Delivering dependable air quality science to Newcastle communities

Four–year review of the Newcastle Local Air Quality Monitoring Network

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Office of Environment and Heritage
59 Goulburn Street, Sydney NSW 2000
PO Box A290, Sydney South NSW 1232
Phone: +61 2 9995 5000 (switchboard)
Phone: 1300 361 967 (OEH and national parks enquiries)
TTY users: phone 133 677, then ask for 1300 361 967
Speak and listen users: phone 1300 555 727, then ask for 1300 361 967
Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au

Report pollution and environmental incidents
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Contents

List of tables iv

List of figures v

Executive summary vii

1. The Newcastle Local Air Quality Monitoring Network 1
   - 1.1 Why was the Network established? 1
   - 1.2 What are the objectives of the Network? 1
   - 1.3 Who is responsible for the Network? 1
   - 1.4 What is the Network? 2
   - 1.5 When was the Network established? 3
   - 1.6 Legislative reporting requirements 4
   - 1.7 Aims of the review 4
   - 1.8 Report structure 4
2. Learnings since the establishment of the Newcastle Local Air Quality Monitoring Network 5
   - 2.1 Network performance 5
   - 2.2 Assessment of regional air quality and meteorology 6
   - 2.3 Emission sources within the region 17
3. How have the Newcastle Local Air Quality Monitoring Network data been used? 33
   - 3.1 Provision of air quality data and information to the community 33
   - 3.2 Air quality research projects and initiatives 34
   - 3.3 Newcastle Local data used by external users 36
   - 3.4 Future potential uses for the NLAQMN data 37
4. Review findings 38
   - 4.1 Is the monitoring program effective in fulfilling its objectives? 38
   - 4.2 Is the Network being run efficiently and cost-effectively? 39
   - 4.3 Can the monitoring program be improved? 45
   - 4.4 Are there any additional matters to consider in relation to the program? 48

References 51

List of tables

Table 1 Online time (%) of particle and wind data from their start date to the end of 2017 5

Table 2 Online time (%) of NO_2, SO_2 and NH_3 data from their start date to the end of 2017 5

Table 3 National ambient air quality standards (also referred to as national benchmarks in this report) and goals for particles (as PM_{10} and $PM_{2.5}$), SO_2 and NO_2 6

Table 4 National Pollutant Inventory PM_{10} emissions by top 10 source categories for the Newcastle LGA – changes from 2013–14 to 2016–17 20

Table 5 National Pollutant Inventory PM_{10} emissions at major industrial facilities in the Newcastle LGA – changes from 2013–14 to 2016–17 21

Table 6 National Pollutant Inventory $PM_{2.5}$ emissions by source categories in the Newcastle LGA – changes from 2013–14 to 2016–17 24

Table 7 National Pollutant Inventory $PM_{2.5}$ emissions at major industrial facilities in the Newcastle LGA – changes from 2013–14 to 2016–17 25

Table 8 National Pollutant Inventory NO_X emissions by top 10 source categories in the Newcastle LGA – changes from 2013–14 to 2016–17 28

Table 9 National Pollutant Inventory NO_X emissions at major industrial facilities in the Newcastle LGA – changes from 2013–14 to 2016–17 29

Table 10 National Pollutant Inventory SO_2 emissions by top 10 source categories in the Newcastle LGA – changes from 2013–14 to 2016–17 31

Table 11 National Pollutant Inventory SO_2 emissions at major industrial facilities in the Newcastle LGA – changes from 2013–14 to 2016–17 32

Table 12 Total OEH capital and operating costs from financial years 2014 to 2017 39

Table 13 Recommendations of the independent audit of the efficiency and cost-effectiveness of the Newcastle Local air quality monitoring program 41

Table 14 Population in the inner city and portside suburbs of Newcastle LGA and Fern Bay in Port Stephens LGA 47

List of figures

Figure 1 Newcastle Local and Lower Hunter air quality monitoring station locations 2

Figure 2 Screenshot of the map on the OEH Newcastle near real-time air quality monitoring data webpage 3

Figure 3 Number of days above the daily PM_{10} and $PM_{2.5}$ benchmarks in the Newcastle region from 2015 to 2017 8

Figure 4 PM_{10} and $PM_{2.5}$ annual averages in the Newcastle region from 2015 to 2017 8

Figure 5 Number of days over the PM_{10} daily benchmark by station for all NSW regions from 2015 to 2017 9

Figure 6 Number of days over the PM_{10} daily benchmark by station for all Hunter regions from 2015 to 2017 10

Figure 7 Number of days over the $PM_{2.5}$ daily benchmark by station for all NSW regions from 2015 to 2017 (at those sites where data are available since 2015) 10

Figure 8 PM_{10} annual averages by station for all NSW regions from 2015 to 2017 11

Figure 9 PM_{10} annual averages by station for all Hunter sites from 2015 to 2017.. 11

Figure 10 $PM_{2.5}$ annual averages by station for all NSW regions from 2015 to 2017 12

Figure 11 Maximum hourly average SO_2 for all NSW regions from 2015 to 2017.... 12

Figure 12 Maximum hourly average NO_2 for all NSW regions from 2015 to 2017.... 13

Figure 13 Total number of days per month over the PM_{10} daily benchmark at Newcastle region stations from 2015 to 2017 14

Figure 14 Total number of days per month over the $PM_{2.5}$ daily benchmark at Newcastle region stations from 2015 to 2017 14

Figure 15 Newcastle region wind rose map from 2015 to 2017 15

Figure 16 Seasonal wind roses using pooled wind data from the Newcastle Local sites (Carrington, Mayfield and Stockton) from 2015 to 2017........ 15

Figure 17 Carrington (top), Mayfield (middle) and Stockton (bottom) pooled hourly average wind speed plots from 2015 to 2017, by season 16

Figure 18 Monthly maximum and minimum hourly temperatures for Newcastle Local sites (Carrington, Mayfield and Stockton) from 2015 to 2017........ 16

Figure 19 Bureau of Meteorology Newcastle Nobbys AWS maximum and average monthly rainfall from 2015 to 2017 17

Figure 20 Locations of major industrial facilities and air quality monitoring stations in the Newcastle LGA port and in inner city areas 18

Figure 21 National Pollutant Inventory PM_{10} emissions by top 10 source categories for the Newcastle LGA in 2013–14 and 2016–17........ 19

Figure 22 National Pollutant Inventory PM_{10} emissions at major industrial facilities in the Newcastle LGA 2013–14 to 2016–17........ 21

Figure 23 Percentage annual average contributions to total $PM_{2.5-10}$ mass at Mayfield and Stockton from March 2014 to February 2015 22

Figure 24 Monthly and annual factor contributions to $PM_{2.5-10}$ at Mayfield and Stockton 23
Figure 25 National Pollutant Inventory $PM_{2.5}$ emissions by source categories in the Newcastle LGA for 2013–14 and 2016–17 24
Figure 26 National Pollutant Inventory $PM_{2.5}$ emissions at major industrial facilities in the Newcastle LGA 2013–14 to 2016–17 25
Figure 27 Percentage annual average contributions to total $PM_{2.5}$ mass at Mayfield and Stockton from March 2014 to February 2015 26
Figure 28 Monthly and annual factor contributions to $PM_{2.5}$ at Mayfield and Stockton 27
Figure 29 National Pollutant Inventory NO_X emissions by top 10 source categories for the Newcastle LGA in 2013–14 and 2016–17 28
Figure 30 National Pollutant Inventory NO_X emissions at major industrial facilities in the Newcastle LGA from 2013–14 to 2016–17 29
Figure 31 National Pollutant Inventory SO_2 emissions by top 10 source categories for the Newcastle LGA in 2013–14 and 2016–17 30
Figure 32 National Pollutant Inventory SO_2 emissions at major industrial facilities in the Newcastle LGA from 2013–14 to 2016–17 31
Figure 33 Unique page views for the NLAQMN map website from 2015 to 2017 33
Figure 34 Map showing the expansion in residential development (green rectangle) north and north-east of the originally proposed Fern Bay site from August 2014 (top) to December 2017 (bottom) 43
Figure 35 Location map showing inner city and portside suburbs in Newcastle LGA and Fern Bay in Port Stephens LGA 47

Executive summary

The Newcastle Local Air Quality Monitoring Network

The Newcastle Local Air Quality Monitoring Network (NLAQMN; also referred to as 'the Network' in this report) is a high-quality, regional air quality monitoring network that continuously measures airborne particles, gaseous pollutants and meteorological parameters.

The Network consists of three monitoring stations at Carrington, Mayfield and Stockton (Figure 1). These stations complement the monitoring sites operated by the NSW Office of Environment and Heritage (OEH) at Beresfield, Newcastle and Wallsend in the Lower Hunter region.

The Network was established during 2014, as a partnership between the NSW Government and Newcastle industries. It is maintained by OEH, administered by the NSW Environment Protection Authority (EPA) and funded by Newcastle industries, in accordance with the Protection of the Environment Operations (General) Regulation 2009 ('the Regulation').

The Regulation specifies that the objectives of the Network and the monitoring program are to provide government, industry and the community with reliable and up-to-date information on air quality in Newcastle that assists in assessing changes in air quality and identifying the major sources of monitored pollutants.

The Regulation required the EPA to review the Network in 2018 and then every four years. This report, by OEH on behalf of the EPA, is the first review of the Network, covering the initial years of operation from August 2014 to December 2017.

Review conclusions

- The extensive data collected by the Network have provided a better understanding of the air quality and meteorology within the Port of Newcastle and inner city suburbs.
- The objectives of the monitoring program are being met, providing stakeholders with reliable and up-to-date Network data which are regularly assessed against air quality standards.
- Sources of pollution impacting the Port of Newcastle area continue to be identified. The air quality data and emerging trends provide community and policy investigators with a growing evidence base for developing and implementing strategies to improve air quality in the region.
- The Network runs efficiently and cost-effectively.
- The minimal change in population distribution, emission sources, topography and meteorology since 2014, validates maintaining the original network design.

Recommendations to ensure ongoing improvement to the Network

This report recommends OEH and the EPA continue to work with the Newcastle Community Consultative Committee on the Environment (NCCCE) to ensure ongoing improvement of the Network monitoring program.

Prior to the next review in 2022, OEH and the EPA will consider and develop better ways of communicating information on air quality with all relevant stakeholders, including improved content available to users of mobile devices.

The findings of the review are discussed in detail in the report.

1. The Newcastle Local Air Quality Monitoring Network

This section introduces the Newcastle Local Air Quality Monitoring Network (NLAQMN), also referred to as 'the Network' or as an air quality monitoring program, as defined in the Protection of the Environment Operations (General) Regulation 2009 ('the Regulation').

1.1 Why was the Network established?

The NLAQMN was established to provide government, industry and the community with credible, reliable and up-to-date information about air quality and trends in air quality within the Port of Newcastle.

This 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.

Information from the Network helps to guide specific investigations into the questions raised by the data, such as those about the distribution of particles and the components making up the fine particle fraction of the particle mix. This information helps NSW Government agencies to develop further monitoring and compliance programs to improve Newcastle air quality.

1.2 What are the objectives of the Network?

The NLAQMN is operated in accordance with Chapter 5A of the Regulation.

The objectives of the Newcastle Local monitoring program are specified under the Regulation, as follows:

> **79O Objectives**
>
> The objective of the monitoring program is to provide government, industry and the community with:
>
> (a) reliable and up-to-date information on air quality in Newcastle, and
>
> (b) information that is of assistance in assessing changes in air quality and identifying the major sources of monitored pollutants.

1.3 Who is responsible for the Network?

The NLAQMN is a partnership between the NSW Government and Newcastle local industries. The sites are operated and maintained by the NSW Office of Environment and Heritage (OEH) using industry contributed funds under Chapter 5A of the Regulation.

The Newcastle Community Consultative Committee on the Environment (NCCCE) advises the NSW Environment Protection Authority (EPA) and OEH on matters specifically related to the design and operation of the Network. The NCCCE has 10 members representing the community, local industries, local government and NSW Government agencies. More information about the committee is available on the EPA Newcastle Community Consultative Committee on the Environment webpage.

To ensure high-quality data are available from the Network, specialist OEH staff undertake regular maintenance, auditing and quality assurance of the monitoring stations, measuring equipment and data collected.

1.4 What is the Network?

The NLAQMN is a high-quality, regional air quality monitoring network that continuously measures particles, meteorology and gases in ambient air in the Newcastle region. The Network consists of three monitoring stations in the Port of Newcastle at Carrington, Mayfield and Stockton. These sites complement the longer-term OEH Lower Hunter Air Quality Monitoring Network (LHAQMN) sites at Beresfield, Newcastle and Wallsend.

The locations of the NLAQMN sites are shown in Figure 1. Further site details are available on the OEH Lower Hunter and Central Coast air quality monitoring stations webpage.

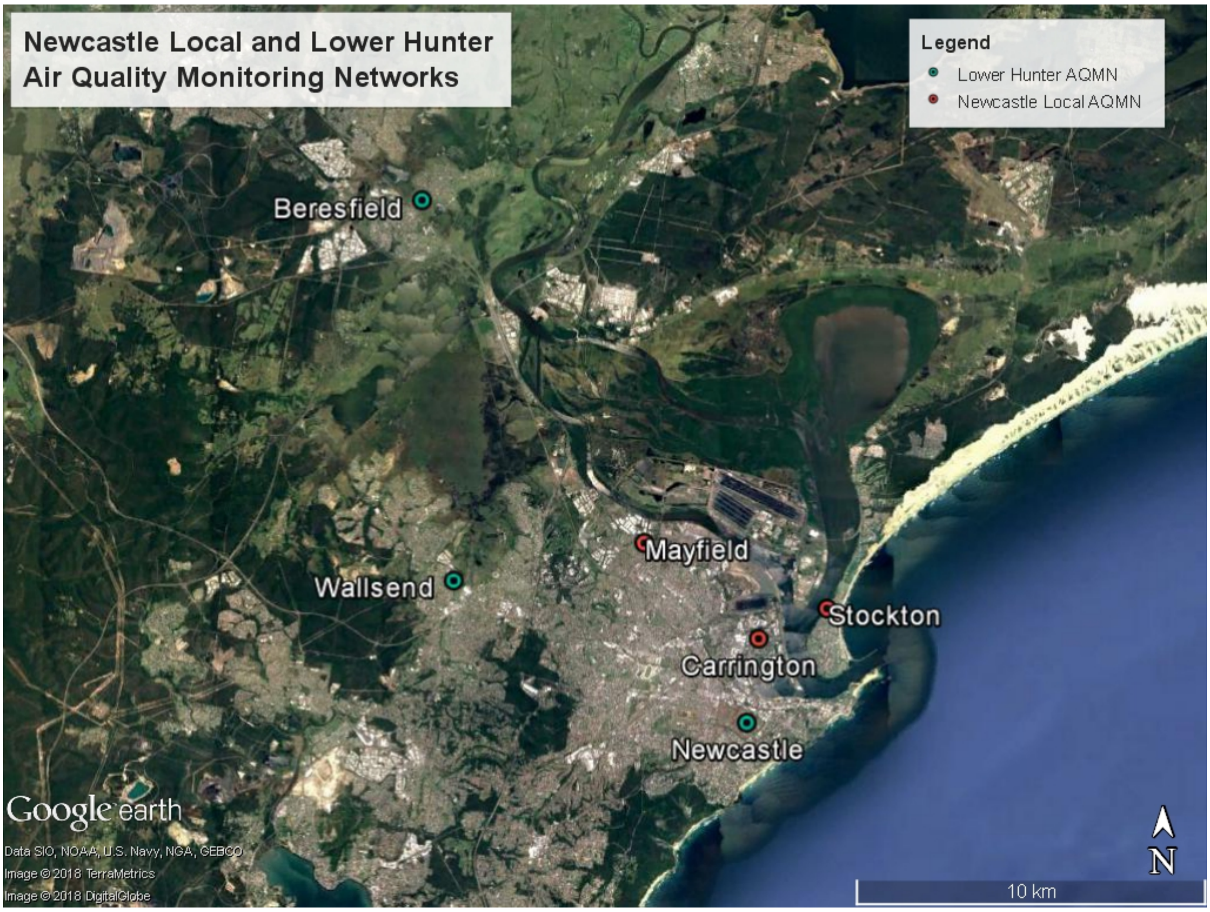

Figure 1 Newcastle Local and Lower Hunter air quality monitoring station locations

The Network provides the community with hourly updates on current air quality in near real-time via OEH's Newcastle Local Air Quality Monitoring Network – Map webpage (Figure 2). The monitoring sites are linked to a central database, from where the data are uploaded hourly to the OEH website.

The Network continuously measures:

- particulate matter PM_{10} (particles less than or equal to 10 micrometres in diameter) and finer particulate matter $PM_{2.5}$ (particles less than or equal to 2.5 micrometres in diameter) at all three monitoring sites
- the gases sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) at all three monitoring sites
- the gas ammonia (NH_3) at Stockton
- wind speed, wind direction, temperature and humidity at all three monitoring sites
- solar radiation at Mayfield.

The location of sites in the Network was based on independent recommendations made by PAE Holmes (2011). These recommendations considered population distribution, location of major emission sources, topography, predominant meteorological conditions and the spatial distribution of predicted PM_{10} impacts. The study anticipated the greatest impacts associated with local industry would occur within the region of the port, therefore giving priority to suburbs with higher population densities within the port area.

OEH assessed potential locations for monitoring sites, in accordance with Australian Standard AS/NZS 3580.1.1:2016 (Standards Australia 2016). The specific locations of the three monitoring sites at Carrington, Mayfield and Stockton were determined by OEH and the EPA, in consultation with the NCCCE.

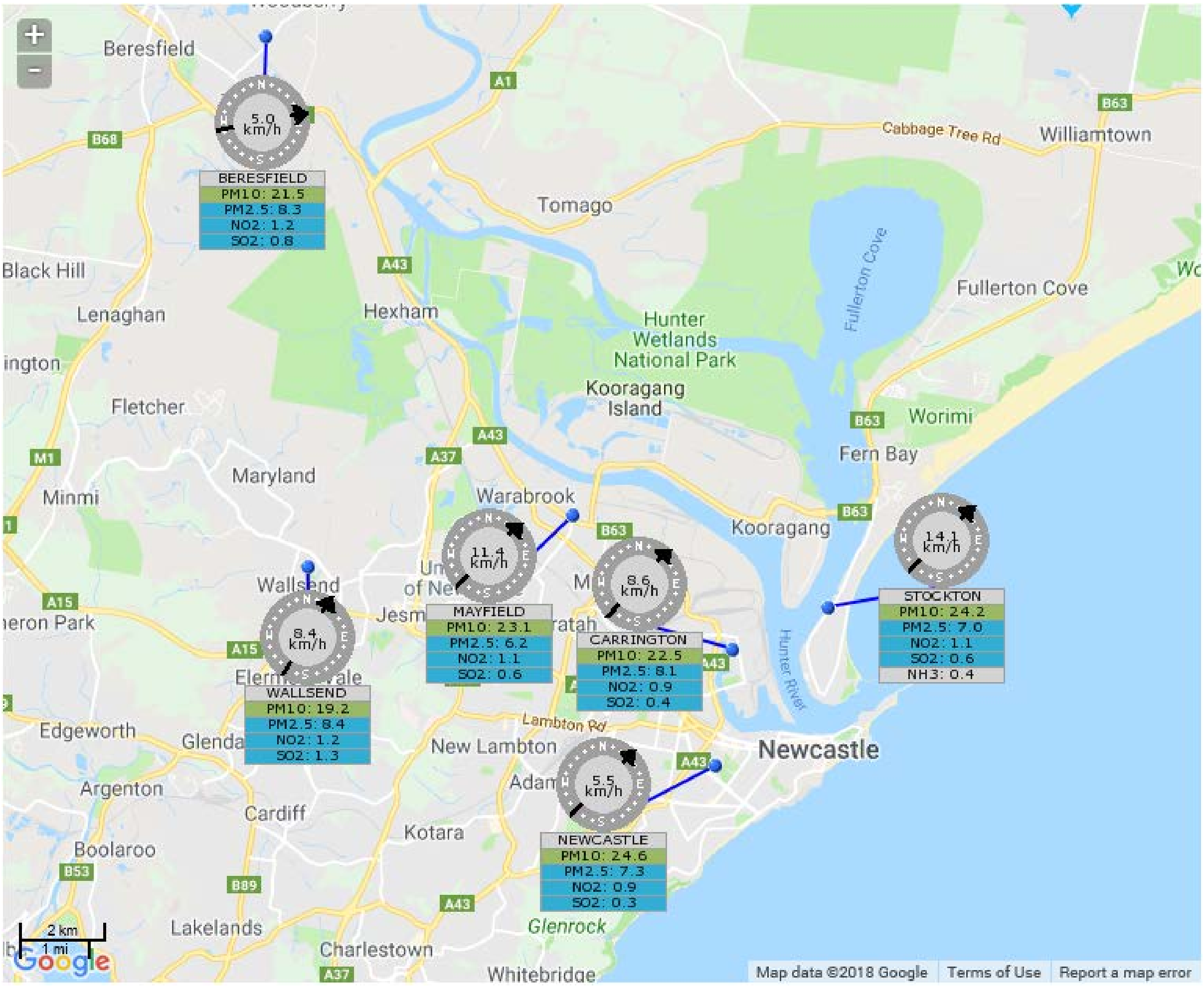

Figure 2 Screenshot of the map on the OEH Newcastle near real-time air quality monitoring data webpage

1.5 When was the Network established?

The Network was fully established by October 2014, with the Mayfield and Carrington stations online in August 2014. The Stockton station, established by industry in October 2012, became part of the OEH-operated network in October 2014. This provides three complete years of data from these stations, from 2015 to 2017.

