Department of Planning and Environment

Upper Hunter Air Quality Monitoring Network

5-year review 2022

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Summary

This report is the second 5-year review of the Upper Hunter Air Quality Monitoring Network, prepared by the Department of Planning and Environment (the department) on behalf of the New South Wales (NSW) Environment Protection Authority (EPA). It covers the period from 2017 to 2021.

The Upper Hunter Air Quality Monitoring Network (the network) measures airborne particles, gaseous pollutants and meteorological conditions in the Muswellbrook, Singleton and Upper Hunter Shire local government areas of New South Wales. The network consists of 14 monitoring stations, extending from Merriwa in the north-west to Singleton South in the south-east.

Monitoring data from the network provide the evidence base for the NSW Government to assess and manage air quality, for the protection of communities in the Upper Hunter.

The NSW Government established the network between 2010 and 2012 in partnership with Upper Hunter coalmining and power generation industries. The network is operated by the department, administered by the EPA and funded by Upper Hunter coal and power industries, in line with the Protection of the Environment Operations (General) Regulation (the Regulation).

The Regulation requires the EPA to report on the Upper Hunter air quality monitoring program every 5 years. The first 5-year review was published in 2017. This second 5-year review includes data from both this review (2017 to 2021) and the previous review (2011 to 2016) so that long-term trends may be described. The monitoring, analysis and reporting practices of the department over more than 10 years have developed our understanding of factors affecting air quality in the Upper Hunter.

Improvements to the monitoring program since the first 5-year review include improvements to online data delivery. For example, the community may view current air quality for the Upper Hunter, updated hourly, on their desktop, mobile or other device, at the NSW Government air quality website.

Current air quality is reported as hourly average concentrations of airborne particles and gases and colour-coded air quality categories, ranging from good to extremely poor, with corresponding health advice for outdoor activities. Web users may view details of pollution concentrations and meteorology measured at the 14 monitoring stations, with data presented in tables and graphs or on an interactive map. Subscribers can receive alerts when pollution levels are above the threshold for poor air quality. Web users and developers may stream Upper Hunter monitoring data for business and mobile applications using advanced service tools such as the air quality application programming interface (API).

Findings of the review

Effectiveness of the Upper Hunter monitoring program in fulfilling its objectives

This review found that the Upper Hunter monitoring program was effective in taking action to meet the 4 objectives set by the Regulation. In summary, the program:

- provided reliable and up-to-date information on air quality in the Upper Hunter to communities, industry and government through online publishing of near real-time data and analyses in the form of newsletters and statements

- assessed air quality against relevant standards by reporting air pollution status online in near real-time and in seasonal and annual publications
- facilitated the identification of sources of air pollution by analysing trends and events where relevant standards were exceeded, and by reporting to the community through seasonal and annual publications
- facilitated the development and implementation of strategies to improve air quality in the Upper Hunter by providing the evidence base that supported programs to reduce particle emissions from mining activity and wood-fired domestic heaters.

The program was perceived by some community members as needing to better demonstrate its effectiveness in meeting the objectives of facilitating the identification of sources of air pollution and the development of strategies to improve air quality (see Section 5.2.4).

Results from an independent audit of the efficiency and cost-effectiveness of the program

The independent audit reported that the network monitoring program:

- provided reliable and up-to-date information on air quality in the region
- allowed for assessment of air quality against relevant standards
- remained valid regarding the sources of air pollution
- assisted with development of air quality programs
- enabled reporting of regional air quality both in real time and in various department publications.

The audit found that, overall, the network remained cost-effective. A material increase in annual average operating expenses (24%) and labour costs (46%) in 2017 to 2021 compared to 2011 to 2016 was attributed to some costs in the earlier years being provided in-kind, while being accounted for more completely in 2017 to 2021. Increased operating and labour costs in 2017 to 2021 were associated with replacement of equipment reaching end of life, and the more frequent maintenance required due to the high particle levels caused by bushfire smoke and dust storms.

The audit report made recommendations regarding cost management for 2022 to 2026 (see Recommendations below).

Review of factors affecting network design

The review found minimal changes during 2017 to 2021 in factors affecting the original design of the network in 2009–10. No changes were recommended to the current network design.

- The population of the Upper Hunter increased by less than 1% during 2016 to 2021 and was predicted to remain stable to 2026.
- Strategic planning by local government showed buffer zones between future urban growth areas and mining activity, to minimise population exposure to poor air quality.
- The extent of coalmining activity expanded marginally during 2017 to 2021.

Recommendations

This review presents the following recommendations (Table 1) from the independent audit for 2017 to 2021 and the Upper Hunter Air Quality Advisory Committee, to ensure that the Upper Hunter monitoring program continues to meet its objectives.

Table 1 Recommendations for improving the Upper Hunter monitoring program

Number	Recommendation
	Recommendations from the independent audit of the program effectiveness and cost-efficiency
1	Annual/seasonal air quality data reviews to be published within a shorter time after each period so that results may be used for progressive review of the network.
2	The Department of Planning and Environment (the department) to benchmark the network against comparable networks and develop key performance indicators for efficiency and cost-effectiveness to identify areas for innovation and improvement, and to provide a more quantitative basis for assessing the network in future audits.
3	The department to develop a formal operation and maintenance procedure manual that is specific for the Upper Hunter network and separate to the controlled documents for the whole NSW network. The manual should include a protocol for procuring new equipment and spare parts, and an inventory of spare parts and costs.
4	The department to reinstate cost forecasting for the network, providing forecasts to the Upper Hunter Air Quality Advisory Committee (the advisory committee) and this be considered a priority. Forecasting would include estimates of levy costs to industry.
4a	Forecasting would provide an ongoing annual review process where estimated costs are shared with the advisory committee and industry for their feedback before finalising the estimate.
4b	Forecasting would enable industries to budget their annual levy cost contributions more accurately and would also provide transparency in accounting for any differences between forecast and actual costs.
4c	With regards to the 5-yearly reviews, in the event that any changes to the network are required, for example, due to changes in mining locations or population centres, the consequential cost from such changes would form part of the annual cost forecasting.
	Recommendations following from the survey of the Upper Hunter Air Quality Advisory Committee
5	EPA and the department to better demonstrate the identification of sources of air pollution.
6	EPA and the department to better demonstrate the development and implementation of strategies to improve air quality.
7	EPA and the department to better communicate the network monitoring program’s actions and achievements in meeting its objectives.
8	EPA and the department to better investigate PM10 exceedances and causes of pollution events.
	Recommendations following from the first 5-year review in 2017
9	EPA and the department to plan annual presentations of the Upper Hunter annual air quality reports to a public or wider audience, in consultation with the advisory committee, especially local government representatives and in line with EPA Upper Hunter air quality communications strategy.

Number	Recommendation
10	EPA and the department to incorporate information into the Upper Hunter annual air quality reports about any closures in industries or approvals of developments with emissions to air.

Conclusion

This review concluded that, based on the evidence presented in the report:

- the Upper Hunter monitoring program was effective in meeting the objectives set by the Regulation
- the design of the Upper Hunter Air Quality Monitoring Network remained valid for meeting the requirements of the Regulation.

The department and EPA will consider the recommendations for ongoing improvement and formulate responses and actions in discussion with the Upper Hunter Air Quality Advisory Committee. Outcomes will be published in advisory committee meeting minutes.

Structure of the report

The structure of the report aligns with the review's purpose, findings and recommendations:

- Section 1 provides an overview of the network and the requirements set by the Regulation.
- Section 2 describes how the network meets its objectives, including reporting, data analysis and facilitating strategies to improve air quality (Regulation, clause 95(2)(a)).
- Section 3 reports on the findings from the independent audit of the efficiency and cost-effectiveness of the network (Regulation, clause 95(2)(b)).
- Section 4 reviews factors influencing the network's design, considering any changes in population and sources of air pollution (Regulation, clause 95(2)(c–d)).
- Section 5 presents feedback from the community, industry and government agencies; the findings of the review; and recommendations for improving the network and monitoring program (Regulation, clause 95(2)(c–d)).

1. Overview

This section introduces the Upper Hunter Air Quality Monitoring Network (the network) and the requirements of the review, set by the Protection of the Environment Operations (General) Regulation (the Regulation).

The Regulation defines the Upper Hunter monitoring program as:

> the environmental monitoring program operated by or on behalf of the EPA in the Muswellbrook, Singleton and Upper Hunter Shire local government areas that monitors air quality in those areas and known as the Upper Hunter Air Quality Monitoring Network, and includes any changes made by the EPA to that program from time to time.

1.1 Setting the scene – air quality in the Upper Hunter

The network was designed and established in 2010 to 2012 to meet the objectives and reporting requirements set by the Regulation.

More than 10 years of monitoring, analysis and reporting practice have developed our understanding of air quality in the Upper Hunter.

1.1.1 Sources of air pollutants and factors affecting air quality

- The major sources of particle pollution in the Upper Hunter are coalmining, coal-fired electricity generation, vehicles and non-road equipment, household wood heating, planned burns and bushfires, and windblown dust.
- Climate, weather, low-lying terrain and local particle sources can influence air quality levels significantly.
- Windblown dust during dry conditions, especially in spring and summer, increases PM10 particle levels (PM10 refers to airborne particles less than or equal to 10 micrometres in diameter). Strong winds raise loose soil and transport dust over long distances. Modelling shows that windblown dust may travel from western parts of the State to the Upper Hunter when conditions are dry. As ground cover improves, windblown dust decreases.
- Smoke from wood heaters increases PM2.5 particle levels in cooler months (PM2.5 refers to airborne particles less than or equal to 2.5 micrometres in diameter). Low-lying areas may trap wood smoke overnight when the air is calm. PM2.5 particles in wood smoke may build to harmful levels in Muswellbrook and Singleton.
- Drought increases dust and bushfire risk. Climate change intensifies hot dry phases in natural climate variability.

1.1.2 Statistics on the monitoring program, 2011 to 2021

- 96% of days met national standards for daily average particle measurements in larger population centres, that is, the monitoring stations at Singleton, Muswellbrook and Aberdeen (see Section 2.3.2 – Figures 5 and 6).
- PM10 annual average measurements met national standards in larger population centres for 9 out of 11 years (see Section 2.3.2 – Figure 7). The highest PM10 annual averages in 2018 and 2019 were associated with prolonged drought and extreme bushfire smoke conditions.
- PM2.5 annual average measurements during the 11 years from 2011 to 2021 met national standards for 7 years at Camberwell, 6 years at Singleton and 1 year at

Muswellbrook (see Section 2.3.2 – Figure 8). The lowest PM2.5 annual average in 2021 was associated with a wetter winter (compared to those in 2018 to 2020) and above average minimum temperatures. These conditions in 2021 were conducive to lower levels of PM2.5 from wood smoke on cold, calm winter nights, less bushfire smoke in warmer months and lower PM2.5 from windblown dust. The highest PM2.5 annual averages in 2019 were associated with extreme bushfire smoke from spring to December.

- Over 8 million data records were collected on air quality and meteorology from 2011 to 2021 (Section 2.2.1).
- Performance for ‘online time’ (see Section 2.1.1) for reporting data hourly was met 93–100% of the time from 14 stations (Table 2 and Table 3).
- Over 40 reports on network performance and air quality were produced and presented at meetings of representative from communities, industry, local councils and government agencies (see link in Section 6.2 – More information).
- Over 30 newsletters on seasonal and annual air quality were published (see link in Section 6.2 – More information).
- Over 500 pocket-sized infographic brochures on air quality in the Upper Hunter Valley were distributed across the Upper Hunter, designed in consultation with the Upper Hunter Air Quality Advisory Committee, and including a downloadable online version.
- Over 165,000 unique views of the Upper Hunter map webpage were recorded, with up to 1,408 daily visits (Table 4).

1.1.3 Improvements to the monitoring program since 2017

- A new interactive webpage was developed, available on desktop or mobile devices.
- Reporting of 1-hour average particle concentrations, revised air quality categories and health advice commenced to more accurately responding to short-term changes in air quality.
- Data from specific stations are provided via telemetry to industry in real time, to monitor PM10 levels and meteorological conditions.
- New, replacement PM2.5 instruments were installed at Muswellbrook, Singleton and Camberwell in 2020; and new gaseous analysers at Muswellbrook and Singleton.
- Rain gauges were installed at 7 of the network’s 14 monitoring stations.

In addition, the Merriwa (background) station was upgraded in 2020 to also monitor PM2.5 and additional gaseous parameters. The installation, operation and maintenance of these additional instruments was funded by the NSW Government Climate Change Fund (DPIE 2021) and is therefore outside the scope of the monitoring program required under the Regulation (Section 1.2).

1.2 Background to the network

In 2010 to 2012, the NSW Government established the Upper Hunter Air Quality Monitoring Network, in partnership with Upper Hunter coalmining and electricity generation industries, in line with the Regulation.

The network continuously measures air quality and meteorological conditions across the Muswellbrook, Singleton and Upper Hunter Shire local government areas. Monitoring data from the network provide the evidence base for the NSW Government to assess and manage air quality, for the protection of communities in the Upper Hunter.

The network’s design was based on the recommendations of an independent report commissioned by the NSW Government (Holmes Air Sciences 2008). Population distribution, location of major emission sources, topography and predominant meteorological conditions were considered to determine the number, location and purpose of monitoring stations in the network and the parameters measured.

The final locations of the 14 monitoring stations were determined in consultation with an advisory committee, representing the interests of community, industry and local governments.

Construction of the network commenced in late 2010. Stations in the large population centres of Muswellbrook and Singleton were the first online, with the network fully operational in February 2012. The hourly particle data (as PM10 and PM2.5) are available for Muswellbrook and Singleton from 8 and 10 December 2010, respectively. This provides 11 calendar years of particle data from these population centres, from 2011 to 2021. Table 2 and Table 3 (Section 2.1) provide the start dates for the particle and gaseous data, respectively, at each station in the network.

1.3 Objectives of the network and monitoring program

The network and monitoring program were designed in 2009 to 2010 to meet the requirements and objectives set by the Regulation in 2009. The objectives are:

1. to provide government, industry and the community with reliable and up-to-date information on air quality in the Muswellbrook, Singleton and Upper Hunter Shire local government areas
2. to enable the air quality in those areas to be assessed against relevant air pollution standards
3. to facilitate the identification of sources of air pollution in those areas
4. to facilitate the development and implementation of strategies to improve air quality in those areas.

1.4 Monitoring stations

The network consists of 14 monitoring stations, extending from Merriwa in the north-west to Singleton South in the south-east (Figure 1). The stations serve diverse purposes:

- Three stations monitor air quality in the **larger population centres** of Singleton, Muswellbrook and Aberdeen.
- Six stations monitor air quality in the **smaller communities** of Bulga, Camberwell, Jerrys Plains, Maison Dieu, Warkworth and Wybong.
- Three **diagnostic** stations at Singleton North West (NW), Muswellbrook NW and Mount Thorley monitor air quality closer to mining operations. They provide data to help diagnose the likely sources and movement of particles across the region. Diagnostic stations do not provide information about air quality in population centres.
- Two **background** stations at Merriwa and Singleton South measure air quality at the north-west and south-east extents of the region. They provide background data by measuring the quality of air entering and leaving the Upper Hunter Valley under predominant winds (south-easterlies in warmer months and north-westerlies in cooler months).

The network continually measures the following air quality and meteorological parameters:

- particulate matter PM10 (particles less than or equal to 10 micrometres in diameter), at all 14 monitoring stations
- fine particulate matter PM2.5 (particles less than or equal to 2.5 micrometres in diameter) at Singleton, Muswellbrook and Camberwell
- the gases sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) at Singleton and Muswellbrook
- wind speed, wind direction, temperature and humidity at all 14 monitoring stations; and rainfall at 7 stations (i.e. Aberdeen, Bulga, Camberwell, Merriwa, Muswellbrook, Singleton and Warkworth).

The Upper Hunter industry-funded network does not monitor ozone, a gaseous air pollutant formed in the atmosphere by photochemical reactions between gases such as oxides of nitrogen and volatile organic compounds, emitted in fossil fuel combustion. Ozone is monitored at stations within the wider government funded NSW air quality monitoring network (see link to NSW Government air quality website in Section 6.2 – More information).

- In July 2020, the NSW Government funded the upgrade of the Merriwa background station to monitor PM2.5, NO_2 and SO_2, ozone, carbon monoxide and visibility through the Climate Change Fund (DPIE 2021). The installation, operation and maintenance of these instruments are not part of the operational costs of the industry-funded Upper Hunter network.

Figure 1 The Upper Hunter Valley, showing the locations coal-fired electricity generation, open-cut coalmining, and the variables measured at stations in the industry-funded Upper Hunter Air Quality Monitoring Network

1.5 Operation of the network

The network is operated by the department, administered by the EPA and funded by Upper Hunter coal and power industries. The network measures airborne particles, gaseous pollutants and meteorological conditions in the Muswellbrook, Singleton and Upper Hunter Shire local government areas of New South Wales.

The network is operated by the Climate and Atmospheric Science Branch of the Department of Planning and Environment. The branch is accredited to the Australian and international standard AS ISO/IEC 17025 by the National Association of Testing Authorities (NATA) for the measurement of air quality parameters. The scope of accreditation can be found on the NATA webpage (see link in Section 6.2 – More information). The methods used to measure the parameters monitored in the network also align with relevant Australian standards and with requirements set by the National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM).

Specialist staff undertake routine maintenance and auditing of monitoring stations and quality assurance of monitoring data, to ensure that the network provides high-quality data. Monitoring data from the 14 stations are transmitted to a central database for processing, validation and hourly upload to a dedicated webpage for Upper Hunter air quality on the NSW Government website (see link in Section 6.2 – More information).

The EPA is responsible for administration of the network, in line with the Regulation (Chapter 6, Part 1). Upper Hunter coal and power industries pay annual levies to the EPA to cover the operational and administrative costs of running the network. The amount of the levy is proportional to the industry's contribution to the total annual particle and gaseous air emissions from participating industries (Regulation, clauses 86–92).

Results of monitoring data from the network help the NSW Government to better understand Upper Hunter air quality. The information can be used to:

- assess changes in air quality
- help identify the major sources of the monitored pollutants
- inform regulatory programs in response to long-term trends.

The Upper Hunter Air Quality Advisory Committee was established in 2010 to advise the EPA on matters related to the design of the network and the operation of the monitoring program. The advisory committee represents the views of the community, the coal and power generation industries, non-coal industries and local government.

1.6 Publication of the monitoring results

The NSW Government publishes the network's monitoring results in line with the Regulation (clause 94).

- Current air quality is reported as a colour-coded air quality category, ranging from good to extremely poor, on NSW Government air quality website (see link in Section 6.2 – More information). Results are updated hourly and may be viewed on desktop or mobile devices.
- Details of air pollution concentrations and meteorological conditions may be viewed in tables, graph and map format on a dedicated webpage for the NSW Government current air quality in Upper Hunter website (see link in Section 6.2 – More information).
- Web users and developers may stream Upper Hunter monitoring data for business and mobile applications using the air quality application programming interface (API) (DPE 2022a).

- Users may subscribe to receive alerts, issued as short text messages or emails, when pollution levels are above the threshold for poor air quality.
- Annual and seasonal reports containing analyses of the results of air quality monitoring are published as Upper Hunter newsletters, which may be viewed and downloaded from the department's website (see link in Section 6.2 – More information). Summary results of annual and seasonal analyses are presented at quarterly meetings of the advisory committee.

1.7 Review of the monitoring program

The Regulation requires the EPA to report on the Upper Hunter air quality monitoring program every 5 years.

The department reviews the monitoring program on behalf of the EPA, in line with the Regulation (clause 95).

Five-yearly reports on the Upper Hunter monitoring program contain the following considerations:

- a review of the effectiveness of the Upper Hunter monitoring program in fulfilling its objectives
- the results of an independent audit of the efficiency and cost-effectiveness of the Upper Hunter monitoring program
- any recommendations for improvements to the Upper Hunter monitoring program
- any other matters that the EPA considers appropriate or that the advisory committee considers appropriate.

The first 5-year report on the Upper Hunter monitoring program was published in 2017 (OEH 2017a), following the network's initial 5 complete years of operation for all 14 stations (i.e. from 2012 to 2016).

This report is the second 5-year review, prepared by the department on behalf of the EPA, covering the period from 2017 to 2021.

2. Objectives of the network

This section describes how the network meets the objectives of the Upper Hunter monitoring program set by the Regulation (clause 85). It includes analysis of air quality and meteorological data recorded for calendar years 2011 to 2021.

As noted in Section 1.3 above, the objectives of the network are:

1. to provide government, industry and the community with reliable and up-to-date information on air quality in the Muswellbrook, Singleton and Upper Hunter Shire local government areas
2. to enable the air quality in those areas to be assessed against relevant air pollution standards
3. to facilitate the identification of sources of air pollution in those areas
4. to facilitate the development and implementation of strategies to improve air quality in those areas.

The network and monitoring program were designed in 2009 to 2010 to meet the requirements and objectives set by the Regulation in 2009.

Key points

- The evidence below demonstrated that the Upper Hunter monitoring program was effective in taking action to meet the objectives set by the Regulation. The program:
  - provided reliable and up-to-date information on air quality in the Upper Hunter to communities, industry and government through online publishing of near real-time data and analyses in the form of newsletters and statements
  - assessed air quality against relevant standards by reporting air pollution status online in near real-time and in seasonal and annual publications
  - facilitated the identification of sources of air pollution by analysing events where relevant standards are exceeded and reporting to the community through seasonal and annual publications
  - facilitated the development and implementation of strategies to improve air quality in the Upper Hunter by providing the evidence base that supports programs to reduce particle emissions from mining activity and wood-fired domestic heaters.

2.1 Summary – meeting the objectives of the monitoring program

This section summarises the discussion in Sections 2.2. to 2.5 below, bringing together evidence to demonstrate how the monitoring program has met the objectives set by the Regulation.

Objective 1

To provide government, industry and the community with reliable and up-to-date information on air quality in the Muswellbrook, Singleton and Upper Hunter Shire local government areas.

Objective 1 is being met.

Evidence of this objective being met includes:

- The network has provided over 8 million valid and accurate data records of air quality and meteorological conditions since 2011. Online time has achieved targets of at least 93% during 2011 to 2021. Maintenance and calibration take up to 5% of the network's operating time.
- The network's online services include data displays in tables and graphs, and an interactive map for desktop and mobile devices. Current air quality in the Upper Hunter is shown as hourly average concentrations and air quality categories that indicate health advice for outdoor activities (see link in Section 6.2 – More information).
- The department's web-based air quality API (DPE 2022a) allows web users and developers to stream network monitoring data for business and mobile applications.
- Data from specific stations are provided via telemetry to industry in real time, to monitor PM10 levels and meteorological conditions.
- The network's reporting program has delivered over 30 publications between 2015 and 2021, reporting air quality against national standards and describing factors affecting high levels of air pollution in the Upper Hunter. This includes 20 seasonal newsletters during 2017 to 2021.

Objective 2

To enable the air quality in those areas to be assessed against relevant air pollution standards.

In this report, 'relevant air pollution standards' (also referred to as 'relevant air quality standards'), refers to national criteria set by the AAQ NEPM. Air quality data from monitoring stations in larger population centres of Aberdeen, Muswellbrook and Singleton have been reported against national standards in NSW annual air quality compliance reports since 2020. Stations in smaller communities and diagnostic stations are often located intentionally near pollution sources. Data from these stations are not intended for compliance reporting against national standards. Therefore, publications of the Upper Hunter monitoring program refer to national standards as benchmarks when assessing data from these stations. This report uses the term 'standard' when assessing data from larger population centres. The term 'benchmark' is used when assessing data from stations in smaller communities and diagnostic stations, or when referring collectively to all relevant Upper Hunter stations.

Objective 2 is being met.

Evidence of this objective being met includes:

- The network's monitoring program has reported PM10 levels above the daily air quality benchmark, quarterly and annually, from 2011 to 2021. The frequency of these events increased during drought and rainfall-deficient years such as 2018 and 2019. The frequency of these events was also higher at diagnostic and certain small population centres near mine operations, compared to lower levels in major population centres, background stations and the remainder of the small population centres. The network recorded fewer days above particle benchmarks since heavy rain fell in February 2020 and later in 2020 and 2021. Higher rainfall and restored ground cover have had the greatest influence on air quality in the Upper Hunter in 2020 to 2021. All stations recorded their highest PM10 annual averages in 2018 and 2019 due to dust and smoke associated with prolonged drought and extensive bushfire smoke, respectively. PM10 annual averages were below the annual benchmark during 2020 and 2021.
- PM2.5 levels over the daily benchmark occurred during winter months in Muswellbrook during 2012 to 2021, primarily due to the impact of wood smoke from wood-fired domestic heaters. Many days over the benchmark were observed at all 3 stations measuring PM2.5 (Muswellbrook, Singleton and Camberwell) during the 2019–20 bushfire season, consistent with levels observed across New South Wales. PM2.5 annual averages were above the benchmark at Muswellbrook each year from 2012 to 2020, at Singleton in 2017 to 2020 and Camberwell in 2013, 2018 and 2019. Bushfire smoke contributed to higher annual averages in 2019 and 2020. All 3 stations recorded PM2.5 annual averages below the annual benchmark in 2021.
- SO_2 levels were below benchmark concentrations during 2017 to 2021. Analysis of SO_2 hourly and daily data for 2012 to May 2021 at Muswellbrook and Singleton showed exceedances of the current, more stringent standards applied from May 2021 forwards (AAQ NEPM May 2021) at Muswellbrook only. Historically between 2012 and 2021, Muswellbrook would have recorded 34 days above the current hourly standard, and 6 days above the current daily standard. Maximum levels at Singleton were below the current 1-hour standard by 0.1 parts per hundred million (pphm), and the 24-hour standard by 0.2 pphm.
- Levels of NO_2 were below relevant national benchmarks in all years.

Objective 3

To facilitate the identification of sources of air pollution.

Objective 3 is being met.

Evidence of this objective being met includes:

- Analysis of the network's extensive pollution and meteorological dataset has provided valuable information on conditions conducive to elevated pollution levels and the transport of pollutants. Climate, weather and low-lying terrain as well as local particle sources can influence Upper Hunter air quality levels significantly. Drought increases dust and bushfire risk. Climate change intensifies hot, dry phases in natural climate variability.
- Seasonal newsletters report the likely sources of pollution when daily particle levels are above national standards. Air pollution sources – such as bushfires, dust storms, wood heaters and industrial emissions – are identified through the analysis of pollution levels and corresponding meteorological data.
- Integration of pollution and meteorological data, the outputs of air dispersion modelling and statewide dust reporting shows that windblown dust during dry conditions,

especially in spring and summer, increases PM10 levels. Strong winds raise loose soil and transport dust over long distances. Modelling shows that windblown dust may travel from western parts of the State to the Upper Hunter when conditions are dry. Long-term records of dust activity show that as ground cover improves, windblown dust decreases.

- Advanced research and case studies show that smoke from wood heaters increases PM2.5 particle levels in cooler months (Hibberd et al. 2013). Low-lying areas may trap wood smoke overnight when the air is calm. PM2.5 particles in wood smoke may build to harmful levels in Muswellbrook and Singleton. Extensive bushfire smoke can lead to extreme levels of PM2.5 particles.

Objective 4

To facilitate the development and implementation of strategies to improve air quality in those areas.

Objective 4 is being met.

Strategies have been implemented by the EPA in partnership with the mining industry and local councils to improve air quality in the Upper Hunter and across the State.

- Dust mitigation practices aimed at reducing high levels of PM10, especially in warmer months, have led to statewide international best practice in dust mitigation during mining operations.
- High levels of PM2.5 – typically recorded in the network's larger population centres on cold, calm nights in the cooler months – led to collaboration between the EPA and local councils to reduce wood smoke emissions. The EPA published a tool kit of educational materials for councils, made available statewide, to raise awareness of the health issues associated with wood heaters. In 2016 and 2019, the EPA introduced successive regulatory amendments requiring all new wood heaters sold in New South Wales to comply with increasingly tighter emission and efficiency standards. Singleton and Muswellbrook councils also participated in an EPA wood smoke reduction program in the winter seasons in 2016 to 2018, including incentives for replacement of wood heaters.
- The NSW Government and science partners are working progressively to extend the capacity of the air quality forecasting system to cover major regional areas, including the Upper Hunter. The data collected from the network provide an essential input in developing this work.

