	7.7	6.7	7.3	8	7.3	7.5	10.4	7.8
	Carrington	-	-	8.1	8.5	8.6	8.2	11	8.9
	Stockton	-	-	9.5	9.7	9.8	10	13	10.4
	Newcastle	-	8.1	7.8	7.8	7.4	7.8	10.9	8.3
	Mayfield	-	-	7.4	7.4	7.5	8.3	11.2	8.4
	Beresfield	8.2	7.5	7.3	7.4	7.6	8.7	12.1	8.4
South West Slopes	Wagga Wagga North	7.9	7.5	7.6	7.4	8.1	8.4	11.3	8.3
Sydney East	Chullora	8.4	9	8	8	9.5	8.6	11.5	9.0
	Earlwood	7.9	7.8	8.5	8.1	7.3	7.8	10.5	8.3
Sydney North West	Richmond	8.3	6.7	7.7	7.9	7	8.1	13.1	8.4
	Prospect	-	-	8.2	8.7	7.7	8.5	11.9	9.0
Sydney South West	Liverpool	9.4	8.6	8.5	8.7	8.9	10.1	12.8	9.6
	Camden	6.5	6.3	6.2	6.4	6.7	7.2	11.8	7.3
UHAQMN									
Larger Populations	Muswellbrook	9.4	9.7	8.7	8.4	9.4	9.4	12.2	9.6
	Singleton	7.9	7.8	7.6	7.9	8.2	8.1	10.9	8.3
Smaller Communities	Camberwell	8.2	7.8	7.2	7.5	7.4	8.4	10.5	8.1

Colour Coding by Percentile (scheme applied independently to annual data and 'all years')

0% (Minimum)	10%	20%	30%	40%	50% (Median)	60%	70%	80%	90%	100% (Maximum)

Table 4.8: Annual and period average $PM_{2.5}$ concentrations by region/group and year (µg/m³)

Region / Group	Year							
	2013	2014	2015	2016	2017	2018	2019	All
Illawarra	7.7	7.0	7.0	7.3	6.9	7.1	11.1	7.7
Lower Hunter & Central Coast	7.5	7.0	7.5	7.8	7.7	8.2	17.3	9.0
South West Slopes	7.9	7.5	7.6	7.4	8.1	8.4	11.3	8.3
Sydney East	8.2	8.4	8.3	8.1	8.4	8.2	16.5	9.4
Sydney North West	8.3	6.7	8.0	8.3	7.4	8.3	20.5	9.6
Sydney South West	8.0	7.5	7.4	7.6	7.8	8.7	18.9	9.4
UHAQMN - LP	8.7	8.8	8.2	8.2	8.8	8.8	18.0	9.9
UHAQMN - SC	8.2	7.8	7.2	7.5	7.4	8.4	17.3	9.1

Colour Coding by Percentile (scheme applied independently to annual data and 'all years')

0% (Minimum)	10%	20%	30%	40%	50% (Median)	60%	70%	80%	90%	100% (Maximum)

Notes: LP – Larger Populations, SC – Smaller Communities.

As consistent with PM_{10} monitoring results, concentrations are elevated across 2018, and 2019, with highest concentrations measured at the UHAQMN Larger Populations. Next highest are the Sydney North West, Sydney South West and Sydney East regions, followed by the UHAQMN Smaller Communities group, with the lowest concentrations are measured in the Illawarra.

Studies into the composition of $PM_{2.5}$ within the Upper Hunter are documented within CSIRO (2013). This study notes a significant contribution from wood smoke to $PM_{2.5}$ concentrations, comprising approximately 62% and 38% of $PM_{2.5}$ over winter months, and 14% and 30% of $PM_{2.5}$ overall at Singleton and Muswellbrook (respectively).

Secondary sulphate, as produced by combustion of sulphur containing fuels, is also noted of significance, while soil (inclusive of fugitive dust from mining operations and other sources) was estimated to comprise 12% and 11% of $PM_{2.5}$ measure at Singleton and Muswellbrook (respectively).

5. ANALYSIS

As relevant to the objective of this project, this section contains an analysis of the following parameters:

- Correlation with coal production
- Correlation with mining emissions
- Correlation with monitoring trends observed elsewhere in NSW.
- Changes in the difference between Diagnostic and Background monitoring stations within the UHAQMN.
- Correlation with rainfall.

Further detail of this analysis is provided in the following sections.

5.1 Correlation with coal production

Raw coal production is considered a general indicator of the intensity of mining operations within the Hunter Valley, and hence provides context on the potential contribution of mining operations to changes in ambient air quality.

Table 5.1 presents a summary of raw coal production across 2013 – 2019.

Table 5.1: Hunter Valley raw coal production (2013 – 2019)

Year	Hunter Valley Raw Coal Production (Mt)	Percentage of 2013 Raw Coal Production
2013	158	100%
2014	160	102%
2015	146	92%
2016	145	92%
2017	146	92%
2018	151	96%
2019	155	99%

As shown in Table 5.1, the annual coal production rates have been generally consistent over the period, ranging between 92% and 102% of the 2013 value. 2013 has been nominated as a reference year in order to show the relative scale of coal production since the beginning of the study period.

The relationship between particulate matter emissions to raw coal production would be influenced by several factors including the following:

- The proportion of new mines in the construction phase, e.g. operations where no or minimal coal is produced despite the presence of construction activities.
- The accessibility of the coal seam, whereby less accessible coal resources would generally require more excavation and/or blasting, thus increasing the quantity of particulate matter emissions per unit of coal produced.
- The ratio of underground to open cut mining operations.

Noting the progressive nature in which the majority of mines have developed within the Hunter Valley, as well as variety of mines operating across different points of their lifecycle, coal production data is considered directly relevant to this analysis as an overall indicator of the intensity of mining operations within the Hunter Valley.

A comparison of annual coal production against the UHAQMN data is provided in Figure 6.1.

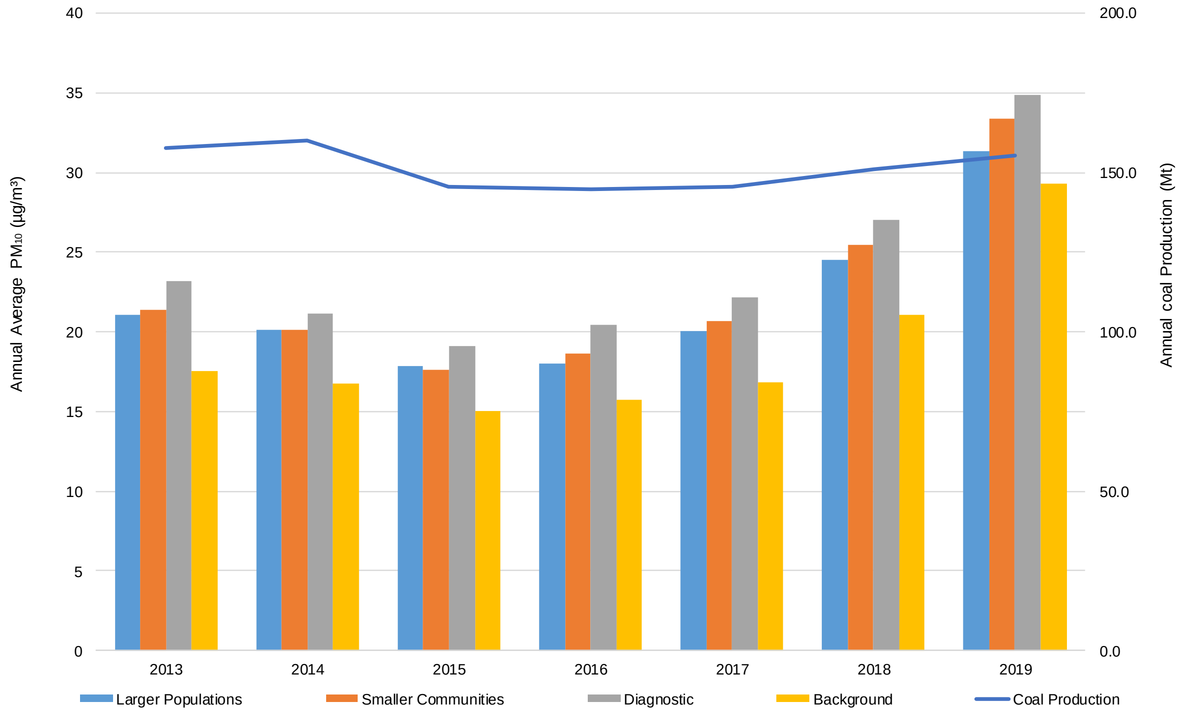


Figure 5.1: Comparison of coal production data and PM_{10} concentrations measured by the UHAQMN

As shown in these data, there is no visually apparent correlation between raw coal production and ambient PM_{10} concentrations measured by the UHAQMN. Figure 6.1 shows inconsistency in the scale of variability in each metric across 2013 – 2019, with minor proportional variability[4] in coal production relative to significant proportional variability in annual average PM_{10}. A detailed regression analysis is contained in Appendix A1.1. The analysis does not identify a statistically significant correlation in the data.

As a further supplement to this analysis, a comparison against NPI reported mining emissions is provided in Section 5.2.

5.2 NPI Reported PM_{10} Emissions from Coal Mining

The National Pollutant Inventory (NPI) is used to track pollution across Australia, providing public access to information about the emission and transfer of toxic substances.

Australian, state and territory governments have agreed to legislation called National Environment Protection Measures (NEPMs), which help protect or manage particular aspects of the environment. Australian industries are required to monitor, measure and report their emissions under this legislation.

The NPI contains data on 93 substances that have been identified as important due to their possible effect on human health and the environment. The data comes from facilities like mines, power stations and factories, and from other sources such as households and transport.