Table 1 and Table 2 (in Section 2) provide the start dates for the particle and gaseous data respectively, at each site in the Network.

1.6 Legislative reporting requirements

Under the Regulation, the EPA is required to report on the Newcastle Local monitoring program. The Regulation defines the Newcastle Local monitoring program as follows:

> 'monitoring program' means the environmental monitoring program operated by or on behalf of the EPA that monitors air quality in Newcastle and is known as the Newcastle Local Air Quality Monitoring Network, and includes any changes made by the EPA to that program from time to time.

Specifically, the Regulation states:

> **79V EPA to publish results of monitoring**
>
> The EPA is to make the results of the air quality monitoring carried out under the monitoring program available on its website.
>
> **79W EPA to report on monitoring program**
>
> (1) The EPA is to prepare a report containing the following matters in relation to the monitoring program:
>
> (a) a review of the effectiveness of the monitoring program in fulfilling its objectives,
>
> (b) the results of an independent audit (to be arranged by the EPA) of the efficiency and cost effectiveness of the monitoring program,
>
> (c) any recommendations for improvements to the monitoring program,
>
> (d) any other matters that the EPA considers appropriate or that an advisory committee established to advise the EPA in relation to the monitoring program considers appropriate.
>
> (2) The report is to be prepared by 1 September 2018 and then by 1 September every fourth year after that.
>
> (3) Each report is to be made available on the EPA's website.

This review by OEH was undertaken to fulfil the EPA's requirement to report on the Newcastle Local monitoring program following its first four years of operations (section 79W of the Regulation).

1.7 Aims of the review

The review sets out to answer the following questions:

- Have the objectives of the monitoring program been met?
- Is the program being run efficiently and cost-effectively?
- Can the monitoring program be improved?
- Are there any additional matters to consider in relation to the program?

1.8 Report structure

The review is structured to address the following:

- the air quality and meteorology data collected by the Network since 2014 and any emerging trends (Section 2)
- how the data have been used and how the Network has assisted in assessing changes in air quality, identifying major sources of air pollutants, and reducing emissions (Section 3)
- the findings from an independent audit of the efficiency and cost-effectiveness of the Network (Section 4.2)
- any changes in the drivers of the Network's design, namely, population distribution, emission sources, topography and meteorology (Section 4.3)
- feedback from stakeholders in the community, industry and government agencies (Section 4.4).

2. Learnings since the establishment of the Newcastle Local Air Quality Monitoring Network

This section discusses the air quality and meteorology of the Newcastle Local region. Since the establishment of the NLAQMN, an extensive and valuable set of air quality and meteorological data has been collected. These data have been used to assess air quality levels against national standards and other regions in New South Wales, determine air quality trends, evaluate meteorological conditions conducive to air pollution, and identify sources of air pollutants within the region.

2.1 Network performance

A network of complex scientific instruments requires regular maintenance and calibration. OEH maintenance and calibration schedules for the NLAQMN comply with the relevant Australian standards for servicing the equipment and ensure that data provided to the community are accurate and timely (OEH 2018). Maintenance and calibration tasks require about 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 the commencement of the program. Valid and accurate particle and meteorological data are available for more than 97% of the total operational time at all monitoring sites, since their establishment (Table 1). For the gaseous parameters, the Network has achieved close to this threshold, with at least 92% valid data availability (Table 2). Due to scheduled daily calibrations, the maximum online time that can be attained for NO_2 and SO_2 data is 96%.

Table 1 Online time (%) of particle and wind data from their start date to the end of 2017

	Particles			Meteorology[a]	
Station	Start date when both PM_{10} and $PM_{2.5}$ online	PM_{10} daily	$PM_{2.5}$ daily	Wind hourly	Temperature / humidity hourly
Carrington	05/08/2014	99	97	98	99
Mayfield	01/08/2014	99	98	99	99
Stockton	29/10/2014	97	98	99	100

[a] The start dates for some meteorological parameters vary from those of the particle data.

Table 2 Online time (%) of NO_2, SO_2 and NH_3 data from their start date to the end of 2017

Station	Start date	Gases NO_2 hourly	Gases SO_2 hourly	Gases NH_3 hourly
Carrington	02/08/2014	93	94	–
Mayfield	30/07/2014	94	95	–
Stockton	30/10/2014	92	94	92

– = not monitored

The seasonal percentage online times from autumn 2015 to summer 2017–18 are published in the Newcastle air quality monitoring network seasonal newsletters on the OEH website.

2.2 Assessment of regional air quality and meteorology

2.2.1 Air quality levels compared with national standards

The National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM) sets standards for levels of PM_{10}, $PM_{2.5}$, NO_2 and SO_2 at air quality monitoring sites near population centres (Table 3).

Table 3 National ambient air quality standards (also referred to as national benchmarks in this report) and goals for particles (as PM_{10} and $PM_{2.5}$), SO_2 and NO_2

Pollutant	Averaging period	Standard (concentration) [a b]	Goal: How often can the standard be exceeded?
Particles as PM_{10}	Daily: 1 calendar day (24 hours)	50 µg/m^3	Never [c]
Particles as PM_{10}	Annual: 1 calendar year (12 months)	25 µg/m^3	Never
Particles as $PM_{2.5}$	Daily: 1 calendar day (24 hours)	25 µg/m^3	Never [c]
Particles as $PM_{2.5}$	Annual: 1 calendar year (12 months)	8 µg/m^3	Never
Sulfur dioxide (SO_2)	Hourly	20 pphm	Maximum 1 day per year
Sulfur dioxide (SO_2)	Daily: 1 calendar day (24 hours)	8 pphm	Maximum 1 day per year
Sulfur dioxide (SO_2)	Annual: 1 calendar year (12 months)	2 pphm	Never
Nitrogen dioxide (NO_2)	Hourly	12 pphm	Maximum 1 day per year
Nitrogen dioxide (NO_2)	Annual: 1 calendar year (12 months)	3 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).

[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. The AAQ NEPM defines an exceptional event as a fire or dust occurrence that adversely affects air quality at a particular location, and causes an exceedance of 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.

The AAQ NEPM and the World Health Organization do not set health standards or guidelines for ambient ammonia (NH_3). In the absence of an Australian standard, OEH uses an hourly assessment goal of 46 pphm, based on the NSW EPA impact assessment criterion for individual toxic air pollutants (*Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales*; NSW EPA 2017).

The NSW Government operates a network of over 80 air quality monitoring stations across the metropolitan area, regional cities and rural areas. Currently, OEH reports annually to the Australian Government on compliance with AAQ NEPM standards at 22 air quality monitoring stations representative of regional population exposures. The LHAQMN sites at Newcastle, Wallsend and Beresfield form part of the NSW Government's AAQ NEPM compliance monitoring sites.

The NLAQMN sites were established specifically to monitor air quality impacts from industry, port activity and transport in the inner city and Port of Newcastle. OEH understands the community's interest in assessing data from the Network against the ambient air quality standards and against other monitoring sites in New South Wales. Therefore, OEH uses the standards as **benchmarks** for reporting data from the Network to the community and for understanding data trends.

The following discussion compares air quality at NLAQMN sites against the benchmarks (i.e. levels of relevant national standards). It also compares air quality against the long-term stations in the Lower Hunter and other NSW regions in OEH's NSW air quality monitoring network. Air quality levels recorded at Stockton, Carrington and Mayfield can be expected to be higher than levels recorded at the compliance air quality monitoring stations at Newcastle, Beresfield and Wallsend, due to their proximity to anthropogenic and natural emission sources.

Particulate matter

From the establishment of the Network in 2014 to the end of 2017, PM_{10} and $PM_{2.5}$ particle levels at all three sites were below the daily benchmarks for 83.5% and 99.4% of days, respectively.

In this review, the analysis of the Network's exceedances of PM_{10} and $PM_{2.5}$ benchmarks included exceptional events related to bushfires, hazard reduction burns or dust storms. Annual comparisons focus on the calendar years 2015 to 2017. As noted above (Section 1.5), the Carrington and Mayfield sites were established in August 2014 and the Stockton site became part of the Network in October 2014.

Particle levels compared with daily benchmarks

In the initial period of operations to December 2014, the Network recorded exceedances of the PM_{10} daily benchmark on three days at Carrington and Mayfield and 18 days at Stockton. $PM_{2.5}$ levels were below the daily benchmark, except on one day at Stockton.

Figure 3 shows that all Newcastle Local and Lower Hunter sites recorded elevated particle levels during 2015 to 2017; however, the number of days with particle levels over the daily benchmarks varied across the sites.

Stockton consistently recorded the highest number of days over the PM_{10} daily benchmark compared to other sites in the region (Figure 3). The total number of days over the PM_{10} benchmark remained similar each year with 60 to 67 days over the benchmark from 2015 to 2017. The Stockton monitoring station is located approximately 300 metres from the coast. The Lower Hunter Particle Characterisation Study (LHPCS; Hibberd et al. 2016a) found sea salt to be a major contributor to particles at Stockton, particularly during the warmer months.

Other sites in the Newcastle Local and Lower Hunter networks recorded between one and 10 days over the PM_{10} benchmark from 2015 to 2017. Sites nearest the port generally recorded the highest number of days over the PM_{10} benchmark compared to the other sites in the region (Figure 3). Most exceedance days were affected by bushfires and dust storms.

The $PM_{2.5}$ daily benchmark was exceeded on six days in 2015 and one day in 2016 and 2017 (Figure 3). Days over the $PM_{2.5}$ benchmark were due to bushfires and hazard reduction burns, except for three days at Stockton under north-west winds in winter 2015. The LHPCS found that Stockton $PM_{2.5}$ levels in winter were mainly influenced by primary[1] ammonium nitrate particles emitted from industry, approximately one kilometre to the north-west, on Kooragang Island (Hibberd et al. 2016a).

[1] Primary pollutants are emitted directly into the air from a source. Secondary pollutants form in the air by chemical reactions between gases or between gases and particles.

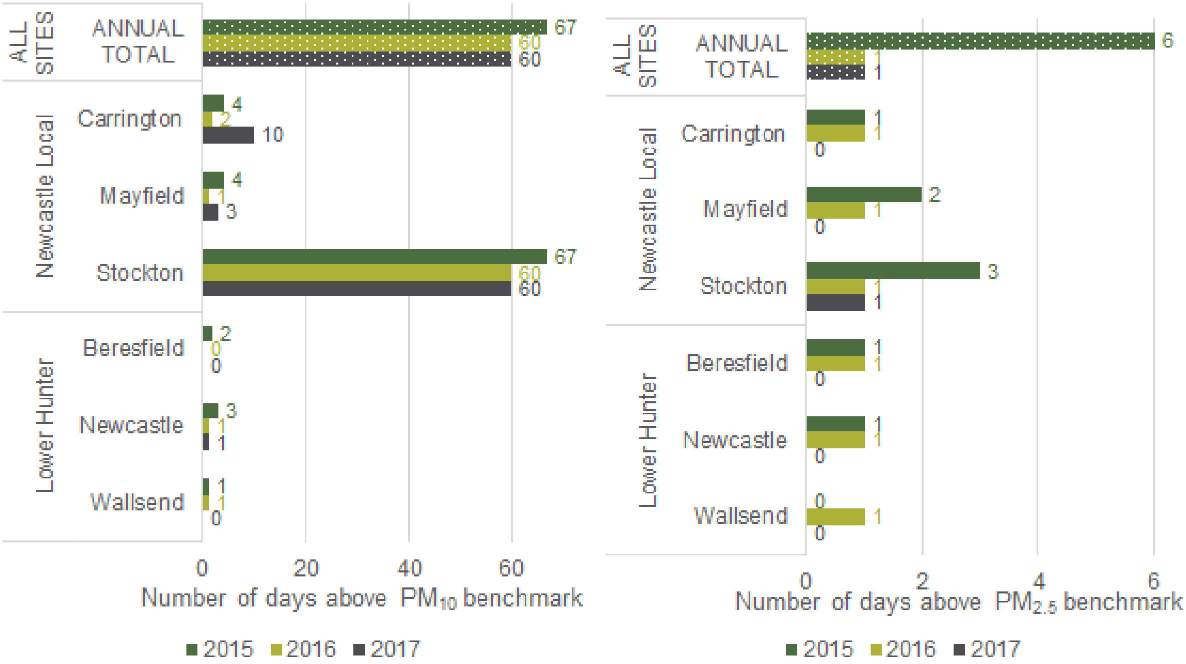

Figure 3 **Number of days above the daily PM_{10} and $PM_{2.5}$ benchmarks in the Newcastle region from 2015 to 2017**

Particle levels compared with annual benchmarks

Annual PM_{10} concentrations increased marginally from 2015 to 2017 at all sites in the Newcastle region. PM_{10} annual average concentrations remained below the benchmark at all sites except Stockton, due mainly to the contribution of sea salt (Figure 4).

Annual $PM_{2.5}$ concentrations exceeded the benchmark each year at Carrington and Stockton (Figure 4). The LHPCS found that compared to Newcastle, Mayfield and Beresfield, higher annual average $PM_{2.5}$ concentrations at Stockton were due to sea salt and primary ammonium nitrate particles emitted directly from industry (Hibberd et al. 2016a).

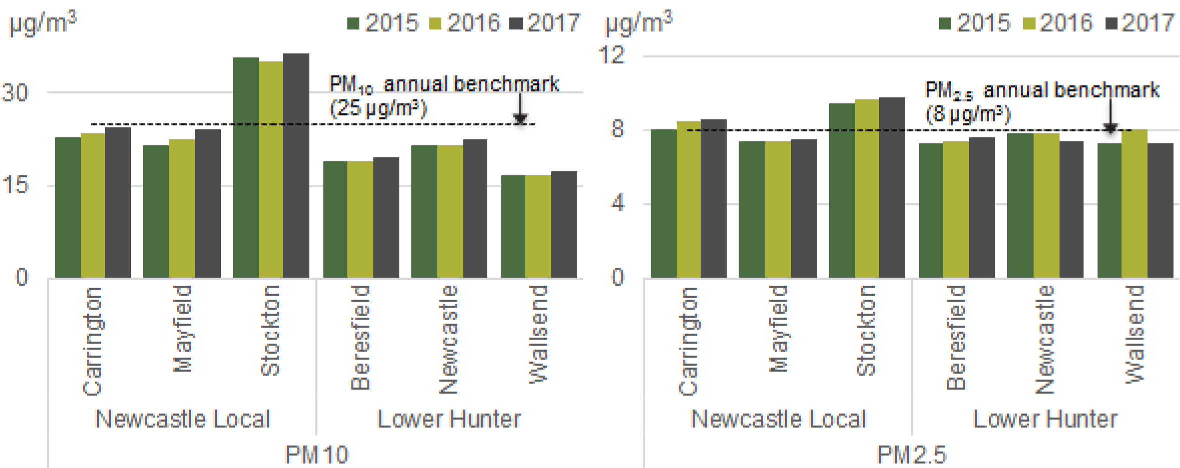

Figure 4 **PM_{10} and $PM_{2.5}$ annual averages in the Newcastle region from 2015 to 2017**

Gaseous parameters

Concentrations of NO_2 and SO_2 have remained below the relevant national benchmarks at all sites since the establishment of the Network.

Concentrations of NH_3 have remained below the NSW EPA impact assessment goal since the establishment of the OEH Stockton monitoring station in October 2014. Prior to this, there were two hours that exceeded the assessment goal, on 14 July 2013 and 22 August 2013, when the site was operated by Orica (from October 2012 to October 2014).

2.2.2 Air quality levels compared with other regions in New South Wales

Particulate matter

Daily PM_{10} levels compared with other regions

Figure 5 shows the number of days over the PM_{10} daily benchmark at the Newcastle Local sites compared with other NSW regions, including the Upper Hunter major population centres, from 2015 to 2017. This shows that from 2015 to 2017:

- Stockton recorded the highest annual number of days over the PM_{10} daily benchmark (67 days in 2015), with air quality affected by sea salt under onshore flows.
- Wagga Wagga recorded the second highest total number of days over the PM_{10} benchmark (33 days), where air quality was predominantly affected by agricultural burning.
- Carrington recorded the third highest total number of days over the PM_{10} benchmark (16 days), where at least nine days were affected by hazard reduction burns, fires or long-range dust storms. Carrington is also likely to be impacted by sea salt[2].

The number of days over the PM_{10} benchmark at Carrington and Mayfield from 2015 to 2017 was comparable to the smaller community sites in the Upper Hunter region (Figure 6).

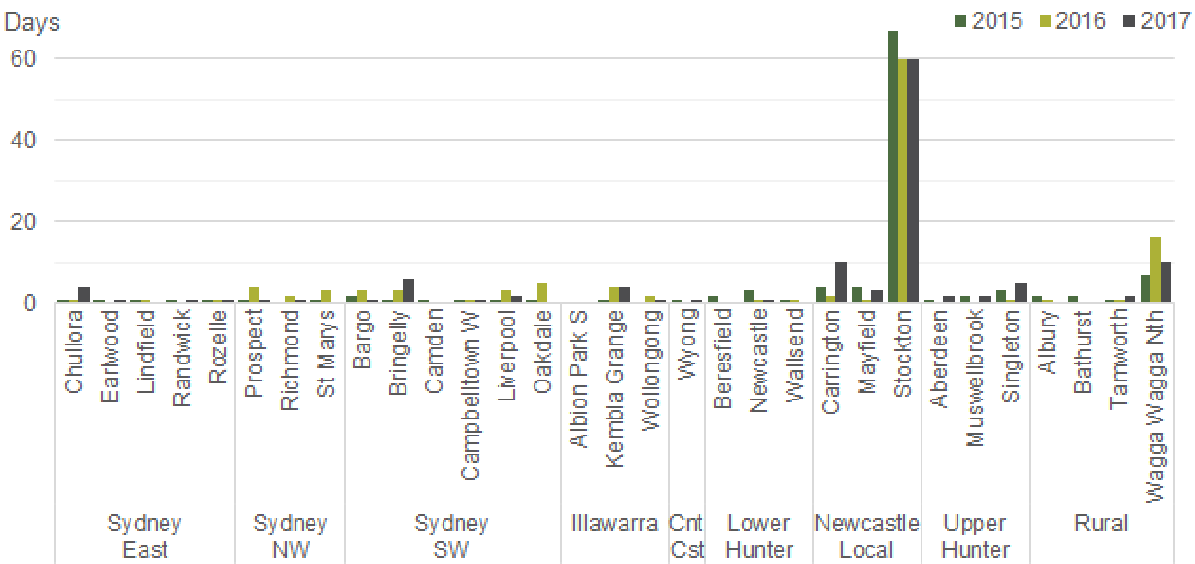

Figure 5 Number of days over the PM_{10} daily benchmark by station for all NSW regions from 2015 to 2017

[2] The LHPCS found that sea salt contributed 40% of the $PM_{2.5-10}$ at Mayfield. Carrington is closer to the coast than Mayfield.

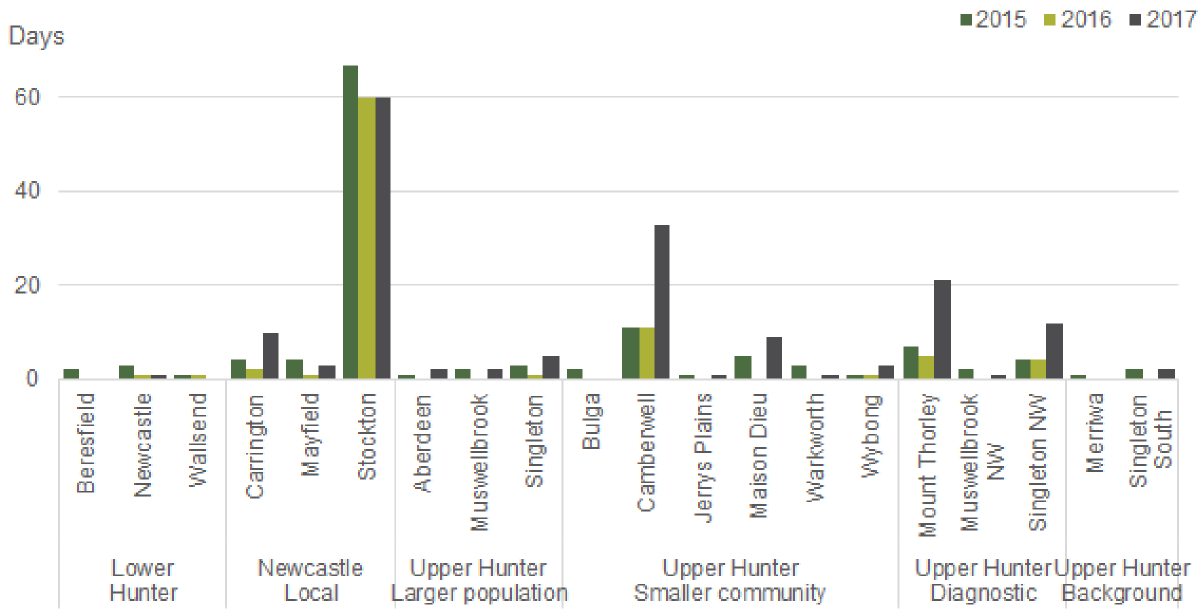

Figure 6 Number of days over the PM_{10} daily benchmark by station for all Hunter regions from 2015 to 2017

Daily $PM_{2.5}$ levels compared with other regions

Figure 7 compares the number of days over the $PM_{2.5}$ benchmark at all NSW AQMN sites. The Newcastle Local region recorded fewer days over the $PM_{2.5}$ daily benchmark than many sites in the NSW monitoring network, particularly compared to Sydney.