2.2 Objective 1 – the provision of reliable and up-to-date information

The network's provision of reliable and up-to-date information as per objective 1 is demonstrated by its consistent online performance and reporting activities since the establishment of the monitoring program.

Key points

- The network has provided over 8 million valid and accurate data records of air quality and meteorological conditions from 2011 to 2021 (including the 2017 to 2021 review period). Online time has achieved targets of 95% for reporting particles and meteorology, and at least 93% for gaseous pollution between 2011 and 2021. Maintenance and calibration take up to 5% of the network's operating time.
- The network's online services include data displays in tables and graphs, and an interactive map. Current air quality in the Upper Hunter (see link in Section 6.2 – More information) is shown as hourly average concentrations and air quality categories that indicate health advice for outdoor activities. Hourly averages replaced rolling 24-hour averages in response to community requests for more accurate information on short-term changes in air quality during the NSW bushfire emergency in spring–summer of 2019–20. During this period, the number of daily unique visits to the Upper Hunter map webpage peaked at 1,408 on 19 November 2019, with a total of 128,726 unique page views over the 5-year period from 1 January 2016 to 31 December 2021. Web users may subscribe to the short messaging service or emails to receive alerts when air pollution levels are above national benchmarks.
- The network's reporting program has delivered over 30 publications, including annual statements and seasonal newsletters reporting air quality against national standards and factors affecting high levels of air pollution in the Upper Hunter. The easy-to-read reporting formats were designed in consultation with the Upper Hunter Air Quality Advisory Committee (see link in Section 6.2 – More information), established in 2011 to advise the NSW Government on matters relating to the network. The 8 NSW annual air quality statements from 2014 to 2021 have a dedicated focus area that reports on Upper Hunter air quality and comparisons with air quality across the State.

2.2.1 Providing reliable data – network performance for online time

The network's scientific instruments require regular maintenance and calibration. The network's schedule for maintaining and calibrating the monitoring and communication instruments complies with Australian standards (AS ISO/IEC 17025) for servicing the equipment. This ensures that data provided to the community are accurate and reliable. Maintenance and calibration tasks require up to 5% of the network's operating time. Therefore, an operational aim of the network is to achieve at least 95% online time for all parameters measured.

The network has provided an exceptional return of valid data since monitoring commenced, delivering over 8 million valid and accurate data records of air quality and meteorological conditions. Valid and accurate particle and meteorological data are available for more than 95% of the total operational time at all monitoring stations since their establishment (Table 2).

For the gaseous parameters, the network has achieved close to this threshold, with at least 93% of valid data available at Singleton and Muswellbrook (Table 3). Due to scheduled daily calibrations, the maximum online time that can be attained for NO_2 and SO_2 data is 96%.

Table 2 Online time (%) of particle and wind data from the start date to 31 December 2021

Station	Particles			Meteorology[a]	
	Start date	PM_{10} daily	$PM_{2.5}$ daily	Wind hourly	Temperature/ humidity hourly
Aberdeen	15/12/2011	99	–	99	100
Bulga	13/8/2011	99	–	100	100
Camberwell	26/7/2011	99	96	99	100
Jerrys Plains	16/12/2011	98	–	99	99
Maison Dieu	31/3/2011	98	–	98	99
Merriwa	21/2/2012	98	–[b]	98	99
Mount Thorley	26/7/2011	97	–	99	99
Muswellbrook	8/12/2010	99	96	99	100
Muswellbrook NW	15/12/2011	99	–	99	100
Singleton	10/12/2010	99	97	99	100
Singleton NW	26/7/2011	99	–	100	100
Singleton South	15/12/2011	99	–	97	99
Warkworth	15/12/2011	98	–	99	99
Wybong	16/12/2011	99	–	100	100

'–' not monitored.

a Start dates for some meteorological parameters vary in comparison to the particle data.

b Measured since July 2020 but not included in the Upper Hunter network.

Table 3 Online time (%) of NO_2 and SO_2 data from the start date to 31 December 2021

Station	Start date	Gases NO_2 hourly	Gases SO_2 hourly
Muswellbrook	18/11/2011	94	94
Singleton	17/11/2011	93	95

The annual percentages of online times from 2011 to 2020 are published in the Upper Hunter Air Quality Monitoring Network annual reports on the department's website (see link in Section 6.2 – More information).

2.2.2 Providing data and information to the community

The NSW Government has collected over 8 million air quality and meteorological records for the Upper Hunter from establishment of the first network sites in late 2010 to the end of 2021. These data have been used extensively by many program stakeholders.

Upper Hunter air quality website

The network provides the community with hourly updates on current air quality via the NSW Government's Upper Hunter air quality webpage (see link in Section 6.2 – More information).

The community may view current air quality for the Upper Hunter, updated hourly, on their desktop or mobile devices, at the NSW Government website. Current air quality is reported as colour-coded air quality categories, ranging from good to extremely poor, with corresponding health advice for outdoor activities.

Web users may view hourly monitoring data for pollution concentrations and meteorology measured at the 14 monitoring stations. Hourly data for PM10, PM2.5, NO_2, SO_2, temperature, humidity, wind direction and wind speed are presented in tables and graphs, and on an interactive map. A newly commissioned NSW Government air quality demonstration website was also released in late 2021 (see link in Section 6.2 – More information).

The number of unique page views (based on the number of unique visits in each 30-minute session) for the period 1 January 2016 to 31 December 2021 for the Upper Hunter map webpages is shown in Figure 2. During this period, the number of daily unique visits peaked at 1,408 on 19 November 2019, with a total of 128,726 unique page views over the 5 year period.

By far the highest numbers of views occurred between October 2019 and January 2020, during the 2019–20 bushfires. At other times, high numbers of page views often occurred during extensive dust storm events that affected the Upper Hunter as well as large parts of the State. These events included widespread dust storms on 22 November 2018; 13 February, 7 March, 10 August and 7 September 2019; and 11 January and 20 August 2020.

During the 2019–20 bushfire season, the website address for the Upper Hunter page was changed on several occasions, as the department managed unprecedented high levels of traffic across the website during the bushfire crisis.

Table 4 Upper Hunter air quality webpage views, 1 January 2012 to 31 December 2021

Date	No. of unique page views	Maximum no. of daily page visits
1 Jan 2012 – 31 Dec 2016	36,371	188
1 Jan 2017 – 31 Dec 2021	128,726	1,408 (19 November 2019)
Total	**165,133**	**1,408 (19 November 2019)**

Figure 2 shows the correlation between the number of unique page views for the network map webpage from 2017 to 2021, and the second highest PM10 daily average across the Upper Hunter sites.

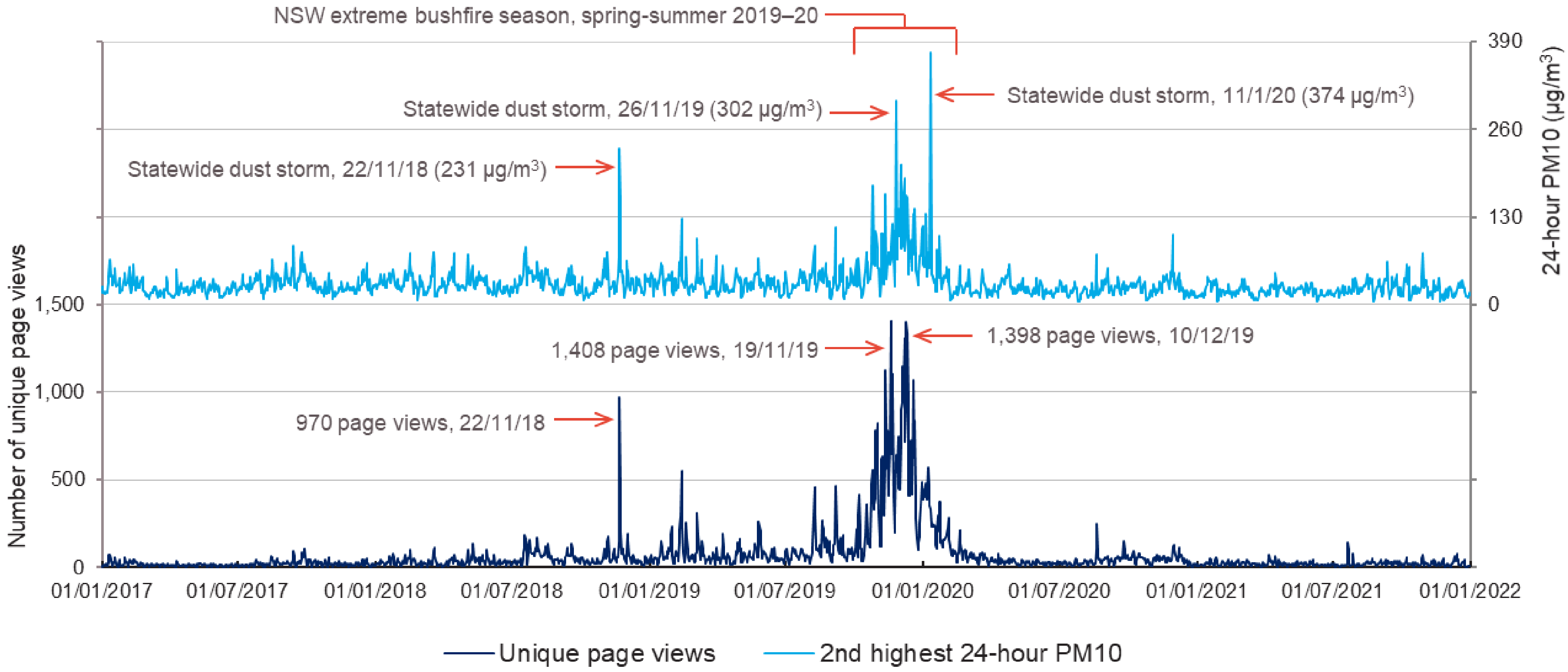


Figure 2 Unique page views for the Upper Hunter Air Quality Monitoring Network map webpage from 2017 to 2021 (dark blue, left axis), plotted against second highest PM10 daily average for Upper Hunter sites (light blue, right axis)

Air quality alerts sent to subscribers

The network monitoring program triggers automatic alerts as text messages via short message services (SMS) and emails to inform alert subscribers when air quality is 'poor' (DPE 2022b). This allows members of the community who may be susceptible to air pollution (e.g. asthmatics, people with respiratory or heart disease, carers for children, and the elderly) to take action to protect health when planning outdoor activities.

The NSW Government has promoted this service via its website, as well as at community meetings and in communications with stakeholders and the media. Subscription to the SMS and email alerts is available online at the department's website (see link in Section 6.2 – More information).

The numbers of subscribers to the Upper Hunter network alerts from 2012 to 2021 are shown in Figure 3 and Figure 4. Most email subscriptions began either in 2012 and 2013, during the first years of the network's operations, or in 2019 and 2020 when bushfires and prolonged drought brought poor air quality across the State.

The largest number of subscribers for both the email and SMS alerts are for alerts at the population centre stations at Muswellbrook and Singleton, as well as the diagnostic stations at Muswellbrook NW and Singleton NW.

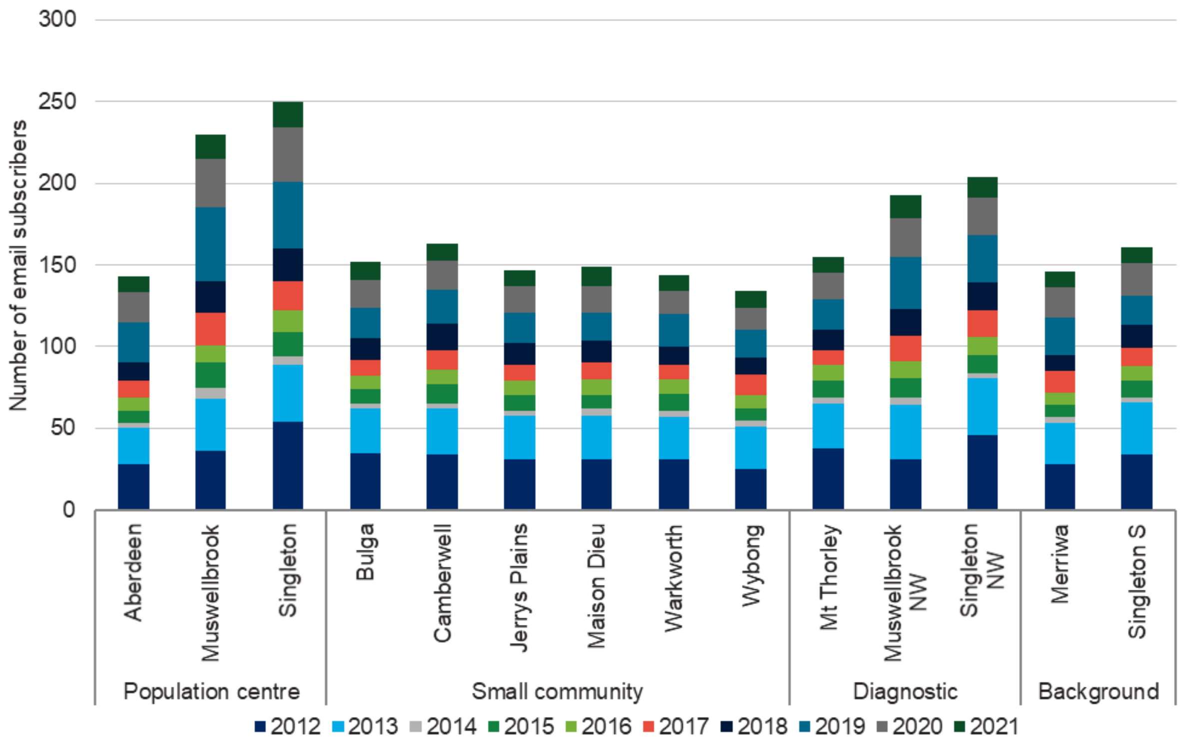


Figure 3 Numbers of public subscribers to email alerts for each air quality monitoring station, as of 17 January 2022

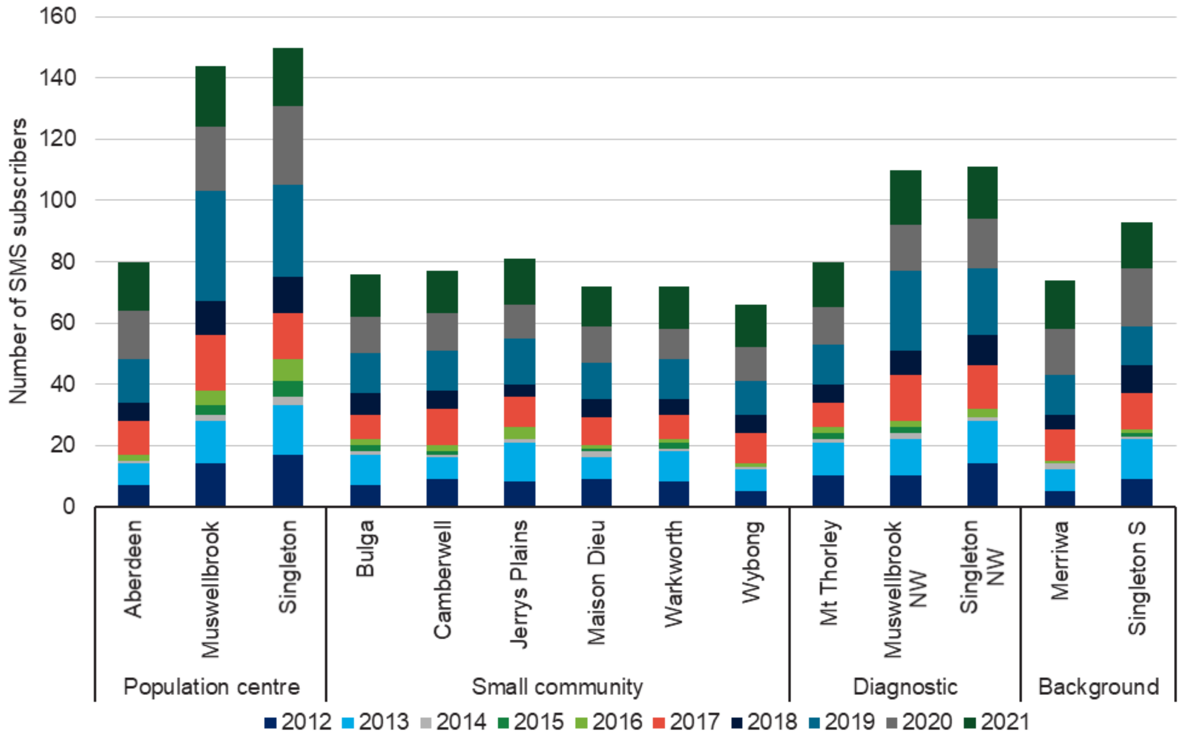


Figure 4 Numbers of public subscribers to SMS alerts for each air quality monitoring station, as of 17 January 2022

In November 2020, changes were made to the method by which alerts were generated and sent by the department. Before this time, alerts were sent based on 24-hour rolling average particle concentrations, in line with health advice provided on the NSW Government website for the same period. The thresholds that triggered these alerts were revised in 2020 in line with changes to live data reporting systems. Reporting of 1-hour average particle measurements was introduced and updated health advice was provided on the website to reflect hourly particle levels.

Alerts since then have been triggered by 1-hour measurements based on nationally agreed thresholds. This has resulted in a higher number of alerts being sent for most stations, because 1-hour levels are breached more frequently than the rolling 24-hour levels. For example, during 2021 the Muswellbrook station triggered 8 alerts: 4 alerts for PM10 and 4 alerts for PM2.5. Under the alert system used previously, based on the rolling 24-hour average, no alerts would have triggered during this period.

Seasonal newsletters

The department analyses data from the network each season and presents a summary newsletter to the advisory committee. The newsletter's content and format were developed in consultation with the committee. Seasonal newsletters from autumn 2015 onwards are available on the department's website (see link in Section 6.2 – More information).

The seasonal newsletters provide:

- annual trends of particle (PM10 and PM2.5) data
- daily time series plots of particle and gaseous data
- number of days above benchmark concentrations and likely sources of particles
- pollution and wind roses

- seasonal comparisons and trends
- meteorological summaries
- network online time performance over the season.

The information included in the seasonal newsletters has changed over time in response to stakeholder needs, with feedback provided through the advisory committee. The committee considered that the seasonal newsletters provided more timely updates on the state of air quality in the Upper Hunter, in contrast to the scheduled annual reports.

Annual reports

The department consolidates data each year into an annual report for the network. Information from the seasonal newsletters is incorporated in these reports, with the addition of air pollution event analyses where appropriate.

The Upper Hunter air quality annual reports from 2012 to 2020 are available on the department's website (see link in Section 6.2 – More information).

NSW annual air quality statements

The department releases NSW annual air quality statements for the whole of the NSW air quality monitoring network in January or February each year (DPE 2021). This statement is released soon after the end of the calendar year to inform the community with summary air quality information for New South Wales.

These statements include:

- comparisons of air quality levels for different NSW regions
- information on days above national standards
- a focus summary on air quality in the Hunter Valley to address additional community needs.

The NSW annual air quality statements from 2013 to 2021 are available on the NSW Government website (DPE 2021).

Upper Hunter air quality infographic fact sheet for communities

The network monitoring program published and distributed a pocket-sized, fold-out infographic fact sheet, *Air quality in the Upper Hunter Valley*, in 2019 (see DPIE 2019). The fact sheet was produced in response to a request from the Upper Hunter Air Quality Advisory Committee. It was designed in consultation with the committee, focusing on air pollutants and their health effects, trends in Upper Hunter air quality, factors affecting air quality and what is being done to protect people and air quality. It also provides advice on how the community can have a say on air quality in the Upper Hunter and where to find more information.

2.2.3 Providing data and information to external stakeholders

Data for business and mobile applications including dust emission control

The NSW Government's web-based air quality API (DPE 2022a) allows web users and developers to stream the network monitoring data for business and mobile applications. Web users may integrate Upper Hunter air quality and meteorological data into their organisation's websites, data systems and decision-support tools. For example, Upper Hunter coal mine operators may access air quality and meteorological data from their nearest network monitoring station to assist in planning day-to-day mining activity. This allows mine operators to minimise dust emissions, especially during weather conditions conducive to uplift and transport of dust.

Upper Hunter mining industry

Air quality and meteorological data from the network are also made available for mining industry operators. In addition to the web-based API (DPE 2022a), monitoring data from specific stations can be provided via telemetry to industries in real time, to monitor changing PM10 levels and meteorological conditions during mining activity.

The NSW Minerals Council commissioned a major study in 2019, focussing on the network monitoring data for 2011 to 2019. The *Upper Hunter air quality monitoring data analysis project* (ERM 2020) investigated whether Upper Hunter air quality had changed since monitoring began, and whether air quality in the Upper Hunter differed from air quality measured at other locations in New South Wales.

Key findings reported by the study included the following:

- Annual average PM10 concentrations within the Upper Hunter generally were consistent with the Lower Hunter, but also higher than a range of other regions in the State. The difference between the Upper Hunter and average concentrations in New South Wales was small relative to the variability observed between years.
- Significant increases were observed in annual average Upper Hunter PM10 concentrations between 2017 and 2019. These increases were found to be generally consistent with trends observed across the remainder of the State, which showed a correlation with the progressive decrease in annual rainfall and increased prevalence of drought conditions.
- Trends in PM2.5 annual average concentrations were also found to be consistent with the remainder of the State.

Local government

Local councils in the Upper Hunter use information from the monitoring program as an evidence base in strategic planning.

For example, the *Singleton Council local strategic planning statement 2041* (Singleton Council 2020) demonstrates council's use of information from the network to assist in strategic planning, with some highlights as follows:

- The statement reported summary statistics (page 21) from network monitoring data and sources of PM2.5 emissions from the findings of the *Upper Hunter fine particle characterization study* (Hibberd et al. 2013).
- The statement noted that '… Council continues to play an advocacy role for improved local air quality outcomes [and] planning mechanisms [help to] separate pollution sources from vulnerable receivers such as housing growth areas' (page 21).
- The statement also noted that 'air quality was raised in community feedback associated with the development of [the] Statement' (page 21).
- The statement refers to the Upper Hunter air quality seasonal newsletters as an information source aligned to its strategic planning priorities to protect the health and amenity of community, and ensure that the mineral resource industry is productive, accountable and considerate of surrounding land uses (pp.74–75).

The *Singleton community strategic plan 2017–2027* (Singleton Council n.d, page 25) has set a strategy to educate and advocate to improve air quality so that council can meet the objective of valuing, protecting and enhancing sustainable development.

Other government agencies

Data collected from the network are used in work practices of government agencies that manage mining approvals and development applications.

The department's Planning and Assessment Compliance Branch reviews network monitoring data in the following matters:

- when a community member reports an air quality complaint
- when there is a suspected 'extraordinary event' (e.g. regional dust events)
- to correlate data from mines and other projects, when mines report air quality criteria exceedances from their own industry-operated monitoring stations.

Air quality impact assessment for industrial development

Proponents of new industrial developments in the Upper Hunter use data from the network to prepare air quality impact assessments. These studies are required as part of the NSW Government's development approval process for proposed developments.

2.3 Objective 2 – air quality assessment against air pollution standards

The discussion on objective 2 summarises the Upper Hunter air quality compared to national standards (benchmarks).

In this report, ‘relevant air quality standards’ refers to national criteria set by the AAQ NEPM. Air quality data from monitoring stations in larger population centres of Aberdeen, Muswellbrook and Singleton have been reported against national standards in NSW annual air quality compliance reports since 2020. Stations in smaller communities and diagnostic stations are often located intentionally near pollution sources. Data from these stations are not intended for compliance reporting against national standards. Therefore, publications of the Upper Hunter monitoring program refer to national standards as benchmarks when assessing data from these stations. This report uses the term ‘standard’ when assessing data from larger population centres. The term ‘benchmark’ is used when assessing data from stations in smaller communities and diagnostic stations, or when referring collectively to all relevant Upper Hunter stations.

Key points

- The monitoring program has reported 94% of days with air quality meeting national standards for daily averaged particle levels in larger population centres (i.e. Aberdeen, Muswellbrook and Singleton stations) between 2011 and 2021. Air quality at these stations met national standards on 98% of days in 2012 to 2016 and 94% of days in 2017 to 2021.
- In the 2017 to 2021 period, particle pollution increased significantly till February 2020. Since then, much lower levels of particles have been observed. The largest influence on overall particle levels in the Upper Hunter was climatic factors which resulted in droughts and bushfires. These conditions led to windblown dust and bushfire smoke respectively, with dust represented best by PM10 levels and smoke impacts by both PM10 and PM2.5 levels.
- PM10 levels above the daily benchmarks occurred each year during 2017 to 2021. The frequency of these events increased during drought (and rainfall-deficient) years such as 2018 and 2019. The frequency of these events also was higher at diagnostic and certain small population centres near mine operations, compared to lower levels at major population centres, background stations and the remainder of the small population centres.
- PM2.5 levels over the daily benchmark occurred during winter months in Muswellbrook due to the impact of wood smoke from wood-fired domestic heathers. Many days over the benchmark were observed at the 3 stations that measured PM2.5 (i.e. Muswellbrook, Singleton and Camberwell) during the 2019–20 bushfire season, consistent with levels observed across New South Wales.
- PM10 and PM2.5 annual averages also followed the trends observed for daily benchmarks, with higher averages in years impacted by drought and bushfire, and higher PM10 annual averages at sites more exposed to mine operations.
- SO_2 levels were below national standard concentrations during 2017 to 2021. However, the strengthening of the national standard in May 2021 meant that, compared with historical measurements, Muswellbrook would have a greater number of days and hours over the current standards (see Section 2.3.3). Levels of NO_2 remained below relevant national standards.

2.3.1 Air quality standards

The following discussion compares air quality data at stations in larger population centres against relevant standards for PM10, PM2.5, NO_2 and SO_2, set by the AAQ NEPM (May 2021) (Table 5).

Table 5 National air quality standards and goals for particles (as PM10 and PM2.5), SO_2 and NO_2, as applied by the AAQ NEPM from May 2021

Pollutant	Averaging period	Benchmark (concentration) [a b]	Goal: How often can the benchmark be exceeded?
Particles as PM10	Daily: 1 calendar day (24 hours)	50 µg/m³	Never [c]
Particles as PM10	Annual: 1 calendar year (12 months)	25 µg/m³	Never
Particles as PM2.5	Daily: 1 calendar day (24 hours)	25 µg/m³	Never [c]
Particles as PM2.5	Annual: 1 calendar year (12 months)	8 µg/m³ [d]	Never
Sulfur dioxide (SO_2)	Hourly	10 pphm [e]	Never
Sulfur dioxide (SO_2)	Daily: 1 calendar day (24 hours)	2 pphm	Never
Nitrogen dioxide (NO_2)	Hourly	8 pphm	Never
Nitrogen dioxide (NO_2)	Annual: 1 calendar year (12 months)	1.5 pphm	Never

a The concentration of particles in the air is measured as the mass of the particle in micrograms (µg) per volume of air in cubic metres (m^3), standardised to 0°C and 1 unit of atmospheric pressure (atm).

b SO_2 and NO_2 are measured in parts per hundred million (pphm) by volume, i.e. parts of pollutant per hundred million parts of air.

c Not including exceptional events. An exceptional event is defined in the AAQ NEPM as a fire or dust occurrence that adversely affects air quality at a particular location, and causes an exceedance of the 1 day average standards in excess of normal historical fluctuations and background levels, and is directly related to: bushfire, jurisdiction-authorised hazard reduction burning, or continental-scale windblown dust.

d From 1 January 2025, the PM2.5 annual average benchmark will fall to 7 µg/m³.

e From 1 January 2025, the SO_2 hourly benchmark will fall to 7.5 pphm.

The concentrations in Table 5 show the standards applied by the update to the AAQ NEPM, from its registration date in May 2021. Before this date, concentrations of NO_2 and SO_2 were compared to the National Environment Protection (Ambient Air Quality) measure from 2016, summarised in Table 6.

The changes to the AAQ NEPM in the 2021 were:

- lowering of allowable hourly concentrations for both SO_2 (from 20 pphm to 10 pphm) and NO_2 (from 12 pphm to 8 pphm)
- lowering of allowable daily concentration of SO_2 (from 8 pphm to 2 pphm)
- lowering of the allowed annual average of NO_2 (from 3 pphm to 1.5 pphm)
- removal of the single allowable exceedance day per annum for both hourly SO_2 and NO_2 benchmarks, and the single allowable exceedance day per annum for the daily SO_2 benchmark
- the removal of the SO_2 annual average standard.