Facility operators determine their own emissions and transfers, and diffuse emissions from households and other sources like motor vehicles are estimated by government agencies[5].

Emissions from coal mining operations are reported in an ongoing annual (July to June) basis under the NPI reporting framework.

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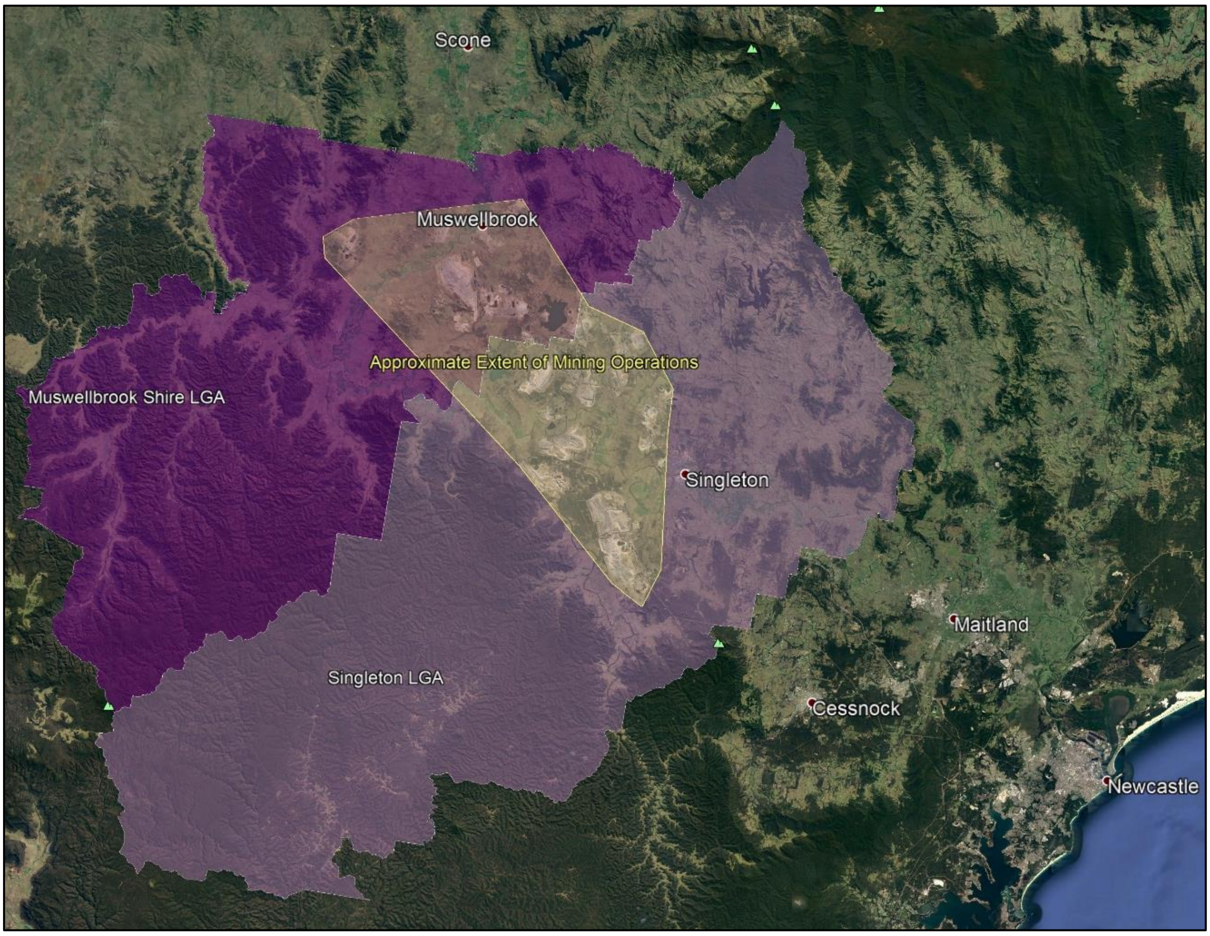
[4] Proportional variability as the relative magnitude of maximum and minimum values within each variable range.

[5] http://www.npi.gov.au/about-npi (accessed May 2020).

To provide context on trends in annual emissions over the analysis period, the NPI has been interrogated for PM_{10} emissions from coal mining operations located within Muswellbrook Shire and Singleton Local Government Areas (LGAs). These two LGAs cover the extent of open cut operations within the Hunter Valley, as shown in Figure 6.2.



Note: Image sourced from Google Earth Pro.

Figure 5.2: Extent of Hunter Valley mining operations within Muswellbrook Shire and Singleton LGAs

Table 5.2 and Figure 6.3 present NPI reported PM_{10} emissions for Hunter Valley mining operations across the seven most recent reporting years (2012/13 through 2018/19) including total PM_{10} emissions across 19 mining entities. Table 5.2 also provides total annual PM_{10} emissions as a percentage of those reported during the 2012/2013 reporting period. 2012/2013 has been nominated as a reference year to show the relative scale of coal production since the beginning of the study period.

As shown in these data, emissions in the most recent (2018/2019) reporting period are approximately 20% lower than those reported in 2012/2013.

Table 5.2: Summary of NPI reported PM_{10} emissions for Hunter Valley mining operations (2012/13 – 2018/19 reporting periods)

Facility Identifier	PM_{10} Emissions by NPI Reporting Period (kt/annum)						
	2012/13	2013/2014	2014/15	2015/16	2016/17	2017/18	2018/19
Ashton Coal Mine Camberwell [Camberwell Via Singleton-NSW]	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Bulga Coal Surface and Underground Operations [Singleton-NSW]	10.6	4.6	4.0	5.2	5.1	3.8	5.1
Hunter Valley Operations [Lemington Via Singleton-NSW]	11.4	9.9	9.7	10.8	11.1	10.8	10.8
Mount Thorley Warkworth Operations [Mount Thorley Via Singleton-NSW]	9.8	8.9	8.2	9.2	9.4	8.6	8.7
Integra Coal Underground Mine [Singleton-NSW]	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Liddell Coal Operations [Ravensworth-NSW]	5.8	6.7	6.2	5.0	4.5	3.9	5.1
Rix's Creek Pty Limited [Singleton-NSW]	0.5	1.2	1.3	1.2	1.6	1.6	1.7
Wambo Mine [Warkworth-NSW]	4.4	6.6	3.0	3.7	3.9	3.4	2.4
Glendell and Ravensworth East [Ravensworth Via Singleton-NSW]	3.0	2.5	2.6	2.8	2.8	3.2	3.2
Ravensworth Mine Complex [Ravensworth Via Singleton-NSW]	5.6	11.4	9.1	5.8	6.1	5.9	6.0
Mt Owen Mine [Ravensworth-NSW]	3.7	2.9	2.9	2.8	3.3	3.7	3.9
Integra Coal Open Cut Mine [Singleton-NSW]	2.3	2.1	0.7	0.0	0.0	0.0	0.0
United Colliery [Warkworth-NSW]	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Drayton Mine [Muswellbrook-NSW]	4.8	2.4	2.0	1.4	0.9	0.0	1.7
Bengalla Operations [Muswellbrook-NSW]	4.5	4.4	4.7	4.5	5.2	4.3	5.0
Mount Pleasant Operations [Muswellbrook -NSW]	0.0	0.0	0.0	0.0	0.0	0.6	0.8
Mt Arthur Coal [Muswellbrook-NSW]	7.7	9.0	10.6	10.1	9.7	10.1	9.0
Muswellbrook Coal No.1 and No.2 Open Cut Mines [Muswellbrook-NSW]	0.5	0.6	0.7	0.7	0.6	0.7	0.7
Mangoola Coal [Muswellbrook-NSW]	4.7	5.9	4.4	4.9	2.6	2.6	3.1
TOTAL (ktpa)	**79.3**	**79.2**	**70.1**	**68.2**	**66.9**	**63.3**	**67.4**
TOTAL (Percentage of 2012/13 reporting Period)	100%	100%	88%	86%	84%	80%	85%