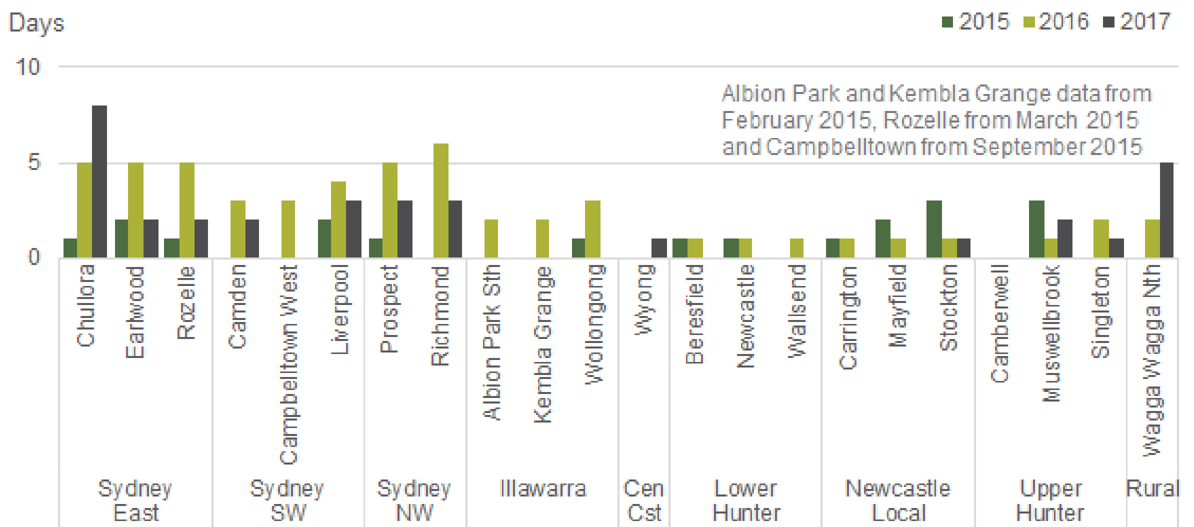

Figure 7 Number of days over the $PM_{2.5}$ daily benchmark by station for all NSW regions from 2015 to 2017 (at those sites where data are available since 2015)

Annual PM_{10} levels compared with other regions

Figure 8 shows the annual average levels of PM_{10} at the Newcastle Local sites compared with other NSW regions, including the Upper Hunter major population centres. Annual PM_{10} levels in the Newcastle region were among the highest in New South Wales (excluding the Upper Hunter sites near mining activity). Annual PM_{10} levels increased at many sites throughout New South Wales from 2015 to 2017, including those in the Newcastle Local region. This was predominantly due to natural drivers, with increases in dust storms and bushfires seen under recent dry and hot climatic conditions in New South Wales.

Figure 9 compares the annual average PM_{10} levels at the Newcastle Local sites and other sites in the Hunter Valley. This comparison shows that PM_{10} annual concentrations were highest at Stockton, due mainly to the contribution of sea salt. Annual PM_{10} levels at Carrington and Mayfield are comparable to Newcastle and some sites in the Upper Hunter, namely those closer to mining operations.

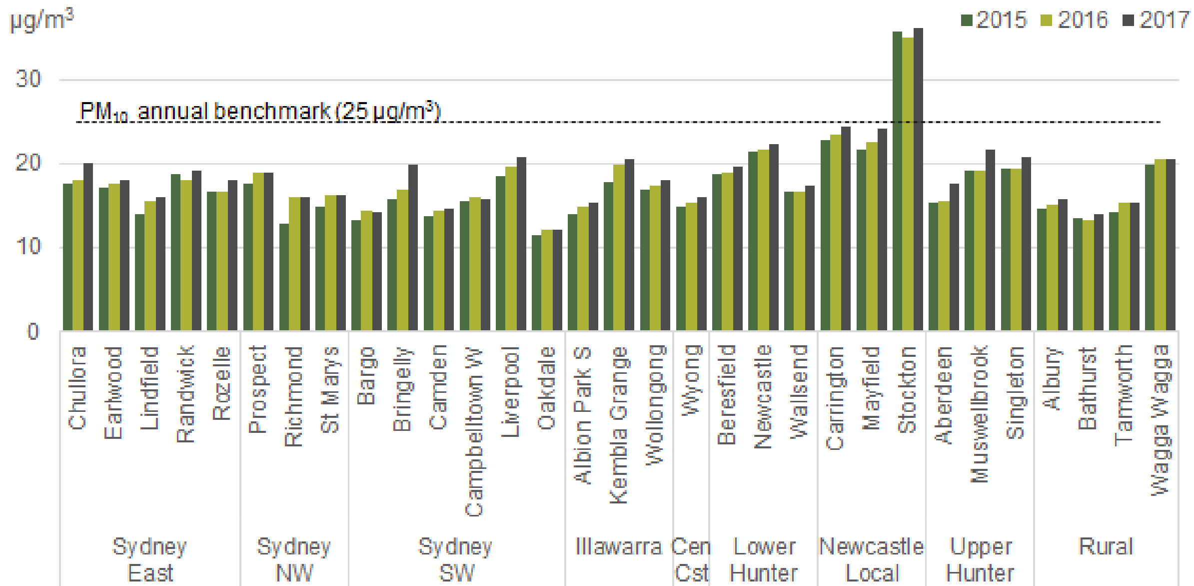

Figure 8 **PM_{10} annual averages by station for all NSW regions from 2015 to 2017**

Cen Cst = Central Coast

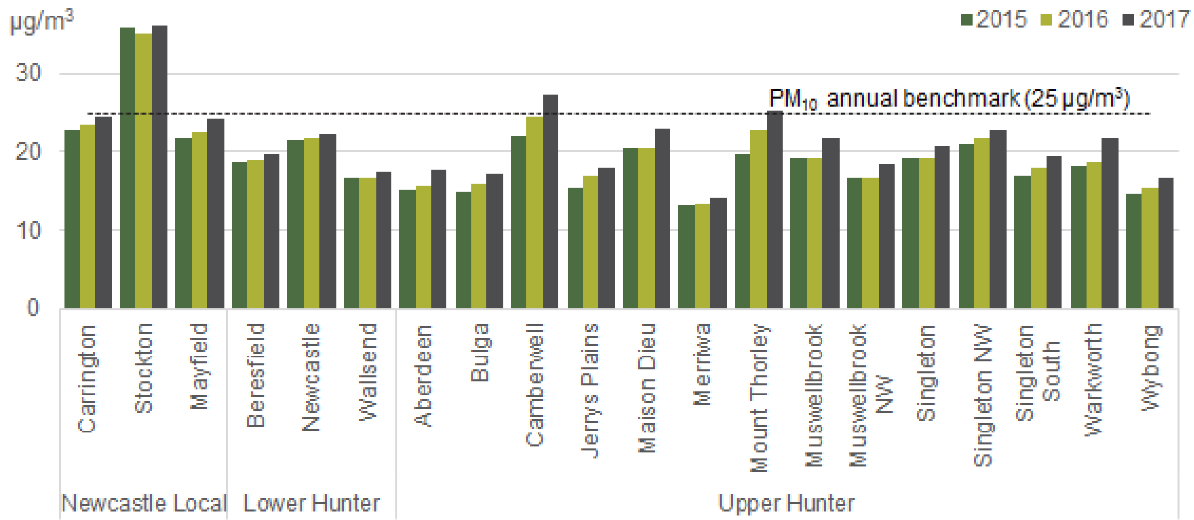

Figure 9 **PM_{10} annual averages by station for all Hunter sites from 2015 to 2017**

Annual $PM_{2.5}$ levels compared with other regions

Figure 10 compares annual average $PM_{2.5}$ concentrations at all NSW AQMN sites. Eight of the 22 sites recorded annual average $PM_{2.5}$ concentrations over the benchmark, including Carrington and Stockton in the Newcastle Local region. Stockton recorded the highest $PM_{2.5}$ annual average concentrations in New South Wales. As noted above, the LHPCS reported Stockton's elevated $PM_{2.5}$ levels directly related to higher levels of sea salt, especially in warmer months, and to ammonium nitrate emissions from industry on Kooragang in cooler months (Hibberd et al. 2016a).

The next highest $PM_{2.5}$ annual average concentrations were at Muswellbrook (in the Upper Hunter), Chullora (in Sydney central-east region) and Liverpool (in Sydney south-west region). Annual average $PM_{2.5}$ levels at Carrington and Stockton have increased since the establishment of the Network.

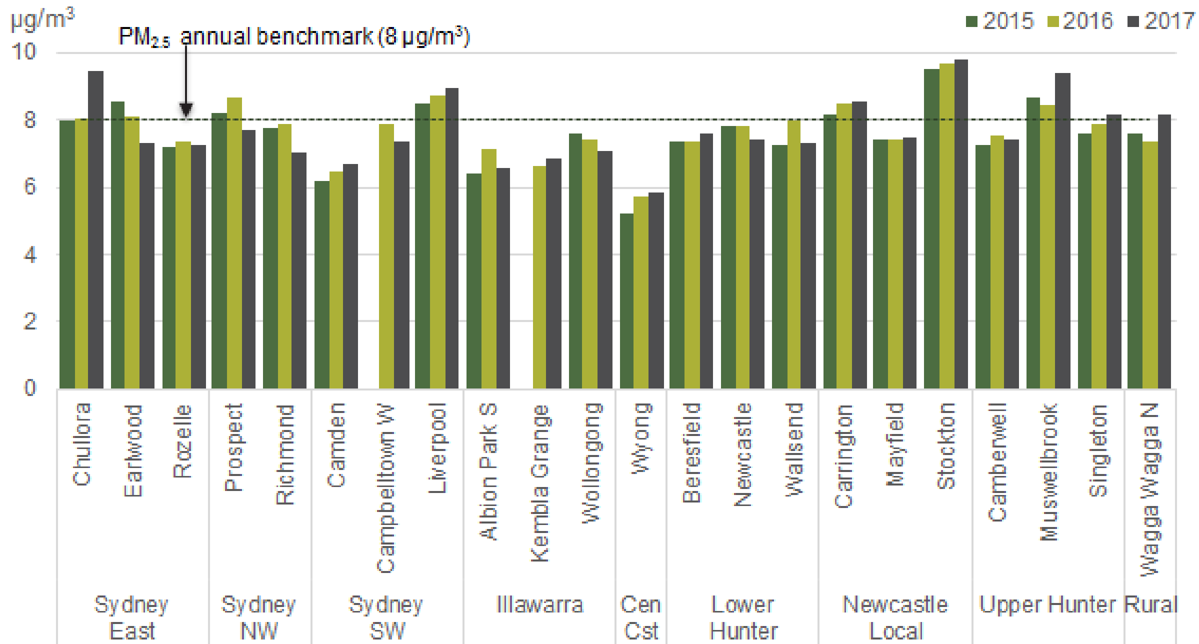

Figure 10 $PM_{2.5}$ annual averages by station for all NSW regions from 2015 to 2017
Cen Cst = Central Coast

Gaseous parameters

Figure 11 compares the maximum hourly SO_2 concentrations for all sites in the NSW network. Maximum hourly SO_2 levels in the Newcastle Local region were comparable to the Lower Hunter and Central Coast (Cen Cst) sites. Levels in the Newcastle region were lower than the Upper Hunter, although higher than Sydney sites.

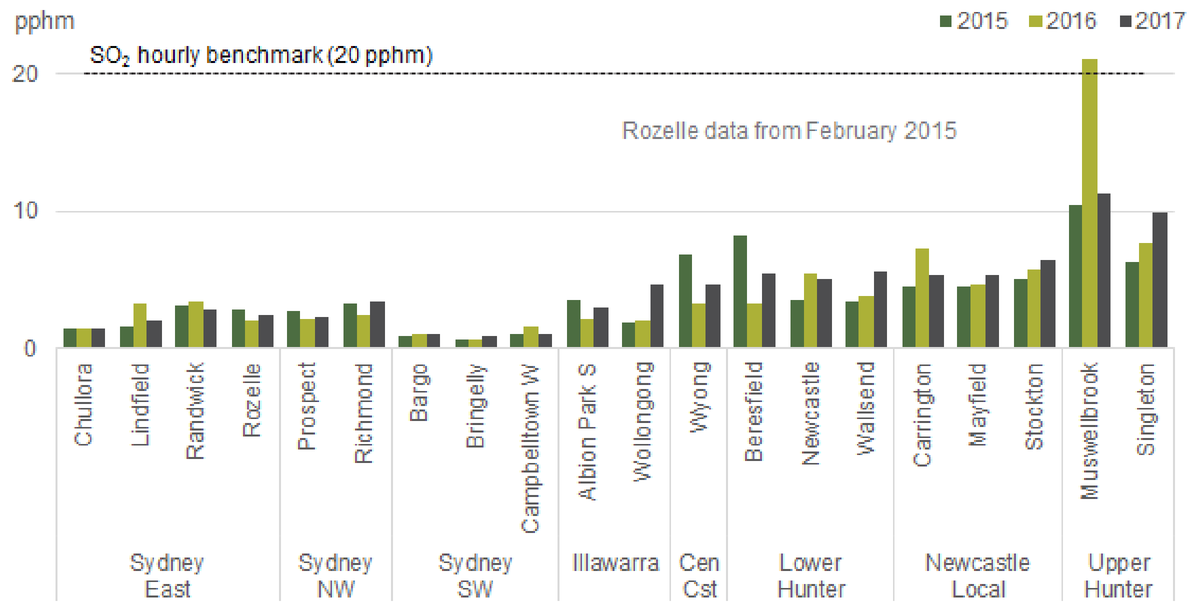

Figure 11 Maximum hourly average SO_2 for all NSW regions from 2015 to 2017
Cen Cst = Central Coast

Figure 12 compares the maximum hourly NO_2 concentrations for all sites in the NSW network. Maximum hourly NO_2 levels in the Newcastle Local region fell in the middle range compared to other sites.

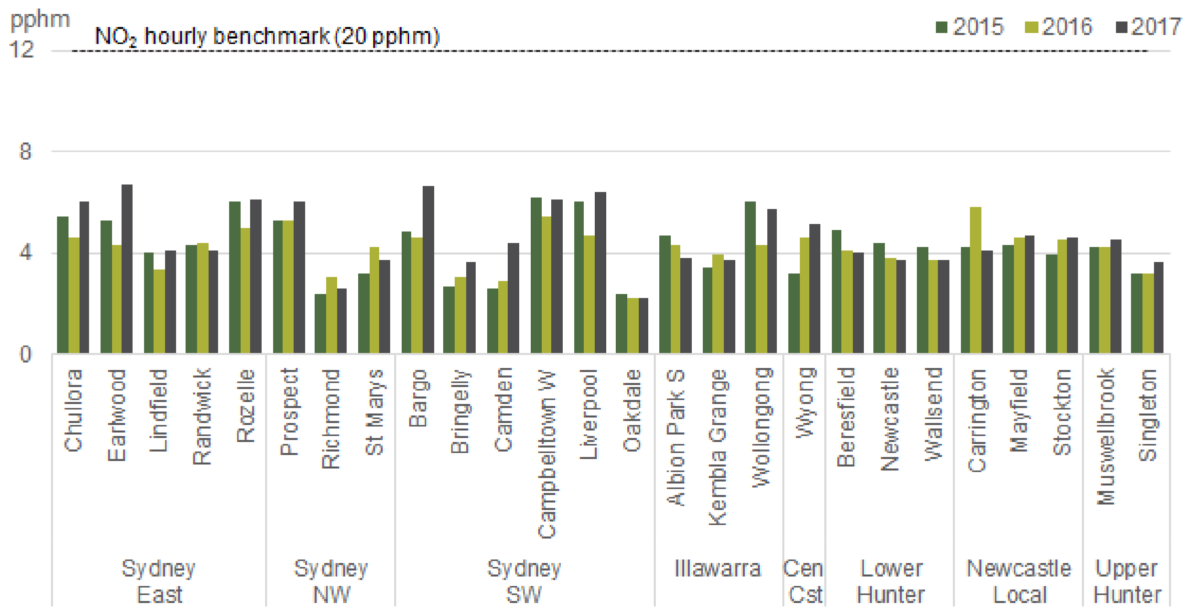

Figure 12 Maximum hourly average NO_2 for all NSW regions from 2015 to 2017

Cen Cst = Central Coast

2.2.3 Seasonal variability in particle levels

PM_{10} and $PM_{2.5}$ pollution in the Newcastle Local and Lower Hunter regions showed seasonal variability.

Since 2015, the Newcastle Local and Lower Hunter networks recorded no days over the PM_{10} benchmark during June and July (Figure 13). Stockton recorded the highest number of days over the PM_{10} benchmark during the warmer months from October to March, when onshore flows are predominant. At the remaining sites, most days over the benchmark occurred in November, predominantly due to bushfires. The event in May 2015, when all sites in the region were over the benchmark, coincided with a dust storm. Events in September 2017 were affected by bushfires and a dust storm.

The Newcastle Local and Lower Hunter networks recorded very few days over the $PM_{2.5}$ benchmark from 2015 to 2017 (Figure 14). No days exceeded the $PM_{2.5}$ benchmark from January to May, nor in October. The days over the benchmark in August 2015, September 2017, November 2016 and December 2015 were affected by bushfires and hazard reduction burns. At Stockton, the three exceedance days in June and July 2015 occurred under north-west winds, most likely due to local industrial emissions.

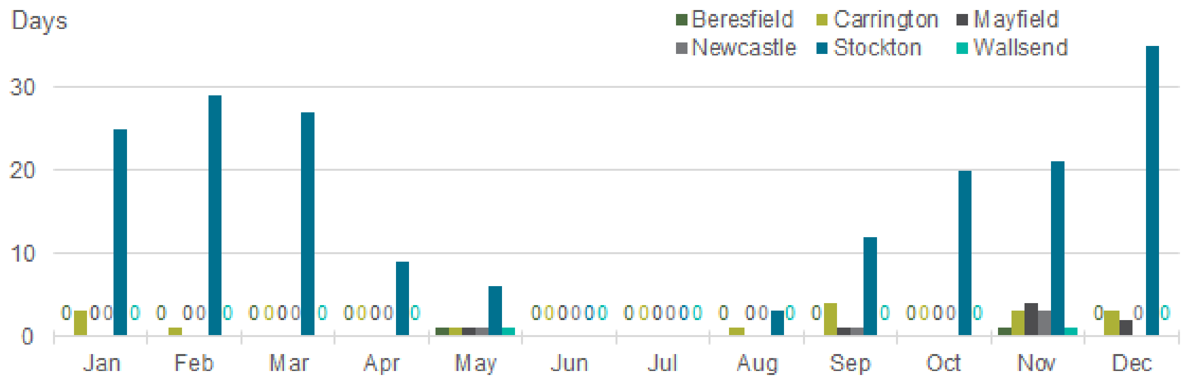

Figure 13 Total number of days per month over the PM_{10} daily benchmark at Newcastle region stations from 2015 to 2017

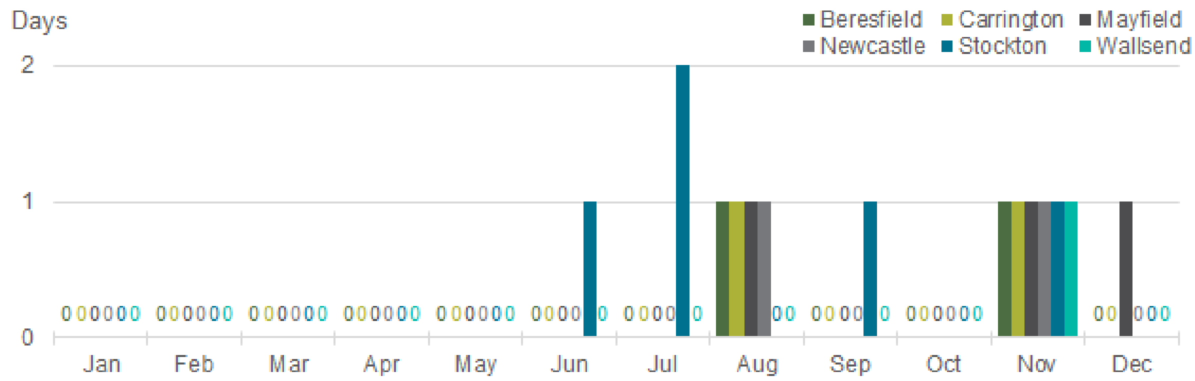

Figure 14 Total number of days per month over the $PM_{2.5}$ daily benchmark at Newcastle region stations from 2015 to 2017

2.2.4 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 from 2015 to 2017 shows that winds were variable in the region, with the highest percentage (approximately 30%) of flows typically from the north-west (Figure 15). Onshore easterly winds are also predominant at these coastal sites. The highest wind speeds were recorded down the Hunter Valley from the north-west at Beresfield and Stockton.