Table 6 AAQ NEPM standards and goals for SO_2 and NO_2 between 2016 to May 2021

Pollutant	Averaging period	Benchmark (concentration) [a b]	Goal: How often can the benchmark be exceeded?
Sulfur dioxide (SO_2)	Hourly	20 pphm	Maximum one day per year
Sulfur dioxide (SO_2)	Daily: 1 calendar day (24 hours)	8 pphm	Maximum one day per year
Sulfur dioxide (SO_2)	Annual: 1 calendar year (12 months)	2 pphm	Never
Nitrogen dioxide (NO_2)	Hourly	12 pphm	Maximum one day per year
Nitrogen dioxide (NO_2)	Annual: 1 calendar year (12 months)	3 pphm	Never

Note: The AAQ NEPM particle standards are not applied directly to the Upper Hunter diagnostic stations (i.e. those monitoring stations that are located purposefully to enable diagnosis of dust sources). For example, Singleton NW monitoring station measures the quality of air moving towards Singleton from the mining areas to the north-west of the larger population centre. The NSW Government understands the community need for assessing air quality levels against the AAQ NEPM standards at all sites in the network, so even those sites away from population centres have been included in this review.

Upper Hunter air quality by national standards

The network data showed that Upper Hunter air quality at larger population centres (i.e. Aberdeen, Muswellbrook and Singleton) met national standards for daily averaged particle levels on 96% of days during 2011 to 2021 (i.e. 160 days were recorded with particle concentrations above the national standards over 11 years).

- In 2012 to 2016 (the first 5 years of the network's operation), 98% of days met national standards, with 39 days recording particle levels above national standards.
- In 2017 to 21 (the second 5 years of the network's operation), the percentage of days meeting national stands dropped to 94%, with 115 days recording particle levels above national standards. Of these 115 days, 71 occurred in the 6-month period between August 2019 and January 2020 inclusively, during the extreme bushfire season (DPIE 2020a) of spring–summer 2019–20.

On one day in 2016, Muswellbrook recorded one hour above the SO_2 benchmark. Under the national standards effective at the time (Table 6), a single daily exceedance of this 1-hour standard was allowed.

2.3.2 Particle pollution levels compared to the national standards

The Upper Hunter network has recorded particle levels above national benchmarks since its establishment in 2010 to 2012. This is particularly so during exceptional events, when air quality was affected by large-scale dust storms or smoke from bushfires and hazard reduction burning. In this review, such exceptional events were included in the analysis.

Daily benchmarks

Figure 5 shows the number of days above the daily PM10 benchmarks from 2012 to 2021. Key points are:

- All stations recorded significantly more days above PM10 benchmarks in 2018 and 2019 than during the 2012 to 2017 period.
- All stations recorded an increase in the number of days above the PM10 benchmark in 2018 compared to previous years. A greater increase in number of days above the benchmark occurred at stations closer to mining operations, such as Camberwell, Mount Thorley and Singleton NW.
- In 2019, stations in larger population centres recorded between 40 days (Singleton) and 58 days (Muswellbrook) over the PM10 benchmark. More days above the benchmark were observed at diagnostic or small community stations, with 87 days recorded at Camberwell in 2019.
- The 2021 calendar year represents the lowest number of days over the PM10 benchmark, with 6 calendar days. The next lowest year was 2016 which had 14 days.

Figure 6 shows the number of days above the daily PM2.5 benchmarks from 2012 to 2021. Key points are:

- Between 2012 and 2018, up to 3 days a year were recorded over the PM2.5 benchmark at Muswellbrook.
- In 2019, 22 days over the benchmark were observed at Muswellbrook, with 24 days at Singleton and 23 days at Camberwell. In addition, the annual averages at all 3 stations were over the annual benchmark in 2019.
- For the first year in the Upper Hunter network since measurements began, no days were recorded over the PM2.5 benchmark in 2021.

Annual benchmarks

Figure 7 shows PM10 annual averages compared to the national benchmark. Key points are:

- In 2018, all stations recorded their highest PM10 annual averages to that date, during intensifying drought conditions. This was eclipsed in 2019 where all stations subsequently recorded higher PM10 annual averages than 2018. This was consistent with measurements observed across the State, which arose from intense drought conditions in 2018–19 and bushfires in late 2019.
- In contrast, the 2021 annual averages fell to the lowest annual concentration observed for 12 of the 14 stations during their 10-year operation period. Jerrys Plains recorded its second lowest average, and Warkworth its third lowest annual average in 2021.

Figure 8 shows PM2.5 annual averages at 3 stations compared to the national benchmark. Key points are:

- Annual averages at Muswellbrook were above the standard between 2012 and 2018.
- Annual averages at all 3 stations increased significantly in 2019.
- The annual averages for 2021 were the lowest levels since monitoring began. This was the first year Muswellbrook recorded an annual average less than the annual benchmark. Historically, smoke from domestic wood heaters has contributed to particle levels at Muswellbrook and Singleton in winter (as found in the *Upper Hunter fine particle characterization study*, Hibberd et al. 2013).

Particle levels in 2018 to 2020

The higher particle levels in 2018 to early 2020 resulted from a combination of factors, including the following:

- Low rainfall in 2018 and 2019 reduced ground cover with subsequent increases in surface soil exposure in the Upper Hunter region. These conditions were observable for all surfaces including those used for agriculture, unsealed roads, mining operations and remediated land.
- Low rainfall reduced ground cover on largely agricultural land in the Central West and the North West Slopes and Plains regions, and to the west and north-west of the Upper Hunter. This resulted in much higher levels of dust transported into the valley. Merriwa and Aberdeen, typically less exposed to local mining activity, recorded an increasing frequency of days above the PM10 benchmark due to windblown dust from wider regions.
- Extreme levels of bushfire smoke extended across New South Wales, including the Upper Hunter, between October 2019 to January 2020. For the Upper Hunter, a combination of smoke transported from Gospers Mountain megafire (in the national park to the south of the Upper Hunter), and long-range transport of smoke on southerly breezes from fires in southern regions, reached the Upper Hunter. This contributed to many days above PM10 and PM2.5 benchmarks in the Upper Hunter.
- The period of extreme bushfire smoke was also the peak of the prolonged drought and loss of ground cover in the Hunter Valley and surrounding regions. Westerly winds were stronger and more frequent. As such, large amounts of dust were generated locally, as well as in other drought-affected regions and transported into the valley.
- In contrast to these conditions, the network has recorded fewer days above particle benchmarks since heavy rain fell in February 2020 and later in 2020 and 2021. Higher rainfall and restored ground cover have had the greatest influence on good air quality in the Upper Hunter in 2020 to 2021. A comparison of the Upper Hunter region with other regions of New South Wales is made below (Figure 9 and Figure 10).

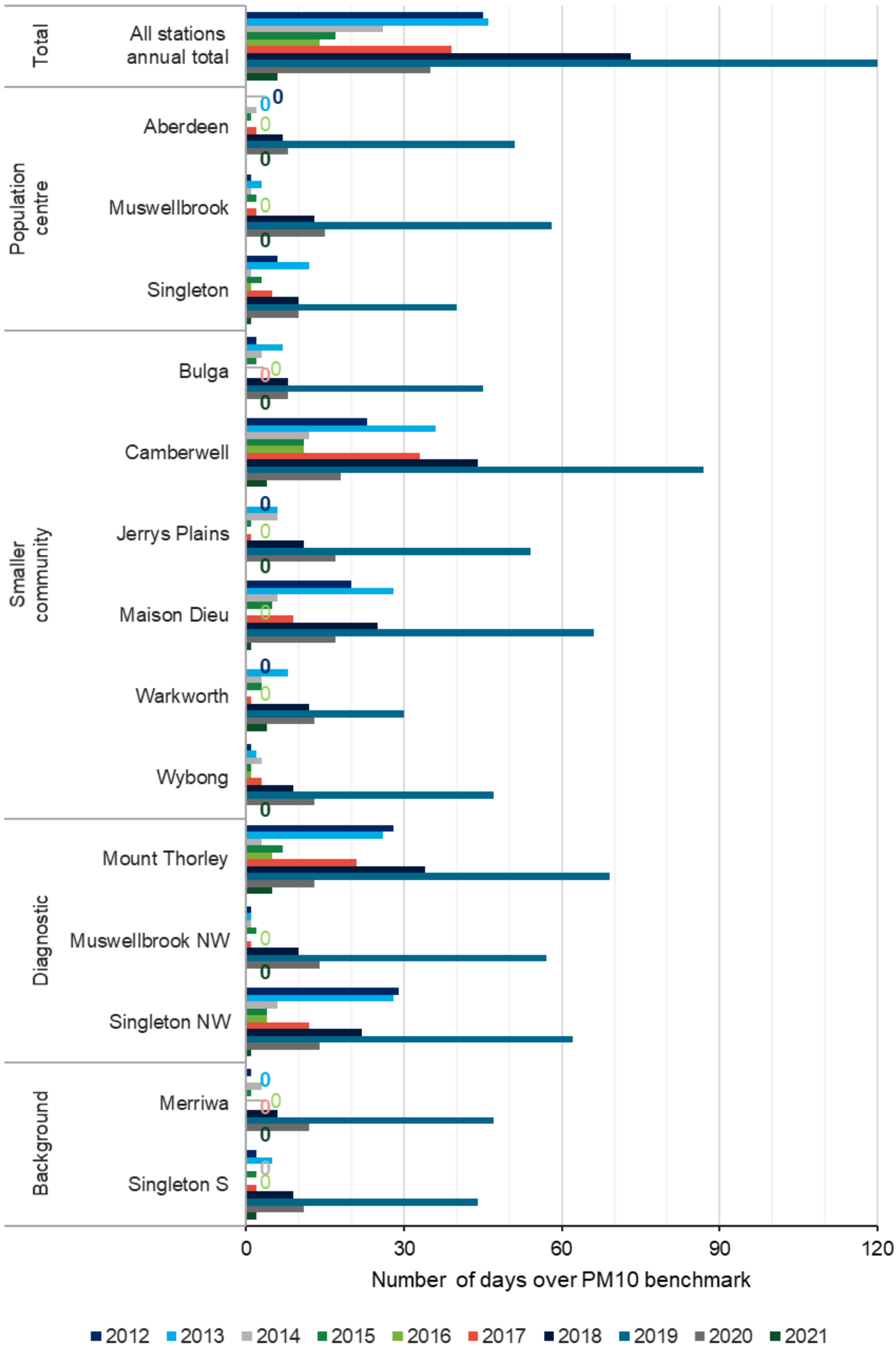


Figure 5 Number of days above the daily PM10 benchmark at 14 monitoring stations, 2012 to 2021

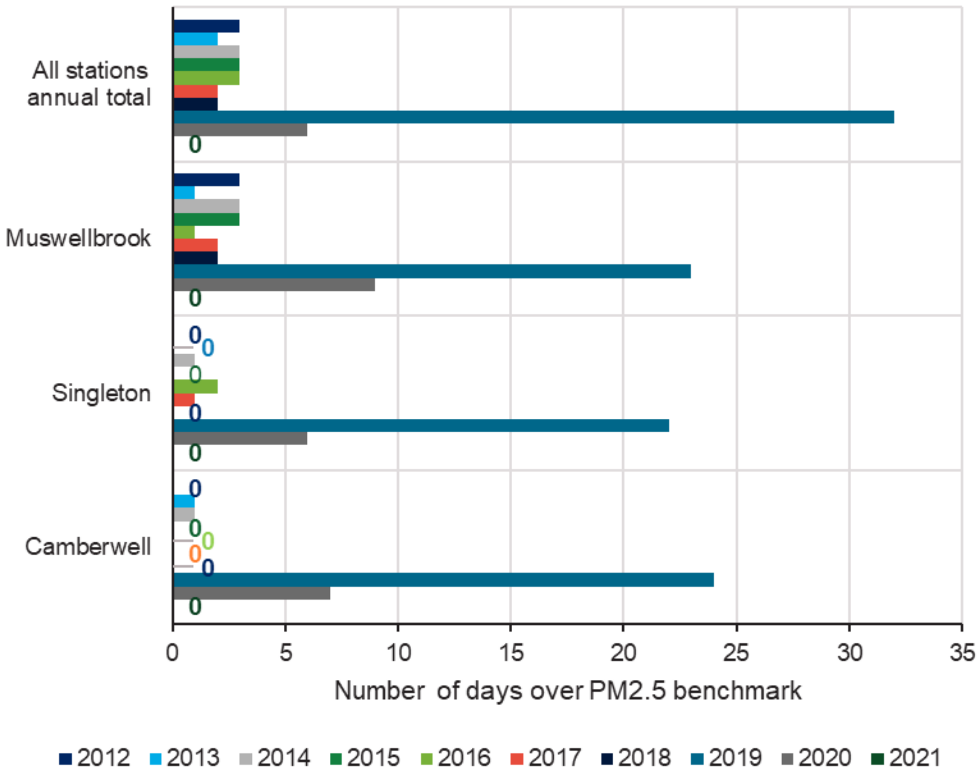


Figure 6 Number of days above the daily PM2.5 benchmark at 3 monitoring stations, 2012 to 2021

Note: Merriwa has had no days over the benchmark since it came online in July 2020 and to the end of 2021.

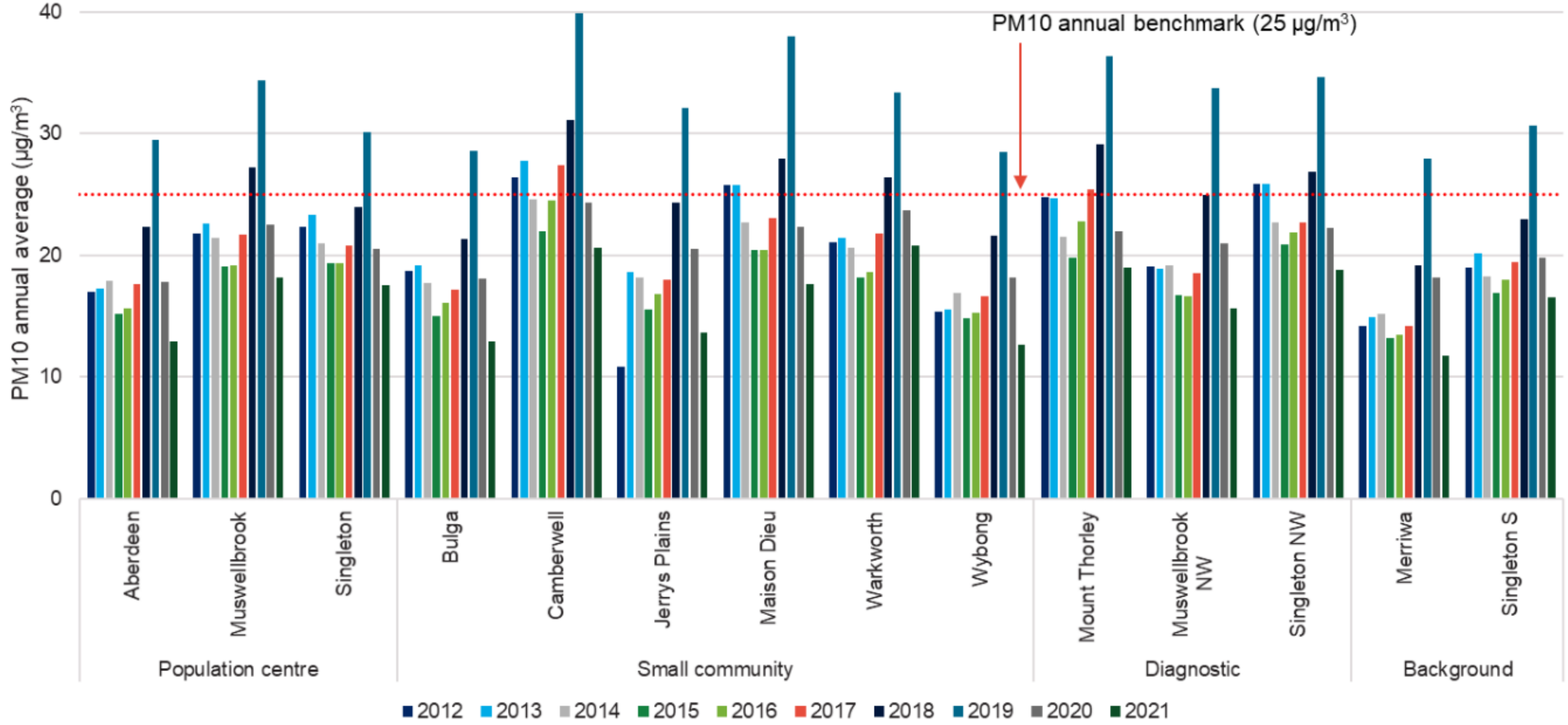


Figure 7 PM10 annual averages at 14 stations, 2012 to 2021

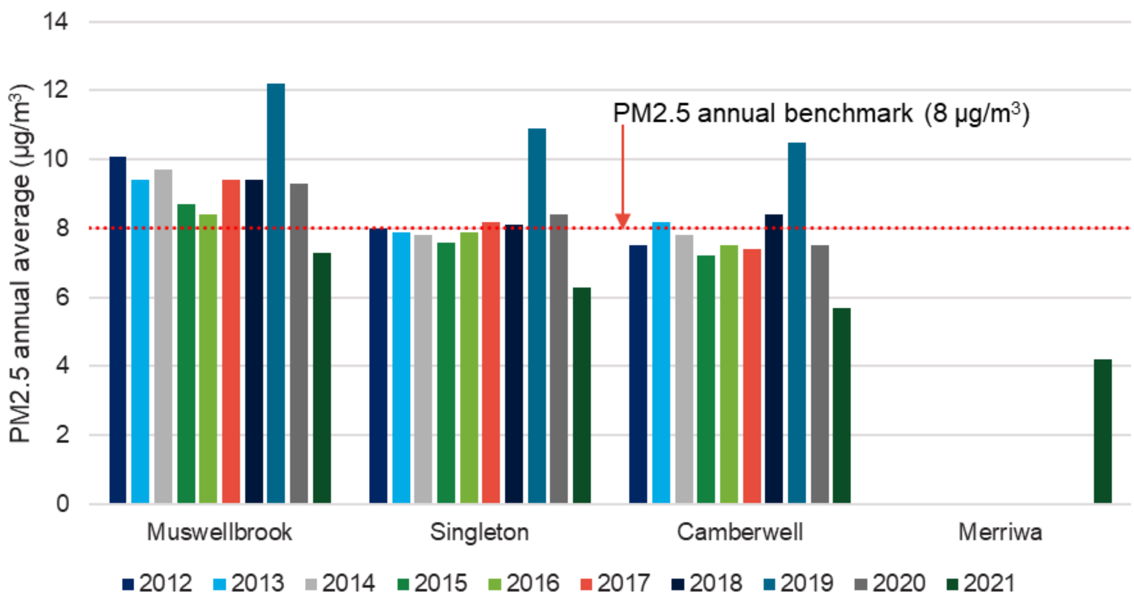


Figure 8 PM2.5 annual averages, 2012 to 2021

Note: PM2.5 monitoring at Merriwa background station commenced in July 2020, installed and maintained under the Climate Change Fund, which is outside of the industry-funded network. Results are reported for comparison.

2.3.3 Gaseous pollution levels compared to national standards

Concentrations of NO_2 and SO_2 measured at Muswellbrook and Singleton have remained below the relevant national standards, except for one event at Muswellbrook. Muswellbrook recorded an hourly SO_2 concentration of 21.0 pphm, at 8 am on 23 December 2016, just above the 1-hour standard of 20 pphm (which was effective between 2011 and May 2021, Table 6). This was the first occasion when an hourly SO_2 level over the standard was recorded across the NSW network since 2001. This event in 2016 is discussed in more detail in Section 2.4.3.

The AAQ NEPM (May 2021) introduced more stringent standards for hourly NO_2, hourly SO_2 and daily average SO_2, as noted above (Table 5). No levels above the more stringent NO_2 and SO_2 standards were observed at either Muswellbrook or Singleton stations between May and December 2021. One day over the standard (effective from May 2021) was noted at Muswellbrook in February 2021. This event was counted in annual reporting for 2021, as the updated standards were applied to all data recorded in 2021.

For readers' interest, here we summarise NO_2 and SO_2 data recorded before May 2021, compared against the more stringent standards (AAQ NEPM, May 2021):

- Analysis of pre-May 2021 NO_2 hourly data at Muswellbrook and Singleton showed no levels over the more stringent 1-hour standard of 8 pphm. The highest 1-hour NO_2 concentrations were 5.8 pphm at Muswellbrook on 17 January 2019 and 4.1 pphm at Singleton on 9 October 2013.
- Analysis of pre-May 2021 SO_2 data at Muswellbrook and Singleton showed levels over both the 1-hour and 24-hour standards at Muswellbrook (Table 7) only:
  - SO_2 levels at Muswellbrook were above the 1-hour standard of 10 pphm on 34 days, and above the 24-hour standard of 2 pphm on 6 days, between 2011 and May 2021.
  - Of the 34 days over 10 years with 1-hour SO_2 levels above the standard, 26 days occurred in the warmer months between December and April inclusively. This is likely due in part to winds being more frequently from the south-east during these

months, with the power stations therefore upwind of Muswellbrook more frequently during these months.
  - The 6 days with SO_2 24-hour averages above the standard occurred in November (twice), January (twice), and February and April (once each).
  - SO_2 levels at Singleton were below the standards between 2011 and May 2021. The highest levels were recorded on 13 June 2017, where Singleton recorded SO_2 maximum 1-hour and 24-hour averages just below the standards; with respectively, a 1-hour average of 9.9 pphm compared to the standard of 10 pphm, and a 24-hour average of 1.8 pphm compared to the standard of 2 pphm.
- The maximum gaseous concentrations recorded at Merriwa since monitoring began in July 2020 (under the Climate Change Fund) were:
  - 3.4 pphm for 1-hour SO_2 on 12 May 2021, compared to the standard of 10 pphm
  - 0.9 pphm for 24-hour SO_2 on 7 October 2020, compared to the standard of 2 pphm
  - 3.4 pphm for 1-hour NO_2 on 6 October 2020, compared to standard of 8 pphm.

Table 7 Number of exceedances for sulfur dioxide (SO_2) when current national standards (AAQ NEPM, May 2021) were applied to data for 2012 to 2021

Station/parameter	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Muswellbrook SO_2 1-hour	1	5	5	1	6	4	3	5	2	1
Muswellbrook SO_2 24-hour	0	2	0	0	1	1	1	1	0	0
Singleton SO_2 1-hour	0	0	0	0	0	0	0	0	0	0
Singleton SO_2 24-hour	0	0	0	0	0	0	0	0	0	0

2.3.4 Comparison against other regions in New South Wales

PM10 annual averages

Figure 9 shows the annual average levels of PM10 at the Upper Hunter major population centres of Muswellbrook and Singleton compared with other NSW regions as well as the background monitoring station at Merriwa.

- No station recorded PM10 levels over the annual benchmark from 2011 to 2017.
- Between 2011 and 2017, the PM10 annual averages in the Upper Hunter major population centres were comparable to stations such as Newcastle (Lower Hunter), Wagga Wagga (South West Slopes), and stations with higher PM10 annual averages across Metropolitan Sydney. For nearly all years, the maximum PM10 annual average in Sydney was recorded at Liverpool.
- In 2018 and 2019, a significant increase in annual averages was noted for all stations across New South Wales (Note: in Figure 9 (right) the regional stations are inland centres, mostly to the west of the Great Dividing Range).
  - Within the Upper Hunter, the 2018 averages increased to proportionally higher levels at Muswellbrook and Merriwa in the western part of the Upper Hunter compared to Singleton, located in the eastern half and closer to the coast.
  - In Singleton, the PM10 average in 2018 was more comparable to those seen in 2012 and 2013, which was consistent with similar observations at Beresfield and Newcastle in the Lower Hunter region. A similar observation may be seen in Figure 7, where annual averages in 2018 at the 5 stations in the western part of the Upper

Hunter (Muswellbrook, Muswellbrook NW, Merriwa, Wybong and Aberdeen) had more significant increases on 2011 to 2017 levels than the 3 Singleton stations (Singleton, Singleton NW and Singleton South). However, some of the stations in the eastern area, such as Jerrys Plains, Warkworth and Mount Thorley, also recorded similar increases in 2018 compared to 2011 to 17 levels.

The general observation is that stations further inland had greater increases in PM10 annual averages in 2018, indicating the influence of the drought and low rainfall being more acute in inland regions before the drought in 2018. Inland areas of the State are typically first to be impacted severely by drought, and greater incidents of windblown dust from lower vegetation ground cover. Therefore, greater increases in PM10 from both local dust and longer-range transport would be expected at stations in these regions.

While there were increases in PM10 annual averages at all stations in 2019, the inland stations recorded higher values than those in coastal regions such as Sydney, Illawarra, Central Coast and the Lower Hunter. Figure 9 shows all inland regional stations, except for Albury in the far south of the State, were over the PM10 annual benchmark in 2019, compared to only a few of the coastal stations.

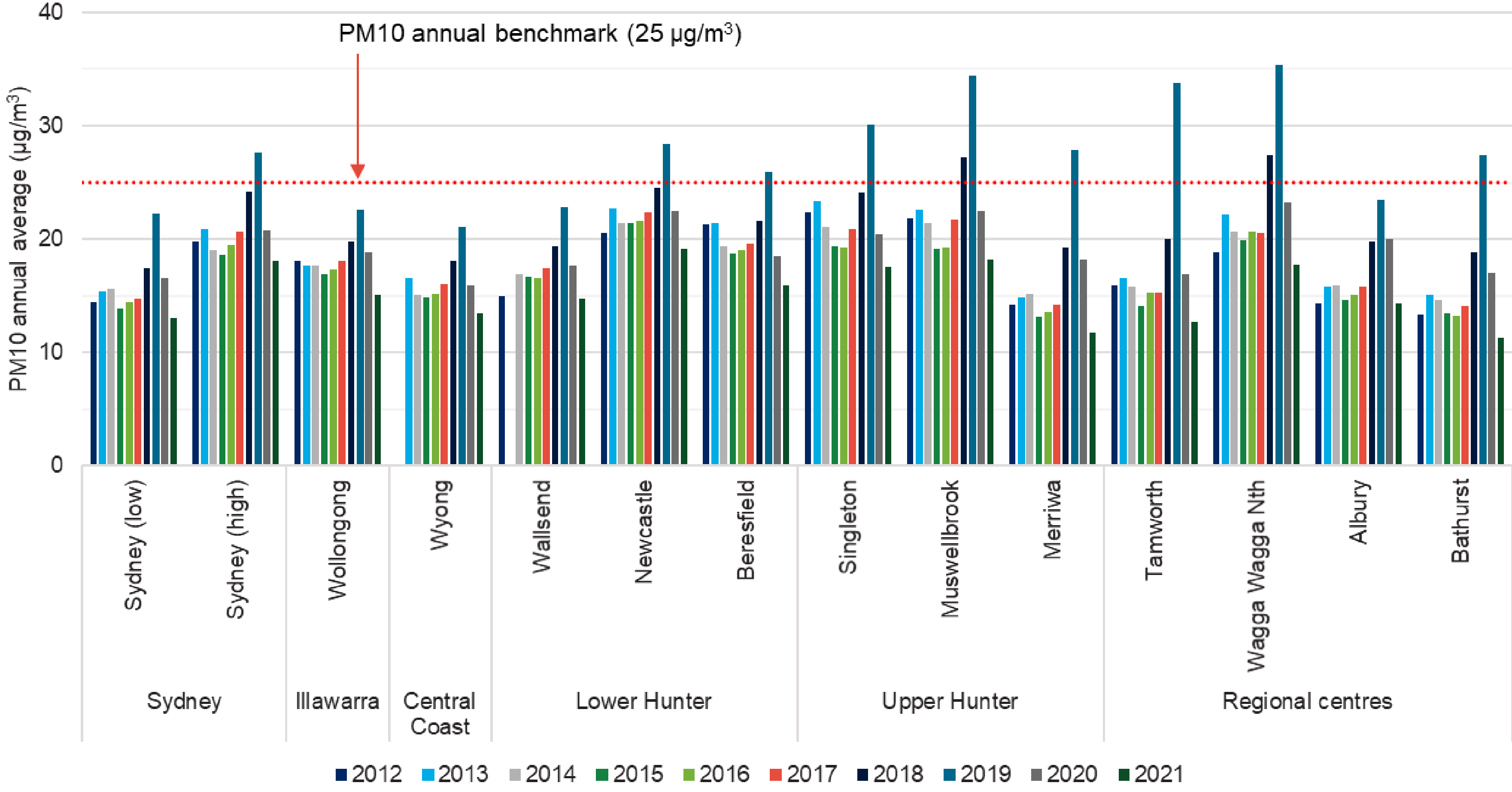


Figure 9 PM10 annual averages by station for different NSW regions, 2012 to 2021

The Sydney averages are taken from the highest and lowest annual averages recorded at stations in populated areas of Sydney during each year.

