NSW Environment Protection Authority

Lower Hunter Dust Deposition Study

Final Report

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Client: NSW Environment Protection Authority

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Executive Summary

The Newcastle Community Consultative Committee on the Environment (NCCCE) administered by the New South Wales (NSW) Environment Protection Authority (EPA) was commissioned in 2011 to advise the Minister for the Environment and the EPA about environmental and amenity issues in the Newcastle local government area (LGA).

Through the NCCCE, the community (both groups and individuals) had raised concerns about the levels of visible deposited dust in the Newcastle LGA. In response to the community concerns, the EPA, at the request of the NCCCE, formed the Lower Hunter Dust Deposition Project Reference Group (LHDDPRG) and initiated the Lower Hunter Dust Deposition Project (LHDDP). The LHDDPRG comprised eight members: two community representatives, two industry representatives, two independent technical experts and two EPA staff members. The reference group acted as a conduit between the broader community and the EPA regarding the study, and advised and guided the EPA on project design and delivery.

After a competitive tender process AECOM was commissioned by the EPA, in consultation with the LHDDPRG, to undertake a twelve month monitoring program to assess dust deposition rates as well as the composition of the deposited dust. The LHDDGRG was integral in planning the project's research questions, scope and methodology. The study design included a peer review of the methodology paper by an independent technical expert.

Through the LHDDPRG, expressions of interest were sent out to the community requesting locations for dust monitoring for a one year period. Responses to the request were collated and those sites within the LHDDP defined area were reviewed for appropriateness with relevant Australian Standard siting guidelines. Twelve representative sites were selected and approved in coordination with the LHDDPRG.

Dust sampling was undertaken during the period October 2014 and October 2015 to identify trends in local dust levels and composition. The dust monitoring program was comprised of:

- A dust monitoring network of 12 dust deposition gauges (DDGs) installed by AECOM and sampled and analysed for insoluble solids and ash residue in general accordance with the Australian Standard AS/NZS 3580.10.1:2003(R2014) and the EPA (DEC 2005a) guidelines;
- Collection of 36 Petri dish and 24 brush samples at spatially variant locations to identify dust composition. Petri dish samples were used to identify short term impacts during specific meteorological conditions, while brush samples were used to identify longer term trends;
- Laboratory analysis of samples including:
  - Dust gauge sample analysis (weighing dust gauge samples and determining dust deposition rates) conducted by Australian Laboratory Services (ALS) Environmental Laboratory, a NATA-accredited and registered laboratory for standard dust gauge sample analysis (NATA accreditation number 825); and
  - Stereomicroscopy, scanning electron microscopy (SEM) and energy dispersive x-ray spectroscopy (EDS) to identify particle composition of Petri dish, brush and selected DDG samples by the University of Queensland Materials Performance (UQMP) laboratory.

For the purpose of the study, black dust refers to the visible, total deposited matter that is deposited at residential locations within the study area and collected during the study.

In the laboratory, microscopic analysis revealed that the samples of total deposited matter, visible to the eye as black dust, were comprised of:

- Brown particles of soil or rock;
- Black particles of coal, soot and rubber; and
- Lighter coloured particles of salt, plant and insect debris, alumina, paint and miscellaneous fibres.

The results of the study found:

- Annual average dust deposition for each of the twelve DDG sites was found to be below the EPA maximum dust deposition criterion of 4g/m^2.month (DEC, 2005a) for all sites with annual averages ranging from 0.5 to 1.1 g/m^2.month. Of the total dust deposited, approximately 17% was identified as black particles (coal, soot and rubber), equating to an annual average deposition rate in the order of 0.09 to 0.19 g/m^2.month for black particles alone
- Results of the composition identification analysis are summarised below and in **Figure 1**.
    - Soil or rock (primarily aluminosilicate) as the primary source of deposited dust averaging 69% of all samples with a range of 40% to 90%;
    - Insect and plant debris accounted for an average of 10% of all samples with a range of 0% to 40%;
    - Coal on average formed 10% of total deposited dust with a range of 0% to 25%;
    - Rubber dust on average made up 4% of total deposited dust with a range of 0% to 20%;
    - Soot accounted for an average of 3% of all samples with a range of 0% to 20%; and
    - The remainder of the deposit dust was largely comprised of halite (salt), fly ash (from burning coal and other materials), alumina, paint and miscellaneous fibres.