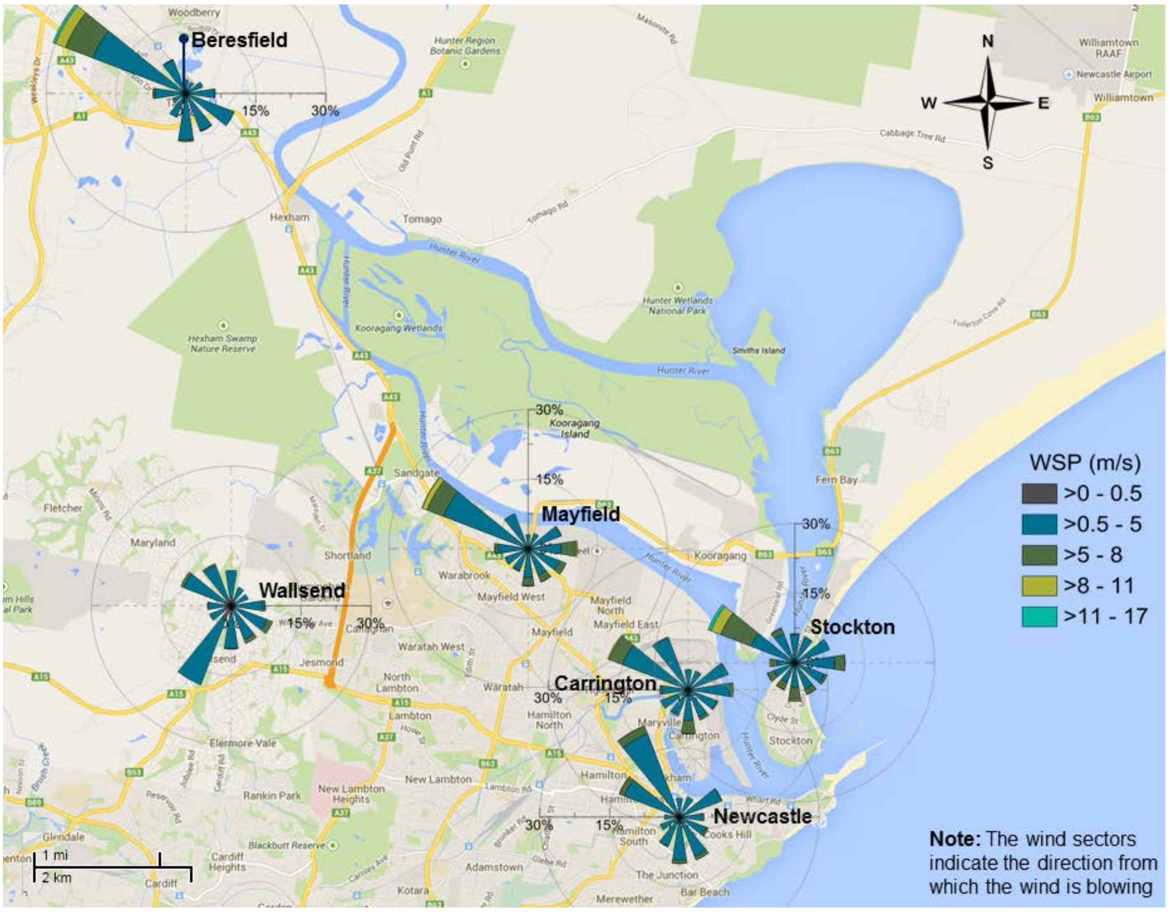

Figure 15 Newcastle region wind rose map from 2015 to 2017

All available data from 2015 to 2017 from the three Newcastle Local sites were analysed to show the seasonal change in wind patterns (Figure 16). In general, winds were predominantly onshore (from north-east to south) in summer and north-west in winter. During autumn, winds turned from predominantly onshore to north-westerly. In spring winds turned from predominantly north-westerly to onshore. Higher wind speeds generally occurred from the north-west in winter and spring.

The diurnal wind speed plots (Figure 17) show that higher wind speeds generally occurred in the afternoon and early evening, especially in summer and spring at Mayfield. At Stockton, wind speeds increased earlier in the day, particularly in winter. Overnight wind speeds were generally light.

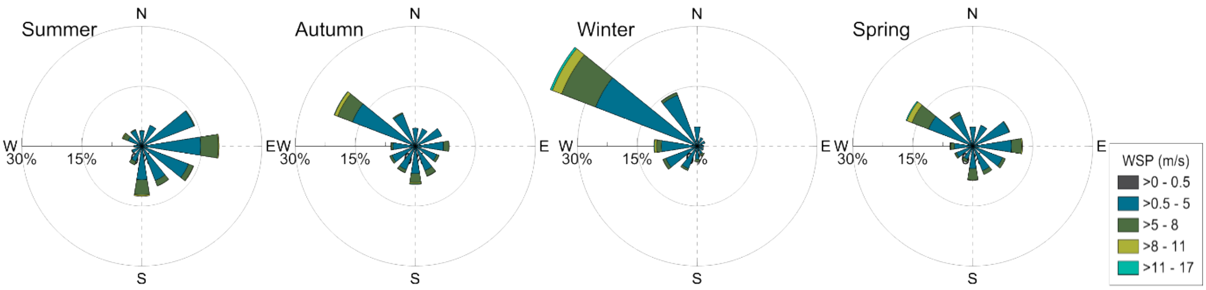

Figure 16 Seasonal wind roses using pooled wind data from the Newcastle Local sites (Carrington, Mayfield and Stockton) from 2015 to 2017

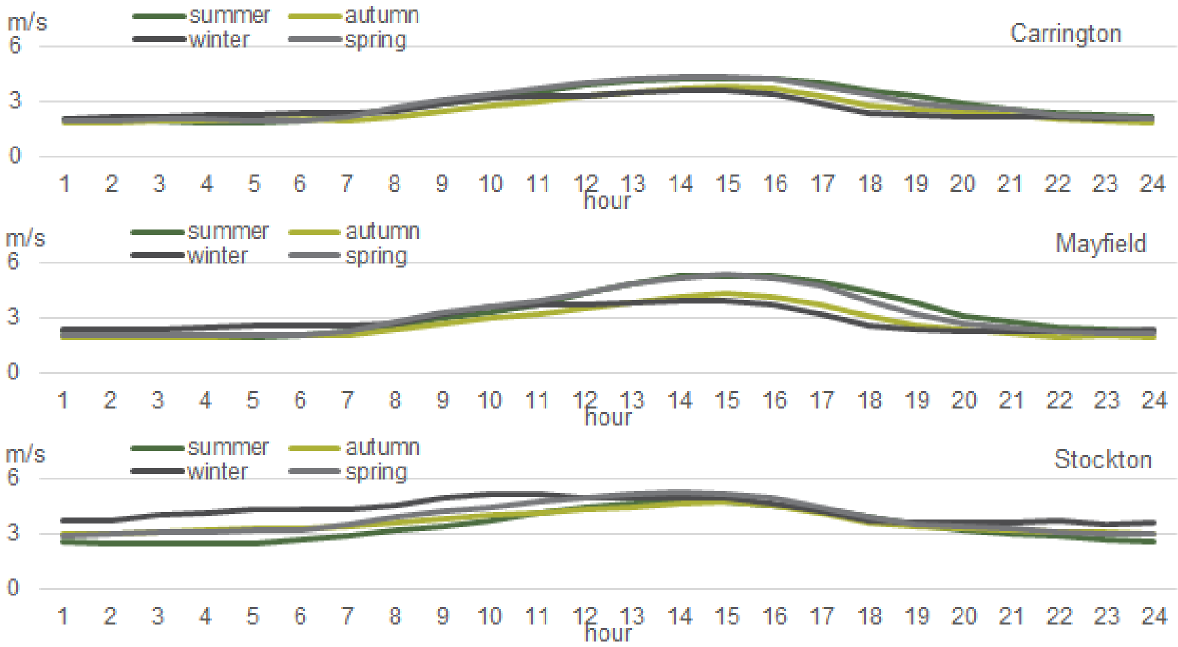

Figure 17 Carrington (top), Mayfield (middle) and Stockton (bottom) pooled hourly average wind speed plots from 2015 to 2017, by season

Temperature

Temperatures varied considerably throughout the year in the region, as shown by the monthly minimum and maximum temperatures from 2015 to 2017 (Figure 18). Temperatures peaked in summer, with hot to very hot temperatures experienced. The lowest temperatures were experienced from June to July with temperatures remaining above zero at these coastal sites.

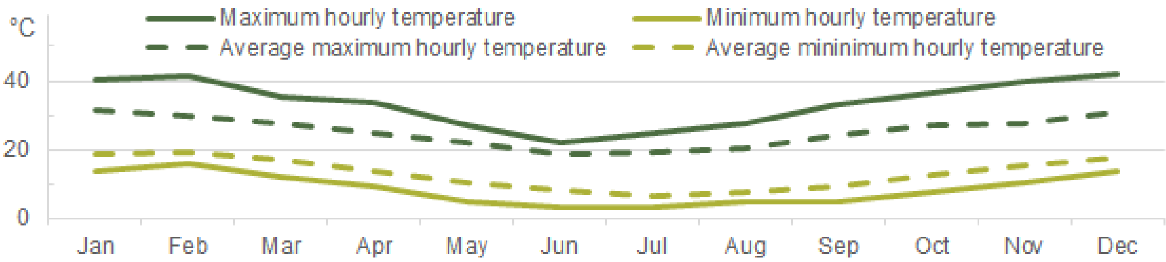

Figure 18 Monthly maximum and minimum hourly temperatures for Newcastle Local sites (Carrington, Mayfield and Stockton) from 2015 to 2017

Precipitation

A review of monthly rainfall levels in the region shows variability across seasons (Figure 19). Since the commissioning of the Network, the highest rainfall has occurred in January, followed by early autumn (March to April). Rainfall has been consistently low in late winter (July to August) followed by spring and early summer.

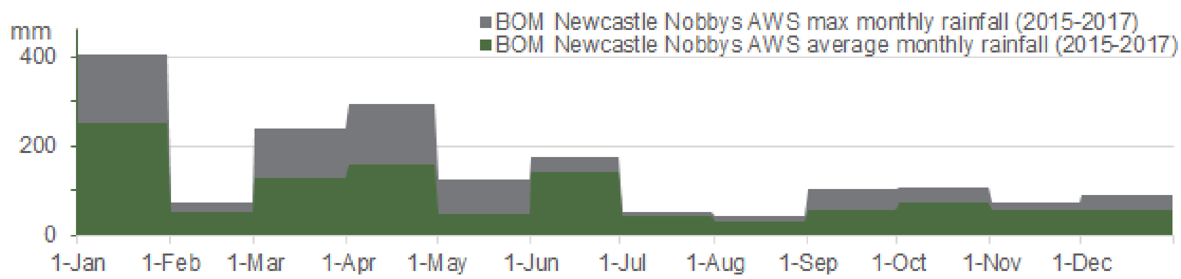

Figure 19 Bureau of Meteorology Newcastle Nobbys AWS[3] (automatic weather station) maximum and average monthly rainfall from 2015 to 2017

2.2.5 Meteorology and particles

Analysis of all Newcastle Local data shows that elevated PM_{10} levels occurred more often during the warmer months. Under warmer conditions, onshore flows are predominant. Due to the proximity of the Network sites to the coast, particle levels are greatly influenced by sea salt carried under onshore flows. This is particularly evident at Stockton, located only about 300 metres from the coast.

Temperatures in the region warm significantly after winter with hot days typically experienced by the end of spring. At the same time, the region becomes drier as lower rainfall is typically experienced, although year-to-year variability occurs. Drier and warmer conditions are conducive to elevated particle levels due to the onset of dust storms and bushfires, with particles transported throughout the region.

Elevated $PM_{2.5}$ levels have occurred from June to December (Section 2.2.3). In winter, winds are predominantly from the north-west, meaning that industrial emissions could be more frequently affecting Stockton. For the remaining months, elevated $PM_{2.5}$ occasionally occur due to bushfires and hazard reduction burns.

2.3 Emission sources within the region

2.3.1 Location of major industrial sources of air emissions

The major industrial sources of air emissions in Newcastle are the portside industrial activities on Kooragang Island (coal loading, bulk materials handling and chemical manufacturing), Carrington (coal loading, grain loading) and Waratah – Mayfield (steel products manufacturing).

Figure 20 shows the major industrial facilities with emissions to air, located in the Newcastle port and inner city areas.

[3] Sourced from the Bureau of Meteorology Climate Data Online website (accessed August 2018).

Figure 20 Locations of major industrial facilities and air quality monitoring stations in the Newcastle Local Government Area (LGA) port and in inner city areas

2.3.2 The National Pollutant Inventory

The National Pollutant Inventory[4] (NPI) reports emissions for substances identified as important due to their possible effect on human health and the environment.

The National Environment Protection (National Pollutant Inventory) Measure requires industrial facilities to report annually on the quantities of air pollutants measured in emissions from industrial stacks and flues, referred to as air pollution point sources. Government agencies provide estimates of emissions from diffuse sources, such as motor vehicles, commercial shipping and boating, wood smoke from domestic wood heaters, smoke from bushfires and hazard reduction burning, and public and domestic lawn mowing[5].

The following section summarises the main sources and emissions of PM_{10}, $PM_{2.5}$, oxides of nitrogen (NO_X) and SO_2 in the Newcastle local government area (LGA) and changes from 2013 to 2017, sourced from the NPI. There is no sources and emissions information available specifically for NO_2 within the NPI.

Additionally, the LHPCS (Hibberd et al. 2016a) was undertaken from March 2014 to February 2015, providing information on particle sources impacting sites in the region. The main findings are summarised in the sections below.

[4] Data from the National Pollutant Inventory were accessed in August 2018.

[5] The NSW EPA air emissions inventory provided to the NPI detailed estimates of diffuse sources for the full range of source categories in industrial, urban and non-urban areas within the Greater Metropolitan Area for 2003.

2.3.3 Sources and emissions

PM_{10} emissions – all source categories

Figure 21 and Table 4 present estimates of PM_{10} emissions for the Newcastle LGA, reported in the NPI for all sources including industrial point sources and diffuse sources.

The NPI data for 2013–14 and 2016–17 show the largest sources of PM_{10} emissions in the Newcastle LGA were water transport support services (coal loading and port operations), domestic solid fuel burning (wood smoke) and motor vehicles, which together made up 68% of annual emissions from all sources in 2013–14 and 65% in 2016–17 (Figure 21).

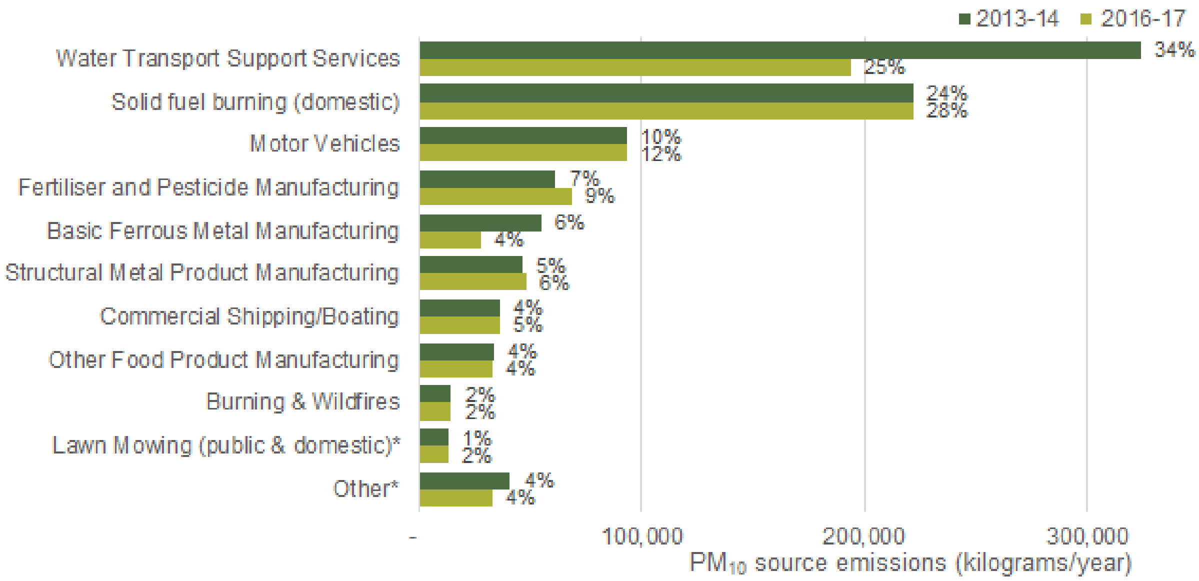

Figure 21 National Pollutant Inventory PM_{10} emissions by top 10 source categories for the Newcastle LGA in 2013–14 and 2016–17

Note: Water transport support services includes coal loading and port operations.

* Lawn Mowing is the combined total for public and domestic lawn mowing. Other is the combined total for the remaining source categories.

PM_{10} emissions from all sources fell by 17% from 2013–14 to 2016–17, mostly due to falls in emissions from water transport support services (coal loading and port operations by 40%) and ferrous metal manufacturing (steel products by 49%) (Table 4).

PM_{10} emissions increased by 11% for fertiliser and pesticide manufacturing and by 4% for structural metal product manufacturing. The remainder of the top 10 emission source categories reported little or no change in emissions from 2013–14 to 2016–17 (Table 4).

Table 4 National Pollutant Inventory PM_{10} emissions by top 10 source categories for the Newcastle LGA – changes from 2013–14 to 2016–17

PM_{10} emissions source categories	Change in PM_{10} source emissions from 2013–14 to 2016–17	
	Kilograms	%
Water transport support services*	–130,548	–40
Solid fuel burning (domestic)	0	0
Motor vehicles	0	0
Fertiliser and pesticide manufacturing	7,036	11
Basic ferrous metal manufacturing	–27,300	–49
Structural metal product manufacturing	1,781	4
Commercial shipping/boating	0	0
Other food product manufacturing	–334	–1
Burning & wildfires	0	0
Lawn mowing (public & domestic)^	0	0
Other#	–7,953	–19
Total	**–157,319**	**–17**

* Note: Water Transport Services includes coal loading and port operations.

^ Lawn mowing is the combined total from public and domestic sources

Other = combined total for remaining emission source categories

PM_{10} emissions – industrial facilities

Figure 22 and Table 5 show annual PM_{10} emissions reported to the NPI by major industrial facilities in the Newcastle LGA for 2013–14 to 2016–17.

The largest industrial sources of PM_{10} emissions in Newcastle were in the portside industrial areas of Kooragang Island (coal loading and chemical manufacturing) and Waratah and Mayfield West (steel products manufacturing).

Total PM_{10} emissions from industrial facilities fell by 29% from 2013–14 to 2016–17. The largest falls were at facilities engaged in coal loading (Newcastle Coal Infrastructure Group by 54% and Kooragang Coal Terminal by 27%) and steel manufacturing (Moly-Cop Waratah by 49%). The largest increase in PM_{10} emissions occurred from fertiliser and industrial chemicals manufacturing (Orica Kooragang Island by 11%).

There were no particle emissions from Pacific Carbon at Kooragang Island from 2014–15, due to its closure. Particle emissions from Hexham Train Support Facility began in 2015–16, when the facility commenced operation.