PM10 daily averages

Figure 10 shows much higher numbers of days over the PM10 daily benchmark in the period 2018 to 2020 across all stations. As with the annual averages, this increase was most significant in inland parts of New South Wales.

For example, in 2019 the highest numbers of days over the benchmark were:

- 63 days at Wagga Wagga North (South West Slopes)
- 58 days at Muswellbrook (Upper Hunter, west)
- 52 days at Tamworth (North West Slopes)
- 47 days at Merriwa (Upper Hunter, west).

In other years, the Upper Hunter larger population stations of Muswellbrook and Singleton had similar numbers of days over the PM10 benchmark compared to other regions. Wagga Wagga North most consistently recorded the highest number of days above the PM10 benchmark across the last 5 years.

- In 2019, PM2.5 annual average concentrations were over the benchmark at all NSW monitoring stations, except for Narrabri (in North West Slopes) (not shown in Figure 11) which was only slightly under the annual benchmark.

PM2.5 daily averages

Figure 12 shows that the number of days over the PM2.5 daily benchmark at Muswellbrook was similar to those at many other NSW stations, including during the 2019–20 bushfires.

Armidale and Orange are both regional centres which, like Muswellbrook, are impacted by domestic wood heating during winter months. Local elevation and topography are conducive to cooler overnight temperatures and the trapping of smoke near ground level.

No days with PM2.5 levels over the benchmark were recorded at any of the 3 PM2.5 Upper Hunter stations in 2021. Across the NSW network there was a lower impact from wood smoke during the winter months in 2021 compared to previous winters. Armidale, for example, recorded more than 20 days with PM2.5 daily averages over benchmark during winter months in 2018 to 2020 from domestic wood heating. Only 3 days over the benchmark were recorded during the 2021 winter season.

PM2.5 annual averages

Figure 11 shows all stations in different NSW regions have recorded PM2.5 annual average concentrations over the benchmark. Since 2017, PM2.5 monitoring has extended to more regional centres, including Tamworth, Armidale, Bathurst and Orange.

In the Upper Hunter, Muswellbrook has recorded a PM2.5 annual average concentration over the benchmark each year, excluding 2021.

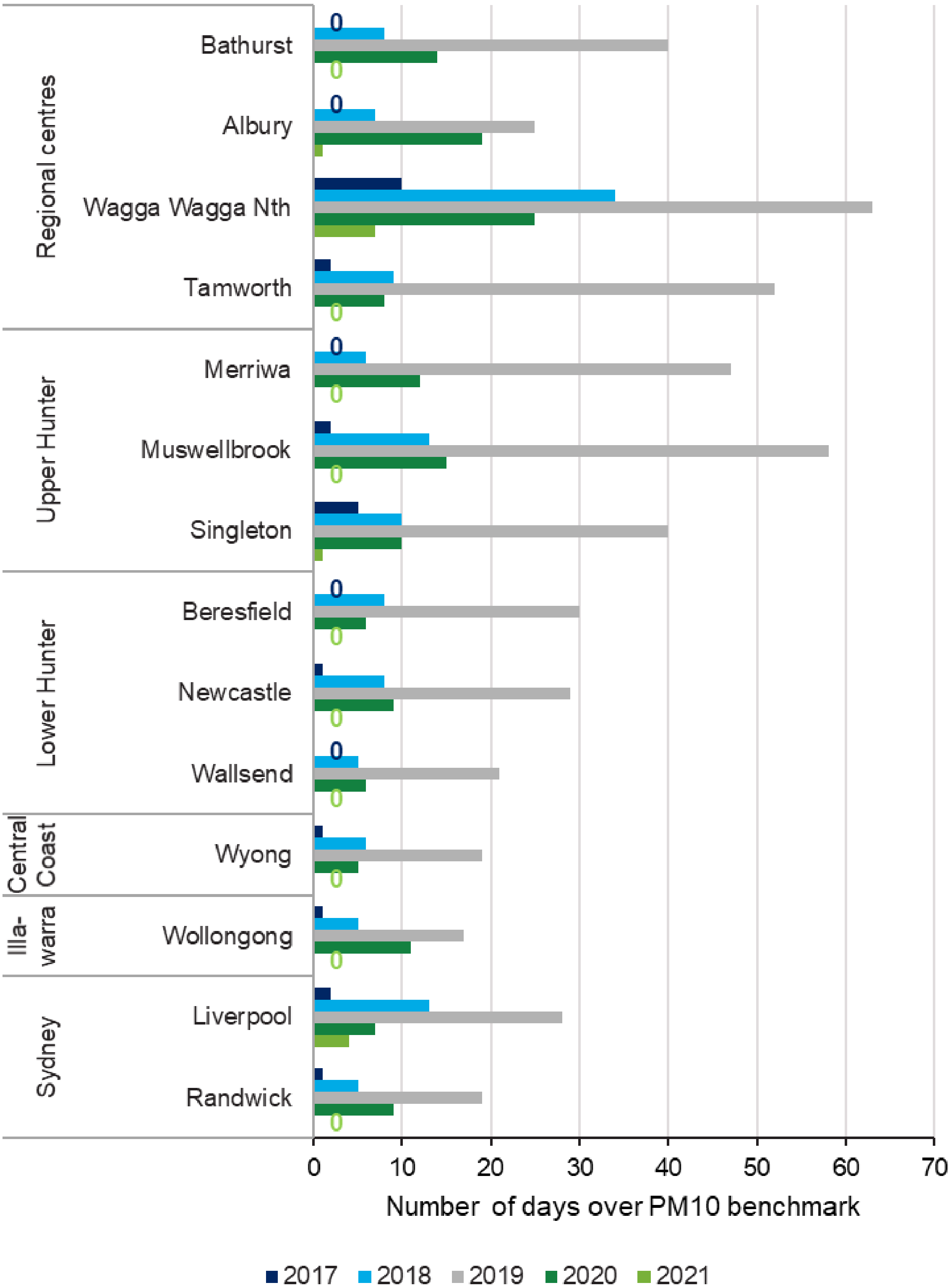


Figure 10 Number of days over the PM10 daily benchmark by station for different NSW regions, 2017 to 2021

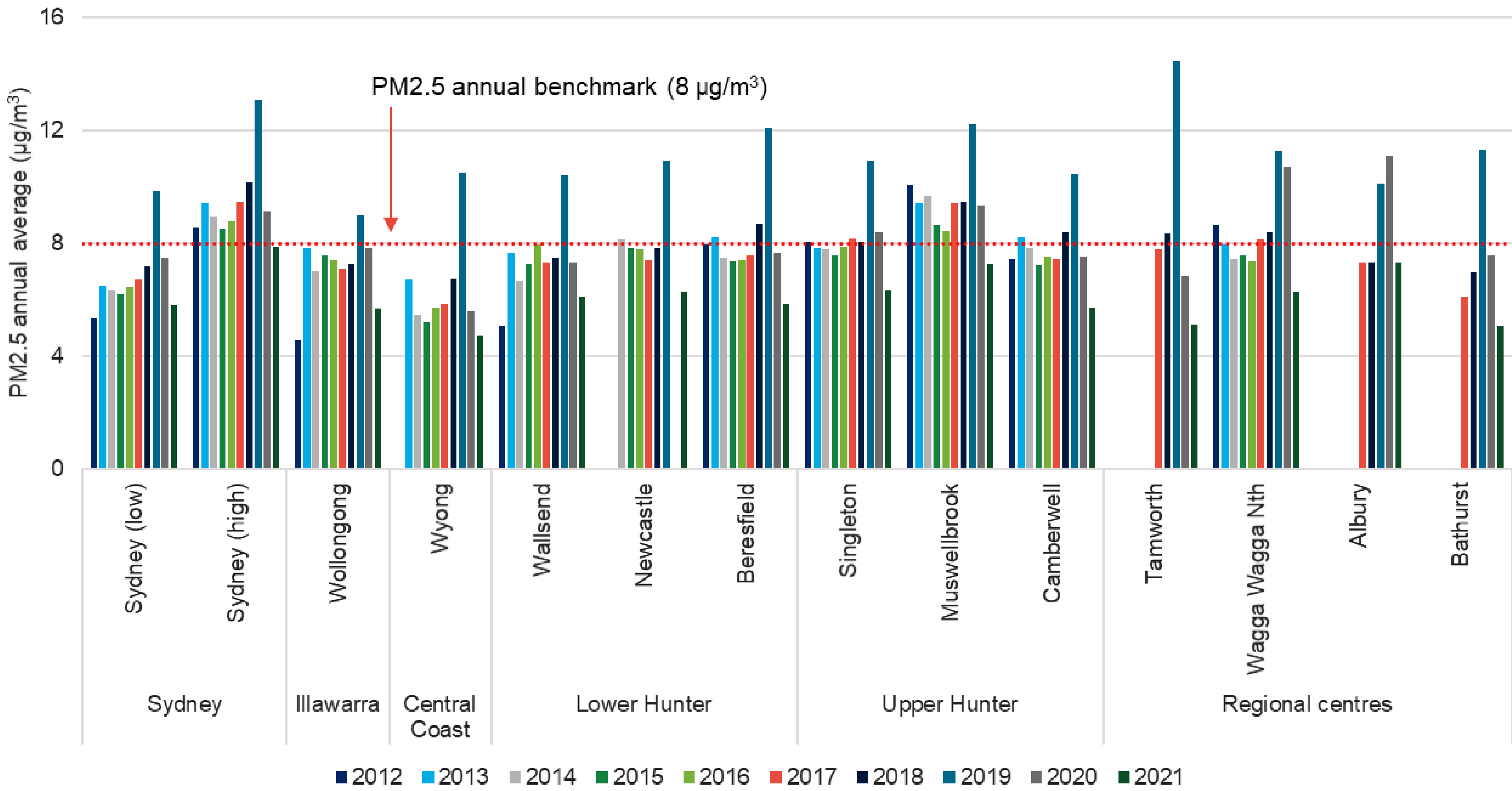


Figure 11 PM2.5 annual averages by station for different NSW regions, 2012 to 2021

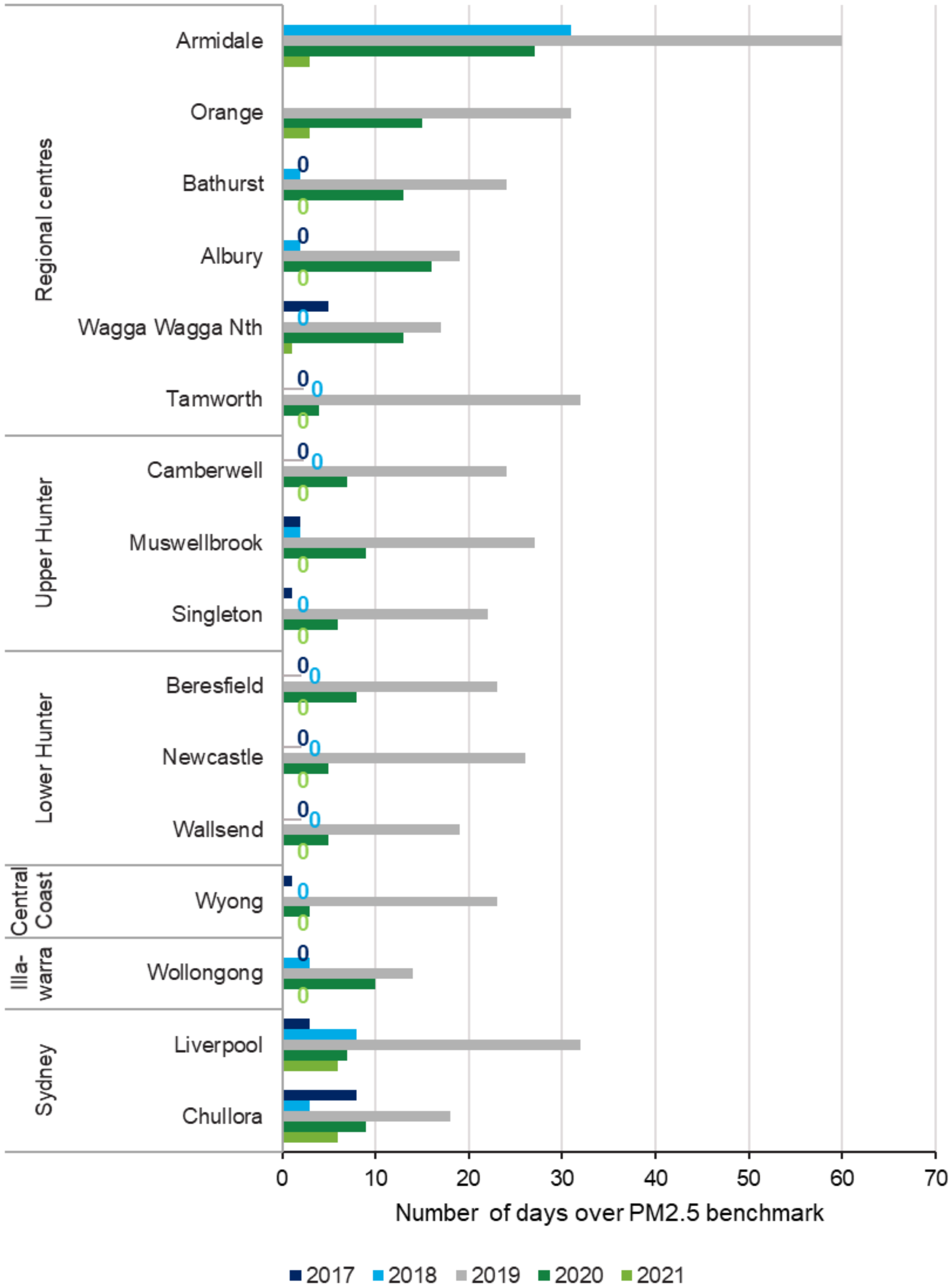


Figure 12 Number of days over the PM2.5 daily benchmark by station for different NSW regions, 2017 to 2021

Note: PM2.5 monitoring was installed at Armidale in 2018 and Orange in 2019.

SO_2 hourly and daily averages

Figure 13 and Figure 14 show the annual maximum hourly SO_2 and daily SO_2 concentrations recorded at all NSW monitoring stations, respectively.

- Maximum hourly and daily SO_2 levels at Muswellbrook are higher than other stations across the State.
- Maximum hourly SO_2 concentrations at Singleton frequently are amongst the second highest across the State, followed by stations from the Central Coast and Lower Hunter, such as Morisset and Stockton respectively. Daily averaged (24-hour) levels show that the Morisset and Stockton stations have similar levels to Singleton.
- The higher SO_2 levels in the Upper Hunter are due to their proximity to the Bayswater and Liddell coal-fired power stations. The 5 coal-fired power stations in operation in the State, and the aluminium smelter at Tomago in the Lower Hunter, are the major human sources of SO_2 emissions.
- For comparison, the Morisset monitoring station in Lake Macquarie, commissioned in late 2020, also has recorded relatively elevated concentrations of SO_2 due to its proximity to coal-fired power stations at Eraring and Vales Point.
- The higher SO_2 levels observed in Port Macquarie in 2019 and 2020 were due to an underground peat fire, specifically the Lindfield Park Road fire. Levels in 2021 are more representative of background levels expected in a smaller coastal city without major sources of SO_2.

Figure 13 and Figure 14 also show that the Upper Hunter was the only region to record levels over the benchmark compared to the new SO_2 hourly and daily national standards (AAQ NEPM, May 2021).

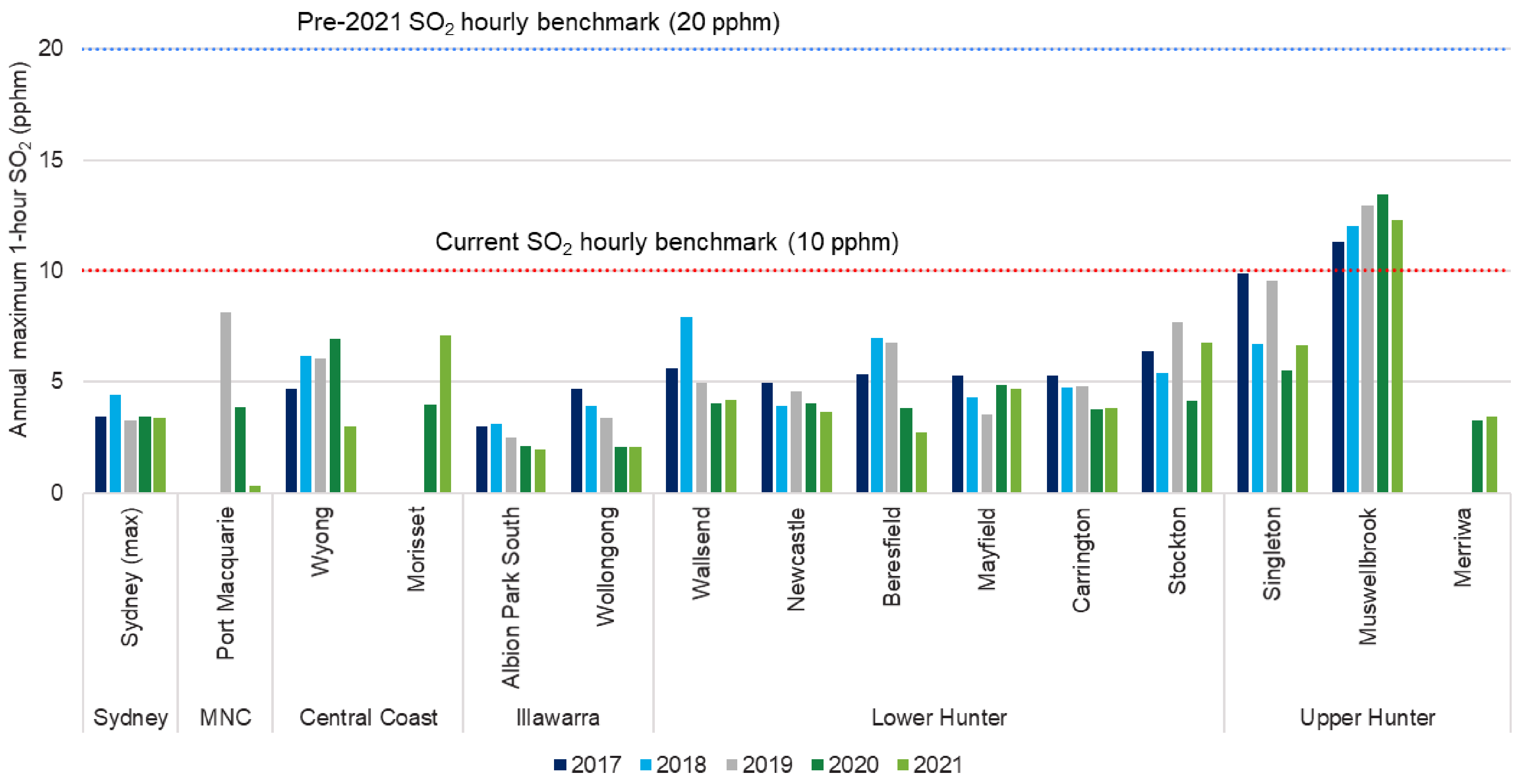


Figure 13 SO_2 annual maximum hourly average concentrations for different NSW regions, 2017 to 2021

Note: MNC = Mid North Coast. Merriwa and Morisset SO_2 monitoring began in 2020, and Port Macquarie in 2019.

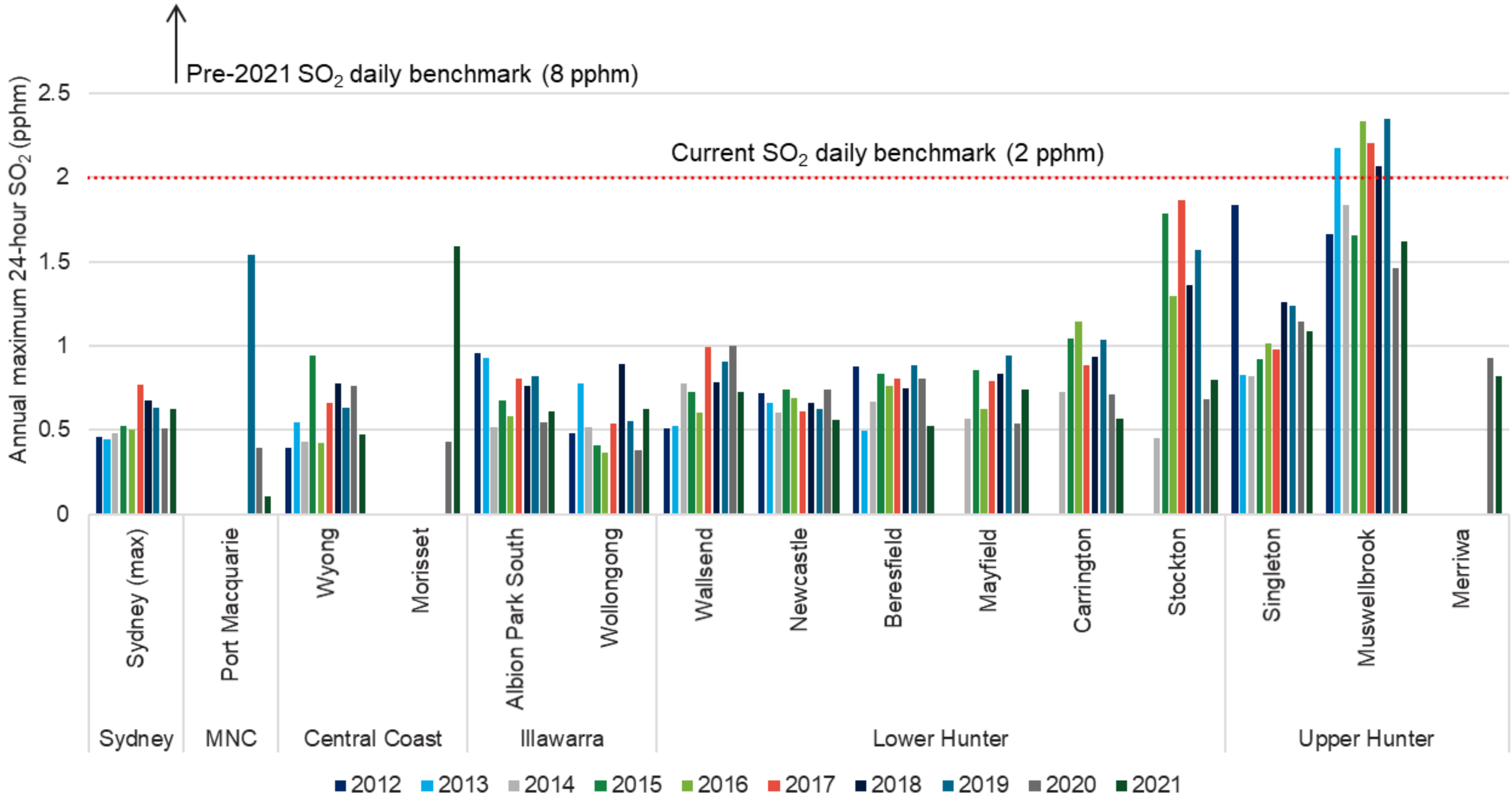


Figure 14 SO_2 annual maximum daily average concentrations for different NSW regions, 2017 to 2021

Note: MNC = Mid North Coast. Merriwa and Morisset SO_2 monitoring began in 2020, and Port Macquarie in 2019.

2.3.5 Annual variability in daily particle levels

Annual variability in daily PM10 and PM2.5 levels can vary considerably across the Upper Hunter. Figure 15 and Figure 16 show the number of days over the PM10 benchmark by month and by station. For this analysis, Figure 16 shows those stations which normally see a larger number of days over the PM10 benchmark each year. These stations are the 3 diagnostic stations (Muswellbrook NW, Singleton NW and Mount Thorley) as well as the smaller community stations of Camberwell and Maison Dieu. For the other stations in Figure 15, the bushfires and dust storms of the 2019–20 season are the major contributor to the large number of days in November, December and January.