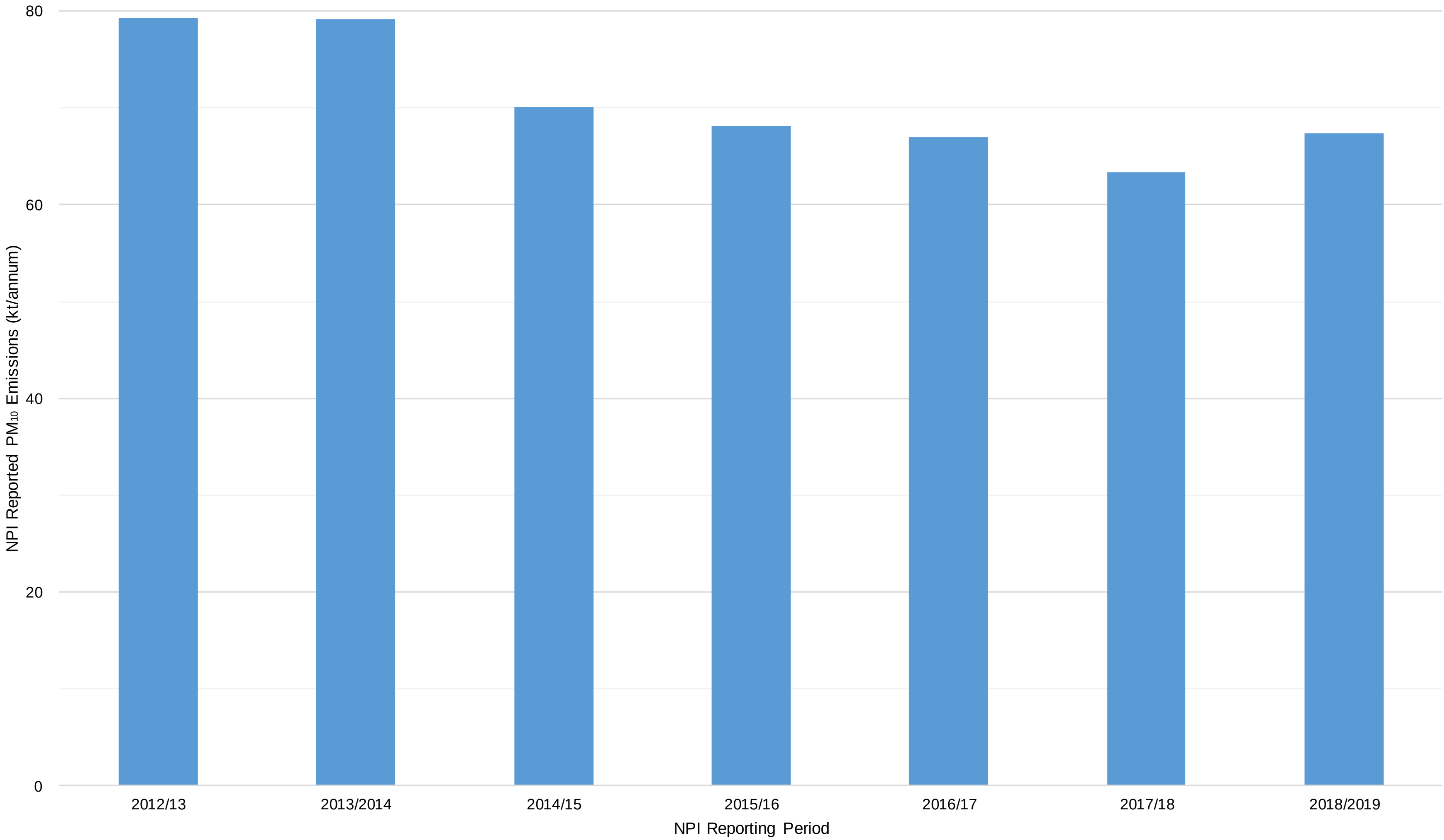


Figure 5.3: NPI reported PM_{10} emissions for Hunter Valley mining operations (2012/13 – 2018/19 reporting periods)

Figure 6.4 presents a comparison of annual PM_{10} trends against NPI PM_{10} emissions from Hunter Valley mining operations.

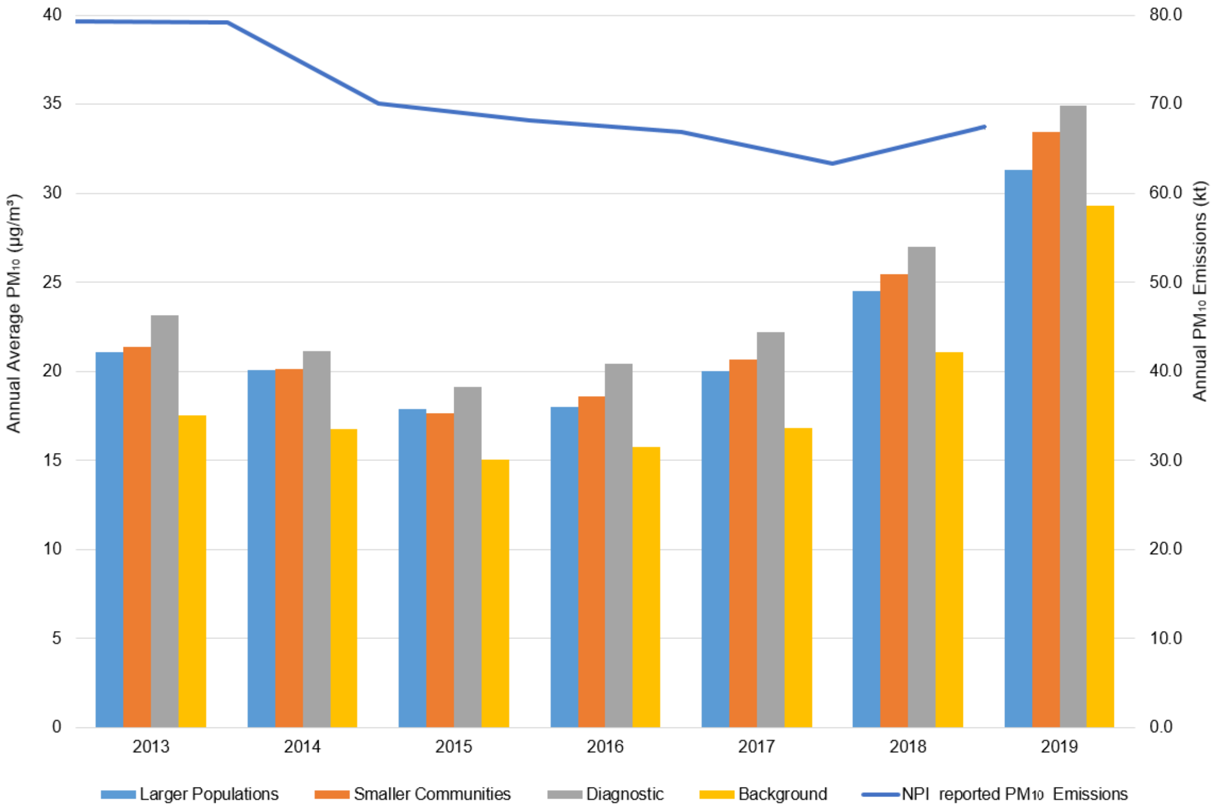


Figure 5.4: Comparison of PM_{10} trends against NPI PM_{10} emissions from Hunter Valley mining

A shown in these data, there is no visually apparent correlation between changes in estimated PM_{10} emissions from mining and changes in annual average PM_{10} concentrations measured within the UHAQMN. A detailed regression analysis is contained in Appendix A1.2. This analysis does not identify a statistically significant correlation in these data.

5.3 Air Quality Data Analysis

The PM_{10} data reviewed in this analysis covers a total of 42 monitoring stations, including 14 within the UHAQMN, and 28 across the remainder of NSW. This constitutes a significant dataset for the analysis of trends, comprising over 300 annual average results across the 7 years of data reviewed.

5.3.1 Comparison of UHAQMN trends with the remainder of NSW

In reviewing the influence of mining operations, it is useful to consider the trends in PM_{10} concentrations observed in the UHAQMN in the context of changes in PM_{10} concentrations measured at other locations in the NSW monitoring network. An increase in the influence from mining would lead to increases in annual average PM_{10} concentrations that are not observed elsewhere in NSW. Conversely consistency with the remainder of NSW would indicate that regional factors are influencing PM_{10} concentrations rather than emissions from mining operations.

Table 5.3 presents a comparison of average PM_{10} concentrations measured across NSW, with the UHAQMN and the remainder of NSW shown separately. Annual data have also been presented as a percentage of the respective 2013-2019 average[6].

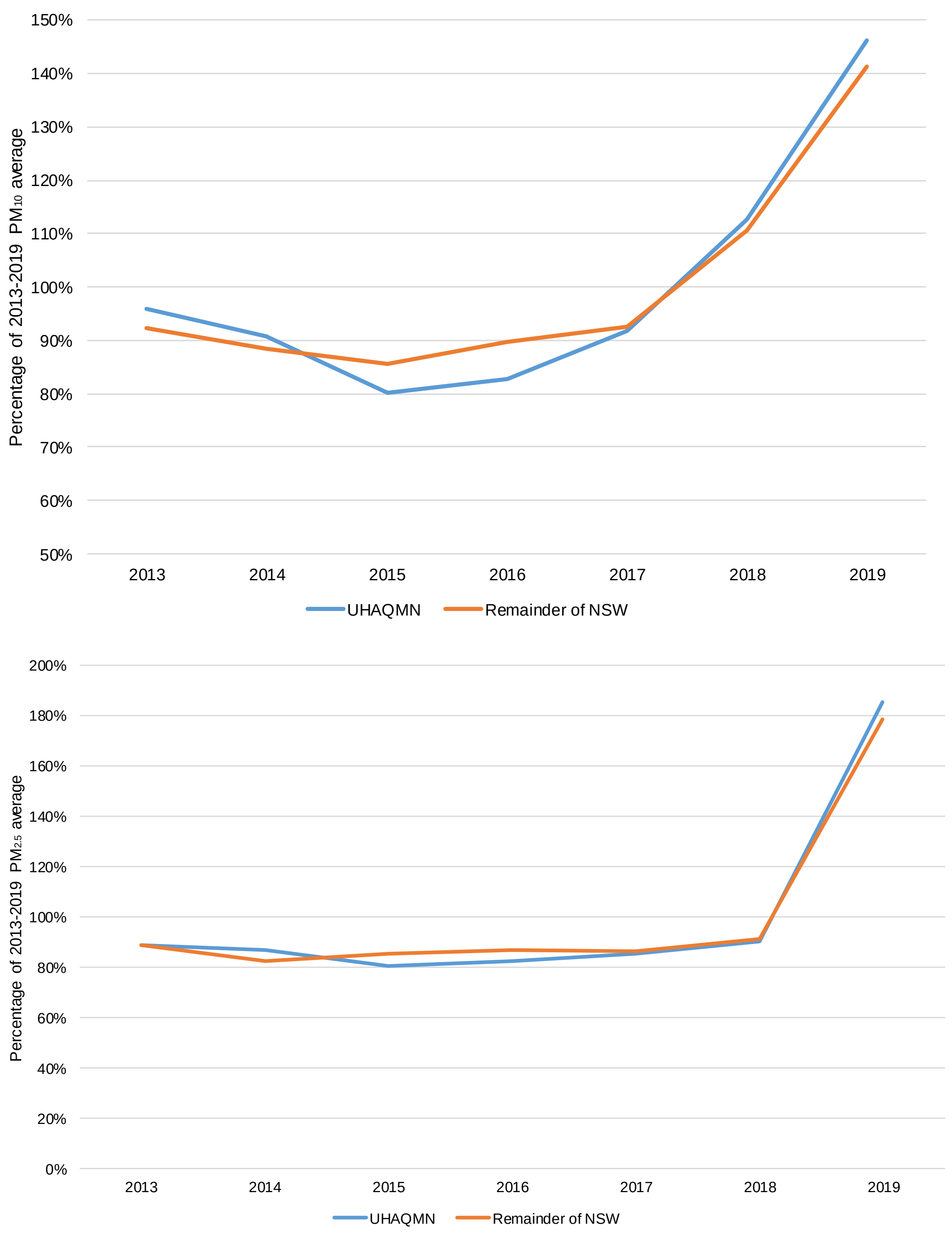
For completeness, this relationship has also been shown for $PM_{2.5}$ which has a lesser association with mechanically generated dust emissions such as those from mining. Figure 6.5 provides a graphical representation of these data.