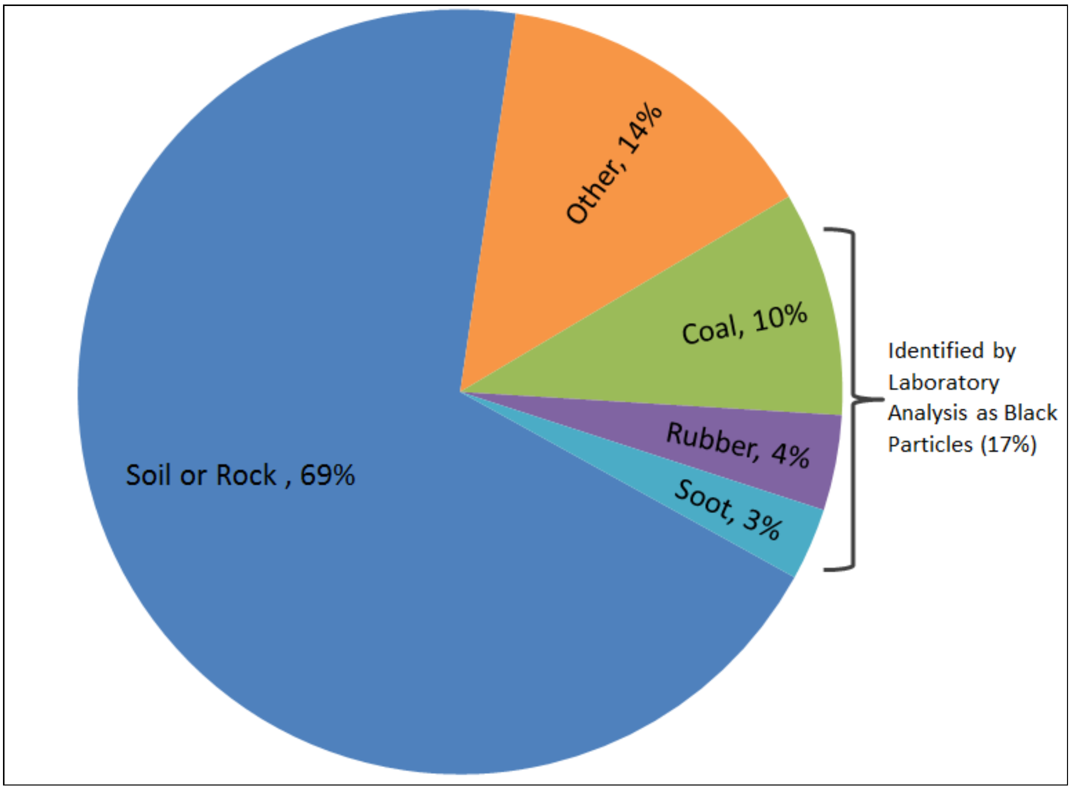

Figure 1 Average Percentage Composition of Deposited Dust Samples (all samples)

Results of the identification analysis determined soil or rock (primarily aluminosilicate) as the primary source of deposited dust averaging 69% of all samples[1]. This is consistent with the findings of the deposited dust composition studies conducted by the Queensland Government (refer to **Section 2.2.4**) which found the major deposited dust to be soil or rock dust.

Photographs detailing the steps taken to collect and analyse a typical sample of deposited dust are shown below. As can be seen from the example sample below, the analysis methods can identify particles both visually and analytically. As can be seen below, the colour of the sample may vary depending on the magnification and

[1] Including brush samples, DDG samples and petri dish samples.

background colour with analytical results for this sample identifying the composition as predominantly soil and rock particles.

Figure 2 **Typical Brush sample location and collection of dust sample which appears as black dust to the human eye.**

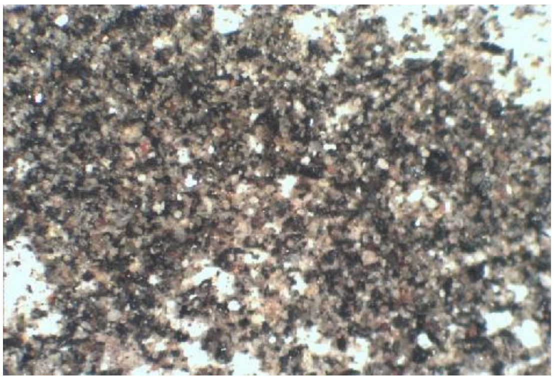

Figure 3 **Stereomicroscopy image showing that the 'black dust sample' is composed of brown, black and lighter particles.**

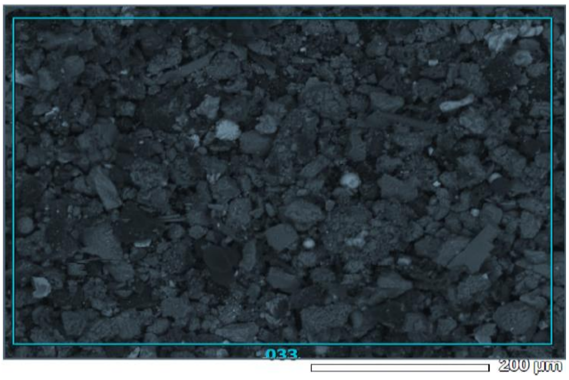

Figure 4 **Scanning electron microscopy (SEM) image of sample, which allows individual particle types to be identified (black and white)**

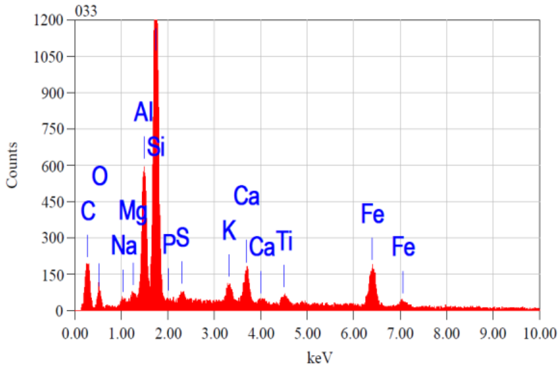

Figure 5 **Energy Dispersive X-ray Spectroscopy (EDS) results showing elemental particle composition of SEM image area.**