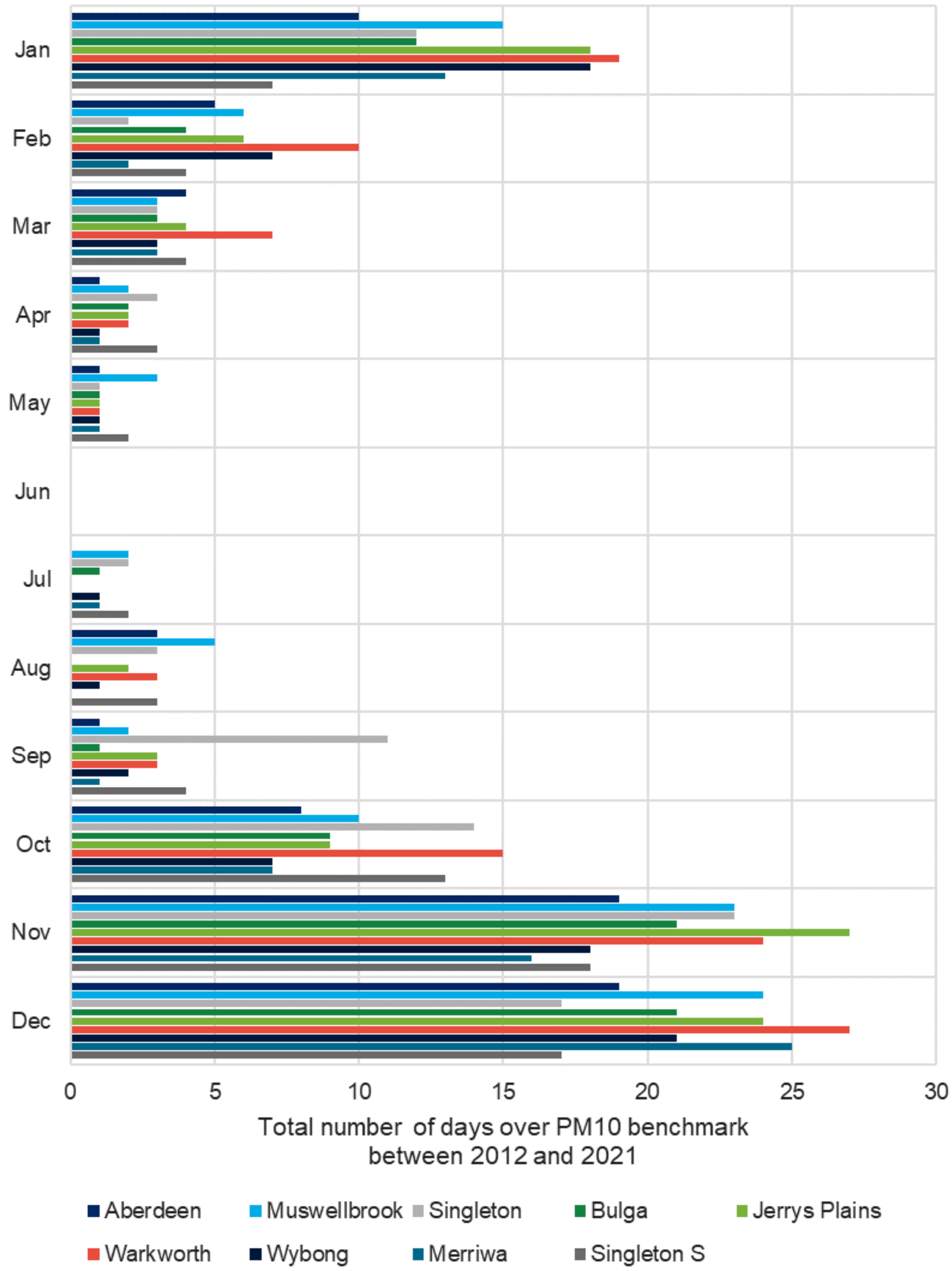


Figure 15 Total number of days per month over the PM10 daily benchmark at large population, background and 4 smaller population stations, 2012 to 2021

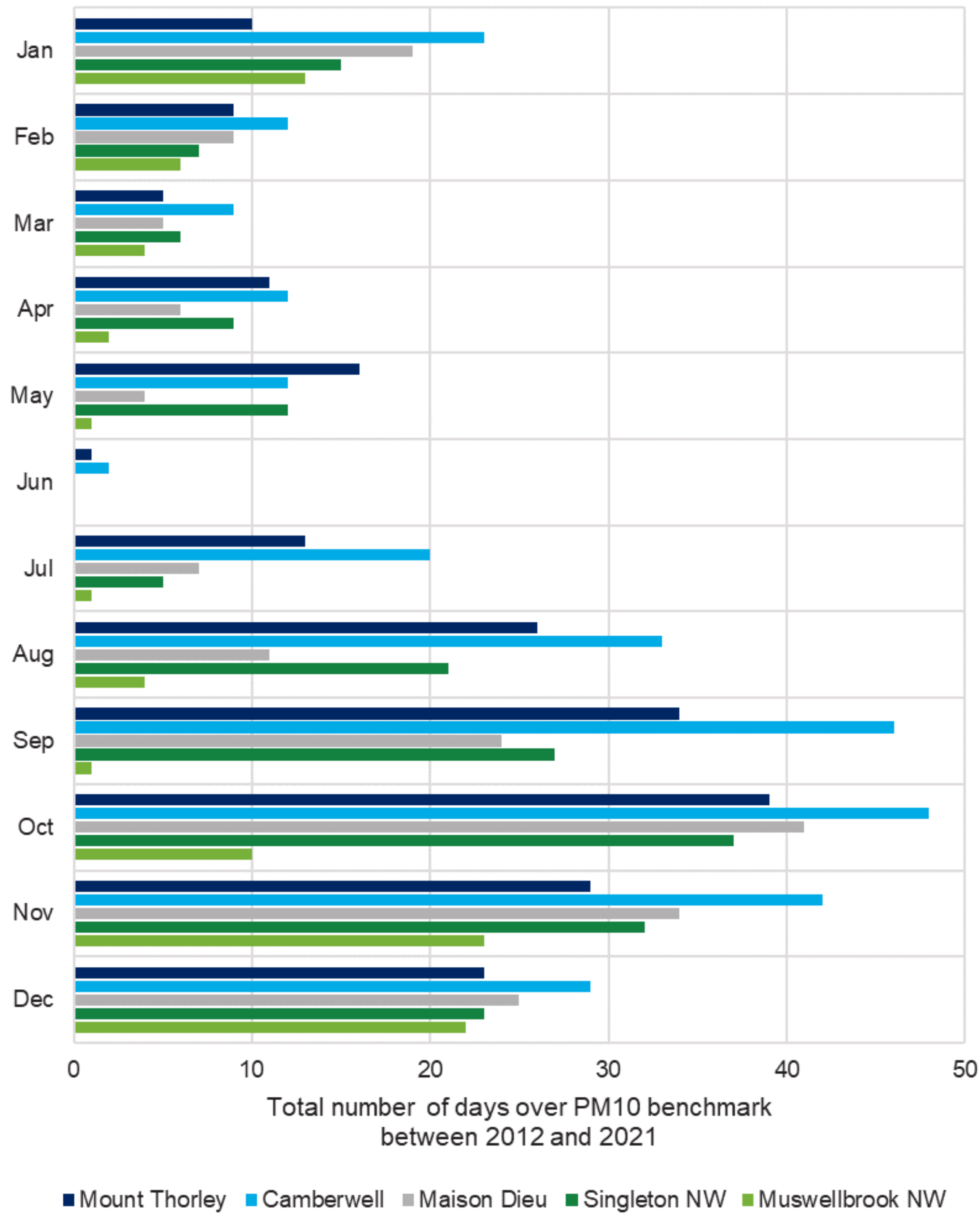


Figure 16 Total number of days per month over the PM10 daily benchmark at Camberwell, Maison Dieu and the 3 diagnostic stations, 2012 to 2021

Figure 17 and Figure 18 show the number of days over the PM10 benchmark by month, excluding a 3-month period related to the 2019–20 spring–summer bushfires. Long-term trends across seasons may be identified by excluding the extraordinary events of those months that dominated the long-term statistics.

Comparison of Figure 17 and Figure 18 shows that those stations located further from mine operations (which are those in Figure 17) experienced days over the PM10 benchmark much more frequently during the warmer months of October to February. For these stations, fewer days over the benchmark occurred in cooler months between April to August compared to the stations shown in Figure 18.

For the 5 stations shown in Figure 18 (i.e. the 3 diagnostic stations, as well as Camberwell and Maison Dieu) a higher number of days over the PM10 benchmark were observed compared to the other 9 stations. Most of these days occurred in July to November, although a greater number of days over the benchmark also were observed in December to April compared to the 9 stations shown in Figure 17.

One of the main contributors to days over the PM10 benchmark was raised dust from any available source, including industrial and agricultural activity, exposed surfaces, or from long-range transport. Major influences on raised dust included the strength and frequency of prevailing winds and the loss of vegetation ground cover, which determine how much free soil may be available to become windblown. Section 2.3.6 shows that the average wind speeds across the Upper Hunter in spring and summer were higher than those observed during winter. Additionally, the seasonal wind roses showed a stronger north-westerly wind component in winter and spring, as well as much lower rainfall in these seasons. It is likely that the combined effects of higher levels of windblown dust caused by reduced rainfall (which decreases ground cover resulting in more loose soil available on the ground to become windswept), as well as higher winds and higher temperatures in spring, led to more days over the benchmark in the winter–spring period.

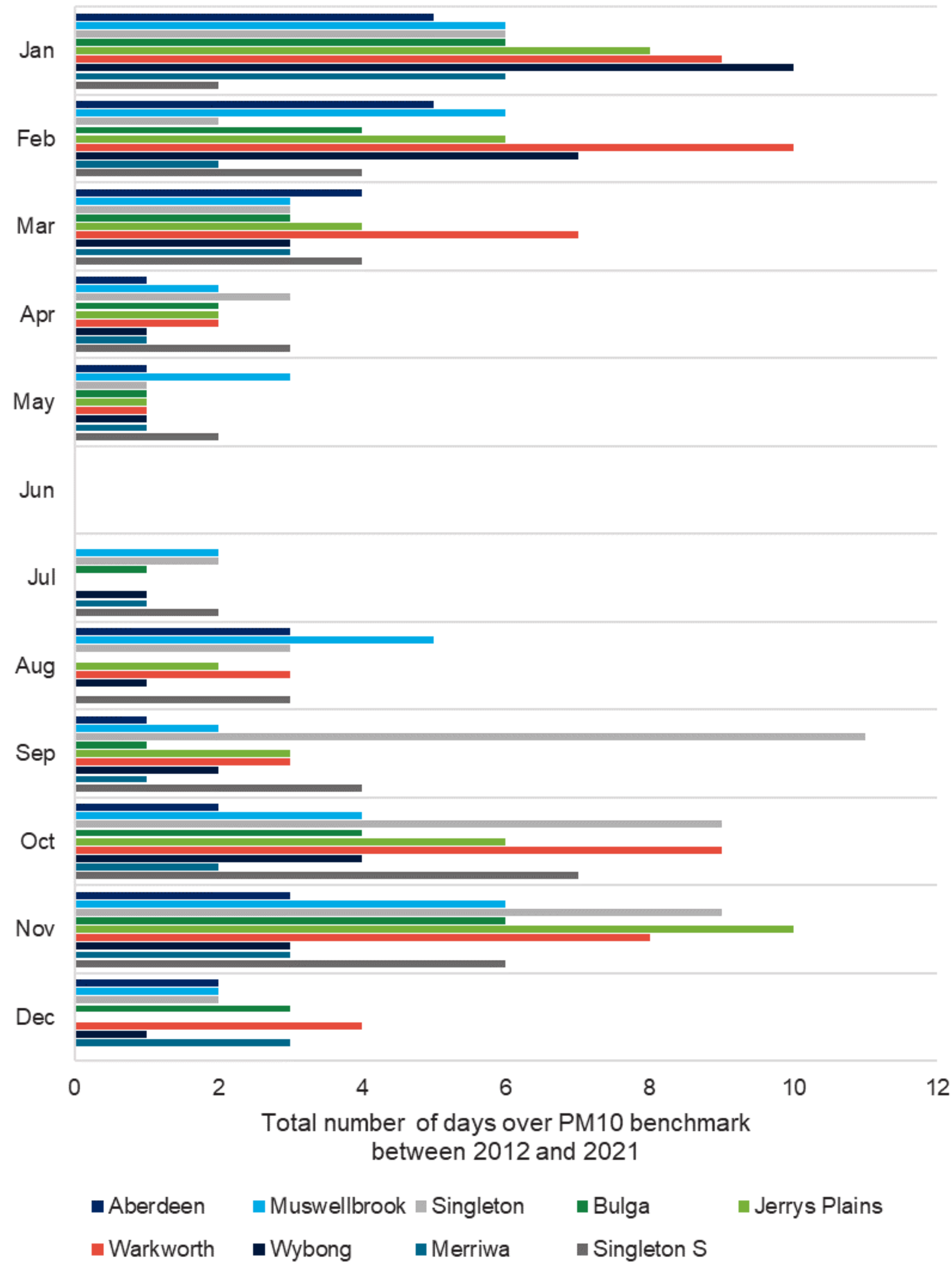


Figure 17 Total number of days per month over the PM10 benchmark at large population, background and 4 smaller population stations, 2012 to 2021

Note: Data excluding days during the 2019–20 bushfire season, 25 October 2019 to 15 January 2020, so that long-term trends across seasons may be identified.

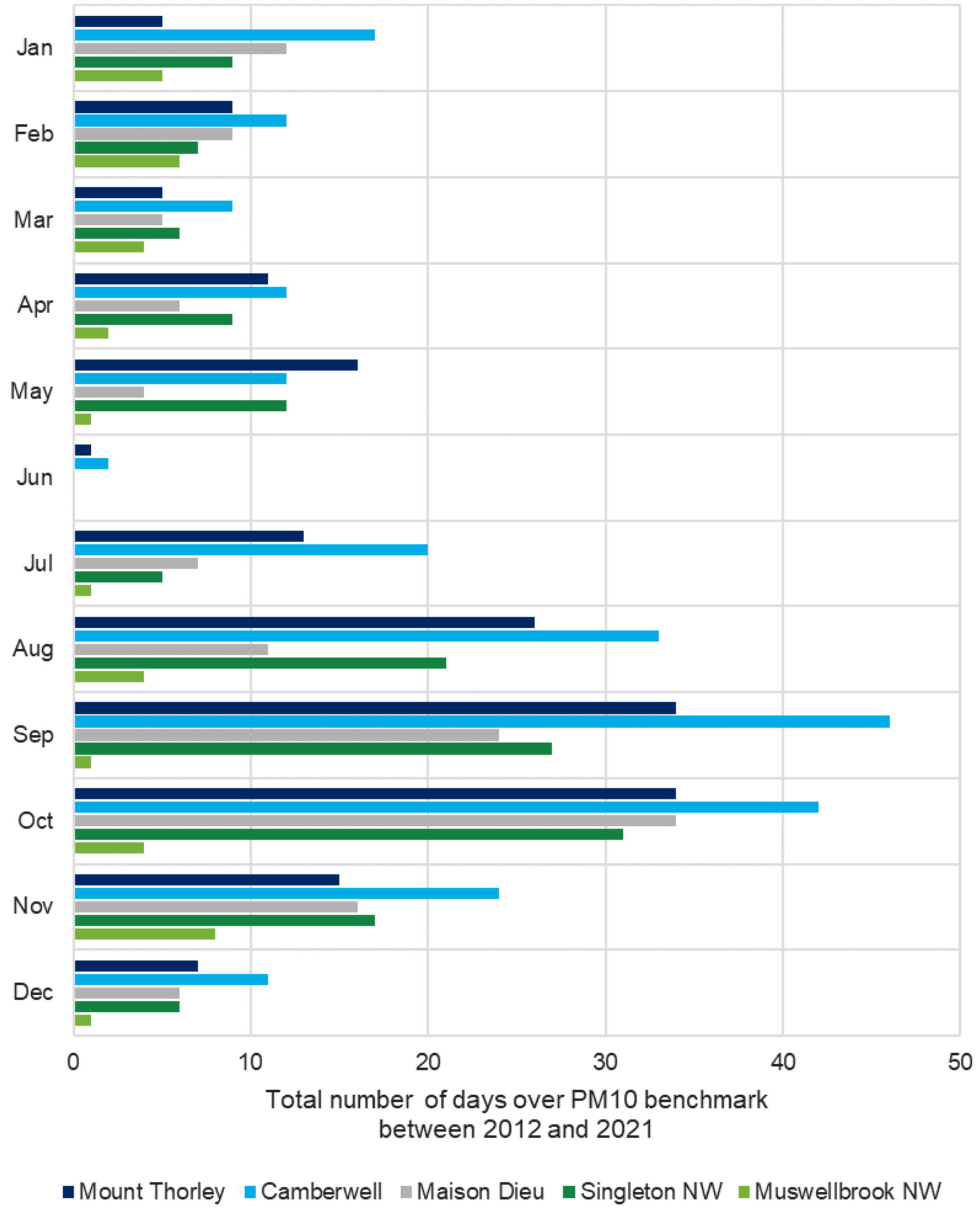


Figure 18 Total number of days per month over the PM10 benchmark at Camberwell, Maison Dieu and the 3 diagnostic stations, 2012 to 2021

Note: Data excludes the significant impact of drought and smoke in spring–summer 2019–20, 25 October 2019 to 15 January 2020, so that trends across seasons may be established.

Figure 19 shows the impact on PM2.5 daily exceedances from bushfire smoke associated with the extreme weather conditions during the 2019–20 spring–summer bushfire season.

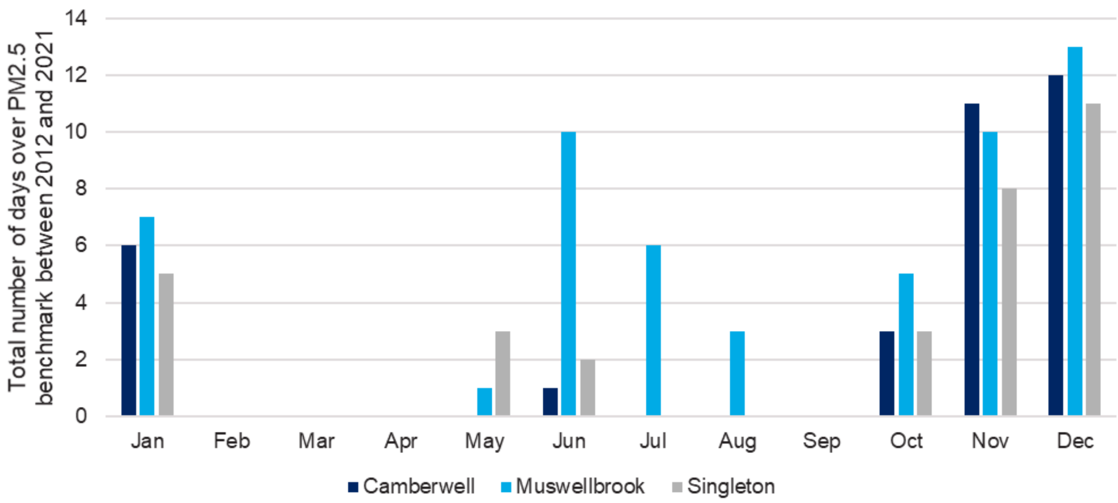


Figure 19 Total number of days per month over the PM2.5 daily benchmark at Camberwell, Muswellbrook and Singleton, 2012 to 2021

Given the significant impact across the State from drought and bushfire smoke in spring–summer 2019–20, Figure 20 excludes data from that period, to establish trends across other seasons. Days over the PM2.5 benchmark were less frequent in this analysis, as shown in Figure 20. The days that were over the benchmark may be caused by occasional planned burns in winter, but most of the days at Muswellbrook were due to the impact of smoke from domestic wood-fired heaters. The exceedances noted in October and November were related to the bushfires in 2013.

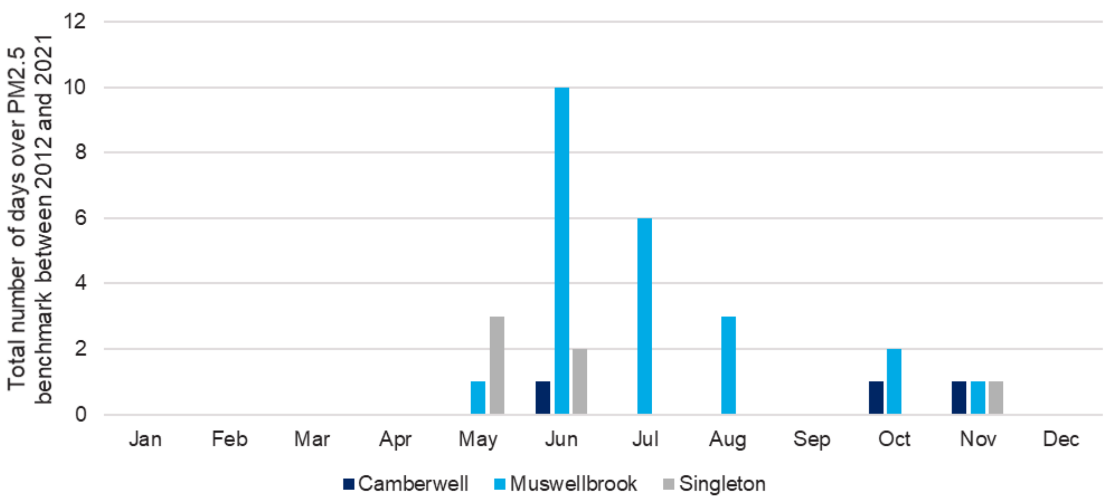


Figure 20 Monthly PM2.5 exceedances at Camberwell, Muswellbrook and Singleton, 2012 to 2021

Note: Data excludes the significant impact of drought and smoke in spring–summer 2019–20, 25 October 2019 to 15 January 2020, so that trends across seasons may be established.

2.3.6 Analysis of meteorology and climate

Meteorological and climatic conditions play an important part in determining the level and distribution of particle pollution in the region.

Wind

The wind rose map of average wind speed and direction for 2011 to 2021 shows that winds flow predominantly north-westerly and south-easterly (Figure 21). Some variability is seen at individual sites due to localised influences, mainly due to topographic effects.

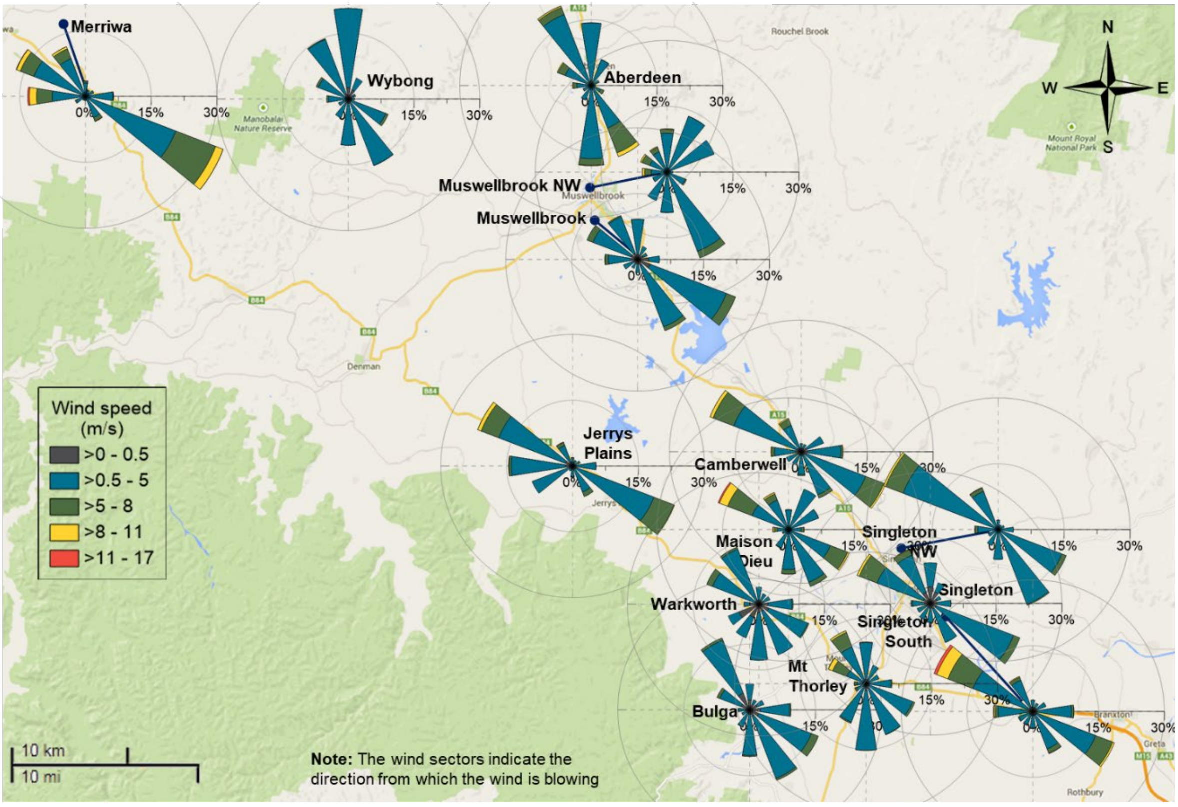


Figure 21 Upper Hunter wind rose map, 2011 to 2021

Wind roses show wind direction and speed at a location. The length of each bar around the circle shows the percentage of time that the wind blows from each direction. The colours along the bars indicate the wind speed (in metres per second, m/s) categories.

All available data from 2011 to 2021 from the 14 monitoring stations were analysed to show the seasonal change in wind patterns (Figure 22). The wind patterns and analysis are largely unchanged from the 2012 to 2016 Upper Hunter review.

In general, winds are predominantly from the south-east in summer and north-west in winter. During the autumn, winds turn from predominantly south-easterly to north-westerly. In spring, winds turn from predominantly north-westerly to south-easterly. Higher wind speeds generally occur from the north-west in winter and spring.

In Muswellbrook and Singleton, higher wind speeds occur in the afternoon and early evening in summer at both stations and also in spring at Singleton (Figure 23). Wind speeds during the day are lowest in autumn and winter at Muswellbrook and autumn at Singleton. Overnight wind speeds generally are light, particularly in the cooler months and at Muswellbrook.

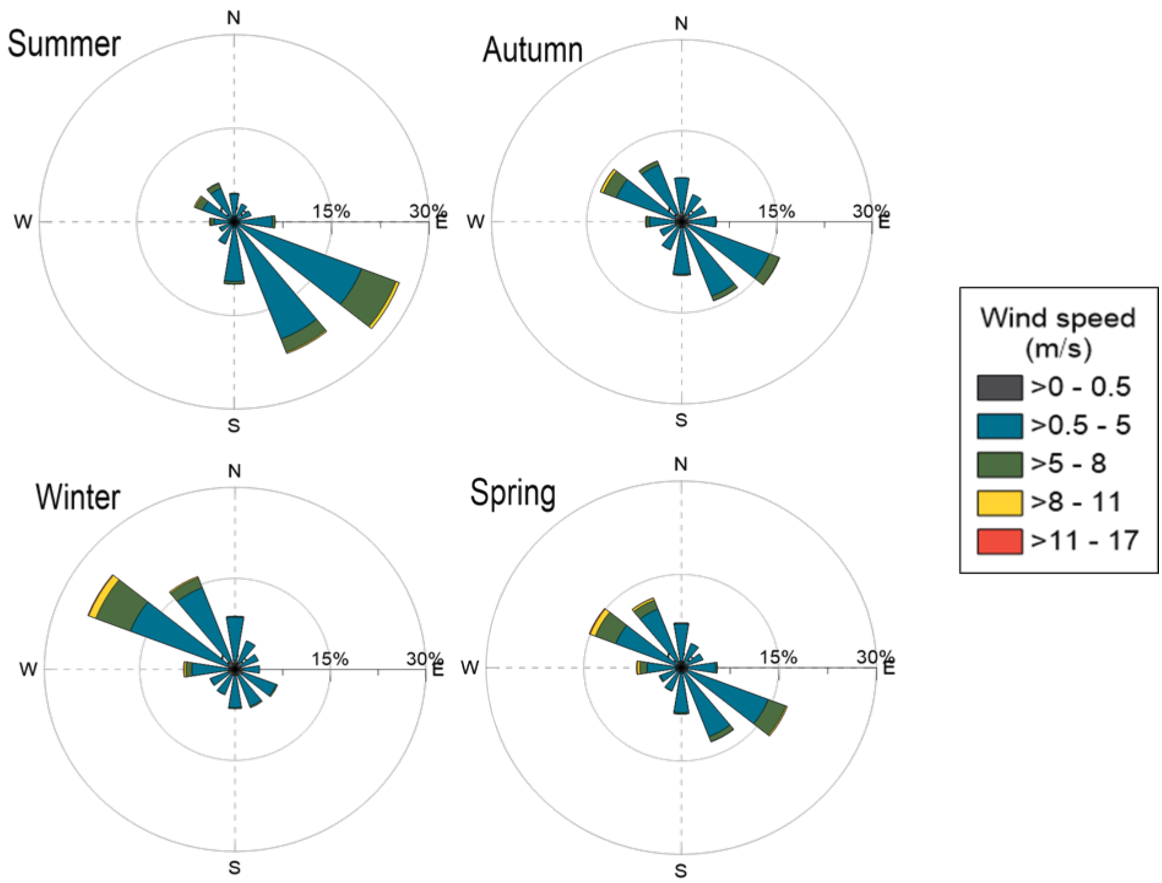
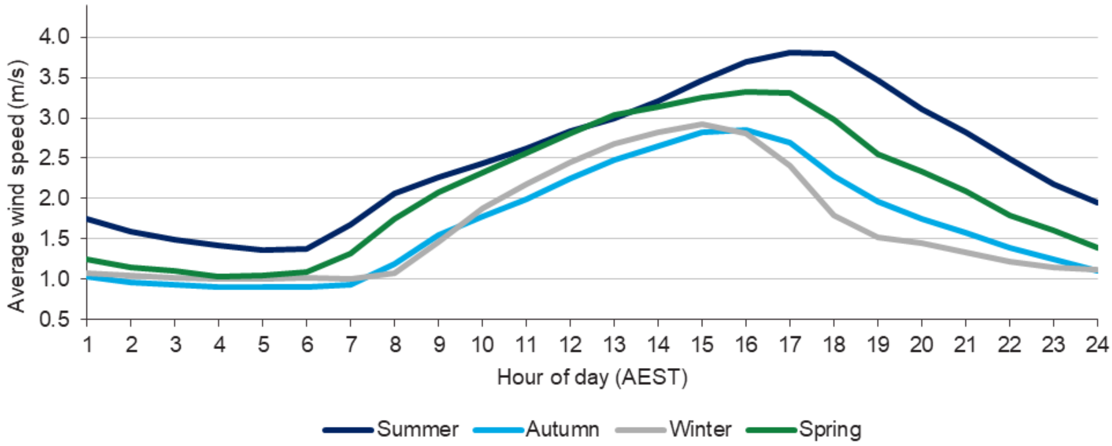


Figure 22 Seasonal wind roses using pooled wind data from all the Upper Hunter stations, 2011 to 2021



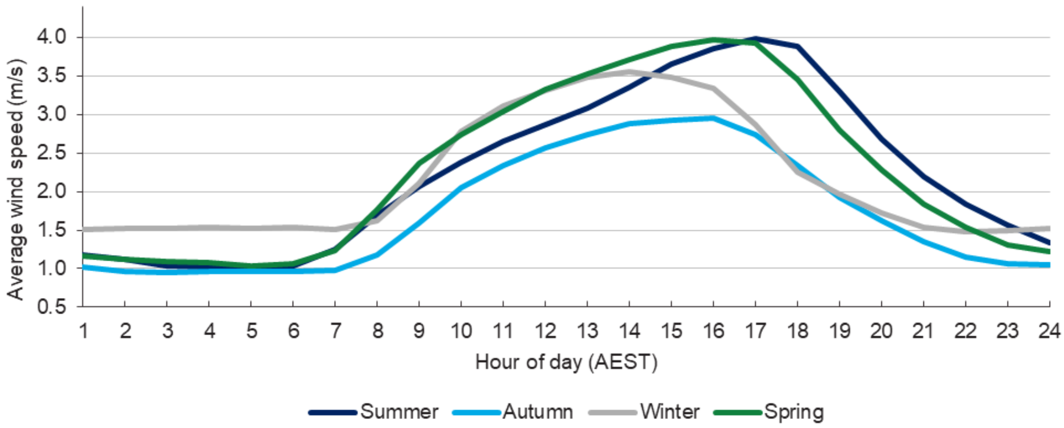


Figure 23 Muswellbrook (top) and Singleton (bottom) pooled hourly average wind speed plots, 2011 to 2021

Note: The hour of the day is shown in Australian Eastern Standard Time (AEST), and represents the averages measured in the hour up to that value. For example, ‘Hour of day 17’ refers to the average from 4 pm to 5 pm in AEST.