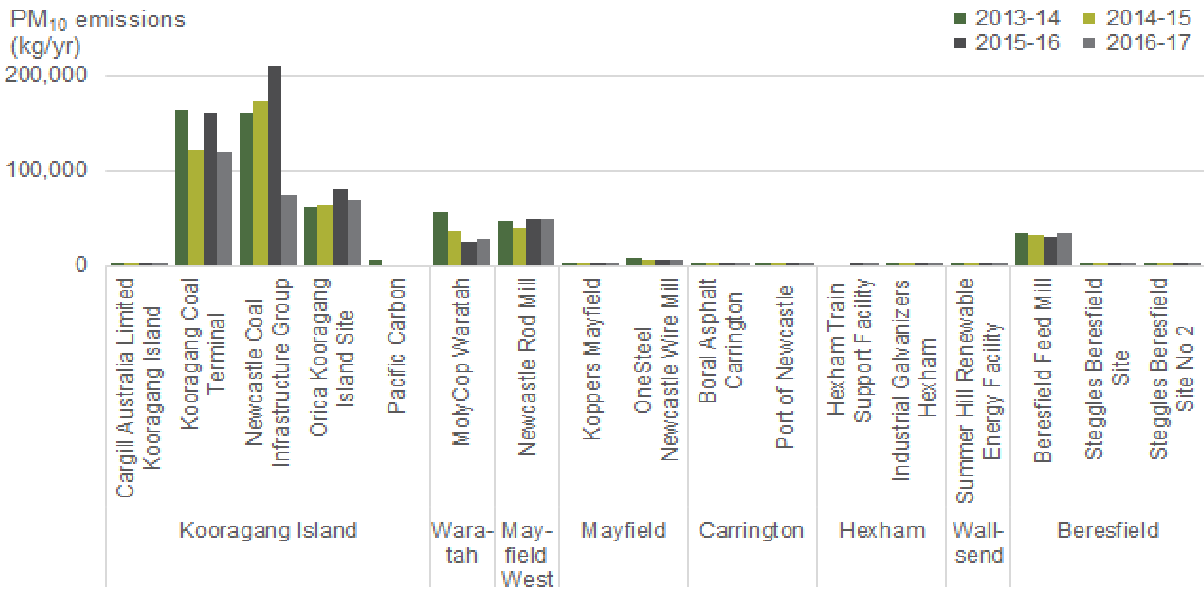

Figure 22 National Pollutant Inventory PM_{10} emissions at major industrial facilities in the Newcastle LGA 2013–14 to 2016–17

Table 5 National Pollutant Inventory PM_{10} emissions at major industrial facilities in the Newcastle LGA – changes from 2013–14 to 2016–17

Location	Industrial facility	Change in PM_{10} emissions from 2013–14 to 2016–17	
		Kilograms	%
Kooragang Island	Cargill Australia Limited Kooragang Island	0	0
Kooragang Island	Kooragang Coal Terminal*	–44,994	–27
Kooragang Island	Newcastle Coal Infrastructure Group	–85,253	–54
Kooragang Island	Orica Kooragang Island Site	7,036	11
Kooragang Island	Pacific Carbon	–6,306	–100
Waratah	Moly-Cop Waratah	–27,300	–49
Mayfield West	Newcastle Rod Mill	1,781	4
Mayfield	Koppers Mayfield	–456	–43
Mayfield	OneSteel Newcastle Wire Mill	–1,238	–16
Carrington	Boral Asphalt Carrington	167	16
Carrington	Port of Newcastle	–301	–18
Hexham	Hexham Train Support Facility	2,094	100
Hexham	Industrial Galvanizers Hexham	889	80
Wallsend	Summer Hill Renewable Energy Facility	–98	–5
Beresfield	Beresfield Feed Mill	–334	–1
Beresfield	Steggles Beresfield Site	–2,003	–79
Beresfield	Steggles Beresfield Site No. 2	–1,003	–75
Total		**–157,319**	**–29**

* Port Waratah's Kooragang operations are below the reporting threshold; however, Port Waratah voluntarily reports NPI particle data (Port Waratah Coal Services media statement, 30 May 2018).

PM_{10} sources – Stockton and Mayfield

The LHPCS found fresh sea salt and pollutant-aged sea salt[6] contributed 69% and 56% to annual concentrations of particulate matter in the size range of $PM_{2.5\text{-}10}$ (2.5 to 10 µm in diameter) at Stockton and Mayfield respectively, during the study period March 2014 to February 2015 (Figure 23).

$PM_{2.5\text{-}10}$ sources at Stockton and Mayfield showed a strong seasonal variation, with peak levels occurring during the warmer months (Figure 24).

The study found that fresh sea salt contributed 63% annually to $PM_{2.5\text{-}10}$ concentrations at Stockton, increasing to 73% during the warmer months (October to April). At Mayfield, fresh sea salt contributed 40% of total annual $PM_{2.5\text{-}10}$ concentrations. The annual average $PM_{2.5\text{-}10}$ concentration at Stockton was 2.5 times higher than at Mayfield, due to much higher concentrations of fresh sea salt at Stockton (Hibberd et al. 2016a).

Pollutant-aged sea salt contributed 16% and 6% to annual $PM_{2.5\text{-}10}$ concentrations at Mayfield and Stockton, respectively.

Light-absorbing carbon contributed 10% to annual PM_{10} concentrations at both sites. The study concluded that coal particles may contribute to this source. An LHPCS supplementary report confirmed that coal contributed 10% on average to the total mass of particles in the size range $PM_{1\text{-}10}$ at Stockton, in winter 2015 on days when winds were from the north-west (Hibberd et al. 2016b).

Following the LHPCS, the EPA and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) conducted particle characterisation on dust samples from industries adjacent to the Port of Newcastle in 2017, to investigate potential sources of non-coal carbon particles identified in the LHPCS Supplementary Report (Hibberd et al. 2016b) (NCCCE meeting minutes – Meeting No. 47 19 July 2017). However, the investigation could not confirm specific sources of fossil fuel combustion without further investigation.

This review notes that under MARPOL (the International Convention for the Prevention of Pollution from Ships), the limit for sulfur in fuel oil used onboard ships will be reduced from 3.50% to 0.50% m/m (mass by mass), from 1 January 2020 (MARPOL action date). The International Maritime Organisation (IMO) expects that limiting sulfur in fuel oil will have major health and environmental benefits for populations living close to ports and coasts, by reducing sulfur oxides and $PM_{2.5}$ levels (IMO Sulphur 2020 media release).

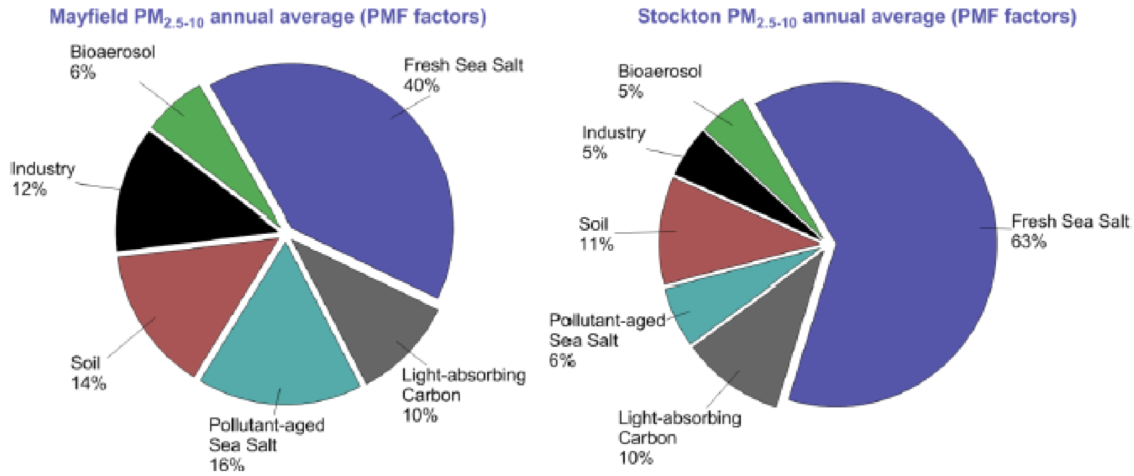

Figure 23 Percentage annual average contributions to total $PM_{2.5\text{-}10}$ mass at Mayfield and Stockton from March 2014 to February 2015

[6] Pollutant-aged sea salt is formed when sea salt reacts chemically in the air with pollution from other sources, such as industry, vehicles and shipping from local and regional sources (Hibberd et al. 2016a).

Source: extracted from the LHPCS report (Hibberd et al. 2016a)

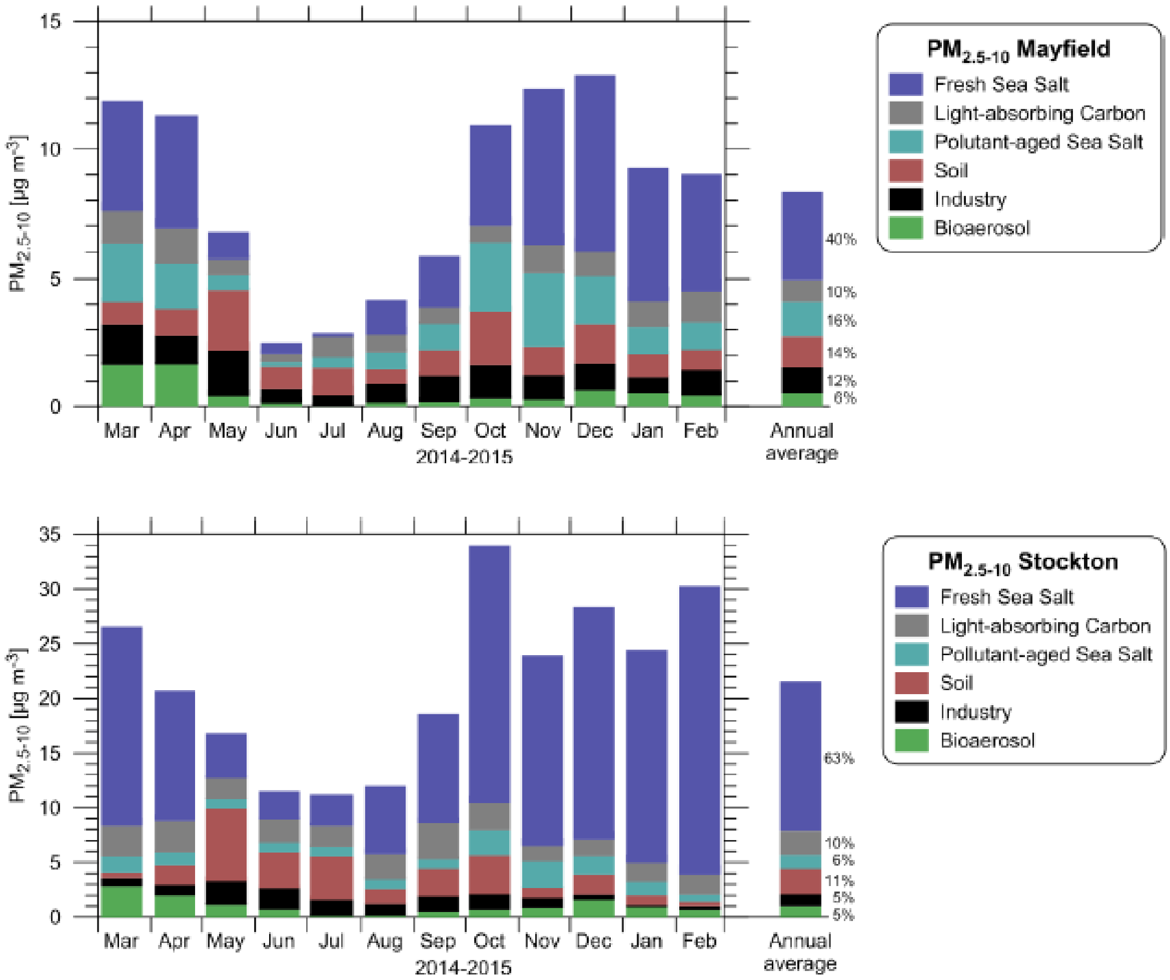

Figure 24 Monthly and annual factor contributions to $PM_{2.5\text{-}10}$ at Mayfield and Stockton

Source: extracted from the LHPCS report (Hibberd et al. 2016a)

$PM_{2.5}$ emissions – all source categories

Figure 25 and Table 6 present estimates of $PM_{2.5}$ emissions for the Newcastle LGA, reported in the NPI for all sources including industrial point sources and diffuse sources.

The NPI data for 2013–14 and 2016–17 show the largest sources of $PM_{2.5}$ emissions in the Newcastle LGA were fertiliser and pesticide manufacturing and basic ferrous metal manufacturing, which together made up 90% of annual emissions from all sources in 2013–14 and 86% in 2016–17 (Figure 25).

$PM_{2.5}$ emissions from all sources fell by 20% from 2013–14 to 2016–17, mostly due to falls in emissions from basic ferrous metal manufacturing (steel products by 61%) (Table 6).

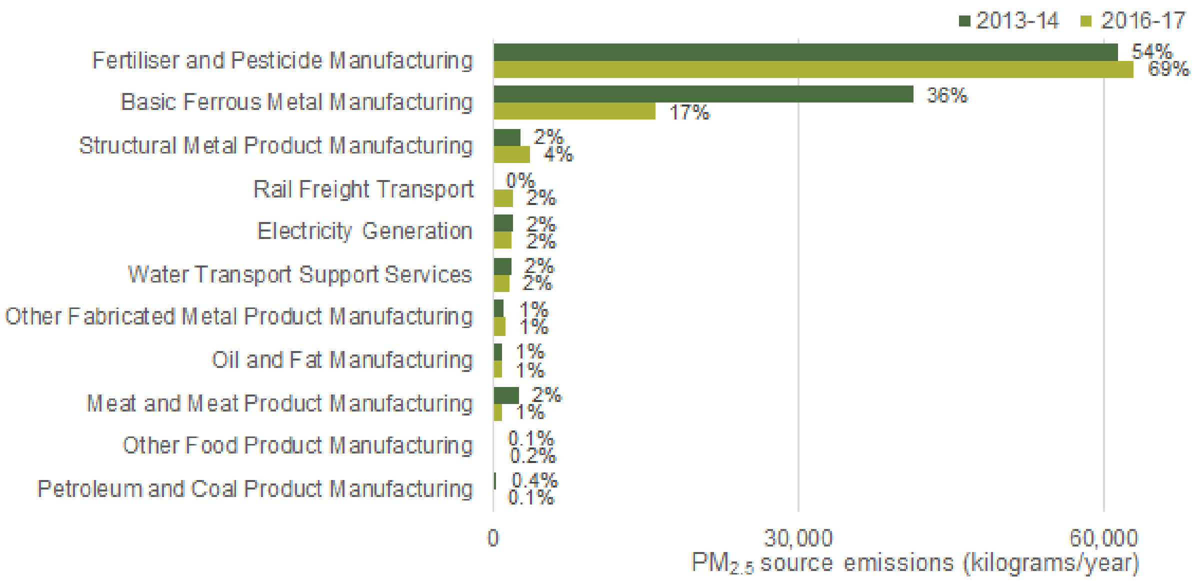

Figure 25 National Pollutant Inventory $PM_{2.5}$ emissions by source categories in the Newcastle LGA for 2013–14 and 2016–17

Note: Water Transport Services includes coal loading and port operations

Table 6 National Pollutant Inventory $PM_{2.5}$ emissions by source categories in the Newcastle LGA – changes from 2013–14 to 2016–17

$PM_{2.5}$ emissions source categories	Change in $PM_{2.5}$ source emissions from 2013–14 to 2016–17	
	Kilograms	%
Fertiliser and pesticide manufacturing	1,633	3
Basic ferrous metal manufacturing	–25,300	–61
Structural metal product manufacturing	964	35
Rail freight transport	2,011	100
Electricity generation	–98	–5
Water transport support services	–277	–15
Other fabricated metal product manufacturing	24	2
Oil and fat manufacturing	0	0
Meat and meat product manufacturing	–1,763	–68
Other food product manufacturing	86	69
Petroleum and coal product manufacturing	–286	–71
Total	**–23,005**	**–20**

$PM_{2.5}$ emissions – industrial facilities

Figure 26 and Table 7 show $PM_{2.5}$ emissions reported to the NPI by major industrial facilities in the Newcastle LGA for 2013–14 to 2016–17.

The largest industrial sources of $PM_{2.5}$ emissions in Newcastle were in the portside industrial areas of Kooragang Island (coal loading and chemical manufacturing) and Waratah (steel products manufacturing).

Total $PM_{2.5}$ emissions from industrial facilities fell by 20% from 2013–14 to 2016–17. The largest fall was for steel manufacturing (Moly-Cop Waratah by 61%). The largest increase in $PM_{2.5}$ emissions occurred from rail freight transport, with Hexham Train Support Facility coming online in 2015–16.

There were no particle emissions from Pacific Carbon at Kooragang Island from 2014–15, due to its closure.

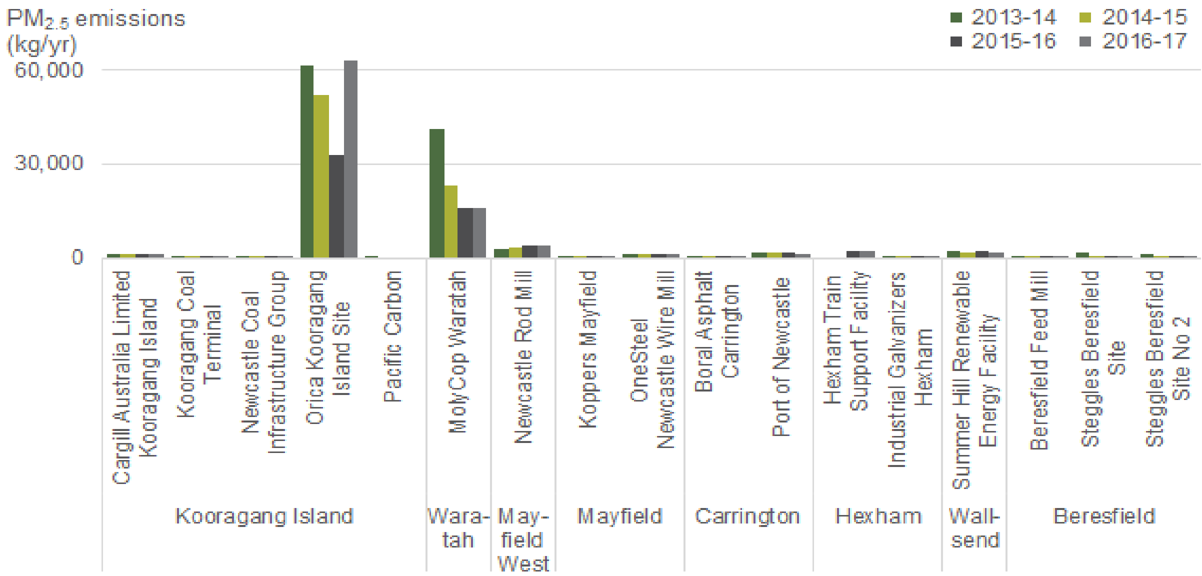

Figure 26 National Pollutant Inventory $PM_{2.5}$ emissions at major industrial facilities in the Newcastle LGA 2013–14 to 2016–17

Table 7 National Pollutant Inventory $PM_{2.5}$ emissions at major industrial facilities in the Newcastle LGA – changes from 2013–14 to 2016–17

Location	Industrial facility	Change in $PM_{2.5}$ emissions from 2013–14 to 2016–17	
		Kilograms	%
Kooragang Island	Cargill Australia Limited Kooragang Island	0	0
Kooragang Island	Kooragang Coal Terminal*	–46	–22
Kooragang Island	Newcastle Coal Infrastructure Group	65	2,252#
Kooragang Island	Orica Kooragang Island Site	1,633	3
Kooragang Island	Pacific Carbon	–342	–100
Waratah	Moly-Cop Waratah	–25,300	–61
Mayfield West	Newcastle Rod Mill	964	35
Mayfield	Koppers Mayfield	5	13
Mayfield	OneSteel Newcastle Wire Mill	35	3
Carrington	Boral Asphalt Carrington	51	212
Carrington	Port of Newcastle	–295	–18
Hexham	Hexham Train Support Facility	2,011	100
Hexham	Industrial Galvanizers Hexham	–10	–9
Wallsend	Summer Hill Renewable Energy Facility	–98	–5
Beresfield	Beresfield Feed Mill	86	69
Beresfield	Steggles Beresfield Site	–1,196	–70
Beresfield	Steggles Beresfield Site No. 2	–567	–63
Total		**–23,005**	**–20**

* Port Waratah's Kooragang operations are below the reporting threshold; however, Port Waratah voluntarily reports NPI particle data (Port Waratah Coal Services media statement, 30 May 2018).

The $PM_{2.5}$ emissions at the Newcastle Coal Infrastructure Group facility increased from 2.9 kg in 2013–14 to 68.2 kg in 2016–17. Although this increase is small, starting with low emissions in 2013–14 results in a large percentage change.

$PM_{2.5}$ sources – Stockton and Mayfield

The LHPCS found that the highest contributions to annual $PM_{2.5}$ concentrations at Mayfield and Stockton during the study period were fresh sea salt (20% and 23%, respectively) and pollutant-aged sea salt[6] (25% and 22%, respectively) (Figure 27).