Table 5.3: Comparison of PM_{10} and $PM_{2.5}$ variability – UHAQMN vs. remainder of NSW regions

Monitoring Subset	Parameter	Year							All Years
		2013	2014	2015	2016	2017	2018	2019	
PM_{10}									
UHAQMN*	Concentration (µg/m³)	21.2	20.1	17.8	18.3	20.4	25.0	32.4	22.2
	% of average (all years)	96%	91%	80%	83%	92%	113%	146%	-
Remainder of NSW	Concentration (µg/m³)	17.4	16.7	16.2	17.0	17.5	20.9	26.7	18.9
	% of average (all years)	92%	88%	86%	90%	92%	110%	141%	-
$PM_{2.5}$									
UHAQMN*	Concentration (µg/m³)	7.9	7.3	7.6	7.7	7.7	8.1	15.9	8.9
	% of average (all years)	89%	82%	85%	87%	86%	91%	179%	-
Remainder of NSW	Concentration (µg/m³)	8.4	8.3	7.7	7.8	8.1	8.6	17.6	9.5
	% of average (all years)	89%	87%	81%	82%	85%	90%	186%	-

Note: *Larger Populations and Smaller Communities station groups.

[6] Data have been referenced against the 2013-2019 average to minimise offset error from scatter that may occur with individual reference years and station groups.



Note: UHAQMN - Larger Population and Smaller Communities station groups.

Figure 5.5: Comparison of PM_{10} and $PM_{2.5}$ variability – UHAQMN vs. remainder of NSW regions

The general consistency of temporal trends in the UHAQMN and 'Remainder of NSW' monitoring subsets show that the changes in PM_{10} concentrations within the Upper Hunter are generally consistent with changes experienced across the rest of NSW. A detailed regression analysis is contained in Appendix A1.3 which identifies a statistically significant correlation between the UHAQMN and 'Remainder of NSW' datasets. This in turn indicates that the changes in annual average PM_{10} concentrations are associated with regional PM sources and that the contribution of mining operations on the UHAQMN to these trends is not discernible. This finding was not sensitive to the inclusion of Stockton data, with ‘Remainder of NSW’ values showing 1% or less variance with the exclusion of Stockton data.

Of note, this consistency was also observed in $PM_{2.5}$, indicating that changes in $PM_{2.5}$ (less likely to be attributed to mining operations) are generally consistent with those observed elsewhere in NSW.

5.3.2 Trends within the UHAQMN

In addition to performance outside of the region, the UHAQMN dataset can be analysed by station group to assess potential changes in the influence from mining operations. In this analysis, an increase in the influence from mining would lead to a greater difference between measurements taken at Diagnostic stations and Background stations:

- Under a hypothesis that air quality trends are driven by an increase in regional and interregional influences (i.e. with no increase in the influence from mining operations), it would be expected that all station groups would follow a similar trend across the years of monitoring data.
- Under a hypothesis that worsening air quality is driven by an increase in localised mining operations, it would be expected to see an increasing disparity between the Background and other station groups, especially the Diagnostic group.

This is due to the fact that air quality impacts are most pronounced close to the emission sources (e.g. Diagnostic stations), while at areas more distant (e.g. Background stations) the impacts, if detectable, are less pronounced. In addition, broad scale regional and/or remote influences will impact Diagnostic and Background stations to an equal or similar extent.

Table 5.4 presents UHAQMN annual average PM_{10} concentrations by station group and year, while Figure 6.6 shows a graphical representation of these data.

Table 5.4: UHAQMN annual average PM_{10} concentrations by station group and year ($\mu g/m^3$)

Station Group	Year							All Years
	2013	2014	2015	2016	2017	2018	2019	
Larger Populations	21.1	20.1	17.9	18.0	20.0	24.5	31.3	21.8
Smaller Communities	21.4	20.1	17.7	18.6	20.7	25.4	33.4	22.5
Diagnostic	23.2	21.1	19.1	20.4	22.2	27.0	34.9	24.0
Background	17.6	16.8	15.1	15.8	16.8	21.1	29.3	18.9

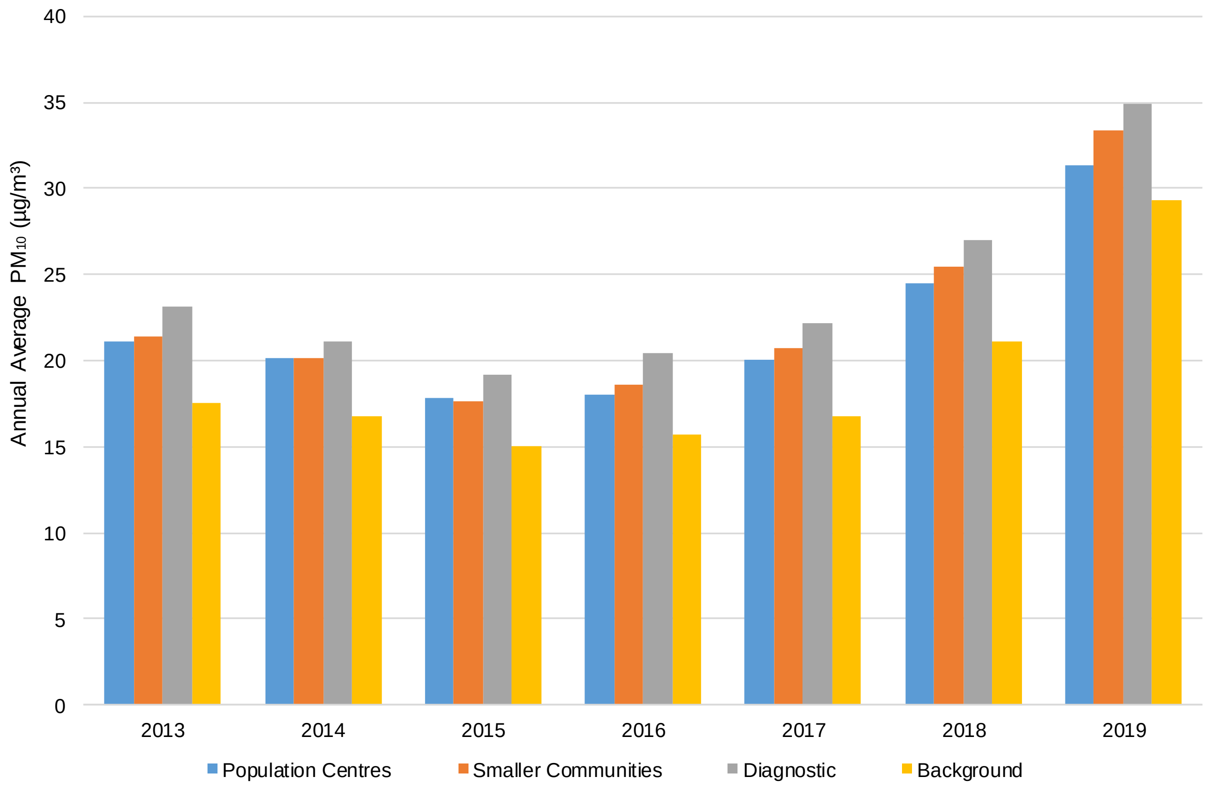


Figure 5.6: UHAQMN annual average PM_{10} concentrations by station group and year

As can be seen in these data, across the years Diagnostic stations report the highest results, while Smaller Communities and Larger Populations stations fall between the Diagnostic and Background stations. The differences in results between these station groups are generally indicative of the influence from mining operations as well as other emission sources within the Upper Hunter. An analysis of the significance of these observed differences is provided in Appendix A2.

For each station group, Table 6.5 shows the annual variance against the 2013 – 2019 average for that particular station group. This process removes the offset bias associated with station groups (e.g. Background stations reporting lower concentrations than Diagnostic stations). This process is instructive in showing changes in the difference between station groups across the study period. The same data are shown graphically Figure 6.7.