Temperature

Temperatures vary considerably throughout the year in the region, as shown by the monthly minimum and maximum temperatures from 2011 to 2021 for Muswellbrook (Figure 24) and Singleton (Figure 25). Temperatures peak in November to February, with hot to very hot temperatures experienced. The lowest temperatures are experienced from May to August with sub-zero temperatures recorded.

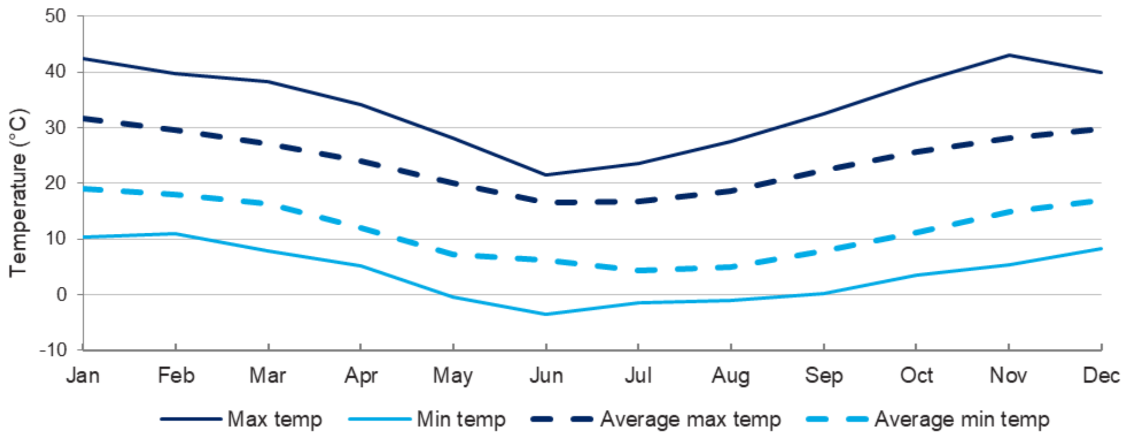


Figure 24 Muswellbrook monthly maximum and minimum temperatures, 2011 to 2021

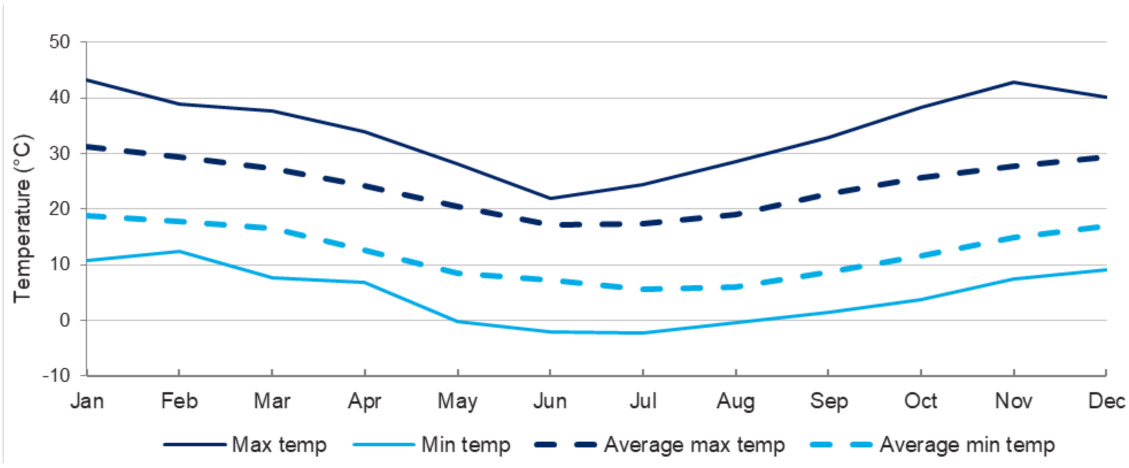


Figure 25 Singleton monthly maximum and minimum temperatures, 2011 to 2021

Precipitation

A review of monthly rainfall levels in the region shows variability across seasons and years (Figure 26). Higher rainfall tends to occur in summer and early autumn (November to April). In contrast, there is low rainfall consistently between mid to late winter and early to mid spring.

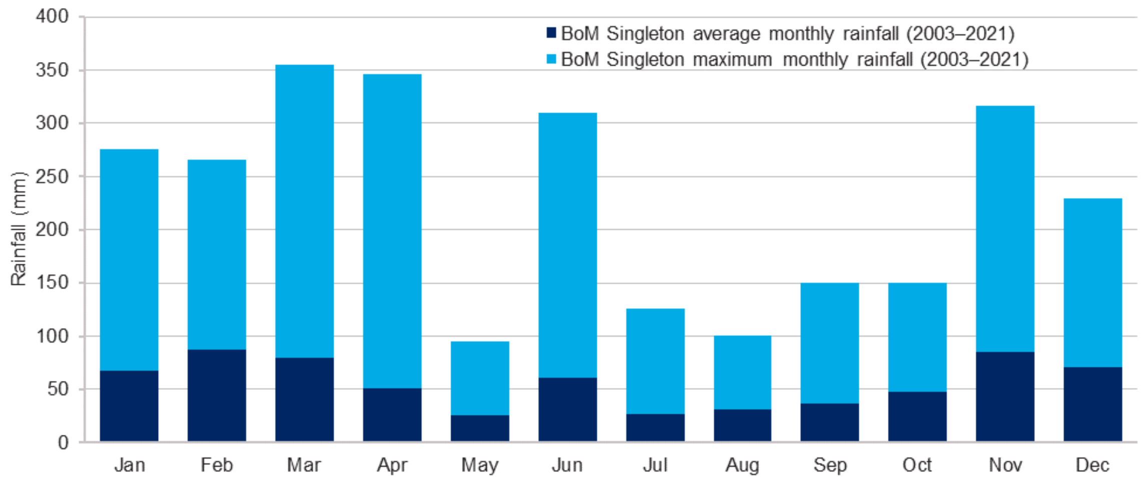


Figure 26 Singleton maximum and average monthly rainfall, 2003 to 2021

Source: Bureau of Meteorology climate data webpage (accessed January 2022).

Annual rainfall measurements at 7 Upper Hunter stations for 2018 to 2021 are shown in Figure 27. Across these 4 years, levels were broadly consistent between stations. There was significant variation across the 4 years of measurements, with much higher levels observed over the years 2020 and 2021 compared to lower levels during the drought in 2018 and 2019. This was consistent with data from the Bureau of Meteorology's Singleton Defence and Singleton Sewage Treatment Plant (STP) automatic weather stations, which saw its highest (1,026 mm) and second highest (946 mm) annual rainfall in 2021 and 2020 respectively, following its lowest year on record (344 mm) in 2019.

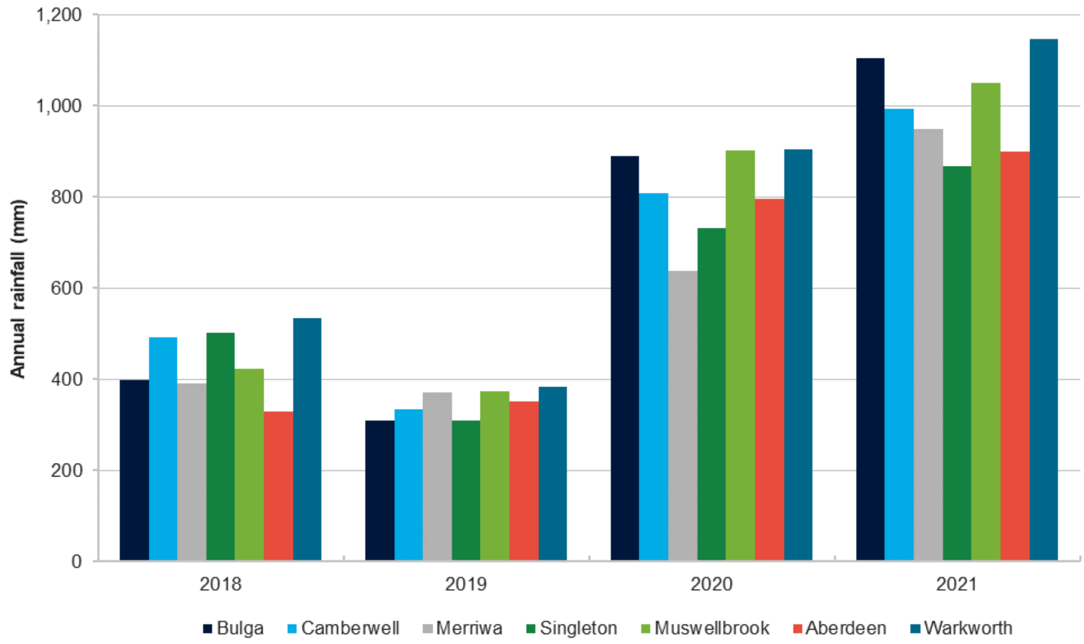


Figure 27 Annual rainfall measured at Upper Hunter stations, 2018 and 2021

Note: Merriwa was offline between February and May 2020. Singleton was offline between December 2020 and February 2021.

Climate variability

Over the past 5 years, the Upper Hunter region was exposed to 2 distinct climatic trends. The first trend was between 2017 and early 2020, with a continual decrease in rainfall and increase in temperatures. This included the severe drought and bushfire period in the spring–summer season 2019–20.

The second trend was a wetter and relatively cooler 2-year period from February 2020. Although cooler compared to 2017 to 2019, temperatures remained higher than average against long-term trends, due to the impacts of climate change. Australia's climate has warmed on average by 1.47 ± 0.24°C between 1910 (when national records began) and 2020. Most of this warming has occurred since 1950 (BOM 2022). An annual climate summary is given below:

- In 2017, rainfall in the Upper Hunter was well below levels observed between 2014 and 2016. Temperatures were well above average. Across the State, 2017 was the warmest on record and the driest since 2006 (BOM 2018b). A short La Niña, declared in December, had little effect on summer rainfall (BOM 2018a).
- In 2018, the short La Niña ended in March. Abnormally warm temperatures and dry conditions rapidly emerged to levels unprecedented for April. Soils rapidly dried out as temperatures stayed above average and rainfall was below average (BOM 2018a). The Upper Hunter region moved into drought conditions. During September to early December, a positive Indian Ocean Dipole most likely contributed to the dry conditions in south-eastern Australia (BOM 2019a). Across the State, 2018 was the warmest year on record and the third driest January to September (BOM 2019a). A positive phase of the Southern Annual Mode from late October to late December brought some rainfall relief to eastern Australia (BOM 2019a).
- 2019 was the warmest and driest on record for the State (BOM 2020b). In January and February, drought conditions extended across 99% of the State (DPI 2019b). By the end of the year the entire State was in drought, with intense drought in the Upper Hunter,

Central West and north-east and south-east regions (DPI 2019a). In December, root-zone soils moisture was the lowest on record in the Upper Hunter (BOM 2020a). These conditions were driven by the combined effects of dry phases in large-scale climate cycles (BOM 2020c), known as the positive phase in the Indian Ocean Dipole (BOM n.d. - a), the negative phase in the Southern Annular Mode (BOM n.d. - c) and a sudden stratospheric warming (BOM 2019b,c). The extreme weather and prolonged, intense drought combined to bring dangerous bushfire conditions in south-eastern Australia and increased dust storm activity across the State.

- In 2020, rainfall returned and was above average across large areas of the State in January to April, spring and December (BOM 2021a). As the positive phase of the Indian Ocean Dipole weakened to neutral, the most significant natural climate driver was La Niña, declared in September (BOM 2021b). Proportionally cooler and wetter conditions were observed across Australia, compared to previous years. In the Upper Hunter (BOM n.d. – b, d), maximum temperatures generally were below average in autumn and summer 2020–21 and average to above average in winter and spring. Minimum temperatures ranged from average in autumn, to above average in winter, to very much above average in spring. Rainfall in the Upper Hunter was average to very much above average. Most of the State returned to non-drought conditions by the end of 2020 (DPI 2020).
- In 2021, the cooling impacts of a negative Indian Ocean Dipole in winter and spring and La Niña events in successive summers brought the coolest year since 2012 and above average rainfall (BOM 2022). However, 2021 was warmer than historical La Niña years (BOM 2022). In the Upper Hunter, winter 2021 was wetter and warmer than previous years (BOM n.d. – b, d) and the first winter in 10 years with all PM10 and PM2.5 daily averages below national benchmarks. November 2021 brought some of the highest rainfall on record to parts of the region (BOM n.d. – b, d).

2.3.7 Trends in Upper Hunter air quality – particles, meteorology and climate

Analysis of the Upper Hunter network data identifies several factors influencing particle levels in the Upper Hunter.

The first, also identified in the 2017 review, is that higher levels of PM10 occur more frequently during spring. This is associated with increased wind speeds observed during the afternoons.

Like most of eastern Australia, rainfall totals in winter typically are lower than observed in summer. This can lead to drier soil conditions which can enhance the formation of windblown dust, both for dust generated within the Upper Hunter region and transported into the region. This observation is largely confined to PM10, with levels of PM2.5 typically remaining below daily benchmarks. However, years with increased PM10 also resulted in increased annual average concentrations of PM2.5.

Over the longer period, the impacts of drought on windblown dust and PM10 levels were more apparent in the 5-year period 2017 to 2021.

The impact of more local sources of windblown dust in the Upper Hunter can be seen in 2018, with those stations closer to more exposed soil impacted to a greater extent during the drought.

Bushfire smoke can occur in warmer months, as observed most acutely in spring–summer 2019–20, but also in late 2013. These smoke events can be both localised to nearby fires but also widespread. PM2.5 particle levels in the Upper Hunter region are typical of those observed in surrounding regions over the last 10 years.

Elevated PM2.5 levels occur more often in winter, especially at Muswellbrook and to a lesser extent at Singleton. Very cold temperatures are experienced in the region during winter (reaching sub-zero temperatures) and winds are calm overnight. These cold, calm conditions are conducive to trapping wood smoke near ground level, leading to elevated PM2.5 levels.

The impact from wood smoke at Muswellbrook is similar to that observed at the monitoring station in Orange (commissioned in 2019), but typically lower than that observed at Armidale (commissioned in 2018).

2.4 Objective 3 – facilitating the identification of sources of air pollution

The discussion on objective 3 describes how analysis of network monitoring data has assisted in identifying the sources of air pollutants.

Key points

- The frequency of PM10 concentrations above the daily benchmark during winter–spring in the initial years of the network led to the EPA's *Dust Stop* program. This required mines to reduce PM10 emissions from the major sources of dust associated with mining practices. The EPA estimated that, by November 2017, improved mining practices reduced PM10 emissions by 22,000 tonnes per year, which was approximately 19% of total mine emissions, mostly from the Upper Hunter.
- The increasing frequency of PM10 levels above the daily benchmark in the Upper Hunter as well as across the State from summer 2017–18 led to computer modelling by the NSW Government that demonstrated the potential for PM10 particles to be transported into the Upper Hunter as windblown dust and bushfire smoke from sources outside of the region. Windblown dust and bushfire smoke were the major sources of particles on days with PM10 levels above national standards in 2018–19.
- The exceedance of the hourly average concentration of SO_2 at Muswellbrook at 8 am on 23 December 2016 led to an investigation by the EPA and a broader review of NSW power stations' environment protection licence conditions.

2.4.1 Identifying sources of PM10 particles

Upper Hunter PM10 particle levels can be affected by local sources as well as extreme events, such as dust storms, bushfires and hazard reduction burns.

Local sources of PM10 particles

In the initial years of the network's operation, concentrations of PM10 particles above national benchmarks were recorded across the Upper Hunter, especially in the warmer months of spring–summer. These events led the EPA to extend its investigations of dust generated by a range of activities in open-cut coal mines (EPA 2020b). The EPA's *Dust Stop* program ran from 2011 to 2017, targeting the main sources of dust associated with mining practices across the State. The EPA's *Operation Bust the Dust* program in 2019–20 was operated to identify specific mining operations that were the source of major dust emissions. Section 2.5.1 provides an update on the EPA's dust mitigation programs.

Sources of PM10 particles outside the region

The increasing frequency of days with high PM10 concentrations during 2018 to early 2020 led the NSW Government to identify that particle sources from outside of the region contributed to exceedances of PM10 national benchmarks across the Upper Hunter network.

For example, the most extensive high PM10 particle event during summer 2017–18 occurred on 15 February 2018, with 37 air quality monitoring stations across the State recording PM10 levels over the benchmark. A detailed data analysis showed how Upper Hunter PM10 concentrations were affected by windblown dust particles and bushfire smoke on this day.

The findings of the analysis can be summarised as follows:

- From late January to 15 February 2018, a large fire in the Wollemi National Park (RFS n.d.) burnt over 8,000 hectares. These conditions increased the likelihood of extensive particle pollution events.
- The monitoring data from the network facilitated a back-trajectory modelling analysis, using HYSPLIT in NSW (DPIE 2020b), to determine the source of the elevated particles on 15 February 2018. The modelling demonstrated that air parcels in the west and south-west of the State travelled over the Wollemi National Park to arrive in the Upper Hunter (generally from the south) on 15 February 2018.
- The analysis concluded that long-range transport of dust and smoke particles into the region, during the passage of a frontal system through New South Wales, combined with local particle sources in the Upper Hunter. This led to elevated PM10 pollution across the network on 15 February 2018.

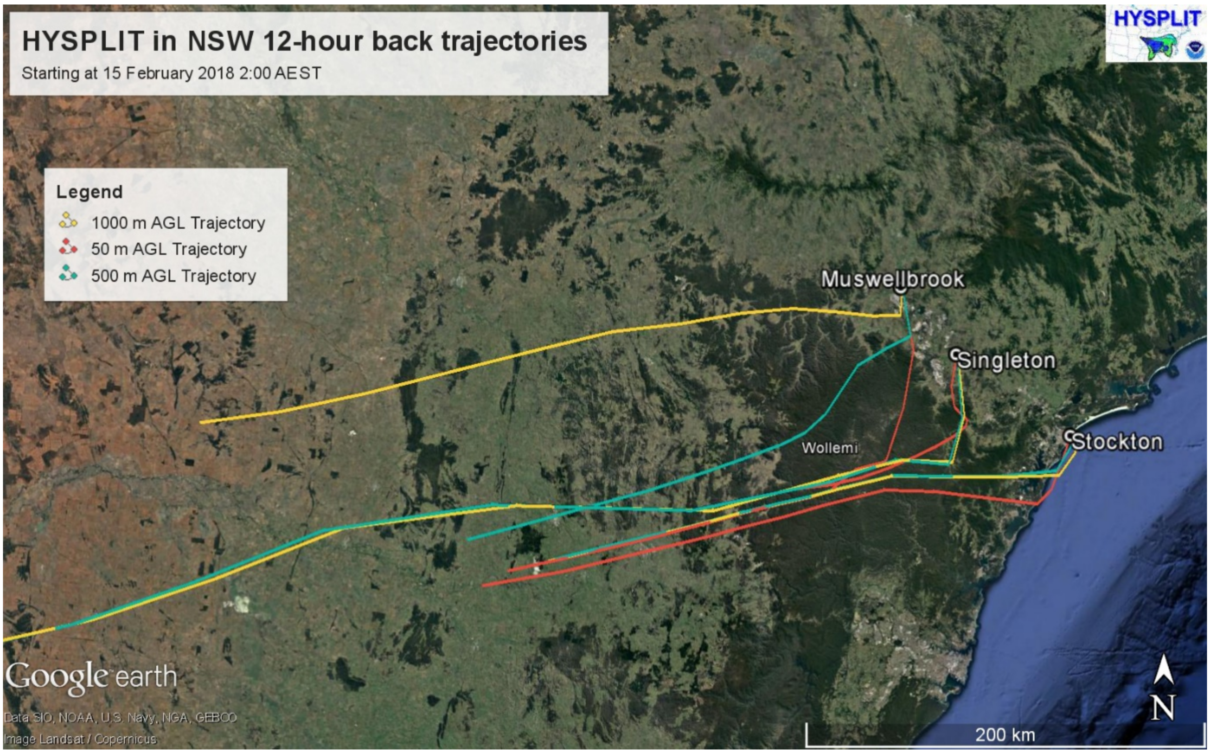


Figure 28 Modelling output from HYSPLIT in NSW, showing the modelled passage of air on 15 February 2018, transporting PM10 particles from west and south-west New South Wales and across Wollemi National Park to the Upper Hunter

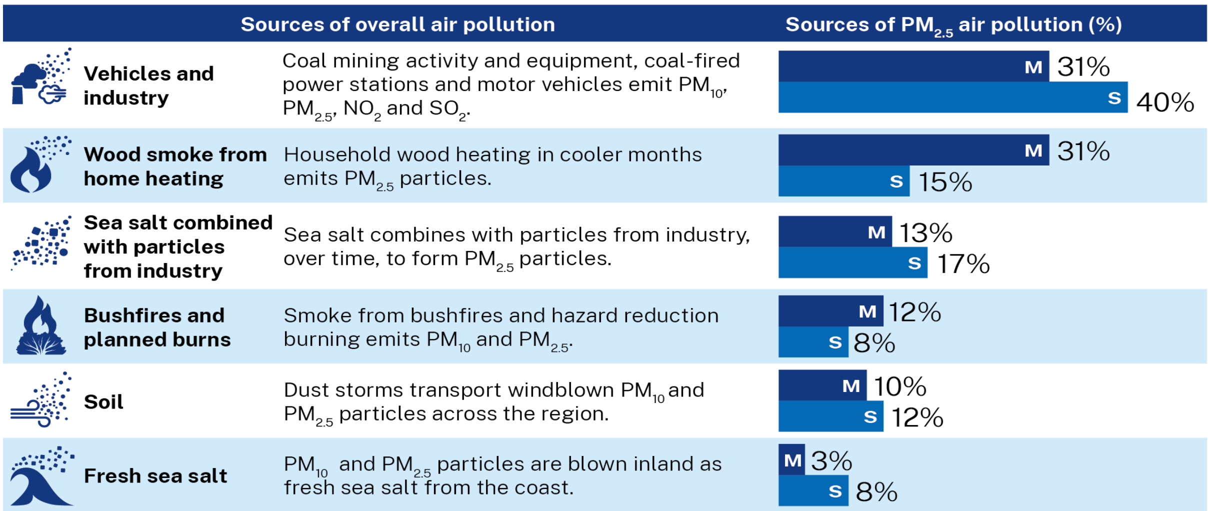
The passage of strong, dry cold fronts, deteriorating soil moisture and loss of ground cover were associated with an increasing frequency of dust storms and days with PM10 concentrations above benchmarks, from summer 2017–18 to summer 2019–20. Back-trajectory modelling demonstrated that windblown dust from semi-arid areas of western Victoria and South Australia and drought-affected western NSW contributed to poor air quality in the Upper Hunter.

2.4.2 Identifying sources of PM2.5 particles

PM2.5 particles typically are emitted in the combustion of solid and liquid fuels, including coal, diesel and petroleum oils, domestic firewood and vegetation. PM2.5 particles also form in the air from chemical reactions between particles and gases such as sulfur dioxide (SO_2) and oxides of nitrogen (NO_X).

Analysis of the Upper Hunter monitoring data showed that peaks in PM2.5 particle levels were associated with domestic wood smoke in winter and with extensive bushfire smoke and hot, dry, windy conditions in spring–summer seasons.

- Daily average PM2.5 concentrations were above the national benchmark on one to 3 days per year during the first 7 years of the network's operation from 2012 to 2018 (Figure 6). Annual average PM2.5 concentrations were above the national benchmark in 10 of the 11 years in the network's operation (Figure 8).
- Analysis of initial data from the 3 network stations monitoring PM2.5 found that peaks in hourly concentrations occurred on cold, calm nights. Elevated PM2.5 concentrations recorded at Muswellbrook in winter during the first 9 months of the network's operation led to the CSIRO's *Upper Hunter fine particle characterization study* (Hibberd et al. 2013).
- CSIRO studied the make-up of PM2.5 particles collected at Muswellbrook and Singleton monitoring stations, in the calendar year 2012 (Hibberd et al. 2013). The study found that wood smoke was the main component of PM2.5 particles in winter, while in summer fine particles were mostly sulfates from industry combined with sea salt. The findings led the NSW EPA and councils to raise community awareness of the potentially harmful levels of PM2.5 from wood smoke in winter. Figure 29 summarises the main findings of the study.
- During spring–summer 2019–20 (DPIE 2020a), extensive bushfire smoke led to extreme levels of PM2.5 particles and consecutive days above the PM2.5 national benchmark across New South Wales. The Upper Hunter network recorded 37 days above the PM2.5 benchmark, occurring on 15% of spring days and 25% of summer days.



2 Air quality in the Hunter Valley

Figure 29 Sources of PM2.5 particles in samples collected at monitoring stations in Muswellbrook (M) and Singleton (S) in 2012

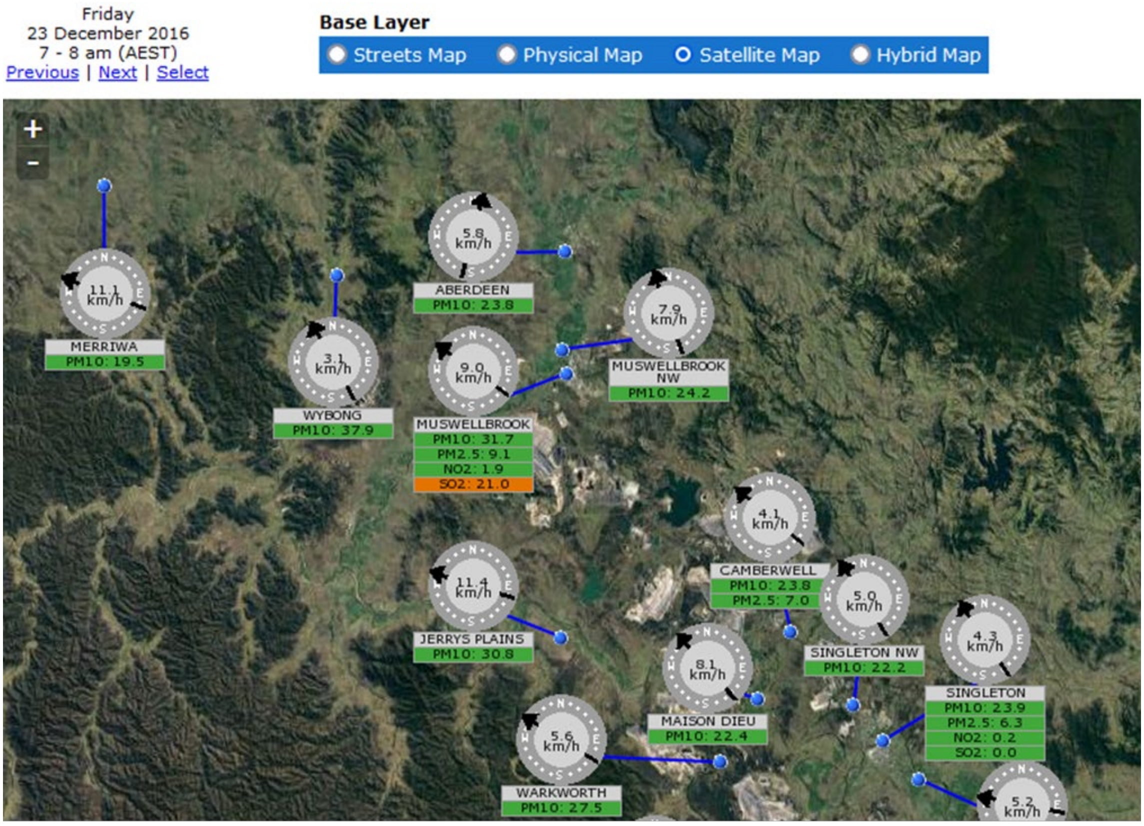
Source: Extracted from the *Upper Hunter fine particle characterization study* (Hibberd et al. 2013).