At Stockton, annual $PM_{2.5}$ concentrations were found to be approximately 40% higher than the other sites due to more sea salt and primary ammonium nitrate particles (which was detected at this one site). Ammonia nitrate contributed on average 19% to the total $PM_{2.5}$ mass (Figure 27), increasing to 40% in winter. The study demonstrated this was due to primary ammonium nitrate particles emitted from Orica's ammonium nitrate manufacturing facility on Kooragang Island.

The study found secondary ammonium sulfate[7] was the third highest contributor to annual $PM_{2.5}$ concentrations at Mayfield (8%) and Stockton (9%) (Figure 27).

The $PM_{2.5}$ sources at Stockton and Mayfield showed a strong seasonal variation, with peak sea salt contributions occurring during the warmer months under onshore air flows (Figure 28). Peak primary ammonium nitrate concentrations at Stockton occurred during the cooler months, when wind flows were predominantly north-westerly.

An LHPCS supplementary report found that coal contributed 1.8% on average to the total mass of particles in the size range $PM_{1-2.5}$ at Stockton, in winter 2015 on days when winds were from the north-west (Hibberd et al. 2016b).

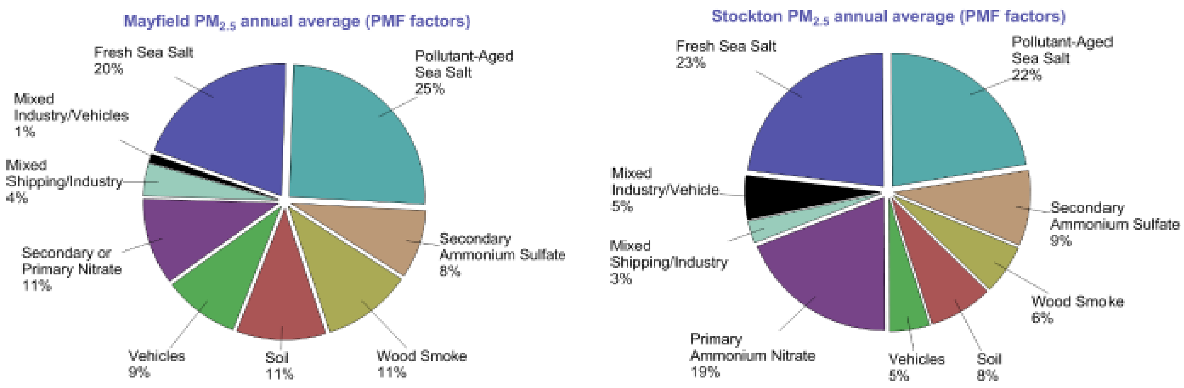

Figure 27 Percentage annual average contributions to total $PM_{2.5}$ mass at Mayfield and Stockton from March 2014 to February 2015

Source: extracted from the LHPCS report (Hibberd et al. 2016a)

[7] Secondary ammonium sulfate forms by chemical reactions between particles and gases in the well-mixed atmosphere, not directly downwind from any given source. Local and regional sources may contribute to secondary ammonium sulfate; for example, ammonia from industry and sulfur dioxide from industrial and mobile (transport) sources (Hibberd et al. 2016a).

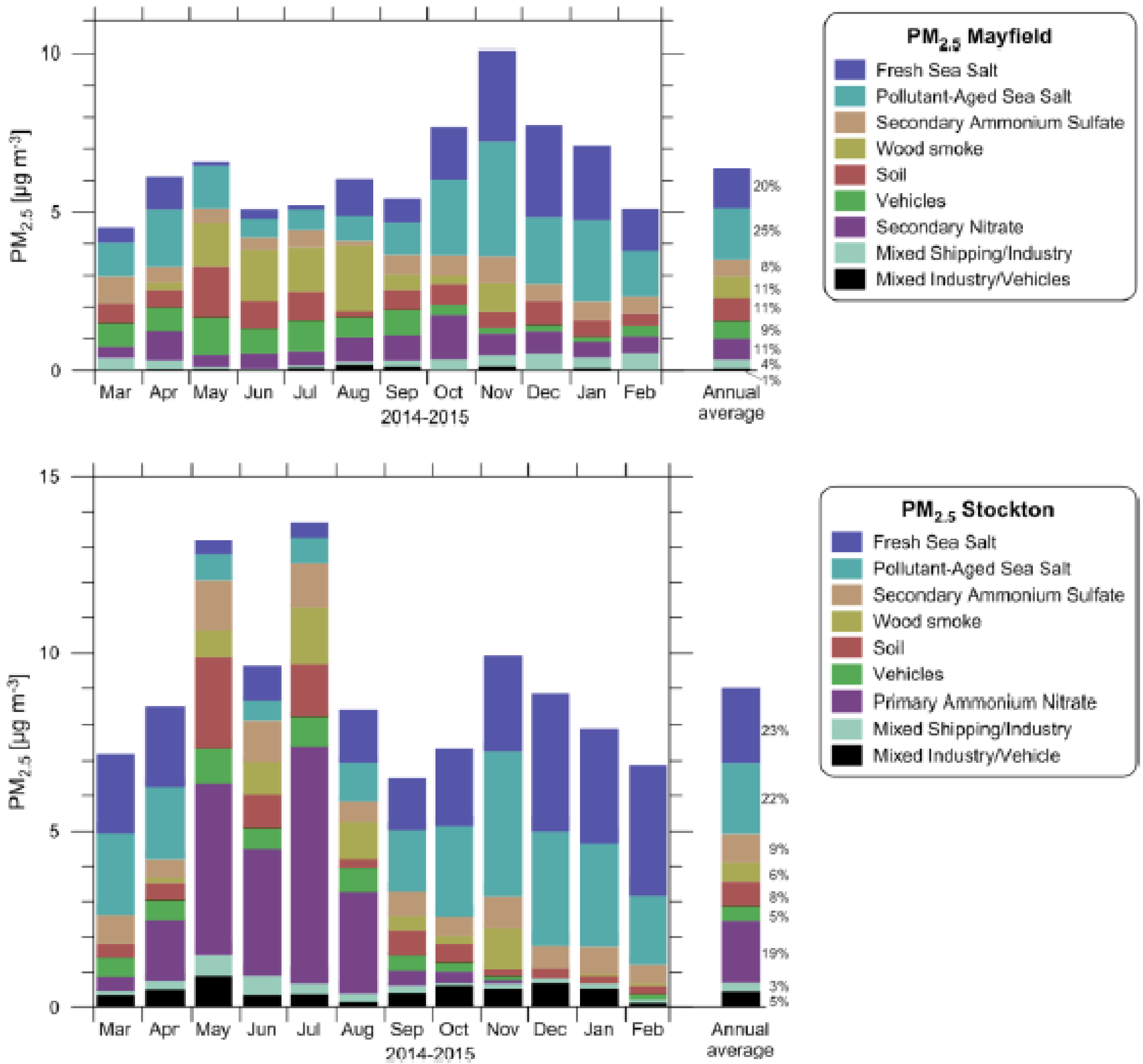

Figure 28 Monthly and annual factor contributions to $PM_{2.5}$ at Mayfield and Stockton
Source: extracted from the LHPCS report (Hibberd et al. 2016a)

NO_x emissions – all source categories

Figure 29 and Table 8 present estimates of NO_x emissions for the Newcastle LGA, reported in the NPI for all sources including industrial point sources and diffuse sources.

The NPI data for 2013–14 and 2016–17 show the largest sources of NO_x emissions in the Newcastle LGA were motor vehicles, commercial shipping/boating, and fertiliser and pesticide manufacturing, which together made up 74% of annual emissions from all sources in 2013–14 and 87% in 2016–17 (Figure 29).

NO_x emissions from all sources fell by 15% from 2013–14 to 2016–17, mostly due to decreases in emissions from petroleum and coal product manufacturing (93%) and basic ferrous metal manufacturing (steel products by 58%). The next significant drop in NO_x source emissions was from fertiliser and pesticide products (3%) (Table 8).

The largest increase in NO_X emissions was from rail freight transport, with Hexham Train Support Facility coming online in 2015–16.

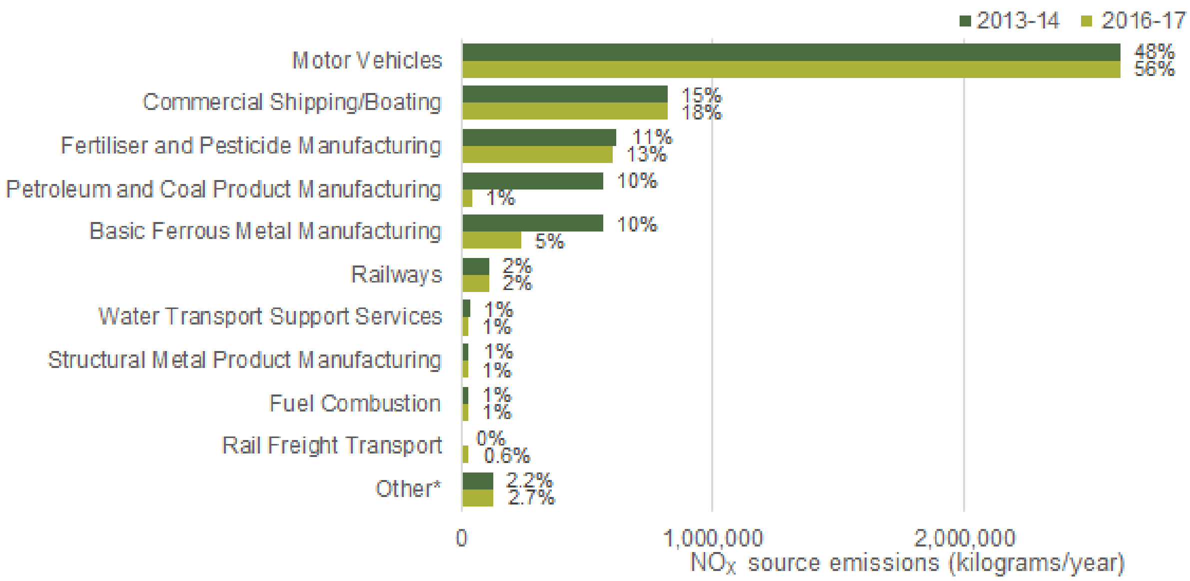

Figure 29 National Pollutant Inventory NO_X emissions by top 10 source categories for the Newcastle LGA in 2013–14 and 2016–17

* Other is the combined total for the remaining source categories.

Table 8 National Pollutant Inventory NO_X emissions by top 10 source categories in the Newcastle LGA – changes from 2013–14 to 2016–17

NO_x emissions source categories	Change in NO_X source emissions from 2013–14 to 2016–17	
	Kilograms	%
Motor vehicles	0	0
Commercial shipping/boating	0	0
Fertiliser and pesticide manufacturing	–19,331	–3
Petroleum and coal product manufacturing	–523,917	–93
Basic ferrous metal manufacturing	–324,000	–58
Railways	0	0
Water transport support services	–7,028	–21
Structural metal product manufacturing	–3,586	–12
Fuel combustion	0	0
Rail freight transport	26,319	100
Other#	4,052	3
Total	**–847,490**	**–15**

Other = combined total for remaining emission source categories.

NO_x emissions – industrial facilities

Figure 30 and Table 9 show NO_x emissions reported to the NPI by major industrial facilities in the Newcastle LGA for 2013–14 to 2016–17.

The largest industrial sources of NO_x emissions in Newcastle are in the portside industrial areas of Kooragang Island (coal loading and chemical manufacturing), Waratah (steel products manufacturing) and Mayfield (petroleum and coal product manufacturing).

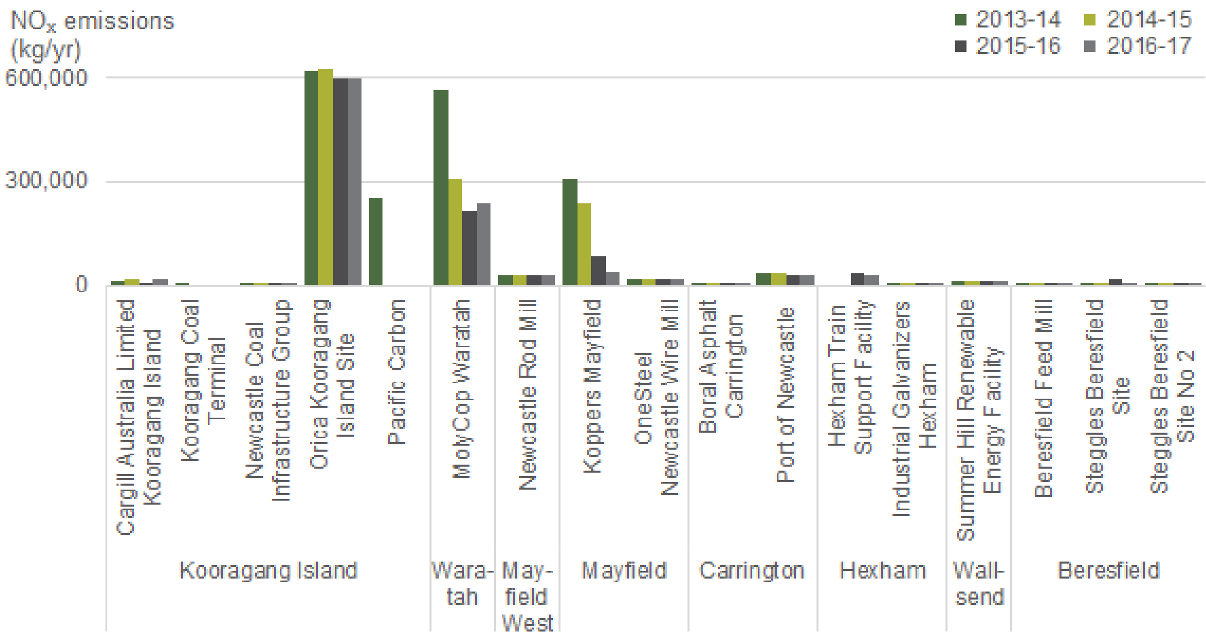

Figure 30 National Pollutant Inventory NO_X emissions at major industrial facilities in the Newcastle LGA from 2013–14 to 2016–17

Table 9 National Pollutant Inventory NO_X emissions at major industrial facilities in the Newcastle LGA – changes from 2013–14 to 2016–17

Location	Industrial facility	Change in NO_x emissions from 2013–14 to 2016–17	
		Kilograms	%
Kooragang Island	Cargill Australia Limited Kooragang Island	3,088	23
Kooragang Island	Kooragang Coal Terminal	–2,107	NA
Kooragang Island	Newcastle Coal Infrastructure Group	386	508
Kooragang Island	Orica Kooragang Island Site	–19,331	–3
Kooragang Island	Pacific Carbon	–253,522	–100
Waratah	Moly-Cop Waratah	–324,000	–58
Mayfield West	Newcastle Rod Mill	–3,586	–12
Mayfield	Koppers Mayfield	–271,121	–88
Mayfield	OneSteel Newcastle Wire Mill	633	3
Carrington	Boral Asphalt Carrington	726	56
Carrington	Port of Newcastle	–5,307	–17
Hexham	Hexham Train Support Facility	26,319	100
Hexham	Industrial Galvanizers Hexham	–852	–24
Wallsend	Summer Hill Renewable Energy Facility	–620	–5
Beresfield	Beresfield Feed Mill	–22	–1
Beresfield	Steggles Beresfield Site	–7	0
Beresfield	Steggles Beresfield Site No. 2	1,832	69
Total		**–847,490**	**–45**

Notes: NA = not applicable as not reported in 2016–17. In early 2016, the NSW EPA concluded that Kooragang Coal Terminal does not reach the threshold required to report on category 2b substances. Port Waratah continues to voluntarily report PM_{10} and $PM_{2.5}$ emissions for community information.

Total NO_x emissions from industrial facilities fell by 45% from 2013–14 to 2016–17. The largest fall was for steel manufacturing (Moly-Cop Waratah by 58%), and petroleum and coal product manufacturing (Koppers Mayfield by 88% and Pacific Carbon by 100% due to its closure in 2013–14). The next highest fall in NO_x emissions occurred at Orica Kooragang Island site (3% decrease).

The largest increase was due to rail freight transport, with Hexham Train Support Facility coming online in 2015–16 (Table 9).

SO_2 emissions – all source categories

Figure 31 and Table 10 present estimates of SO_2 emissions for the Newcastle LGA, reported in the NPI for all sources including industrial point sources and diffuse sources.

The NPI data for 2013–14 and 2016–17 show the largest sources of SO_2 emissions in the Newcastle LGA were commercial shipping/boating, petroleum and coal product manufacturing, and motor vehicles, which together made up about 90% of annual emissions from all sources (Figure 31).

SO_2 emissions from all sources fell by 17% from 2013–14 to 2016–17, mostly due to decreases in emissions in petroleum and coal product manufacturing (67%) and meat and meat product manufacturing (99%) (Table 10).

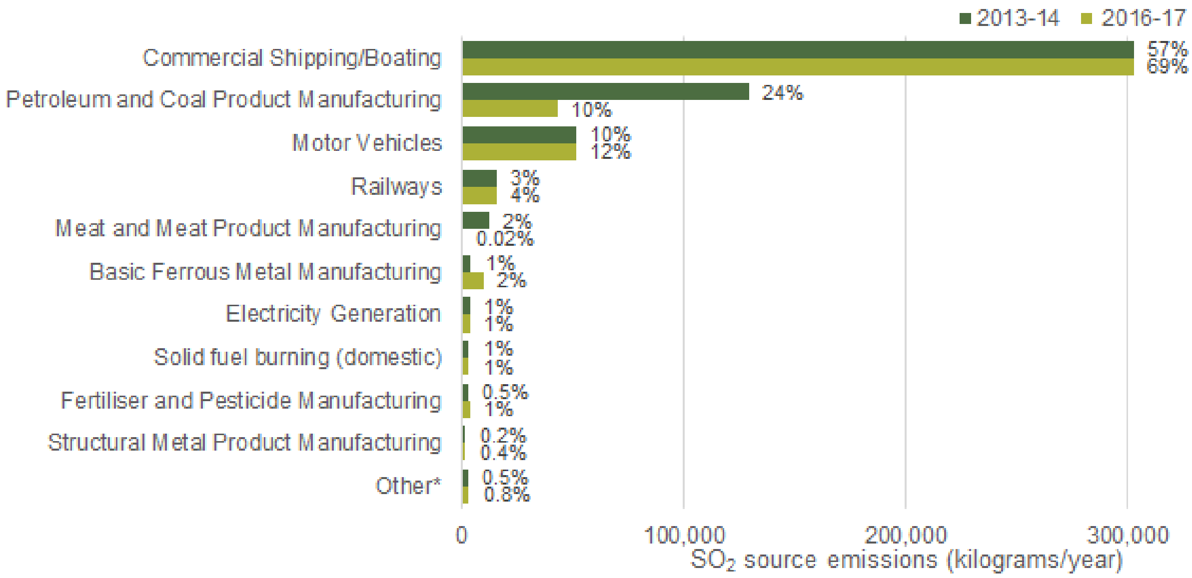

Figure 31 National Pollutant Inventory SO_2 emissions by top 10 source categories for the Newcastle LGA in 2013–14 and 2016–17

* Other is the combined total for the remaining source categories.

Table 10 National Pollutant Inventory SO_2 emissions by top 10 source categories in the Newcastle LGA – changes from 2013–14 to 2016–17

SO_2 emissions source categories	Changes in SO_2 source emissions from 2013–14 to 2016–17	
	Kilograms	%
Commercial shipping/boating	0	0
Petroleum and coal product manufacturing	–86,331	–67
Motor vehicles	0	0
Railways	0	0
Meat and meat product manufacturing	–12,089	–99
Basic ferrous metal manufacturing	5,790	138
Electricity generation	–196	–5
Solid fuel burning (domestic)	0	0
Fertiliser and pesticide manufacturing	1,193	45
Structural metal product manufacturing	568	48
Other*	617	22
Total	**–90,448**	**–17**

* Other = combined total for remaining emission source categories.

SO_2 emissions – industrial facilities

Figure 32 and Table 11 show SO_2 emissions reported to the NPI by major industrial facilities in the Newcastle LGA for 2013–14 to 2016–17.

The largest industrial sources of SO_2 emissions in Newcastle are in Mayfield (petroleum and coal product manufacturing).

Total SO_2 emissions from industrial facilities fell by 59% from 2013–14 to 2016–17. The largest fall was for petroleum and coal product manufacturing (Pacific Carbon by 100% due to its closure in 2013–14 and Koppers Mayfield by 33%).

Hexham Train Support Facility came online in 2015–16.