Table 5.5: Annual variance against 2013 – 2019 station group average (µg/m³)

Station Group	Year						
	2013	2014	2015	2016	2017	2018	2019
Larger Populations	-1	-2	-4	-4	-2	3	9
Smaller Communities	-1	-2	-5	-4	-2	3	11
Diagnostic	-1	-3	-5	-4	-2	3	11
Background	-1	-2	-4	-3	-2	2	10

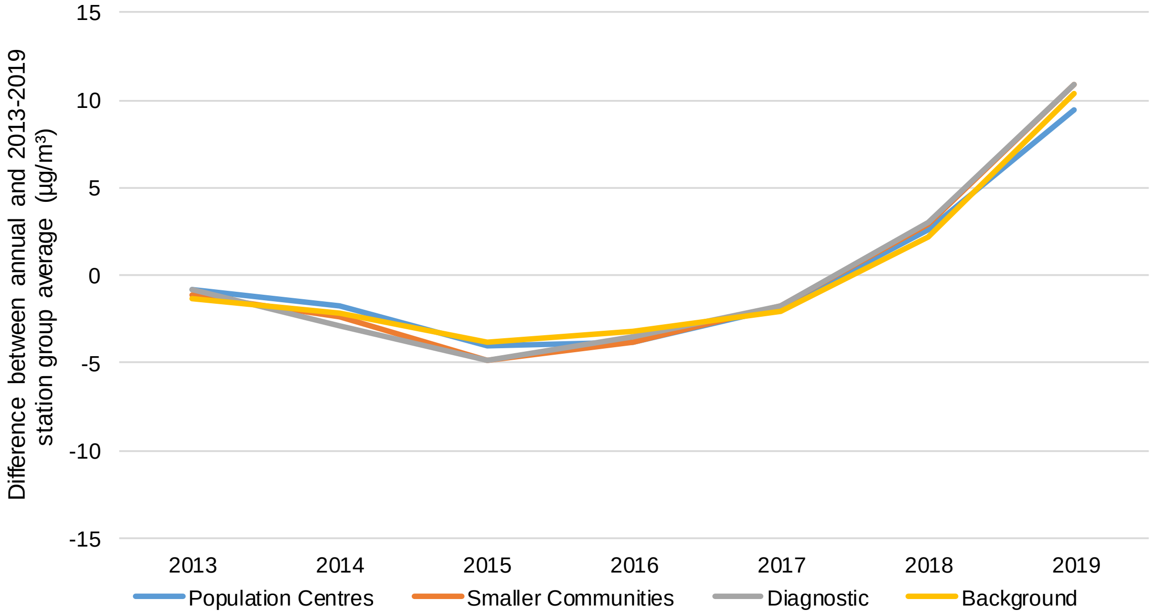


Figure 5.7: Comparison of trends between each UHAQMN monitor group

As shown in Figure 6.7, the differences between PM_{10} concentrations at Background stations and Diagnostic stations are near identical across 2013-2019 (i.e. up to 2 µg/m³ variability), while the range in annual average concentrations across this period is in the order of 15 µg/m³. As consistent with previous analysis, this indicates that changes in Upper Hunter PM_{10} concentrations are associated with regional conditions and are indicative of a minimal change in the contribution from local emission sources inclusive of mining.

5.4 Comparison against rainfall

The Bureau of Meteorology provide regional averaged rainfall trends as both total rainfall, and rainfall anomaly from the year 1900 onwards (BoM, 2020). Figure 6.8 presents the NSW/ACT annual rainfall anomaly[7] for the period 1900 – 2019, which is referenced against the 1961-1990 (30 year) average. As shown in this figure, with the exception of 2016, all years between 2013 and 2019 have featured below average rainfall, with 2019 comprising the driest year on the record.

[7] Rainfall anomaly represents the difference of a given year against the 1961-1990 average.

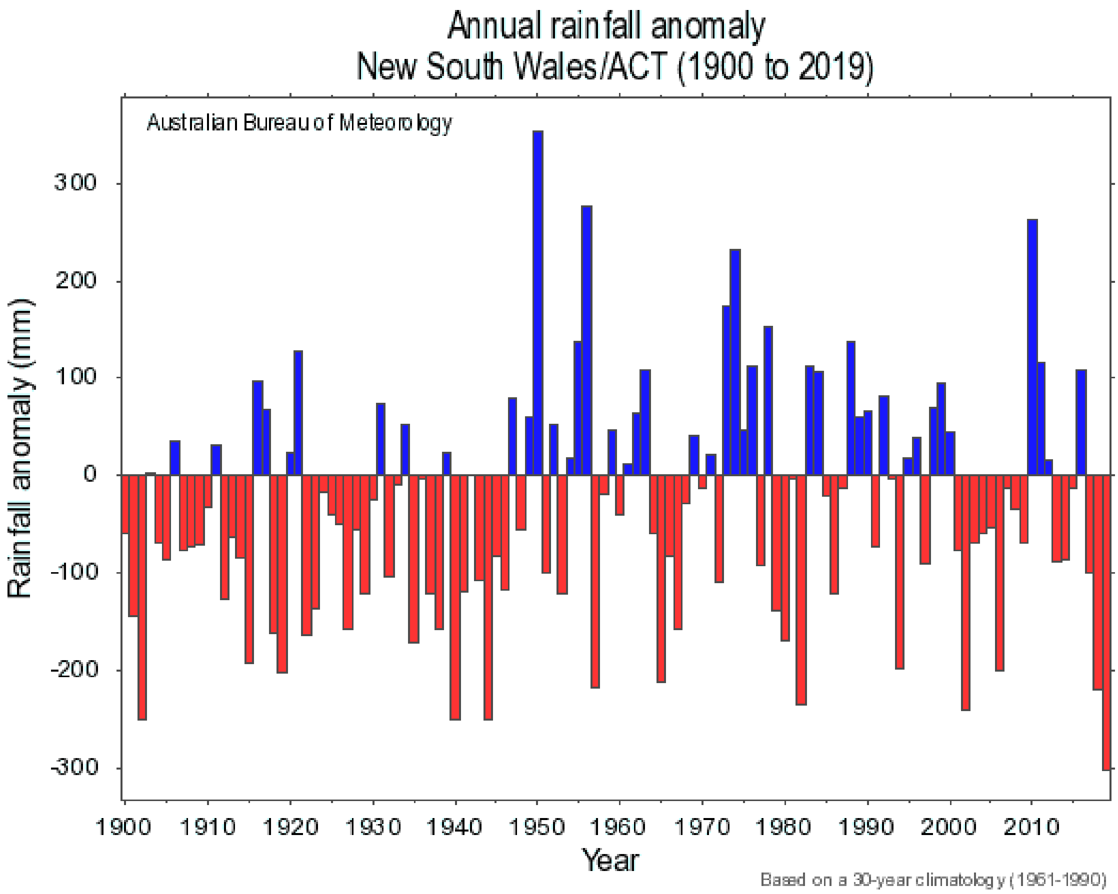


Image source: BOM (2020)

Figure 5.8: BoM NSW/ACT annual rainfall anomaly 1900 – 2019

Table 5.6 presents BoM NSW/ACT annual rainfall and UHAQMN annual average PM_{10} over the period 2013-2019. These data are shown in Figure 6.9.

Table 5.6: BoM NSW/ACT annual rainfall and UHAQMN annual average PM_{10}

Parameter	Year						
	2013	2014	2015	2016	2017	2018	2019
UHAQMN PM_{10} (µg/m³)*	21	20	18	18	20	25	32
NSW Rainfall	464	467	541	661	453	333	250

Note: *Larger Populations and Smaller Communities station groups.

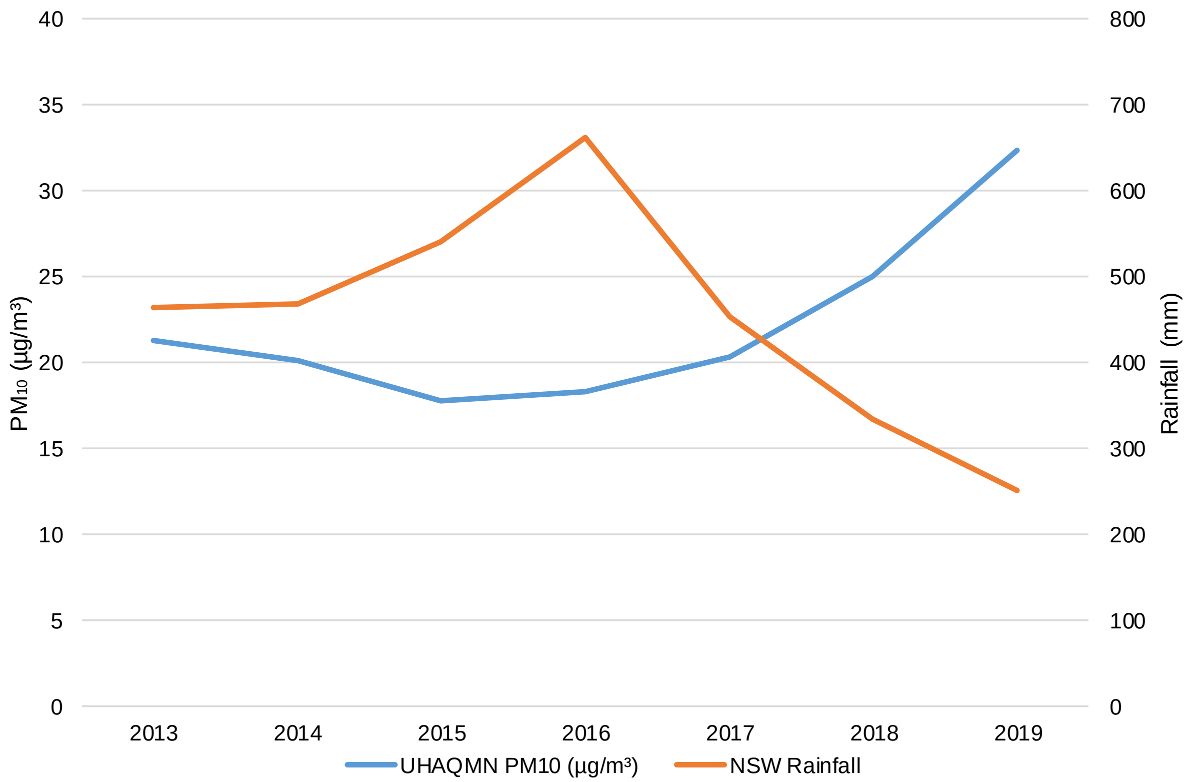


Figure 5.9: NSW/ACT annual rainfall and UHAQMN annual average PM_{10}

As shown in these data, there is a negative correlation between rainfall and particulate matter concentrations across the UHAQMN. Further review of these data is presented in Appendix A1.4, which identifies a statistically significant correlation in these data. Given the consistency between PM_{10} trends across NSW and the UHAQMN, this relationship also holds for NSW PM_{10} concentrations more broadly.