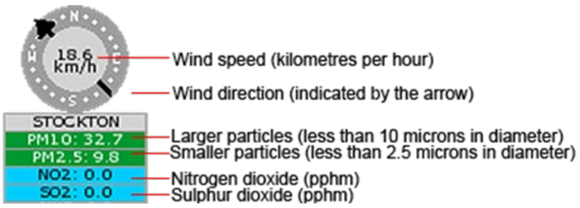
2.4.3 Identifying sources of sulfur dioxide and oxides of nitrogen

A lone peak in the hourly SO_2 concentration at the Muswellbrook monitoring station led to an Upper Hunter power station installing continuous SO_2 monitoring on all its power generation units and a statewide review of emissions monitoring at coal-fired power stations.

- The network's Muswellbrook station recorded SO_2 at 21 pphm at 8 am on 23 December 2016, just exceeding the 1-hour national benchmark of 20 pphm, as applied for national standards at that time (Figure 30).
- The major sources of SO_2 and NO_X in the Muswellbrook area are power stations operated at Bayswater and Liddell, approximately 15 kilometres south-east of Muswellbrook. These power stations operate continuously, emitting over 100 kilotonnes of SO_2 and over 50 kilotonnes of NO_X per year.
- The network's monitoring data showed a peak in SO_2 and NO_X at Muswellbrook occurring at the same time at 8 am. A smaller peak was recorded at the industry-operated monitoring station at Mitchell Line Road, south-east of Muswellbrook and north-west of the power stations.
- The NSW EPA Environment Line received calls about sulphurous odours detected east-south-east of Muswellbrook in the week before the SO_2 event on 23 December 2016.
- The prevailing light south-easterly breeze on 23 December 2016 potentially directed the power stations' plumes towards Muswellbrook. Stack emissions from power stations cannot disperse upwards when cooler air near the ground is overlain by warmer above the stack height. These conditions most often occur during the morning and can trap the plume at ground level. However, no data were available on changes in temperature with altitude that could confirm the presence of these conditions at Muswellbrook on 23 December 2016.
- The prevailing light south-easterly breeze on 23 December 2016 potentially collected smaller amounts of SO_2 emitted during spontaneous combustion of coal, at mines located between the power stations and Muswellbrook.

- The peaks in SO_2 and NO_X at the same hour in the monitoring data suggested that the most likely source of SO_2 affecting the Muswellbrook from 7 am to 8 am on 23 December 2016 was SO_2 emissions from the power stations.
- In response, the EPA investigated whether the peak was higher because of a spike in SO_2 emissions from the power stations. The continuous monitoring records for the 4 power generation units at Liddell power station showed a constant emission rate of SO_2 during the morning of 23 December 2016. Therefore, the focus of the EPA's investigation moved to Bayswater power station, where continuous monitoring operated on one of 4 power generation units. The data showed no change in SO_2 emissions on the morning of 23 December 2016. The EPA inspected coal handling facilities at the power stations in June 2017. Coal from various mines was blended by dozers to manage sulfur content. Since the investigation, the power station operators installed continuous SO_2 monitoring on all power generation units at Bayswater.
- Following the SO_2 incident at Muswellbrook, the EPA conducted a wider review (EPA 2018) of emissions from the State's coal-fired power stations to ensure consistency in monitoring of appropriate substances at appropriate limits with appropriate techniques (UHAQAC 2017). The findings of the review were published in 2018.
- The discussion above demonstrates how analysis of monitoring data from the network identified a potential source of SO_2 pollution affecting Muswellbrook and led to a review of EPA regulation of power stations across New South Wales.





	SO_2 (pphm)
Good	< 13.3
Fair	13.3 – 20
Poor	20 – 30
Very poor	30 – 40
Extremely poor	> 40

Figure 30 Muswellbrook recorded sulfur dioxide at 21 pphm at 8 am on 23 December 2016

The discussion in Section 2.4 supports the conclusion that the monitoring program meets the objective of facilitating the identification of sources of air pollution.

2.5 Objective 4 – facilitating strategies to improve air quality

The discussion for objective 4 describes how data generated by the network has provided an evidence base for programs and practices to improve Upper Hunter air quality.

Key points

- Dust mitigation practices aimed at reducing high levels of PM10, especially in warmer months, have led to the statewide adoption of international best practice in dust mitigation during mining operations.
- High levels of PM2.5, typically recorded in the network's larger population centres on cold, calm nights in the cooler months, led to statewide collaborations between the EPA and local councils to reduce wood smoke emissions. The EPA published a tool kit of educational materials for councils to raise awareness of the health issues associated with wood heaters. The EPA progressively tightened efficiency standards for wood heaters from 2016 to 2019.
- The NSW Government and science partners are working progressively to extend the capacity of the air quality forecasting system to cover major regional areas, including the Upper Hunter. The data collected from the network provide essential inputs in developing this work.

2.5.1 Dust mitigation strategies

The *Dust Stop* program, 2011 to 2017

High levels of PM10 were recorded in the early years of the network's operation, especially in warmer months (as noted in Section 2.4.1). The EPA's *Dust Stop* program aimed to ensure best practice dust management on coal mines across New South Wales. The program drew on the *NSW Coalmining benchmarking study* (Katestone Environmental 2011), a review of international best practices to minimise dust. Over the following years, the EPA added 4 pollution reduction programs to the mines' environment protection licences to reduce dust from the main sources.

Mining operations in the Upper Hunter now incorporate the following best practice methods:

- 80% control of wheel-generated dust
- modifying operations during adverse weather
- minimising dust from overburden handling
- minimising wind erosion of exposed surfaces.

The EPA reported in November 2017 that the *Dust Stop* program had reduced coal mine PM10 emissions by 22,000 tonnes per year (EPA 2017), which was 19% of total mine emissions (UHAQAC 2017).

Dust assessment handbook for mining operations, 2019

The EPA first published the *Dust assessment handbook* in 2012, in consultation with the mining industry and the department. The handbook used photographs to illustrate an expected level of dust control, achieved by water spraying on haul roads and around drilling rigs. The handbook was designed to fit into the glovebox of vehicles of mine workers and regulators.

In 2019, the EPA updated the handbook (EPA 2019) to demonstrate water spraying to reduce dust during loading and dumping of overburden. Best practices introduced by individual mines during the *Dust Stop* program set the benchmark for achieving consistent best practice at all mines.

Operation Bust the Dust, spring–summer 2019 and 2020

The EPA's *Operation Bust the Dust* (EPA 2020b) campaign focused on compliance, awareness and management of dust at open-cut coal mines in the Hunter Valley (EPA 2020a). The strategy involved EPA inspections to check that extra controls were in place at mines to minimise dust on hot, dry and windy days. As noted above, best practice at coal mines requires watering of unsealed roads, avoiding dust-generating activities during windy weather and minimising dust from drilling and handling overburden.

The EPA's regulatory operations staff used the network's PM10 and meteorological data as the evidence source to identify wind and weather conditions most conducive to high levels of PM10 and to investigate dust generation on these days. Drones assisted in viewing mining operations that were obscured by trees, bunds and ridges and other obstacles. The community was informed via social media tweets and medial releases sent out the day before as well as on the day of the inspection.

The findings and outcomes of the operation are as follows:

- *Operation Bust the Dust*, during September 2019 and January 2020:
    - the EPA made 51 off-premises inspections of mining operations over 21 days
    - the drone was used on 16 days
    - Department of Planning and Environment compliance officers attended on 2 days (compliance officers regulate a mine's compliance with the conditions of the company's approval to operate mining activity)
    - most mines were observed implementing best practice dust controls and complying with licence conditions
    - mines that were contacted by the EPA made operational changes.
- *Operation Bust the Dust*, September 2020
    - the EPA made fewer inspections than spring–summer 2019–20 due to wetter weather conditions
    - community calls to the EPA reporting dust concerns decreased notably compared to spring 2019
    - EPA officers attended inspections across the Upper Hunter on 8 days
    - Department of Planning and Environment compliance officers attended on one day.

The EPA observed the following challenges to the campaign:

- windy weather limited the use of drones
- dust storms hampered the campaign
- bushfire conditions presented safety risks to officers.

In November 2021, the EPA advised the Upper Hunter Air Quality Advisory Committee that the EPA was not conducting *Operation Bust the Dust* in spring–summer 2021–22, due to predicted high rainfall. However, the EPA would continue to monitor conditions and respond if conditions were conducive to increased dust levels. When the EPA observed moderate to high PM10 readings at network stations, and where the source of the dust was identified as a mine, the licensee was requested to provide PM10 data from licensed monitoring points and information about actions taken by to reduce dust (UHAQAC 2021).

Dust risk forecasting trial 2017

The Upper Hunter dust risk forecasting scheme (OEH 2017b) aimed to predict days when more vigilant surveillance and dust control would be needed on coalmining operations. The EPA and the Climate and Atmospheric Science Branch of the department (formerly the Office of Environment and Heritage) trialled the dust risk forecasting system during September to November 2017.

The system involved 2 dust risk forecast models that combined PM10 and meteorological data from the network, and daily weather forecasts, upper air data and rainfall records from the Bureau of Meteorology.

The trial defined a high dust risk day as a day when there was a difference of 25 μg/m^3 or more in the PM10 24-hour average concentrations at Merriwa and Singleton.

Mines participated in the trial by providing daily estimates of material moved at each mine on each day and data from their continuous monitoring of PM10, upwind and downwind of mining operations.

Bushfire and dust storm conditions and incidents of high PM10 levels across the State were included in the modelling when information was available.

The model demonstrated moderate skill in forecasting. The study concluded that improvements in the forecasting scheme may be achieved through application of more sophisticated analytical methods (OEH 2017b).

2.5.2 Wood smoke reduction

Analysis of PM2.5 and meteorological monitoring data from the network identified wood smoke as the likely source from levels of PM2.5 above the daily benchmark in the Upper Hunter each winter season from 2012 to 2020 (see link to seasonal newsletters in Section 6.2 – More information).

The EPA progressively tightened emission and efficiency standards for wood heaters (EPA 2016) during 2016 and 2019. A media campaign to reduce wood smoke emissions (EPA 2021b) was launched in 2018. Slogans included 'Wood smoke isn't good smoke' and 'If you can smell it, you're breathing it'. Educational materials developed for the campaign, including short animations (EPA 2021b) and resources for local councils (EPA 2021d), were and continue to be used to raise awareness of the health issues associated with wood heaters (UHAQAC 2018).

Wood smoke reduction program in Singleton and Muswellbrook, 2016 to 2018

Singleton and Muswellbrook councils participated in an EPA wood smoke reduction program in the winter seasons of 2016 to 2018. The program offered incentives for chimney cleaning and wood heater replacement. While chimney cleaning rebates were popular, the uptake of wood heater replacement rebates was less popular. Table 8 shows the number of heaters replaced each year, with total of 45 replacements during the program.

Table 8 Uptake of $1,500 financial incentive for wood heater replacements, 2016 to 2018

Wood heater replacements	2016	2017	2018	Total
Singleton	7	5	1	13
Muswellbrook	16	10	6	32
Total replacements	**23**	**15**	**7**	**45**

Source: EPA internal report.

2.5.3 Use of network data in assessing mines' compliance with planning approvals

The department's Planning and Assessment Compliance Branch uses network monitoring data to assist in the following work practices:

- investigating an air quality complaint from a community member
- investigating extraordinary air pollution events such as regional dust events
- comparing network data with monitoring data from industry-operated monitoring stations when mines report exceedances of air quality criteria.

2.5.4 Use of the network data in air quality forecasting

A reliable and accurate air quality monitoring and forecasting system plays an important role in regional air quality management. The NSW Air Quality Forecast Framework was designed in 2015 by the NSW Government to progressively advance its capability for forecasting air quality within the Greater Metropolitan Region and key regional areas in New South Wales.

The framework is implemented through a major ongoing forecasting program, entitled *Enhancing air quality forecasting in NSW* (DPIE 2020b). The program aims to progressively expand the scope and enhance the accuracy of air quality forecasting in the State.

The NSW air quality forecasting system currently provides next-day air quality predictions for particles and ground-level ozone over the Sydney Metropolitan Region. The NSW Government is extending this forecasting capacity progressively to the cover major regional areas including the Upper Hunter. The experience of trialling the Upper Hunter dust risk forecasting scheme (OEH 2017b) and data collected from the network provide essential inputs in developing this capability.

2.5.5 Use of network data to support local strategic planning

Local governments' use of information from the network in strategic planning is demonstrated by Singleton Council. The *Singleton Council local strategic planning statement 2041* (Singleton Council 2020) acknowledges an alignment between the network's reporting of seasonal air quality and councils' delivery of the following 2 strategic planning priorities:

- protecting the health and amenity of the community (Priority 1.1)
- ensuring that the mineral resource industry is productive, accountable and considerate of surrounding land uses (Priority 4.4).

The statement used network data to report Singleton's air quality against national benchmarks, noting the number of days with PM10 and PM2.5 levels above benchmarks.

The statement also reported summary findings on the sources of PM2.5 pollution from the *Upper Hunter fine particle characterization study* (Hibberd et al. 2013).

2.5.6 Use of network data to support government regulation of mines

The department's Planning and Assessment Compliance Branch uses network monitoring data in work practices related to the management of mining approvals and development applications, as described in Section 2.2.3.

2.6 Conclusion

This review concludes that the evidence presented above demonstrates that the Upper Hunter monitoring program was effective in meeting the objectives set by the Regulation.

The online survey of the Upper Hunter Air Quality Advisory Committee, conducted as part of this review (see Section 5.1.1), found that committee members agreed that the monitoring program met objectives 1 and 2; providing reliable air quality data, which are assessed regularly against relevant standards.

Some committee members questioned the effectiveness of programs to meet objectives 3 and 4; to facilitate identification of sources of pollution and the development of strategies to improve air quality in the Upper Hunter. The discussion in Sections 2.5.5 and 2.5.6 presented evidence to demonstrate that the monitoring network has been fundamental in the development of such strategies.

The review recommended action by the EPA and Department of Planning and Environment to better demonstrate to stakeholders how the government uses network data and the monitoring program to facilitate the identification of sources of pollution and development of strategies to improve air quality in the Upper Hunter.

3. Independent audit of network efficiency and costs

This section presents the summary of costs for operating the network and the results of an independent audit of its efficiency and cost-effectiveness, as required by the Regulation (clause 95(2.b)).

Key points

- A material increase in annual average operating expenses (24%) and labour costs (46%) in financial years 2017 to 2021, compared to financial years 2011 to 2016, was attributed to some resourcing costs being provided in-kind before 2013.
- The audit found that the network monitoring program meets the following criteria for efficiency and effectiveness:
  - provides reliable and up-to-date information on air quality in the region
  - allows for assessment of air quality against relevant standards
  - remains valid with regards to the sources of air pollution
  - assists with the development of air quality programs
  - enables the reporting of regional air quality both in real time and in various department publications.
- The audit considered the reasons for the increase in annual average costs and concluded that the network and monitoring program remained cost-effective. Recommendations were made to improve cost management.

3.1 Costs of operating the network

The costs to the NSW Government of operating the network include the cost of assets, such as monitoring instruments and station infrastructure, as well as labour for maintenance, calibrations, audits, quality assurance and reporting. There is an additional cost for the EPA to administer the Regulation and support the advisory committee.

Costs are recovered annually through levies to the coalmining and power generation industries in the Upper Hunter. These levies are based on the annual individual emissions from each industry. The calculation of the levy is specified within the Regulation (clauses 87 and 88). Table 9 presents the costs for the NSW Government to establish, operate and maintain the network during the financial years (FY) 2011 to 2016, compared to FY 2017 to FY 2021.

Table 9 Network costs for the financial years (FY) 2011 to 2016 compared to 2017 to 2021

Expenses	Costs FY 2011 to 2016	Annual average (6-year period)	Costs FY 2017 to 2021	Annual average (5-year period)
Capital (including site construction costs)	$2,230,029	NA[a]	$367,883	NA[a]
Operational	$709,347	$118,225	$733,076	$146,615
Labour	$2,023,055	$377,196	$2,456,294	$491,259
Total	**$4,962,431**	**NA[a]**	**$3,557,253**	**NA[a]**

a 'NA' - not applicable. Capital costs for financial years 2011 to 2016 include the costs of constructing the 14 monitoring stations, as such comparison for capital may be misleading.

3.2 Efficiency and cost-effectiveness of the network

This section reports on the independent audit of the efficiency and cost-effectiveness of the network (Air Earth Environment 2021), required by the Regulation (clause 95).

Air Earth Environment Pty Ltd was selected to undertake the independent review due to their expertise in the field and as they have not been involved in the operation of the network. Air Earth Environment reviewed network reports and costs as well as minutes of meetings of the Upper Hunter Air Quality Advisory Committee, to conduct an independent audit of the efficiency and cost-effectiveness of the Upper Hunter monitoring program during the financial years ending 30 June 2017 to 2021 (Air Earth Environment 2021).

The independent audit aimed to determine whether the network was effective in providing regional air quality data to the community and stakeholders, and was cost-effective as an operation that is managed by NSW Government and funded by the coal and electricity generation industries in the Upper Hunter Valley.

In assessing whether the network was fit-for-purpose and represented value for money during the financial years 2017 to 2021 (FY17–21), the audit considered the following aspects:

- monitoring site infrastructure
- monitoring equipment
- network maintenance and reporting program and associated labour costs
- operating costs such as communications, power costs, fees and other expenses.

The audit assessed cost-effectiveness based on a review of capital and operational expenditure by the department during the FY17–21. The audit noted that there was a material increase in annual average operating expenses of 24% (from $118,225 to $146,615), and labour costs of 46% (from $377,196 to $491,259) in FY17–21 (compared to FY11–16). The increased annual costs were attributed to some costs not being recovered before FY2013, when resourcing and associated on-costs were provided in-kind.

This audit considered the reasons for the increases in costs and concluded that, overall, the network remained cost-effective. However, 4 recommendations were made regarding cost management for the next 5-year period, that is, FY22–26. The recommendations are set out below.

3.3 Findings and recommendations of the independent audit

The independent audit found that the network monitoring program:

- provides reliable and up-to-date information on air quality in the region
- allows for assessment of air quality against relevant standards
- remains valid regarding the sources of air pollution
- assists with development of air quality programs
- enables the reporting of regional air quality in both real time and in various department publications.

Table 10 summarises the recommendations of the independent audit, to ensure future efficiency and improvements to cost management of the network.

Table 10 Summary of recommendations of the independent audit of the efficiency and cost-effectiveness of the Upper Hunter air quality monitoring program

Number	Independent audit recommendation
1	Annual/seasonal air quality data reviews to be published within a shorter time after each period so that results may be used for progressive review of the network.
2	Department of Planning and Environment to benchmark the network against comparable networks and develop key performance indicators for efficiency and cost-effectiveness to identify areas for innovation and improvement and to provide a more quantitative basis for assessing the network in future audits.
3	The department to develop a formal operation and maintenance procedure manual that is specific for the Upper Hunter network and separate to the controlled documents for the whole NSW network. The manual should include a protocol for procuring new equipment and spare parts, and an inventory of spare parts and costs.
4	The department reinstate cost forecasting for the network, providing forecasts to the Upper Hunter Air Quality Advisory Committee and this be considered a priority. Forecasting would include estimates of levy costs to industry.
a	Forecasting would provide an ongoing annual review process where estimated costs are shared with the advisory committee and industry for their feedback before finalising the estimate.
b	Forecasting would enable industries to budget their annual levy cost contributions more accurately and would also provide transparency in accounting for any differences between forecast and actual costs.
c	With regards to the 5-yearly reviews, in the event that any changes to the network are required, for example, due to changes in mining locations or population centres, the consequential cost from such changes would form part of the annual cost forecasting.

Source: Air Earth Environment (2021).

4. Factors affecting network design

The original network design considered the location of major pollution sources, population centres, the topography of the Hunter Valley and its influence on air movement (Holmes Air Sciences 2008). This section describes changes in these factors during 2016 to 2021.

Key points

- The review found minimal changes in factors affecting the original design of the network in 2009 to 2010.
- The population of the Upper Hunter increased by less than 1% during 2016 to 2021 and is predicted to remain stable to 2026.
- Strategic planning by local government shows buffer zones between future urban growth areas and mining activity, to minimise population exposure to poor air quality.
- The broad extent of coalmining activities expanded marginally during 2017 to 2021.
- No changes are recommended to the current network design.

4.1 Topography and meteorology

4.1.1 Wind patterns

The original siting of the 14 monitoring stations considered local topography and the north-west to south-east alignment of prevailing winds along the Upper Hunter Valley (Holmes Air Sciences 2008).

Analysis of the network's wind data showed that average wind patterns were unchanged since establishment of the network. Winds flow predominantly north-westerly in winter and south-easterly in summer (Figure 21 and Figure 22). Variability at individual sites reflects localised topographic effects. Although extensive open-cut mining has modified local topography of the undulating land above the floodplain, the effects of topography on regional wind patterns remains unchanged.

4.1.2 Rainfall and air quality

Long-term trends showed an association between particle levels and annual rainfall. For example, Figure 31 shows that increases in PM10 annual averages from 2016 to 2019 were accompanied by falls in total annual rainfall. In these years, the region experienced intensifying drought and extensive bushfire smoke in spring–summer 2019–20.

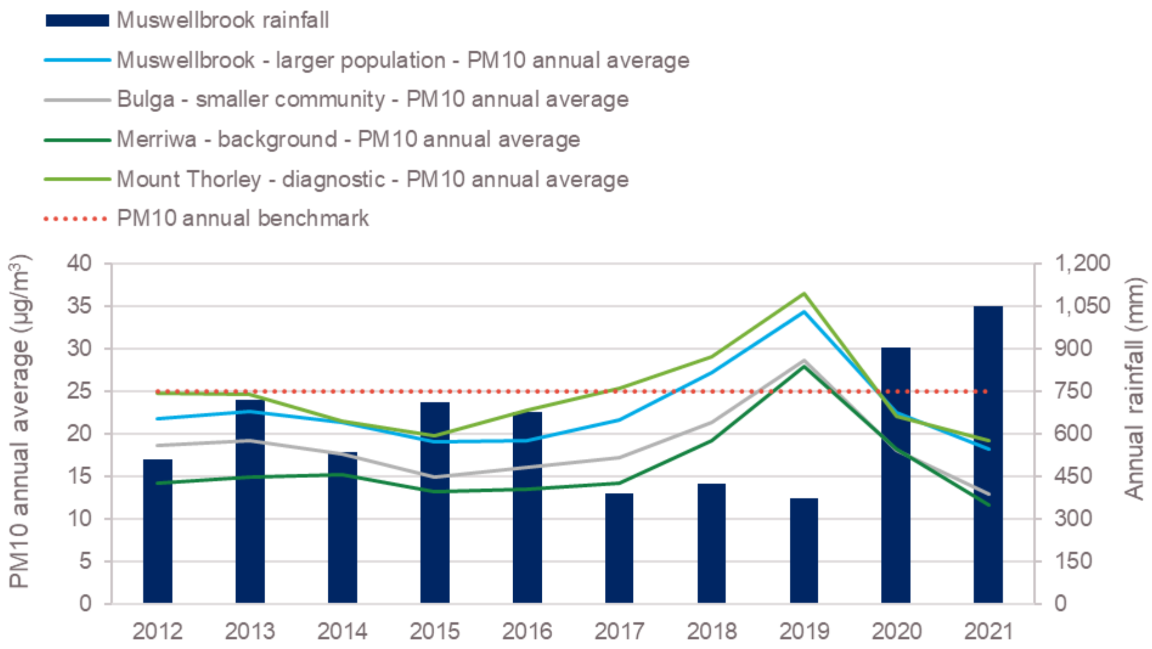


Figure 31 Comparison of PM10 annual average concentrations (lines) and total annual rainfall (bars)

Source: Rainfall data between 2012 and 2017 sourced from Muswellbrook (St Heliers) Bureau of Meteorology station, accessed from the Bureau of Meteorology Climate Data Online webpage (accessed January 2022). Data from 2018 to 2021 sourced from the network rainfall data at Muswellbrook air quality monitoring station.

4.2 Population

A review of available data indicated that the population in the Upper Hunter changed minimally during 2017 to 2021.

NSW Government projections (2019) estimated that the population of the region increased by 700 people in the 6 years 2016 to 2021, an increase of less than 1%. Population was estimated to remain stable to 2026, with approximately 54,400 people. Natural increase in population was predicted to be offset by families leaving the region.

Population trends and projections for local government areas (LGAs) are summarised below.

4.2.1 Population change, 2016 to 2021

Table 11 shows the projected trends in Upper Hunter population for 2016 to 2021.

- Total population of the region was estimated to increase by 700 people, from approximately 54,400 to 55,100 at an annual growth rate of 0.2%.
- The population of Singleton LGA was estimated to increase by 200 people, from approximately 23,600 to 23,800 at an annual growth rate of 0.2%, largely due to natural increase.
- The population of Muswellbrook LGA was estimated to increase by 650 people, from approximately 16,450 to 17,100 at an annual growth rate of 0.8%, largely due to natural increase.
- The population of the Upper Hunter LGA was estimated to fall by 150 people, from approximately 14,350 to 14,200 at an annual growth rate of –0.2%, as young families moved away.

Table 11 Upper Hunter population changes, by local government area, 2016 to 2021

Population centre	Population 2016	Population projection 2021	Population change 2016–2021	Projected annual growth 2016–2021
Singleton	23,600	23,800	+ 200	+ 0.2%
Muswellbrook	16,450	17,100	+ 650	+ 0.8%
Upper Hunter	14,350	14,200	– 150	– 0.2%
Total	**54,400**	**55,100**	**+ 700**	**+ 0.2%**

Note: Australian Bureau of Statistics Census data for 2021 will be available in June 2022.
Source: DP (2019a–c).

4.2.2 Population projections, 2021 to 2026

Projections for the 6 years 2021 to 2026 estimated that the population of the region would remain stable, increasing by 300 people, to 55,400 in 2026 (DP 2019a–c).

Table 12 shows the projections for 2021 to 2026.

- Total population of the region was estimated to increase by 300 people, from approximately 55,100 to 55,400 at an annual growth rate of less than 1%.
- The population of Singleton LGA was estimated to increase by 50 people, from approximately 23,800 to 23,850.
- The population of Muswellbrook LGA was estimated to increase by 500 people, from approximately 17,100 to 17,600 at an annual growth rate of 0.6%.
- The population of the Upper Hunter LGA was estimated to fall by 250 people, from approximately 14,200 to 13,950 at an annual growth rate of –0.4%, as young families moved away.

Table 12 Upper Hunter population changes, by local government area, 2021 to 2026

Population centre	Population projection 2021	Population projection 2026	Population change 2021–2026	Projected annual growth 2021–2026
Singleton	23,800	23,850	+ 50	0.0%
Muswellbrook	17,100	17,600	+ 500	+ 0.6%
Upper Hunter	14,200	13,950	- 250	- 0.4%
Total	**55,100**	**55,400**	**+ 300**	**+ 0.0%**

Source: DP 2019a–c.

4.2.3 Changes in urban development 2016 to 2021

NSW population projections (DP 2019a–c) and strategic urban planning statements by Upper Hunter councils indicate that urban development extended minimally from 2016 to 2021 (Singleton Council 2020; Muswellbrook Shire Council 2020; Upper Hunter Shire Council 2020).

Singleton Shire Council population projections suggest that approximately 1,000 new dwellings were established in the LGA during 2016 to 2021. Growth was mainly in current strategic growth areas (Figure 32, inset 1):

- 951 new urban and lifestyle dwellings (93%) estimated in strategic growth areas, including Huntlee, Hunterview-Wattle Ponds, Singleton Heights and Gowrie
- 77 new lifestyle dwellings across Lower Belford, Branxton, Segefield and Jerrys Plains.

Muswellbrook Shire Council (personal communication, 29 November 2021) reported 180 new dwellings in the LGA during 2017 to 2021, mostly in current land release areas (87%):

- 120 new dwellings were spread evenly between north-side and south-side new urban release areas (Figure 33, inset 2)
- 40 new dwellings were in Denman, mostly near Almond Street (Figure 33, inset 3)
- 20 new dwellings on rural lots spread from Jerrys Plains, west to Baerami.