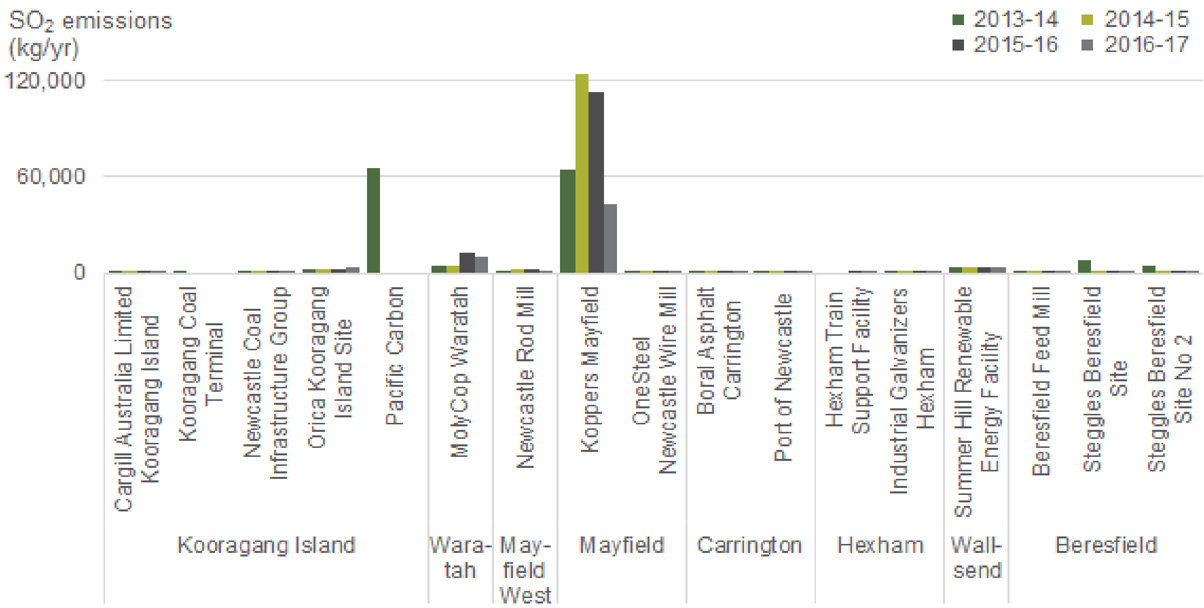

Figure 32 National Pollutant Inventory SO_2 emissions at major industrial facilities in the Newcastle LGA from 2013–14 to 2016–17

Table 11 National Pollutant Inventory SO_2 emissions at major industrial facilities in the Newcastle LGA – changes from 2013–14 to 2016–17

Location	Industrial facility	Change in SO_2 emissions from 2013–14 to 2016–17	
		Kilograms	%
Kooragang Island	Cargill Australia Limited Kooragang Island	–1	–1
Kooragang Island	Kooragang Coal Terminal	–11	NA
Kooragang Island	Newcastle Coal Infrastructure Group	0	0
Kooragang Island	Orica Kooragang Island Site	1,193	45
Kooragang Island	Pacific Carbon	–65,105	–100
Waratah	Moly-Cop Waratah	5,790	138
Mayfield West	Newcastle Rod Mill	568	48
Mayfield	Koppers Mayfield	–21,241	–33
Mayfield	OneSteel Newcastle Wire Mill	618	207
Carrington	Boral Asphalt Carrington	15	13
Carrington	Port of Newcastle	–9	–87
Hexham	Hexham Train Support Facility	10	100
Hexham	Industrial Galvanizers Hexham	–2	–10
Wallsend	Summer Hill Renewable Energy Facility	–196	–5
Beresfield	Beresfield Feed Mill	11	61
Beresfield	Steggles Beresfield Site	–7,865	–99
Beresfield	Steggles Beresfield Site No. 2	–4,223	–99
Total		**–90,448**	**–59**

Notes: NA = not applicable as not reported in 2016–17. In early 2016, the NSW EPA concluded that Kooragang Coal Terminal does not reach the threshold required to report on category 2b substances. Port Waratah continues to voluntarily report PM_{10} and $PM_{2.5}$ emissions for community information.

3. How have the Newcastle Local Air Quality Monitoring Network data been used?

OEH collected close to one million air quality and meteorological records for Newcastle Local Network sites, from its establishment in mid-2014 to the end of 2017. This section reports on how these data have been used extensively by many program stakeholders.

3.1 Provision of air quality data and information to the community

Data collected from the Network are readily available to the public. Air quality information is provided to the community through online services and published reports, with regular updates including media releases.

3.1.1 OEH website

The Network provides the community with hourly updates on current air quality in near real-time via the OEH Newcastle Local Air Quality Monitoring Network – Map website.

The Network website provides facilities for viewing the Newcastle Local air quality monitoring data through an interactive display of air pollutant concentrations at each monitoring site in the Newcastle Local and Lower Hunter networks. Air pollutant levels are presented as hourly data readings, colour-coded for easy comparison with benchmark concentrations.

The interactive map provides a hover function to view pop-out graphs for each site, showing a time series of pollution and wind data for the current day and previous six days. Web-users can view and download the hourly PM_{10}, $PM_{2.5}$, NO_2, SO_2, NH_3, wind direction and wind speed data and create their own graphs of hourly data. Displays of historical data may be viewed by selecting the date and hour of interest.

The OEH website provides a Search air quality data facility for viewing and downloading graphs and tables of historical data and comparing Newcastle Local data to those for other sites in the NSW air quality monitoring network. Feedback in an online survey of OEH air quality web-users reported that the download feature was ‘probably one of the best in the world as it is very comprehensive, down to the hour’ (von Lupin et al. 2018).

Figure 33 shows the number of unique page views[8] for the OEH NLAQMN map website, from 1 January 2015 to 31 December 2017. During this period, the number of daily visits reached 84, with a total of 9201 unique page views. The highest number of views occurred on 7 November 2016 during bushfires in the Port Stephens area, north-east of Stockton.

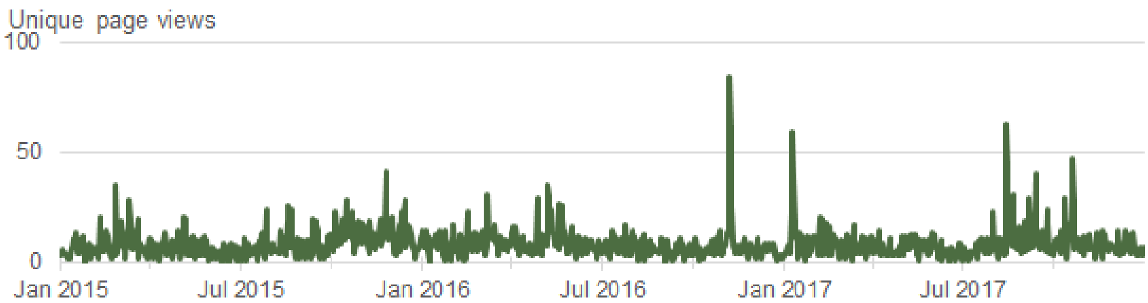

Figure 33 Unique page views for the NLAQMN map website from 2015 to 2017

[8] Unique page views are based on the number of unique visits in each 30-minute session.

3.1.2 Newcastle monitoring reports

OEH reports regularly to the community on air quality in the region.

Seasonal newsletters

OEH analyses data from the Network each season and presents a summary newsletter to the NCCCE. OEH developed the format of the newsletter in consultation with the committee. OEH publishes the newsletters on its website.

Seasonal newsletters from autumn 2015 onwards are available on the OEH Lower Hunter and Central Coast air quality monitoring reports webpage.

The seasonal newsletters provide:

- annual trends of particle (PM_{10} and $PM_{2.5}$) data
- daily time series plots of particle and gaseous data
- number of days above benchmark concentrations
- pollution and wind roses
- seasonal comparisons and trends
- meteorological summary
- Network performance over the season.

The information included in the seasonal newsletters has been enhanced over time in response to stakeholder needs, with feedback provided through the NCCCE.

3.1.3 NSW annual air quality statements

In January each year, OEH releases an annual air quality statement for the whole of the NSW air quality monitoring network. This statement provides the community with summary air quality information for New South Wales.

These statements include:

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

The NSW Annual Air Quality Statements from 2015 to 2017 (and earlier) are available on the OEH website.

3.2 Air quality research projects and initiatives

A number of Lower Hunter air quality studies have used data from the Network to add to the evidence base for air quality management in general and to develop pollution reduction initiatives.

3.2.1 Lower Hunter Particle Characterisation Study

The LHPCS (Hibberd et al. 2016a) and supplementary reports (Hibberd et al. 2016b and Emmerson et al. 2016), used particle and meteorological data recorded at the Stockton and Mayfield sites, which were being established during the study period.

The EPA commissioned the LHPCS to investigate the composition and major sources of airborne particle pollution, measured as finer $PM_{2.5}$ and coarser $PM_{2.5-10}$ particles, in the Newcastle region. The study investigated finer $PM_{2.5}$ particle pollution at monitoring stations in Mayfield and Stockton (NLAQMN) and Newcastle and Beresfield (LHAQMN), and coarser $PM_{2.5-10}$ particles in Mayfield and Stockton.

The study was undertaken by OEH, CSIRO, and the Australian Nuclear Science and Technology Organisation (ANSTO), with oversight by NSW Health. Sampling for one year, from March 2014 to February 2015, preceded detailed analysis to determine the chemical composition and sources of $PM_{2.5}$ and $PM_{2.5-10}$.

The study's key findings were:

- $PM_{2.5}$ and $PM_{2.5-10}$ were composed of primary particles emitted directly into the air and secondary particles formed in air by chemical reactions between gases or gases and particles.
- For finer $PM_{2.5}$ particles:
  - Annual average $PM_{2.5}$ concentrations were similar at Newcastle, Mayfield and Beresfield (6.4 to 6.7 µg/m^3) and about 40% higher at Stockton (9.1 µg/m^3).
  - The largest contributor to $PM_{2.5}$ concentrations at all sites was fresh sea salt (24% at Newcastle, 23% at Stockton, 20% at Mayfield and decreasing to 13% at Beresfield) followed by pollutant-aged sea salt[6] (approximately 23% at all sites).
  - The higher levels of $PM_{2.5}$ at Stockton were attributed to higher levels of sea salt and primary ammonium nitrate particles (19%).
  - Other sources of $PM_{2.5}$ at the sites included smoke from domestic wood heaters, secondary ammonium sulfate[7], soil dust, vehicles, industry factors and mixed shipping/industry.
- For coarser $PM_{2.5-10}$ particles:
  - The main source of $PM_{2.5-10}$ particles was fresh sea salt.
  - The annual average $PM_{2.5-10}$ concentration was 2.5 times higher at Stockton (21 µg/m^3) than at Mayfield (8.3 µg/m^3).
  - Other sources of $PM_{2.5-10}$ included industry, pollutant-aged sea salt, light-absorbing carbon, soil and bioaerosol.

The accompanying LHPCS Supplementary Report – Chemical Transport Modelling Case Studies (Emmerson et al. 2016) investigated the distribution of fine particles over the broader region. The study concluded that the levels and composition of fine particles across the region were similar to those at the study monitoring sites.

The LHPCS Supplementary Report – Quantifying the coal particle component of airborne particulate matter at Stockton (Hibberd et al. 2016b) studied the upper limit of coal within PM_{10} and $PM_{2.5}$ particles at Stockton on days when winds were from the north-west. The study found that coal particles made up on average 10% of the total mass in PM_{1-10}, and 1.8% of the total mass in $PM_{1-2.5}$.

3.2.2 Further investigations to identify major sources of monitored air pollutants

The LHPCS identified the Orica Kooragang Island site as a contributor to fine particulate matter ($PM_{2.5}$), in the form of ammonium nitrate, at the Stockton air quality monitoring station. In 2018, activities required by a Pollution Reduction Program (PRP) were completed, including:

- further analysis of samples from the air monitoring station
- identifying sources of fine ammonium nitrate at the site
- identifying technologies to reduce $PM_{2.5}$ emissions.

The prill tower was found to be the main contributor from the Orica site to $PM_{2.5}$ ammonium nitrate at Stockton. After a comprehensive investigation of potential emission reduction technologies, irrigated fibre-bed scrubbing was identified as the most technically suitable. Further detailed investigations are now underway to determine the feasibility of installing this technology.[9]

[9] Orica, personal communication 19/11/2018. The PRP may be viewed in Orica's Environmental Protection Licence on the EPA website.

3.2.3 Lower Hunter Dust Deposition Study

The EPA commissioned the Lower Hunter Dust Deposition Study (AECOM 2016) to examine the quantity, composition and likely sources of deposited dust in the region. The study used wind data from the Network sites as part of its assessment.

The study's key findings were:

- Dust deposition rates ranged from 0.5 to 1.1 grams per square metre per month (g/m^2/month) and were below the EPA's annual criterion of 4 g/m^2/month.
- Dust particle composition in the 12 dust deposition samples contained:
  - 69% soil or rock particles
  - 10% coal
  - 4% rubber
  - 3% soot
  - 14% other particles including salt, fly ash (from coal burning), alumina, paint and insect and plant material.
- Coal contributed 0.05 to 0.11 g/m^2/month to annual average dust composition.

3.2.4 NSW Government programs and initiatives

The extensive information collected from the NLAQMN has been used to inform numerous programs and initiatives undertaken by the NSW Government. These include:

- Managing particles and improving air quality in NSW
- Clean air for NSW consultation paper.

These programs were considered as part of an independent external review of the Network. The review found that the NLAQMN '*assists with the development of air quality programs*' in the region (Jacobs Group Australia 2018).

3.3 Newcastle Local data used by external users

Data collected from the NLAQMN have been used in various ways by external organisations.

Stakeholders are able to search and download all the data collected from the Network sites, reported in near real-time, through OEH's online air quality data search tool.

A number of external stakeholders are automatically supplied with air quality and meteorological data from the Network sites on a regular basis. The current automatic data feeds are listed in the sections below.

OEH is currently improving data provision to external organisations, by developing an application programming interface. The aim, in the future, is for automatic data feeds set up by external users directly.

3.3.1 Community groups and media outlets

Community groups and media outlets refer to Hunter Valley air quality data in enquires and media articles.

In 2018, an online survey of OEH air quality web-users gathered information about web-users' needs and explored the usability, design and relevance of web content (von Lupin et al. 2018).

The survey identified the range of people using air quality data. Web-users defined themselves as either:

- members of the general public (68.1%)
- NSW Government employees (22%)
- environmental activists (7.8%).

The interests of web-users lay in four main categories:

- personal health reasons (62.4%)
- general interest in air quality (46.8%)
- concerned about health of friends or family (36.9%)
- needed it for work (29.8%).

Participants who provided feedback on the Newcastle Local Air Quality Map accounted for 19.1% of respondents. Positive feedback on the interactive map included the following direct quotes:

- 'The map with hover function is an intuitive way to view the data'
- 'they provide wind direction and strength information so that I can decide if the bas [*sic*] air is coming towards my cycling route or away from route'
- 'Provide a quick snapshot of what has happened recently'.

The survey results provided recommendations from web-users to inform the ongoing improvement of OEH air quality web content.

3.3.2 Industry

Newcastle Coal Infrastructure Group is provided with hourly particle and wind data from all Newcastle region sites automatically each hour. OEH has provided this data for over two and a half years.

3.3.3 Universities

The University of Wollongong is provided with hourly data from the entire NSW AQMN, including sites in the Newcastle Local region. OEH has provided these data automatically each month since April 2018.

3.3.4 Federal government

CSIRO in Newcastle is provided with hourly meteorological data from Mayfield. OEH has provided these data automatically each month since September 2016.

The CSIRO/Bureau of Meteorology Forecasting Demonstration Project is provided with data from several sites in the network, including Stockton hourly gaseous and meteorological data. OEH has provided these data automatically each week since November 2015.

The CSIRO smoke forecasting project is provided with the last three days of hourly data from all network sites, including the Newcastle Local sites, on a daily basis. OEH has provided these data since December 2015.

3.3.5 Air quality impact assessment for industrial development

Proponents for new industrial developments in the Lower Hunter use data from the Network to prepare air quality impact assessments. These studies are required as part of the development approval process set by the *Environmental Planning and Assessment Act 1979* for proposed developments.

3.4 Future potential uses for the NLAQMN data

The data collected from the Network provide valuable information that can support future research programs designed to further improve the understanding of regional air quality.

4. Review findings

This section presents an analysis of Sections 2 and 3 above, and considers feedback from stakeholders in the community, industry and government agencies. The focus questions address the legislative reporting requirements in the Regulation, as listed in Section 1.6.

4.1 Is the monitoring program effective in fulfilling its objectives?

Objective 1

To provide government, industry and the community with reliable and up-to-date information on air quality in Newcastle.

Objective 1 is being met.

Evidence of this objective being met includes:

- The Network design was developed to take into account population centres and emission sources within the Newcastle Port area.
- The region incorporates a high density of sites compared to most other regions in the OEH NSW monitoring network. Six of the current 47 NSW air quality monitoring network stations are in the Newcastle region.
- The Network is robust and reliable, shown by the high online times for particle (>97%), gaseous (>92%) and meteorological (>98%) data measured throughout the Network.
- Data collected from the three Newcastle Local and three Lower Hunter monitoring sites are available in near real-time on the OEH website.
- The Network data can be readily downloaded by external users.
- Industries and local governments in the region are provided with data regularly to better inform their operations.
- The near real-time data on the website are colour-coded to allow for easy comparison against the national benchmarks.
- The Network data can be compared to other sites in the statewide air quality monitoring network.
- The Hunter region is a focus of the NSW annual air quality statements, provided to the community via the OEH website early in January each year.

Objective 2

To provide government, industry and the community with information that is of assistance in assessing changes in air quality and identifying the major sources of monitored pollutants.

Objective 2 is being met

Evidence of this objective being met includes:

- The NSW Government and key stakeholders have gained extensive knowledge of air quality and meteorological processes in the region since the establishment of the Network, through the Network data and associated air quality studies and reports. This information is also available to the wider community on the OEH website.

- Seasonal newsletters are regularly provided to the community, with the newsletters available from autumn 2015 on the OEH website. These newsletters incorporate:
  - assessment of Network data against air quality benchmarks
  - comparison of seasonal data with previous years to assess any differences and establish trends
  - event analyses, with source types (such as bushfires, dust storms and industrial emissions) identified through the analysis of particle levels and corresponding meteorological data
  - a focus section for Stockton PM_{10} seasonal data.
- An extensive meteorological network has provided supporting information on conditions conducive to elevated particle pollution and the transport of pollutants.
- Long-term trends can be established from the increasing amount of air quality and meteorological data collected in the Network.
- The Lower Hunter Particle Characterisation Study (Hibberd et al. 2016a) used data from the Network to assist in identifying the contributions of air pollution sources to levels of PM_{10} and $PM_{2.5}$ measured at Stockton and Mayfield.
- The LHPCS identified the Orica Kooragang Island site as a contributor to fine particulate matter ($PM_{2.5}$), in the form of ammonium nitrate, at the Stockton air quality monitoring station. This resulted in a PRP to reduce $PM_{2.5}$ emissions.

4.2 Is the Network being run efficiently and cost-effectively?

4.2.1 How much has the monitoring program cost?

The cost of the Network includes assets and ongoing operating costs (including maintenance, calibrations, audits, quality assurance and reporting). In addition, there is a cost for the EPA to administer the Regulation and support the NCCCE.

These costs are recovered annually through levies to industries in the Newcastle LGA that hold Environment Protection Licences related to air emissions[10]. These levies are based on the annual individual emissions from each industry. The calculation of the levy is specified within the Regulation.

The total annual capital and operating costs to establish and maintain the Network from financial years 2014 to 2017 are outlined in Table 12.

Table 12 Total OEH capital and operating costs from financial years 2014 to 2017

Expenses	Costs to FY17
Capital (including site construction costs)	$626,525
Operational	$181,010
Labour	$884,256
TOTAL	**$1,691,791**

[10] Protection of the Environment Operations (General) Regulation 2009, clause 79Q (6) allows an industry to not pay an annual levy for a levy period if the levy amount when calculated is less than $100

4.2.2 Independent audit of efficiency and cost-effectiveness

This section reports on the independent audit of the efficiency and cost-effectiveness of the Network, required by the Regulation.

Jacobs Group (Australia) Pty Ltd[11] reviewed Network reports and costs to conduct the independent audit of the efficiency and cost-effectiveness of the Newcastle Local monitoring program (Jacobs Group Australia 2018).

The independent audit found that:

> Overall the NLAQMN is considered to be efficient and cost-effective in providing reliable and accurate air quality monitoring data that can be available in near real time to the NSW Government, community, industry and other stakeholders.

The conclusions of the independent audit were:

> The Newcastle Local Air Quality Monitoring Network:
>
> - Provides reliable and up-to-date information on air quality in the region.
> - Allows for assessment of air quality against relevant standards.
> - Assists with the identification of sources of air pollution.
> - Assists with the development of air quality programs.
>
> The NLAQMN has provided high-quality, continuous data on air quality in Newcastle. Information is provided in regular seasonal and annual reports, as well as being available in numerical format on the OEH website. Recent improvements to data provision and resolution have improved transparency and reach for the data produced from the monitoring network.
>
> - Monitoring site infrastructure is fit-for-purpose and represents value for money.
> - Monitoring equipment is fit-for-purpose and represents value for money.
> - Network maintenance and reporting program and associated labour costs are cost-effective.
> - Operational costs of the program are fit-for-purpose and represent value for money.
>
> The network has achieved a high valid data capture rate since commissioning. The network has achieved >95% capture since autumn 2015. This indicates that the processes in place are effective at producing reliable and effective information on air quality.