6. CONCLUSIONS

ERM has been commissioned by the NSW Minerals Council to undertake a review of ambient air quality monitoring data collected across the NSW Department of Planning, Industry and Environment (DPIE) air quality network, inclusive of the Upper Hunter Air Quality Monitoring Network (UHAQMN).

The objective of this analysis is to address the following two questions:

1. *Has the air quality in the Upper Hunter Valley changed since monitoring began?; and*
2. *Is the air quality in the Upper Hunter Valley measured at the monitoring stations different from air quality measured at other locations in NSW?*

Based on this analysis, the following findings are made:

- Annual average PM_{10} concentrations within the Upper Hunter are broadly consistent with Lower Hunter, but also higher than a range of other regions within NSW. The difference between the Upper Hunter and average concentrations in NSW is small relative to the variability observed between years.
- Across the UHAQMN, the difference between Background, Diagnostic and population-based station groups is indicative of an influence from mining as well as other anthropogenic sources. Lower concentrations are observed at Background stations, and higher concentrations are observed at Diagnostic stations. Concentrations observed at population-based stations fall between these two monitor groups.
- A further analysis of the trends in station group values was conducted for the review period. This analysis has shown a consistent difference between station groups (within each year), indicating that changes in Upper Hunter PM_{10} concentrations over time are associated with regional conditions such as rainfall and are indicative of a minimal change in the contribution from local emission sources inclusive of mining
- Significant increases were observed in annual average UHAQMN PM_{10} concentrations between 2017 and 2019. These increases have been found to be generally consistent with trends observed across the remainder of NSW, which show a correlation with the a progressive decrease in annual rainfall and increased prevalence of drought conditions.
- A review of trends in mining operations has not found a correlation between ambient PM_{10} concentrations and coal production, or ambient PM_{10} concentrations and NPI reported PM_{10} emissions.
- A review of NSW/ACT average rainfall has shown a correlation between below average rainfall and above average UHAQMN PM_{10} concentrations.
- As consistent with PM_{10} monitoring results, $PM_{2.5}$ concentrations are elevated across 2018, and 2019, with highest concentrations measured at the UHAQMN Larger Populations station group, which likely contains a significant influence from wood smoke (CSIRO, 2013). Trends in annual average concentrations were also found to be consistent with the remainder of NSW.

In the context of the objectives of this analysis:

1. ***Has the air quality in the Upper Hunter Valley changed since monitoring began?***

   Yes, concentrations have varied significantly over the period reviewed, but in a manner that is generally consistent with monitoring data collected at DPIE stations across the remainder of NSW.

   While correlations with mining emissions and coal production were not identified, a correlation with regional average rainfall was observed. Lower than average rainfall is associated with above average particulate matter concentrations. The mechanisms for this are associated with progression of drought conditions, including increased prevalence of wind erosion/dust storms and bushfire activity.

An increase in the contribution from mining operations would be expected to produce an increasing difference between the concentrations measured at Diagnostic stations and those measured at Background stations. Such a trend was not observed, with the differences between PM_{10} concentrations at Background stations and Diagnostic stations found to be near identical across 2013-2019 (i.e. up to 2 µg/m³ variability). The range in annual average concentrations across this period is of the order of 15 µg/m³. In this respect, the trends in Upper Hunter PM_{10} concentrations are not considered indicative of an increased contribution from mining operations.

2. ***Is the air quality in the Upper Hunter Valley measured at the monitoring stations different from air quality measured at other locations in NSW?***

Yes, the UHAQMN data does feature higher PM_{10} concentrations than a range of regions across NSW, but is also broadly consistent with concentrations measured within the Lower Hunter and Central Coast. In addition, the difference between the Upper Hunter and the remainder of NSW is small in scale relative to the variability in concentrations across NSW. $PM_{2.5}$ concentrations are higher than elsewhere in NSW, and are likely to be influenced by wood smoke, as identified in CSIRO (2013).

7. REFERENCES

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APPENDIX A TECHNICAL ADDENDUM: STATISTICAL ANALYSES

A1 REGRESSION ANALYSES

This section presents a brief summary of regression analyses that assess the statistical significance relationships reviewed in Section 5, including:

- Annual Average UHAQMN PM_{10} concentration vs Hunter Valley Coal Production (as discussed Section 5.1)
- Annual Average UHAQMN PM_{10} concentration vs NPI reported PM_{10} emissions from Hunter Valley coal mining (as discussed in Section 5.2)
- Annual percentage variance against 2013-2019 average: UHAQMN vs 'Remainder of NSW', PM_{10} and $PM_{2.5}$ (as discussed in Section 5.3).
- Annual Average UHAQMN PM_{10} concentration against NSW mean annual rainfall (as discussed in Section 5.4)

Within this analysis, the UHAQMN annual average PM_{10} concentrations incorporate the Larger Populations and Smaller Communities station groups, as relevant to population exposure. The findings of this analysis may also be extended to the entire UHAQMN, noting that annual average values are similar (within 1% on average) when all station groups are included.

For each relationship, the statistical significance has been examined by application of a linear regression, where it is assumed that annual average PM_{10}, as a dependent variable, is a linear function of the relevant independent variable (e.g. coal production or rainfall).

Statistical significance has been assessed with review of the correlation coefficient (r^2) and P-value, where:

- the r^2 value represents the proportion of sample variability that is attributable to the least square error regression.
- the P-value represents the probability that the two variables are unrelated.

The P-value has been established by testing the probability of a null hypothesis, which represents a scenario where the two variables are independent. Mathematically, this involves testing the probability that the linear coefficient of the independent variable is equal to zero, in which case, the variability of the results against the independent variable (as defined by a least square error linear regression) is random.

A lower P-value represents a lower probability that the two variables are unrelated. In this analysis, the conventional metric of $P < .05$ has been adopted to define a correlation as statistically significant.

A1.1 Coal Production

Figure A1.1 presents Hunter Valley coal production against 2013-2019 UHAQMN annual average PM_{10} concentration. Figure A1.2 presents these data excluding 2019 (i.e. treating it as an outlier). In the absence of a strong correlation across the range of curve fitting options examined[8] the most simplistic (linear) regression has been presented for both datasets.

[8] Microsoft Excel-based exponential, linear, logarithmic, polynomial and power law regressions were examined.

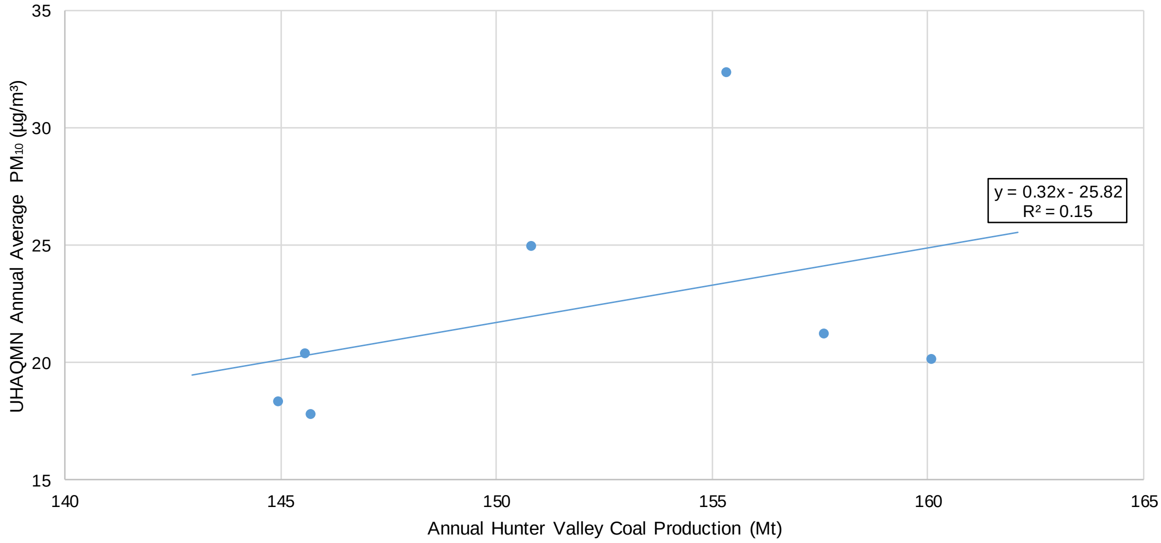

Figure A1.1: Scatter plot showing annual Hunter Valley coal production against 2013-2019 annual average UHAQMN PM_{10} concentration (with linear regression).