Upper Hunter Shire Council (personal communication, 1 February 2022) reported 144 new dwellings in the LGA from 2016 to 2021, mostly in larger towns (66%):

- 95 new dwellings were in the towns of Scone (59), Merriwa (16), Aberdeen (12) and Murrurundi (8)
- 7 new dwellings were across 5 villages including Blandford and Wingen
- 42 new dwellings were across 13 rural areas including Segenhoe, Moobi and Middlebrook.

4.2.4 Projections for urban development, 2021 to 2026

Urban development in the region in the next 5 years is expected to be within existing population centres and current residential land release areas.

NSW Government population projections for 2021 to 2026 (DP 2019a–c) estimated:

- 250 new dwellings (2.5% increase) in Singleton LGA
- 400 new dwellings (4.9% increase) in the Muswellbrook LGA
- 50 new dwellings (0.7% increase) in the Upper Hunter LGA.

Singleton Council's local strategic planning statement (Singleton Council 2020) demonstrated how longer-term strategic planning aims to protect the health of residents and minimise exposure to poor air quality, by limiting how close housing growth areas can be to industries that generate such impacts. For example, Figure 32 (inset 1) shows how land-use planning uses buffer zones around urban settlement and growth areas as mechanisms to restrict the encroachment of extractive industries and associated air quality impacts.

Muswellbrook Council's local strategic planning statement reported that new housing in the next 5 years was expected to be in current north-side and south-side urban release areas (personal communication, 29 November 2021) (Figure 33). Additional residential urban release areas would only be provided if existing supply could not meet a 10-year demand. The pattern and scale of urban release areas would integrate with infrastructure availability (Muswellbrook Shire Council 2020).

Upper Hunter Council's land use planning strategy (Upper Hunter Shire Council 2017) reported that demand for new dwellings was projected to be 50 to 60 dwellings per year, of which 35 to 40 would be in the larger towns and the remainder mainly in the villages. No new settlement areas were anticipated to be required to 2031.

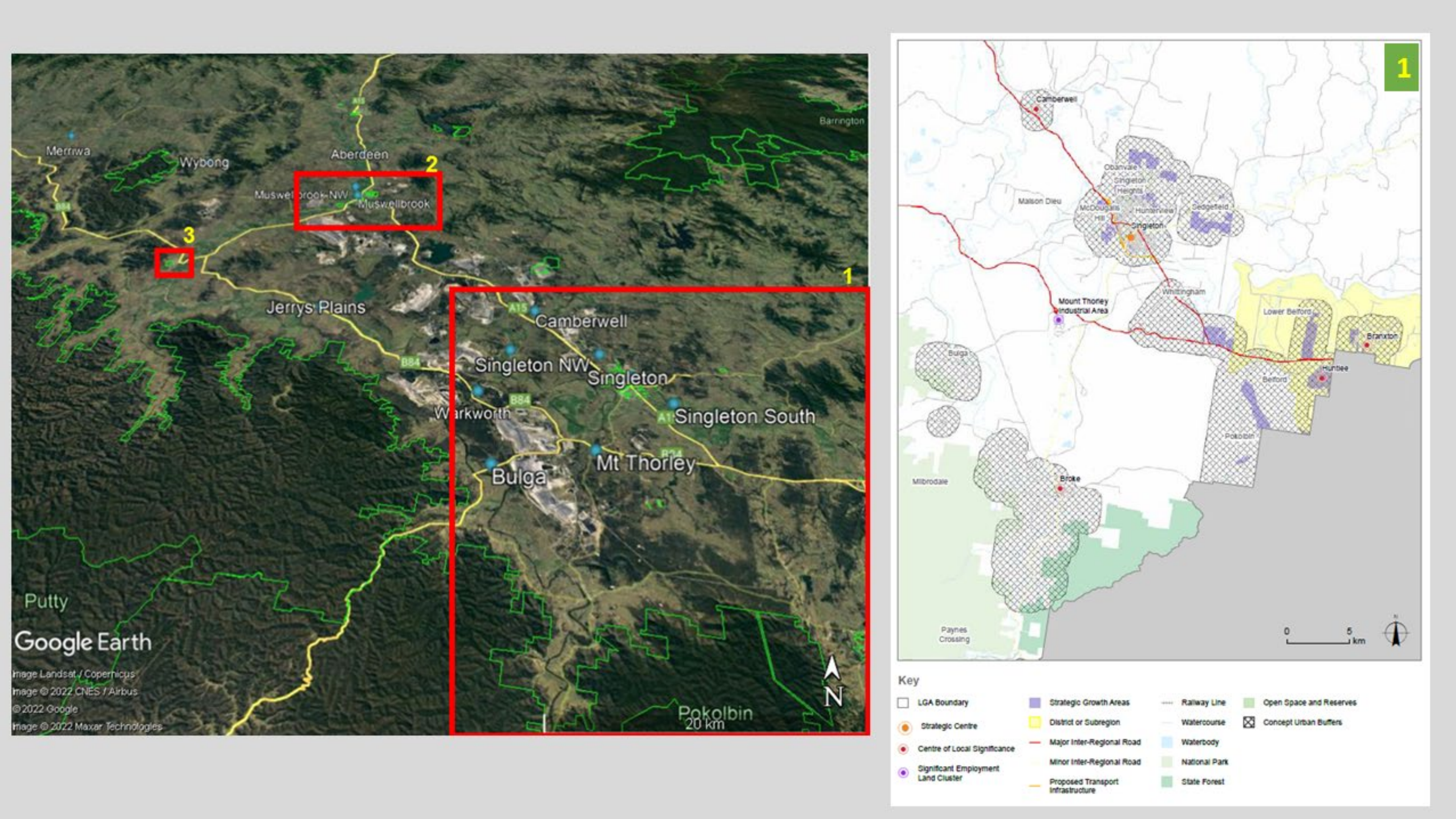


Figure 32 Upper Hunter, showing areas of urban growth planned for Singleton Local Government Area (1) and buffer zones between urban development and current mining activity (hatched areas on right)

Source: Singleton Shire Council (2020) (right).

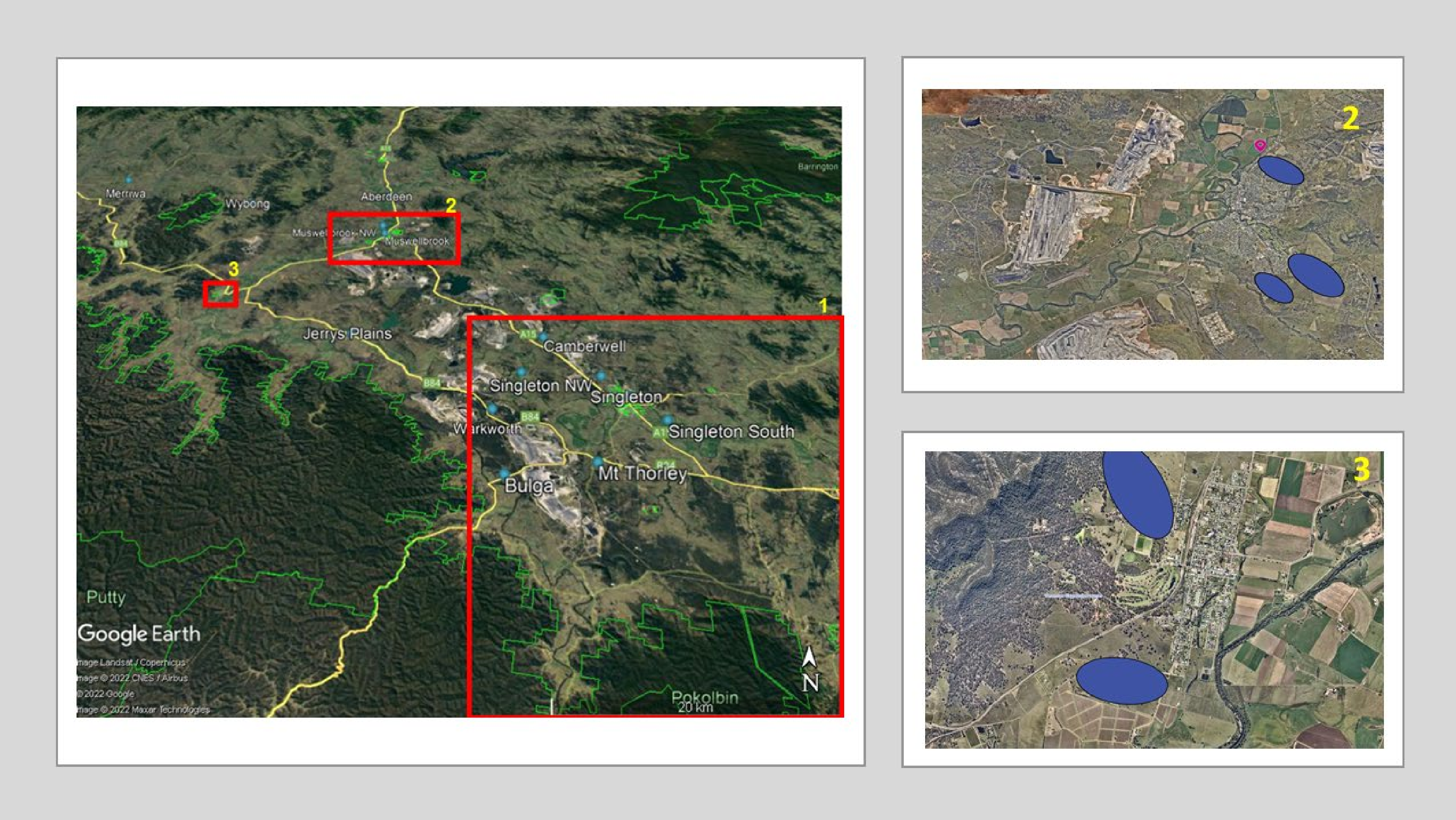


Figure 33 Upper Hunter, showing areas of urban growth planned for Muswellbrook (inset 2, top right) and Denman (inset 3, bottom right), in the Muswellbrook Local Government Area

4.3 Mining activity

This review investigated changes in mining activity during the last 5 years and the potential for change over the next 5 years. Findings are summarised as follows, with further details in the following sections:

- mining activity extended marginally during 2017 to 2021
- satellite imagery showed that the main areas of marginal expansion were at the Mount Pleasant coal mine, approximate 3 kilometres north-west of Muswellbrook, and the Warkworth-Mount Thorley-Bulga mines, approximately 2 kilometres east of the village of Bulga.

4.3.1 Changes in location of coalmining activity

Changes in the footprint of mining activity

A comparison of historical satellite imagery showed that the footprint of coalmining operations extended marginally from 2016 to 2020.

Satellite images in Figure 34 show marginal extension of mining activity from 2016 (Figure 34, left) to 2020 (Figure 34, right) in the following areas:

- Mount Pleasant open-cut mine – north-eastward extension to approximately 3 kilometres north-west of Muswellbrook
- Mangoola Coal Operations – southward extension to approximately 8 kilometres south-south-east of Wybong and 12 kilometres north of Denman
- Mount Arthur coal mine – eastward extension to approximately 5 kilometres south of Muswellbrook
- Ravensworth open-cut coal mine – southward extension to approximately 5 kilometres east-north-east of Jerry Plains
- Warkworth-Mount Thorley-Bulga open-cut mines – some west and southward extension to approximately 2 kilometres east of Bulga.

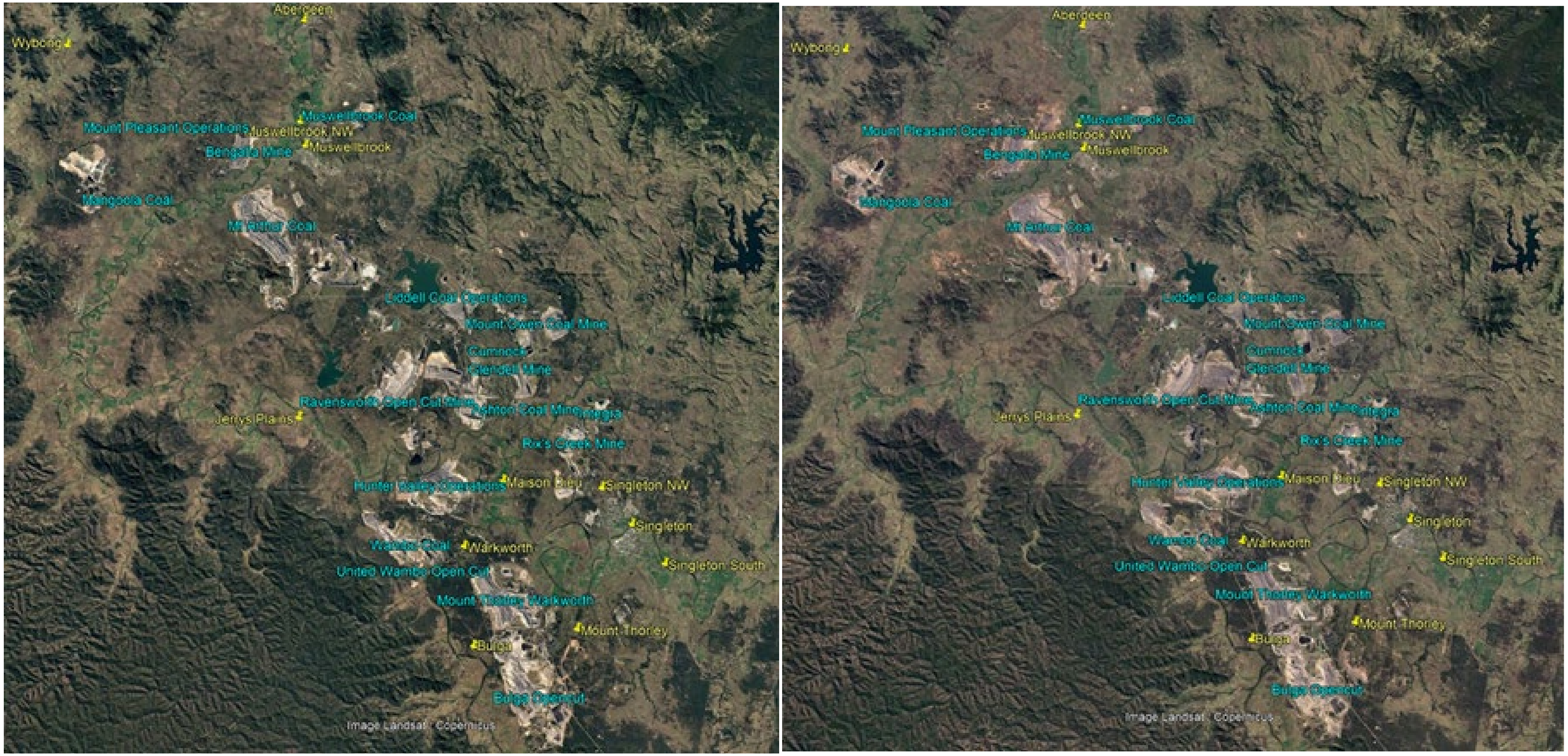


Figure 34 Satellite images of the Upper Hunter comparing the extent of mining operations in and 2016 (left) and 2020 (right)

Source: Google Earth maps, historical satellite imagery, accessed November 2021.

5. Feedback, findings and recommendations for improving the Upper Hunter air quality monitoring program

The Regulation (clause 95(2)(c) and (d)) requires the EPA to report recommendations for improvements to the Upper Hunter monitoring program or any other matters considered appropriate by the EPA or the Upper Hunter Air Quality Advisory Committee.

Key points

- The Upper Hunter Air Quality Advisory Committee (the advisory committee) members agreed that the monitoring program meets objectives 1 and 2, of providing reliable up-to-date information, to enable the air quality to be assessed against relevant air pollution standards. The committee members were divided in their opinions about whether the monitoring program meets objectives 3 and 4, to facilitate the identification of sources of air pollution and the development of strategies to improve air quality.
- Actions by the NSW Government in response to recommendations from the first 5-year review of the network included:
  - the EPA published fact sheets to raise community awareness about how to report a pollution event (EPA 2021c) and how the EPA regulates mines (EPA 2021a), and a infographic brochure describing what we have learned from the network about *Air quality in the Upper Hunter Valley* (DPIE 2019)
  - the Department of Planning and Environment (the department) launched a new interactive website on Upper Hunter air quality (see link in Section 6.2 – More information), accessible on mobile devices
  - the department developed an air quality API (DPE 2022a) to allow web users and developers to stream real-time data from the network, for use in business applications.
- Recommendations for ongoing improvement of the network monitoring program included:
  - the department to benchmark the network costs against similar networks
  - the EPA and the department to reinstate annual forecasting and reporting of network costs to advisory committee
  - the department to develop control documents for operation of the network that are specific to the Upper Hunter and separate from the whole NSW monitoring network, to streamline budget forecasting, reporting and review.

Feedback and recommendations are described in more detail below.

5.1 Feedback from stakeholders

5.1.1 Upper Hunter Air Quality Advisory Committee

The advisory committee is the forum for the EPA and the department to gather feedback and recommendations from members representing the range of stakeholders. Committee members represent the views of the general community, the coal and power generation industries, non-coal industries and local government in matters relating to the design of the network and the operation of the monitoring program (as noted above in Section 15 and in line the Regulation, clause 95(2)(d)).

The EPA invited committee members to participate in an online survey during December 2021 to provide feedback on the network and monitoring program. Participants indicated their preferences for sharing or not disclosing their responses. A summary of shared responses and comments is provided in Table 13.

Table 13 Summary of responses to online survey of the Upper Hunter Air Quality Advisory Committee

Item	Feedback from online survey on the Upper Hunter air quality program
1	Respondents represented industry and community.
2	Respondents viewed the online map of the network once a week, for up to 8 minutes.
3	Respondents searched the data up to 2 to 3 times per year.
4	Respondents were most interested in 8 to 14 monitoring stations.
5	All respondents ‘strongly agreed’ that the program met objectives 1 and 2, providing reliable and up-to-date information and assessing air quality against relevant air pollution standards.
6	Respondents were divided in opinions on whether the program met objective 3, facilitating the identification of sources of air pollution. Respondents either ‘agreed’ or ‘strongly disagreed’, or ‘neither agreed nor disagreed’.
7	Respondents were divided in opinions on whether the program met objective 4, facilitating the development and implementation of strategies to improve air quality. Respondents either ‘strongly agreed’ or ‘strongly disagreed’ or ‘disagreed’.
8	One respondent praised the ‘great improvement’ to the website, noting ‘information is easier to find and it is better presented’. One respondent had not noticed anything specific being done towards reaching the objectives, though liked the current reports to community (data, website, reports, alerts).
9	One respondent advised more could be done to respond to community feedback. For example, more resources are needed to investigate exceedances and causes of pollution.
10	One respondent recommended ‘Keep going. It’s a world leader, which not enough members of the community realise’.

Note: ‘Respondents’ refers only to those committee members who agreed to the publication of their responses.

5.1.2 Government mining compliance branch

The department's Planning and Assessment Compliance Branch supports the continuation of the network and monitoring program.

As described in Section 2.2.3 above, the branch uses network monitoring data in work practices related to the management of mining approvals and development applications and compliance with conditions of consent.

5.2 Findings of the review

5.2.1 Effectiveness of the Upper Hunter monitoring program in fulfilling its objectives

This review concluded that the evidence presented demonstrated that the Upper Hunter monitoring program was effective in meeting the objectives set by the Regulation.

In summary, the program's actions:

- provided reliable and up-to-date information on air quality in the Upper Hunter to communities, industry and government by online publishing of data in near real-time and analyses in the form of newsletters and statements
- assessed air quality against relevant standards by reporting air pollution status online in near real-time and in seasonal and annual publications
- facilitated the identification of sources of air pollution by analysing events where relevant standards are exceeded and reporting to the community in seasonal and annual publications
- facilitated the development and implementation of strategies to improve air quality in the Upper Hunter by providing the evidence base that supports programs to reduce particle emissions from mining activity and wood-fired domestic heaters.

The program is perceived by some community members as being less effective in fulfilling the objectives of facilitating the identification of sources of air pollution and the development of strategies to improve air quality (see Section 5.2.4).

The discussion in Section 2.4 and Section 2.5 presents evidence to demonstrate that the monitoring network has been fundamental in meeting objectives 3 and 4.

The review recommends action by the EPA and the department to better demonstrate to stakeholders how the government uses network data and the monitoring program as the evidence base that facilitates identification of sources of pollution and the development of strategies to improve air quality in the Upper Hunter.

5.2.2 Findings of the online survey of committee members

The online survey found that the advisory committee members agreed that the monitoring program met objectives 1 and 2, providing reliable air quality data, assessed regularly against relevant standards.

Some committee members questioned the effectiveness of programs to meet objectives 3 and 4, to facilitate identification of sources of pollution and the development of strategies to improve air quality in the Upper Hunter.

The findings of the online survey suggest that the network program could by improved by the following considerations:

- how to better demonstrate the identification of sources of air pollution
- how to better demonstrate the development and implementation of strategies of improve air quality
- how to better communicate the program's actions and achievements in meeting its objectives.

5.2.3 Results of an independent audit of the effectiveness and cost-efficiency of the program

The independent audit found that the network monitoring program:

- provides reliable and up-to-date information on air quality in the region
- allows for assessment of air quality against relevant standards
- remains valid regarding the sources of air pollution
- assists with development of air quality programs
- enables the reporting of regional air quality in both real time and in various department publications.

The audit found that, overall, the network remains cost-effective and noted a material increase in annual average operating expenses (24%) and labour costs (46%) in the financial years 2017 to 2021 compared to 2011 to 2016. The increase in costs was attributed to some costs in 2011 to 2013 being provided in-kind, while accounted for in 2017 to 2021.

The audit report made recommendations regarding cost management for the financial years 2022 to 2026 (see below).

5.2.4 Review of factors affecting network design

The review found minimal changes to 2021 in factors affecting the original design of the network in 2009 to 2010. No changes are recommended to the current network design.

- The population of the Upper Hunter increased by less than 1% during 2016 to 2021 and is predicted to remain stable to 2026.
- Strategic planning by local government shows buffer zones between future urban growth areas and mining activity, to minimise population exposure to poor air quality.
- The extent of coalmining activity expanded marginally from 2017 to 2021.

5.2.5 Responses to recommendations from 2016

Recommendations from the first 5-year review in 2017 (OEH 2017a) and the status of the response by the EPA and the department are presented in Table 14.

One of 6 recommendations is outstanding, 3 are progressing and 2 were implemented.

Table 14 Responses to recommendations from the first 5-year review, 2017

Item	Recommendations in 2016[a]	Responses in 2017 to 2021	Status
1	Consider benchmarking the cost of the network against others or competitively testing the work and including in the budget reports to the Upper Hunter Air Quality Advisory Committee (the advisory committee).	The cost-effectiveness of the network is independently reviewed as part of the 5-yearly review. The recommendation is noted for consideration in the next 5 years.	Outstanding
2	Consider a presentation on the previous year's network air quality results provided annually to the Muswellbrook and Singleton communities via a public forum.	The EPA continued to work with the advisory committee to develop better ways of communicating information on air quality to all relevant stakeholders. The EPA developed an Upper Hunter air quality communications strategy. As part of the strategy, the EPA and the advisory committee held a community drop-in event at Muswellbrook on 24 October 2019. Guided tours of the monitoring station were conducted. The EPA distributed materials developed for the day: • two fact sheets on how to report a pollution event to the EPA (EPA 2021c) and how the EPA regulates mines (EPA 2021a) • an infographic brochure on air quality in the Upper Hunter Valley (DPIE 2019). The next event will be held in Singleton (UHAQAC 2019).	Progressing
3	Work with councils to raise community awareness of air quality monitoring reporting.	The EPA continued to work with the advisory committee to develop better ways of communicating information on air quality to all relevant stakeholders. The EPA developed an Upper Hunter air quality communications strategy. As part of the strategy, a community drop-in event was held in Muswellbrook on 24 October 2019. The EPA distributed the brochure, *Air quality in the Upper Hunter Valley* (DPIE 2019) to Upper Hunter councils. Copies of the pocket-sized, fold-out brochure are available from the EPA. Content may be downloaded in A4 format. The next event will be held in Singleton.	Progressing
4	Better inform the community on changes of sources in the region by incorporating a comment on any new industry closures or approvals in each Upper Hunter annual report.	Changes in the mining footprint are reported in the 5-yearly review of the network. The recommendation is noted for implementation in future annual reports.	Progressing

Item	Recommendations in 2016[a]	Responses in 2017 to 2021	Status
5	Improve access for industry to the network's real-time data to aid them to incorporate these data into models or trigger response action plans in a suitable timeframe.	The department developed an air quality API (DPE 2022a) to allow web users and developers to stream real-time data from the network, for use in business applications. The department has also provided station-based data access via telemetry by interested mines.	Implemented
6	Consider setting guidelines around the longevity of monitors that are complementary or play an investigative role when they are implemented, to aid in removing redundant monitors once their specific purpose has been met.	The EPA has worked with mine operators to optimise monitoring by industry. Mines' environmental protection licences have been updated to establish monitoring at points upwind and downwind of active mining operations.	Implemented

a Source: OEH (2017a).

5.3 Recommendations for ongoing improvement

This report presents the following recommendations (Table 15) proposed by the independent audits and the advisory committee to ensure that the network continues to meet its objectives.

Table 15 Recommendations for improving the network and monitoring program

Number	Recommendations from the independent audit of the program effectiveness and cost-efficiency
1	Annual/seasonal air quality data reviews to be published within a shorter time after each period so that results may be used for progressive review of the network.
2	The Department of Environment and Planning (the department) to benchmark the network against comparable networks and develop key performance indicators for efficiency and cost-effectiveness to identify areas for innovation and improvement, and to provide a more quantitative basis for assessing the network in future audits.
3	The department to develop a formal operation and maintenance procedure manual that is specific for the Upper Hunter network and separate to the controlled documents for the whole NSW network. The manual should include a protocol for procuring new equipment and spare parts, and an inventory of spare parts and costs.
4	The department reinstate cost forecasting for the network, providing forecasts to the Upper Hunter Air Quality Advisory Committee (the advisory committee) and this be considered a priority. Forecasting would include estimates of levy costs to industry.
4a	Forecasting would provide an ongoing annual review process where estimated costs are shared with the advisory committee and industry for their feedback before finalising the estimate.
4b	Forecasting would enable industries to budget their annual levy cost contributions more accurately and would also provide transparency in accounting for any differences between forecast and actual costs.
4c	With regards to the 5-yearly reviews, in the event that any changes to the network are required, for example due to changes in mining locations or population centres, the consequential cost from such changes would form part of the annual cost forecasting.
	Recommendations following from the survey of the Upper Hunter Air Quality Advisory Committee
5	EPA and the department to better demonstrate the identification of sources of air pollution.
6	EPA and the department to better demonstrate the development and implementation of strategies to improve air quality.
7	EPA and the department to better communicate the network monitoring program’s actions and achievements in meeting its objectives.
8	EPA and the department to better investigate PM10 exceedances and causes of pollution events.
	Recommendations following from the first 5-year review in 2017
9	EPA and the department to plan annual presentations of the Upper Hunter annual air quality reports to a public or wider audience, in consultation with the advisory committee, especially local government representatives and in line with EPA Upper Hunter air quality communications strategy.
10	EPA and the department to incorporate information into the Upper Hunter annual air quality reports about any closures in industries or approvals of developments with emissions to air.

5.4 Conclusion

This review concluded that, based on the evidence presented in the report:

- the Upper Hunter monitoring program was effective in meeting the objectives set by the Regulation
- the design of the Upper Hunter Air Quality Monitoring Network remained valid for meeting the requirements of the Regulation.

The EPA and the department will consider the recommendations and formulate responses and actions in discussion with the Upper Hunter Air Quality Advisory Committee. Outcomes will be published in committee meeting minutes.

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6.1 Legislation

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Protection of the Environment Operations (General) Regulation 2021

Protection of the Environment Operations (General) Regulation 2009, historical version for 31 March 2017 to 18 May 2017, accessed 7 December 2017.

6.2 More information

- Bureau of Meteorology climate data online webpage
- Current air quality in Upper Hunter website (Air Quality), NSW Government website
- Google Earth maps webpage
- NATA website
- NSW Government air quality website
- Population projections webpage, NSW Government
- Subscribe to air quality updates, NSW Government website
- Upper Hunter Air Quality Advisory Committee website
- Upper Hunter air quality monitoring data analysis project

- Upper Hunter air quality monitoring reports, including annual reports and seasonal newsletters
- Upper Hunter map webpage (DPIE), NSW Government website