Table 13 presents the recommendations provided in the independent audit for future efficiency improvements and cost-effectiveness of the NLAQMN.

[11] Jacobs Group (Australia) Pty Ltd was selected to undertake the independent review due to their expertise in the field (having undertaken the review of the cost-effectiveness of the proposed NLAQMN prior to its establishment); and as they have not been involved in the operation of the Network or been engaged by industry who contribute funding to the Network to undertake any projects relating to the NLAQMN since its commissioning.

Table 13 Recommendations of the independent audit of the efficiency and cost-effectiveness of the Newcastle Local air quality monitoring program

Source: Jacobs Group Australia (2018)

Number	Independent audit recommendation
1	Fern Bay was initially included as a monitoring location for the NLAQMN on the basis of predicted impacts from the Port (PAE Holmes 2011) and proximity as a community bordering the Port precinct to the north-east. During network commissioning the population was relatively low, but has since increased following extensive residential development in the area. On that basis, it is recommended that OEH, EPA and NCCCE reconsider Fern Bay for monitoring. Consideration could be given to campaign monitoring to understand potential for any impacts, or an air quality assessment using dispersion modelling using updated emission data.
2	Consistent with the recommendation made in the initial audit report (Jacobs 2014), it would be beneficial to allow industry to rationalise the cost of individual site monitoring. It is recommended that the EPA provide a framework for industry outlining how to undertake this rationalisation and remove redundant air quality monitoring from their regulatory requirements if there is overlap. Of note is the example of improved data transparency and reduced monitoring burden for Orica at Stockton, with the incorporation of the Orica air quality monitoring station into the NLAQMN.
3	Rapid changes to the way information is distributed and received have occurred in recent years, with a large increase in the uptake of handheld devices. This change necessitates consideration of mobile methods of communication to provide up-to-date information from the network to all members of the community. EPA is currently reviewing their communication strategy and should specifically assess the costs and benefits of information presented for mobile platforms, along with more traditional methods. It is acknowledged that at time of writing, this review was underway by NSW Government.

4.2.3 Consideration of changes in Network design recommended by the independent audit and stakeholder feedback

Each of the recommendations provided within the independent audit (Table 13) is considered below.

Audit recommendation 1 – Reconsider Fern Bay for monitoring

The independent audit suggested reconsidering Fern Bay as an additional location for monitoring, given the impacts from the Port of Newcastle, predicted in the original study on network design (PAE Holmes 2011), and the increase in population since the commissioning of the Network.

OEH does not support the recommendation for an additional air quality monitoring station at Fern Bay, nor the need for campaign studies or additional air quality assessments. The analysis in this review concluded that air quality data recorded at the Stockton monitoring station remains representative of air quality approximately three kilometres to the north at Fern Bay.

In summary, this conclusion was based on:

- the evidence for similar wind patterns across the local region and efficient dispersion of air pollutants close to the coast
- the greater population in Stockton (4160) compared to Fern Bay (2763) (ABS 2016)
- the cost of operating one monitoring station at Stockton, compared to the cost of operating two monitoring stations within three kilometres of each other in a coastal location
- an environmental assessment process being undertaken, including air quality modelling, for any future proposed industrial developments that may increase air quality impacts to Fern Bay.

The evidence supporting this conclusion is presented in more detail below.

Proximity of Fern Bay residential development to air quality impacts from portside industries

The Fern Bay residential developments are located approximately one to four kilometres north-east of the major sources of air pollution surrounding the port of Newcastle. This suggests that south-westerly winds are generally required for primary air pollutants from portside industrial sources to be transported directly downwind towards Fern Bay.

Modelled wind patterns for Fern Bay for 2006 to 2010 found that prevailing winds were similar across the Newcastle inner city and portside suburbs, with south-westerly winds at Fern Bay expected to be experienced less than 4% of the time (PAE Holmes 2011).

The review of wind data from 2015 to 2017 confirmed that similar wind patterns were experienced across the Network sites (Figure 15). Based on comparison with Stockton's wind patterns from 2015 to 2017, Fern Bay is likely to experience:

- south-westerly winds 9.3% of the time
- westerly winds 10.2% of the time
- north-westerly winds 22.6% of the time.

This suggests that primary air pollution from portside areas would be transported most frequently towards Stockton, rather than towards Fern Bay.

The LHPCS (Hibberd et al. 2016a) found $PM_{2.5}$ concentrations of non-sea salt secondary air pollutants were similar across all monitoring sites. The LHPCS Supplementary Report (Emmerson et al. 2016) concluded that non-sea salt secondary particles were well mixed across the Lower Hunter region. The study demonstrated similar concentrations would be experienced at locations across Newcastle as well as in neighbouring local government areas, such as Toronto (Lake Macquarie LGA) and Maitland (Maitland LGA).

This review found that air quality at Stockton was very good to fair 82% of the time from October 2014 to December 2017. The highest particle pollution at Stockton occurred during the warmer months. The LHPCS (Hibberd et al. 2016a) found that sea salt in the predominant north-easterly sea breeze elevated particle measurements during the warmer months.

From this analysis, it is reasonable to deduce that air quality at Stockton remains representative of air quality experienced at Fern Bay; and that air quality at Fern Bay, on average, is likely to be very good to fair at least 82% of the year.

Fern Bay population increase

The analysis of ABS Census data (ABS 2011 and ABS 2016) found that Fern Bay experienced the highest increase in population numbers and density among portside suburbs, increasing by 1138 people from 2011 to 2016. There were 483 residential lots created for Fern Bay from 2014 to 2018[12]. Figure 34 shows the expansion of the retirement village in northern Fern Bay and the residential development in north-east Fern Bay, from 2014 to 2017. There are at least 300 additional dwellings proposed under current planning proposals[12].

Although Fern Bay has experienced a large relative growth in population (70%), the net population of 2763 in 2016 remains lower than Stockton, with 4160 residents in 2016 (Table 14). Based on the current planning proposals, the population in Fern Bay is expected to remain lower than or similar to Stockton within the next review period.

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[12] The number of new lots and current planning proposals were provided by Port Stephens Council (personal communications, September and October 2018).

Figure 34 Map showing the expansion in residential development (green rectangle) north and north-east of the originally proposed Fern Bay site from August 2014 (top) to December 2017 (bottom)

Estimated costs for an additional monitoring station at Fern Bay

The costs of commissioning a new air quality monitoring station would need to consider the:

- location of the monitoring station, for example, whether it would require site works, flood mitigation, electrical works or fencing
- purpose of the monitoring station, for example, what parameters need to be monitored.

The cost of a monitoring station can vary significantly based on these requirements.

Using an average of the costs to establish and maintain the existing Network stations, an additional monitoring station at Fern Bay would be estimated to cost:

- $200,000 capital costs for the construction of the station
- $80,000 annual operating costs.

These estimated costs have been made assuming:

- the same parameters would be monitored as at the other stations in the Network
- operational costs would be similar to recent years now that the Network is established
- there would be no extraordinary costs, such as for electrical works.

Fern Bay and increased impacts of future industrial development

Industrial developments in New South Wales require an environmental impact assessment, as part of the approval process set by the *Environmental Planning and Assessment Act 1979*. Assessment of air quality impacts may involve campaign (short-term) monitoring of air quality before the development, or modelling of air quality dispersion from the proposed development.

Air quality modelling uses detailed estimates of local and regional air emissions as inputs to the computer model. The NSW Air Emissions Inventory provides continuously updated and detailed estimates of emissions from point sources and all categories of diffuse sources of air pollutants for the NSW Greater Metropolitan Region. This region includes Fern Bay, in the Port Stephens LGA and neighbouring LGAs. Consequently, air quality impact assessments for future industrial developments near Fern Bay would be assessed using the most accurate and up-to-date estimates of local and regional air emissions.

Therefore, this report does not support the recommendation for additional campaign monitoring or air dispersion modelling for Fern Bay.

Audit recommendation 2 – Rationalisation of industry monitoring

The independent review suggested the EPA provides a framework for industry to undertake the rationalisation of industry-operated air quality monitoring.

Industries around the Port of Newcastle conduct limited off-site air quality monitoring. During establishment of the NLAQMN, an existing air quality monitoring site at Stockton was transferred to OEH management and became part of the NLAQMN. Since then, other industries, including Koppers Mayfield, have been permitted to reduce their monitoring because it duplicated monitoring conducted as part of the NLAQMN. Industries are welcome to apply to the EPA if they consider there is scope to rationalise their off-site monitoring. Each application is assessed on its individual merits.

Therefore, this report does not support an additional procedure for rationalisation of industry monitoring.

Audit recommendation 3 – Improvement to the air quality information presented on mobile and traditional platforms

The independent review recommended considering mobile methods to communicate up-to-date information from the Network. The OEH air quality data management system currently provides hourly-updated air quality data from the Network to mobile phones and tablets (handheld internet browser devices).

OEH is committed to continuously improving the communication of air quality data and information, in line with the evolution of webpage management systems. Focus interviews and an online survey in 2018 explored ways to better meet the needs of air quality webpage users (von Lupin et al. 2018). Participants included nominees from stakeholder groups including the NCCCE, Asthma Australia, NSW Health, the NSW Rural Fire Service, the Bureau of Meteorology, the Clean Air Society of Australia and New Zealand, and councils with NSW air quality monitoring stations in their local government areas. The online survey found web-users accessed the air quality webpages using desktop computers or laptops (73%), smartphones (46.6%) and tablets (32.6%) (von Lupin et al. 2018). A key goal for OEH is to improve the function and visualising of online air quality information, for easier interpretation by increasing numbers of people using mobile devices.

OEH is in the process of reviewing its data provision facilities and the next generation data system. As part of the new content design, OEH plans to review the compatibility of the air quality data presentation websites on other platforms. This will include a cost-benefit analysis.

Therefore, this report recommends improvement to the air quality information presented on mobile and traditional platforms.

4.3 Can the monitoring program be improved?

The original network design was driven by the location of major pollution sources, population centres, the topography of the Newcastle port area and its influence on air movement.

Re-analysis shows that these drivers have not changed significantly since the Network was established. The evidence presented below validates the original design. This report recommends no change in the design of the Network.

4.3.1 Recommendations for the original Network design

In 2011, OEH commissioned a report to recommend locations for air quality monitoring sites, based on a review of meteorology and air pollution sources in the neighbourhood of Newcastle's inner city and port area.

The report by PAE Holmes (2011) identified the following points.

The highest predicted PM_{10} impacts associated with local industry were anticipated to occur (across all relevant averaging periods) within the suburbs of:

- Warabrook
- Mayfield
- Carrington
- Fern Bay.

It was, therefore, suggested that additional PM_{10} monitoring would be most valuable within the above suburbs, with priority given to those that represent higher population densities. Reference to Australian Bureau of Statistics Census data indicated that Mayfield had a population significantly higher than Warabrook, Fern Bay and Carrington.

The meteorological review of winds from 2006 to 2010 showed prevailing wind patterns were very similar across all locations (onshore winds prevailing from the east-north-east through to east-south-east and offshore winds from the west and west-north-west). This pattern was reflected at all distances from the coast.

There was also a similar pattern across all the modelled years. Dispersion was favourable closer to the coastal areas as a result of higher wind speeds, increased mechanical mixing and a lower frequency of stable conditions (PAE Holmes 2011).

In 2012–13, EPA and OEH consulted the NCCCE on the establishment of an air quality monitoring network. The NCCCE reviewed site assessment reports and visited 11 candidate site locations.

In conclusion, the EPA favoured three of four sites endorsed by the NCCCE, at Mayfield West (CSIRO site), Carrington (Hargrave Street reserve) and Stockton (Orica monitoring station at Fullerton Street) (NCCCE meeting minutes – Meeting No.11, 10 September 2012 and Meeting No.21, 16 September 2013).

The EPA considered that the industry-operated monitor at Stockton would be a reliable indicator of air quality approximately three kilometres to the north-north-east in Fern Bay.

4.3.2 Review of the Network design drivers

Topography and meteorology

The current topography and meteorology of Newcastle's inner city and port area remain consistent with descriptions at the time of the original design of the Network.

The terrain between the residential suburbs and major sources of air pollution is low-lying, with an absence of features that would affect prevailing wind patterns.

The wind data collected by the Network from 2015 to 2017 confirmed the prevailing seasonal wind patterns were similar at monitoring sites across the port area (Figure 15). Onshore winds from the north-east to south-east prevailed in warmer months and offshore winds from the north-west prevailed in cooler months (Figure 16). This pattern was consistent with the meteorological review by PAE Homes (2011) preceding the Network design.

Changes in population distribution

The population of Newcastle's inner city and portside suburbs increased by 6%, or 2017 people (from 32,604 to 34,621), from 2011 to 2016[13] (Table 14 and Figure 35). The largest net increases in population occurred at Fern Bay (1138 people, 70%), followed by Newcastle inner city (369 people, 15%).

The population of the City of Newcastle was 162,358 in 2017[14]. This is projected to increase by 0.91% on average each year, reaching a population of 171,307 by 2021 (at the next four-yearly review). The largest increase in population is expected to be in the Newcastle–Newcastle East–Newcastle West region (3.74% per annum on average).

[13] Australian Bureau of Statistics 2011 and 2016 census data (accessed September 2018)

[14] The City of Newcastle community profile and population forecasts (accessed October 2018)

Figure 35 Location map showing inner city and portside suburbs in Newcastle LGA and Fern Bay in Port Stephens LGA

Table 14 Population in the inner city and portside suburbs of Newcastle LGA and Fern Bay in Port Stephens LGA

Population centre	Population 2011 (ABS 2011)	Population 2016 (ABS 2016)	Population net change 2011–2016	Population % change
Carrington	1,874	1,929	55	3
Fern Bay	1,625	2,763	1,138	70
Hexham	179	130	–49	–27
Islington	1,806	1,883	77	4
Kooragang	18	0	–18	–100
Maryville	1,420	1,444	24	2
Mayfield	9,070	9,314	244	3
Mayfield East	1,710	1,692	–18	–1
Mayfield West	1,771	1,895	124	7
Newcastle	2,384	2,753	369	15
Newcastle East	991	1,004	13	1
Newcastle West	594	618	24	4
Sandgate	309	305	–4	–1
Stockton	4,195	4,160	–35	–1
Tighes Hill	1,615	1,680	65	4
Warabrook	2,091	1,972	–119	–6
Wickham	952	1,079	127	13
Total	**32,604**	**34,621**	**2,017**	**6**

Changes in the location of major emission sources

There has been little change in the location of the major industrial emission sources since the commissioning of the Network. During this time:

- Hexham Train Support Facility came online in 2015–16. This facility is a source of PM_{10} and $PM_{2.5}$ particles and NO_X.
- Pacific Carbon at Kooragang Island closed in 2013–14. This facility was a source of NO_X and SO_2, along with a smaller source of particles.

The NPI data show that anthropogenic emissions from industrial sources decreased from 2014 to 2017 in the Newcastle region (see Section 2.3 for details).

In summary, from 2013–14 to 2016–17:

- PM_{10} emissions from all sources fell by 17%, with a 29% fall from industrial facilities
- $PM_{2.5}$ emissions from all sources fell by 20%, with a 20% fall from industrial facilities
- NO_x emissions from all sources fell by 15%, with a 45% fall from industrial facilities
- SO_2 emissions from all sources fell by 17%, with a 59% fall from industrial facilities.

In September 2018, the Department of Planning and Environment (DPE) released the Greater Newcastle Metropolitan Plan 2036, outlining the longer-term plan for the region (DPE 2018). The plan states that the desired roles for the Newcastle Port in Greater Newcastle over the next 18 years are:

- global gateway, providing international freight connections servicing Greater Newcastle and the Hunter Region
- emerging tourism gateway centred around the Newcastle Cruise Terminal
- providing capacity to generate port-associated industry and regional and local employment while planning for land-use compatibility, acknowledging the high demands on land and infrastructure affecting surrounding lands and requiring a separation from adjoining land uses to sustain their success.

While the plan for the Newcastle Port is to increase the area's transport connections (both for tourism and imports/exports), most port precinct plans outline that DPE and other authorities will work with operators and industry to minimise the impacts of the planned activities on residential communities. Likely development is expected to remain within the existing industrial footprint around the port.

4.3.3 Conclusion regarding the existing NLAQMN monitoring program

Based on the outcomes of this review, as discussed above, OEH recommends developing better ways of communicating air quality information to all relevant stakeholders, including improved content available to users of mobile devices.

4.4 Are there any additional matters to consider in relation to the program?

4.4.1 Positive outcomes in the first four year of Network operations

The following stakeholder feedback has been received from the NCCCE (Meeting No. 50):

- The Network provides reliable and valuable information.
- The web links to air quality information and Network data on the EPA and OEH websites are very good.
- The Network provides useful information for the EPA's investigations to determine whether air quality changes are regional or localised.

- Local ambient data helps the EPA to understand how its regulatory activities are leading to changes in air quality.
- Network monitoring has been useful in identifying air quality issues at the Orica facility, both through the data obtained and particle characterisation studies.
- OEH's analysis of data over the long-term provides useful information regarding seasonal patterns of air quality and the impact of meteorology on air quality.

4.4.2 Additional considerations for the program in the next four years

Feedback from stakeholders in the community, industry and government agencies raised the following eight additional considerations. A response has been provided for each consideration.

1. Improving the timeliness of the air quality summary reports and the review time for the NCCCE to consider the summary reports before its meetings

OEH and EPA aim to:

- provide seasonal newsletters to the NCCCE at least three days before the committee meetings
- publish seasonal newsletters online as soon as possible in the following season after full data validation.

2. Improving and simplifying the written interpretation of air quality data

The structure of the seasonal newsletter has been developed and improved over time in consultation with the NCCCE. OEH can continue to discuss any suggestions for further improvement with the NCCCE.

3. Reporting data as 15-minute averages to:

- capture the peaks in air quality associated with short-term emissions from factories or shipping and wind variability in the port area
- improve monitoring of operational responses by industry.

One hour is the shortest averaging period for data provided by OEH. This is consistent with air quality reporting in major cities internationally. In collaboration with OEH, industries in the Newcastle area may consider installing data loggers at Network sites to access data directly. Some mines in the Upper Hunter collect data in this way at their own expense.

4. Consistency in terms of what is monitored across New South Wales to allow for statewide comparisons of air quality

OEH applies a consistent approach to monitoring in the NLAQMN compared to the other regions within New South Wales, such as the Lower Hunter, Upper Hunter, Sydney, Illawarra, Central Coast and some regional centres. Standard operating procedures apply to monitoring instruments and quality assurance procedures, making the data directly comparable.

The NLAQMN has additional monitoring to assess air quality specific to the region, such as monitoring ambient ammonia.

5. Ensure the community has accurate information

OEH will continue to provide the community with accurate and reliable air quality information through:

- near real-time and historical data on its website
- seasonal summary newsletters providing interpretation and analysis of air quality events in the region
- NSW annual air quality statements available soon after the end of the year.

6. More monitoring stations with monitoring of more pollutants – benzene, toluene, diesel emissions and wood smoke – as technology improves, focusing on what is reasonable and cost-effective

There are currently six monitoring sites in the Newcastle region (LHAQMN and NLAQMN), providing one of the highest densities of air quality monitoring stations in the NSW Greater Metropolitan Region. The location and number of air quality monitoring stations in the NLAQMN was thoroughly investigated prior to the establishment of the Network, in consultation with the NCCCE. This review finds that the original design continues to be supported. Further to this, industries monitor impacts of their emissions providing summary air quality data to the community.

The air pollutants monitored within the NLAQMN, such as PM_{10}, $PM_{2.5}$, SO_2 and NO_2, capture diesel and wood smoke emissions in the region.

OEH and the EPA will continue to review the monitoring programs as ambient air quality monitoring technology evolves and in the context of the broader air quality strategy for New South Wales.

7. Improving community awareness of available air quality information and ease of access by:

- developing a mobile app for improving access to air quality information, especially for younger audiences
- greater use of all social media sites to notify the community of air quality information
- greater use of infographics to convey air quality levels and narratives, potentially in collaboration with the City of Newcastle
- considering the use of short videos
- improving content and functionality of air quality data accessible via mobile devices
- considering a hard copy newsletter.

OEH and EPA will consider each of these recommendations in developing an air quality communications strategy for the region. The merits and costings will be taken into account to ensure the best value-for-money outcome occurs. For example, feedback from a committee member suggested that enhanced accessibility on mobile devices could be achieved without a potentially costly mobile app.

Infographics and other communication tools will be considered and developed; for example, the downloadable infographics fact sheet about understanding particles in the Lower Hunter.

8. Engage with local journalists to address issues of misinterpretation of air quality media reports

OEH and EPA stakeholder engagement to consider this recommendation is part of the air quality communication strategy.

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