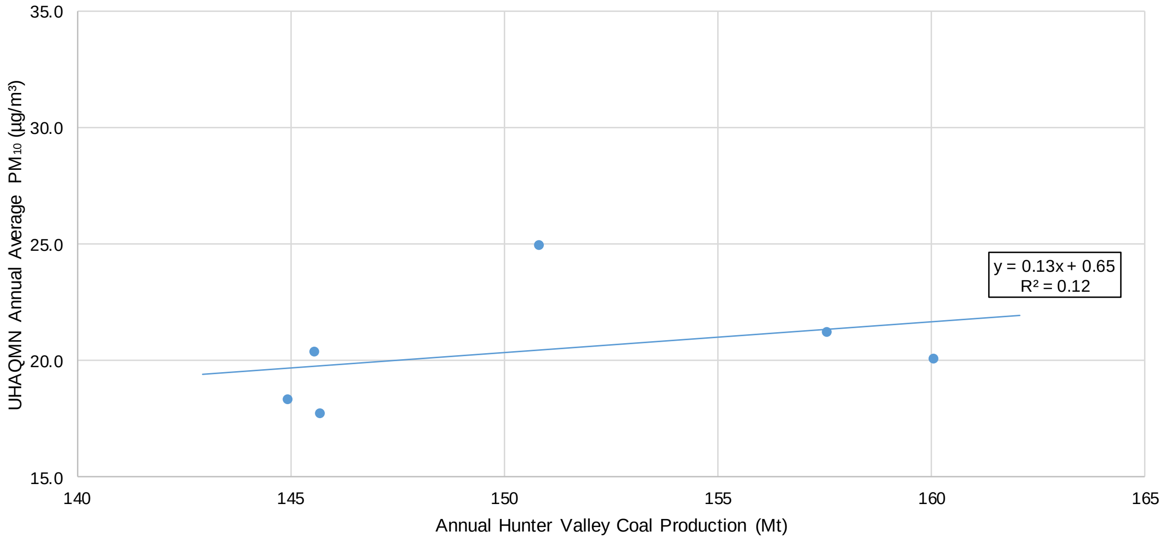

Figure A1.2: Scatter plot showing annual Hunter Valley coal production against 2013-2018 annual average UHAQMN PM_{10} concentration (2019 excluded) (with linear regression).

Analysis of the conformity of the data to these regressions provides P-values of .38 (2013-2019) and .51 (2013-2018), which are outside of the significance threshold (i.e. $P < .05$), thus indicating that the relationship between annual coal production and annual average PM_{10} in these data is not significant. The respective r^2 values of 0.15 and 0.12 indicate that the least squares regressions account for 15% and 12% of the variability observed under a hypothesis that annual average PM_{10} is a linear function of annual coal production.

A1.2 NPI Reported PM_{10} Emissions

Figure A1.3 presents NPI reported PM_{10} emissions for Hunter Valley coal mining against 2013-2019 UHAQMN annual average PM_{10} concentration. Figure A2.4 presents these data excluding 2019 (i.e. treating it as an outlier). In the absence of a strong correlation across the range of curve fitting options examined[9] the most simplistic (linear) regression has been applied to both datasets.

[9] Exponential, linear, logarithmic, polynomial and power law regressions were examined.

For simplicity, NPI reported emissions have been forward-dated 6 months to align with calendar years, thus representing a limitation of this analysis. Noting this, the annual NPI data presented in Section 5.2 show a fairly consistent trend, with a monotonic decrease between 2013-2018, hence this limitation is considered minor.

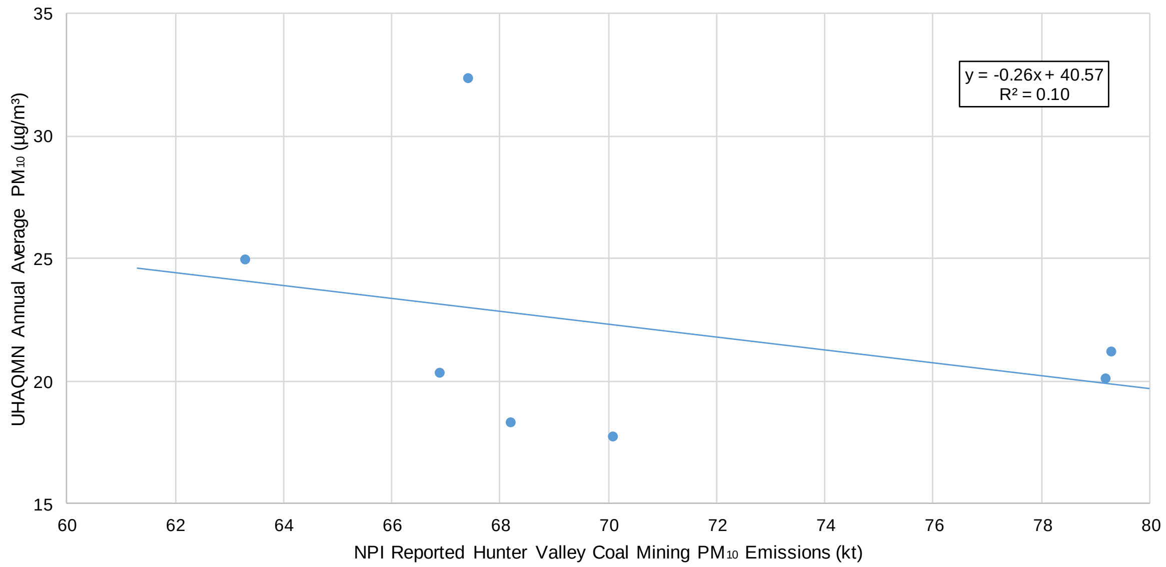

Figure A1.3: Scatter plot showing NPI reported PM_{10} emissions for Hunter Valley coal mining against 2013-2019 annual average UHAQMN PM_{10} concentration (with linear regression).

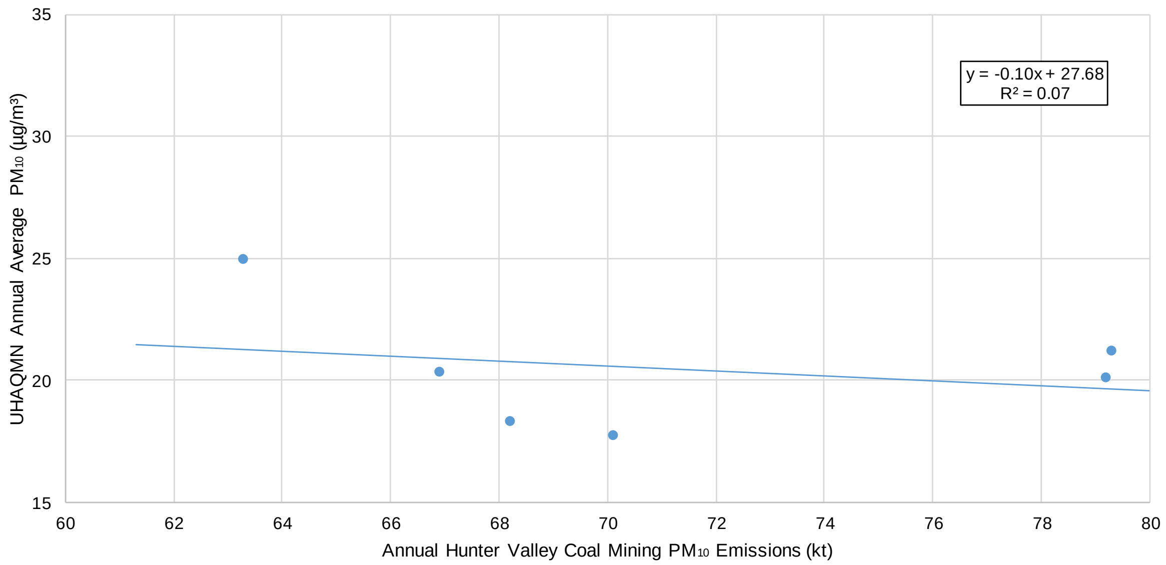

Figure A1.4: Scatter plot showing NPI reported PM_{10} emissions for Hunter Valley coal mining against 2013-2019 annual average UHAQMN PM_{10} concentration (with linear regression).

Analysis of the conformity of the data to these regressions provides P-values of 0.48 (2013-2019) and 0.61 (2013-2018), which are outside of the significance threshold (i.e. $P < .05$), thus indicating that the relationship between annual NPI reported PM_{10} emissions and annual average PM_{10} in these data is not significant. The respective r^2 values of 0.10 and 0.07 indicate that the least squares regressions account for 10% and 7% of the variability observed under a hypothesis that annual average PM_{10} has a linear relationship with NPI reported PM_{10} emissions from Hunter Valley coal mining.

Considering the physical implications of this regression, the negative gradient implies that there is a reduction of ambient PM_{10} with an increase in PM_{10} emissions. Based on conservation of mass assumptions, this relationship is not considered plausible, thus corresponding with the lack of significance observed.

A1.3 Annual Variance against 2013-2019 Average (PM_{10} and $PM_{2.5}$)

Figure A1.5 presents annual percentage variance against 2013-2019 averages for UHAQMN vs 'Remainder of NSW' datasets, with a linear regression.

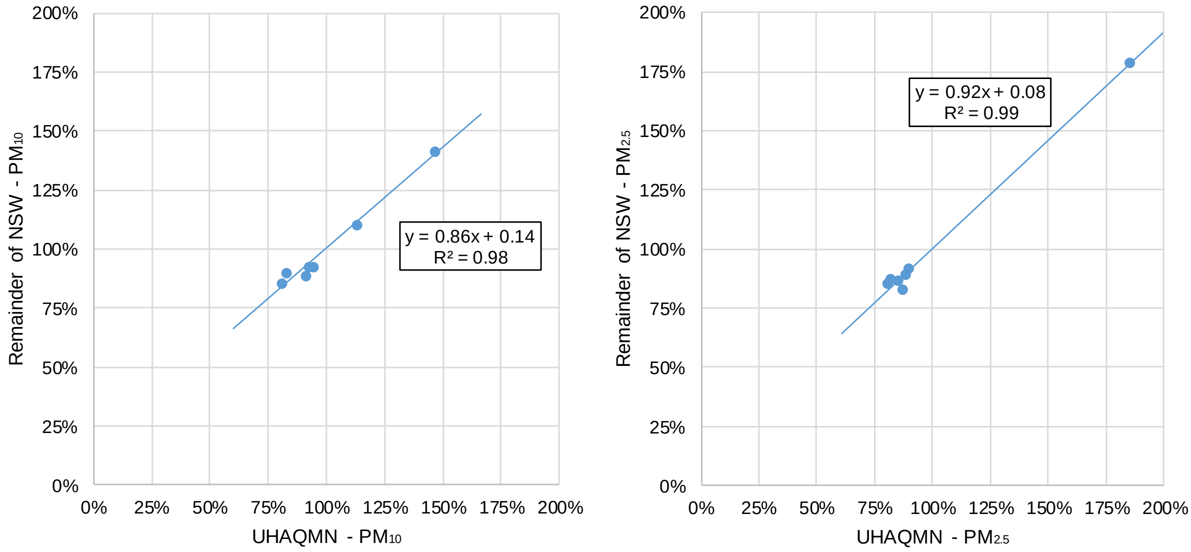

Figure A1.5: Annual percentage variance against 2013 – 2019 average (PM_{10} and $PM_{2.5}$)

As shown in these data, there is a linear relationship in the annual proportional variability experienced in the UHAQMN and the remainder of NSW. Analysis of the conformity of the data to these regressions provides a P-values of < .001, which are within the significance threshold (i.e. P < .05), and indicates a strong relationship between in the annual variability of the datasets.

A1.4 Rainfall

Figure A1.6 presents NSW mean annual rainfall against 2013-2019 UHAQMN annual average PM_{10} concentration.

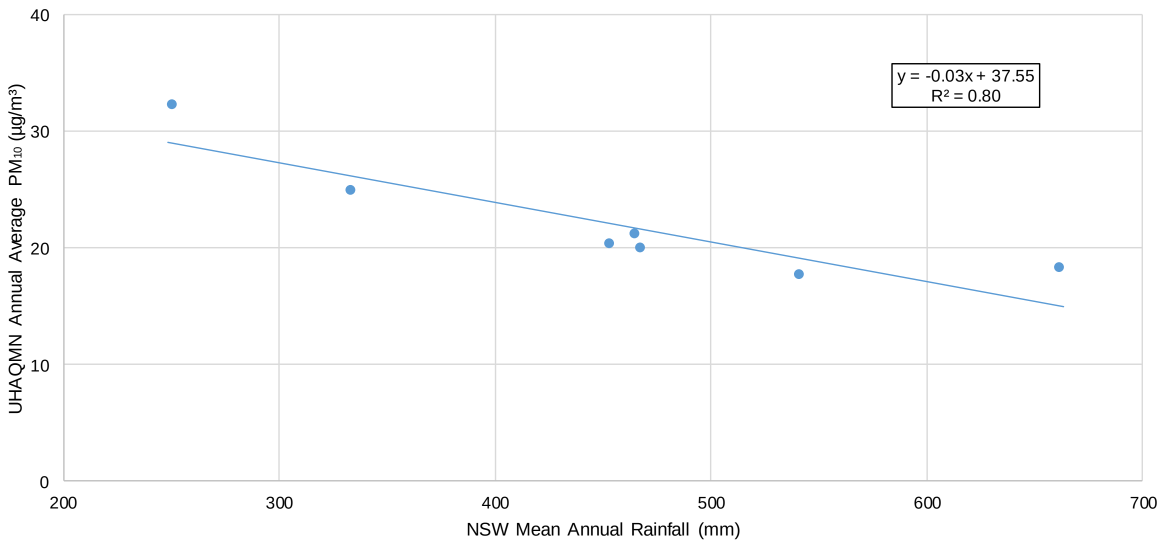

Figure A1.6: Scatter plot showing average 2013-2019 UHAQMN PM_{10} concentration against NSW mean annual rainfall (with linear regression).

Analysis of the conformity of the data to these regressions provides a P-value of .007, which is within the significance threshold (i.e. $P < .05$), thus indicating that the relationship between NSW mean annual rainfall and annual average PM_{10} in these data is significant. The r^2 value of 0.80 indicates that the least squares regression accounts for 80% of the variability observed under a hypothesis that annual average PM_{10} has a linear relationship with NSW mean annual rainfall. The use of a power law based regression offered minor refinement beyond a linear regression, resulting in an r^2 value of 0.93. This was not investigated further given the significance of the linear regression.

In a physical context, this observed correlation is supported by the known interrelationship between rainfall, drought, and the prevalence of particulate matter generating phenomena such as dust storms and bushfires.

A2 SIGNIFICANCE OF STATION GROUP DIFFERENCES

This section presents a brief supporting analysis that assesses the significance of differences in observed period average PM_{10} concentrations across various station groups. For each station group, comparison has been made against the UHAQMN Larger Populations and Smaller Communities (UHAQMN [LP/SC]) average.

For a given station group comparison, the following statistics have been prepared from the seven annual averages within the review period:

- Mean difference
- Sample standard deviation of annual mean difference.

The significance of these stations has then been assessed

The P-value has been established by testing the probability of a null hypothesis, which represents a scenario where the compared datasets share a common mean.

A lower P-value represents a lower probability that the two datasets share a common mean. In this analysis, the conventional metric of $P < .05$ has been adopted as being indicative that an observed difference in sample means is statistically significant. P-values have been estimated using a Student's *t* distribution with n-1 degrees of freedom.

Table A2.1 presents the annual average PM_{10} concentration by region / station group, while Table A2.2 presents the differences between UHAQMN (LP/SC) and each respective region/station group.

Table A2.1 Annual average PM_{10} concentration by region / station group (µg/m³)

Region / Group	Year						
	2013	2014	2015	2016	2017	2018	2019
Lower Hunter & Central Coast	20.2	18.2	21.7	22.0	22.9	25.2	29.1
Lower Hunter & Central Coast (exc. Stockton)	20.2	18.2	19.4	19.8	20.7	23.0	26.7
Lower Hunter (exc. Stockton)	22.1	19.2	20.3	20.7	21.6	23.9	27.8
Sydney Regions	17.2	16.6	15.6	16.6	17.1	19.8	23.9
Illawarra	16.9	17.1	16.2	17.4	18.0	20.1	22.5
North West Slopes	16.6	15.8	14.1	15.3	15.3	20.1	33.7
Central Tablelands	15.1	14.6	13.4	13.3	14.1	18.8	27.4
South West Slopes	19.0	18.3	17.3	17.9	18.2	23.6	29.4
Remainder of NSW Regions	17.4	16.7	16.2	17.0	17.5	20.9	26.7
UHAQMN (LP/SC)	21.2	20.1	17.8	18.3	20.4	25.0	32.4
UHAQMN Background	17.6	16.8	15.1	15.8	16.8	21.1	29.3
UHAQMN Diagnostic	23.2	21.1	19.1	20.4	22.2	27.0	34.9

Table A2.2: Annual average PM_{10} concentration difference - UHAQMN (LP/SC) vs region / station group (µg/m³)

Region / Group	Year						
	2013	2014	2015	2016	2017	2018	2019
Lower Hunter & Central Coast	1.0	1.9	-4.0	-3.6	-2.6	-0.2	3.3
Lower Hunter & Central Coast (exc. Stockton)	1.0	1.9	-1.6	-1.5	-0.3	2.0	5.7
Lower Hunter (exc. Stockton)	-0.8	0.9	-2.5	-2.4	-1.2	1.0	4.6
Sydney Regions	4.0	3.5	2.2	1.7	3.2	5.2	8.4
Illawarra	4.3	3.0	1.5	0.9	2.4	4.9	9.8
North West Slopes	4.6	4.3	3.7	3.0	5.1	4.9	-1.3
Central Tablelands	6.1	5.5	4.4	5.0	6.3	6.2	5.0
South West Slopes	2.3	1.8	0.5	0.5	2.2	1.4	3.0
Remainder of NSW Regions	3.8	3.4	1.6	1.4	2.9	4.1	5.6
UHAQMN (LP/SC)	-						
UHAQMN Background	3.7	3.4	2.7	2.6	3.6	3.9	3.1
UHAQMN Diagnostic	-1.9	-1.0	-1.4	-2.1	-1.8	-2.0	-2.5

Table A2.3 presents an analysis of the mean differences with corresponding P-values and findings of statistical significance.

Table A2.3: Analysis of PM_{10} concentration difference - UHAQMN (LP/SC) vs region / station group

Region / Group	Mean Difference (µg/m³)	Sample Standard Deviation (µg/m³)	P-value	Statistical Significance of Mean Difference
Lower Hunter & Central Coast	-0.6	2.8	.59	Non-significant ($p > .05$)
Lower Hunter & Central Coast (exc. Stockton)	1.0	2.5	.32	
Lower Hunter (exc. Stockton)	-0.1	2.5	.94	
Sydney Regions	4.0	2.2	.003	Significant ($p < .05$)
Illawarra	3.8	3.0	.01	
North West Slopes	3.5	2.2	.01	
Central Tablelands	5.5	0.7	< .001	
South West Slopes	1.7	0.9	.003	
Remainder of NSW Regions	3.2	1.5	.001	
UHAQMN (LP/SC)	-			
UHAQMN Background	3.3	0.5	< .001	Significant ($p < .05$)
UHAQMN Diagnostic	-1.8	0.5	< .001	

As shown in these data:

- The observed mean difference between the UHAQMN (LP/SC) and the Lower Hunter region is small relative to other regions, and statistically non-significant within the observed data.
- The observed mean difference between the UHAQMN (LP/SC) and other regions / station groups is statistically significant within the observed data.

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