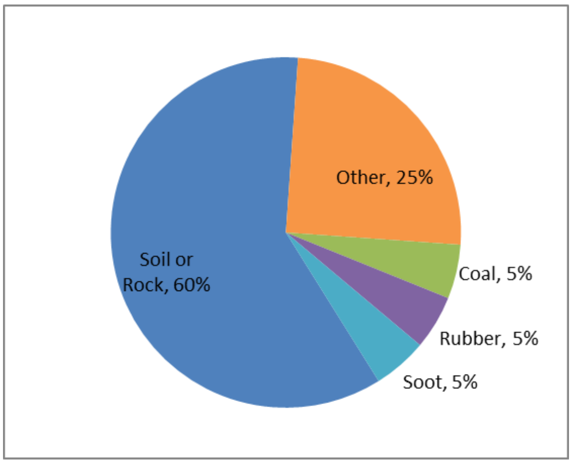

Figure 6 **Pie chart detailing laboratory results of the brush sample collected in Figure 2.**

The initial brief highlighted a number of research questions that the study should address. The project research questions are addressed below:

1) What is the association between proximity to potential sources, such as the rail corridor, and rate of dust deposition?

There was little association between the proximity to potential sources and the rate of dust deposition. The average dust deposition rate for the sampling period was 0.8 g/m^2.month. Of the locations in close proximity to the rail line the averages were:

- Waratah 0.8 g/m^2.month
- Islington 1.1 g/m^2.month
- Tighes Hill 0.9 g/m^2.month
- Hamilton 0.8 g/m^2.month

Other potential sources such as industrial facilities in Waratah/Mayfield and coal handling facilities in Tighes Hill were also in proximity to these locations.

Newcastle received the lowest annual deposition rate of 0.5 g/m^2 month. It is noted that there is no industrial rail corridor or industry in this location.

2) What is the level of dust deposition that is representative of specific areas in the Lower Hunter, including the rail corridor?

Dust deposition was measured at 12 locations across the Newcastle LGA with annual average deposition rates for insoluble solids found to be between 0.5 and 1.1 g/m^2 month for the study period. **Table 10** gives the annual averages for each of the specific dust gauge locations.

3) How do measured dust deposition rates compare with international dust deposition criteria and NSW criteria? - What is the composition of deposited dust?

As part of this study dust deposition was measured at 12 locations for a 12 month period. Annual dust deposition rates for insoluble solids ranged between 0.5 and 1.1 g/m^2.month, below the NSW EPA maximum criteria of 4 g/m^2.month. The deposition rates were also below the international criteria listed in **Table 5** of **Section 3.0**. Analysis indicates that the dust is generally comprised of soil and rock particles with smaller fractions of coal, rubber and soot as well as inorganic matter such as insects and vegetation.

4) Is coal dust deposited at residential properties and/or other locations within the study area?

Coal dust was found in the majority of DDG, brush and Petri dish samples collected during this study. Samples were collected from both residential and non-residential areas within the Newcastle LGA. On average, coal accounted for 10% of the dust within samples analysed.

5) What is the composition of the 'black dust' identified at residential properties within the study area?

Noting that for the purpose of this study that 'black dust' was considered to be the total dust observed by residents on surfaces around their properties, the following was found. On average, samples were primarily comprised of soil and rock, accounting for 69% of the composition of samples. Following this, coal was the second largest contributor at 10%, with rubber (4%) and soot (3%) accounting for smaller portions. Particles identified as black by laboratory analysis (coal, soot and rubber) therefore on average accounted for 17% of the total deposited dust analysed.

6) What are the potential attributable sources of deposited dust/black dust?

Potential sources of deposited dust/black dust include natural ground (soil and rock dust). Such areas may include natural earth, beaches, farming operations, construction sites and mining operations. Potential sources of black particles (coal, soot and rubber) are likely to include coal handing operations, industrial activities, shipping and automobile traffic and tyre degradation.

7) Are there geographical or spatial variations in dust deposition/black dust?

While there is some variation between dust deposition annual averages across the 12 DDG monitoring locations selected for this study, it is relatively minimal. The Newcastle site returned the minimum annual average at 0.5 g/m^2.month with Islington recording the maximum of 1.1 g/m^2.month. The other 10 sites recorded annual averages ranging from 0.7 to 0.9 g/m^2.month resulting in overall average deposition rate of 0.8 g/m^2.month for the study area.

Black dust, or more specifically black particles did show some geographical variations. Coal was at times observed in higher concentrations when sampling was performed downwind of coal handling operations however at other times, samples contained relatively low concentrations under these conditions. Generally the percentages of coal found were higher in those areas surrounding the port and coal handing areas.

Soot was also found in higher concentrations around and downwind of the port operations. Sources may include ships, trains and trucks as well as industry located around the port area.

No observable pattern was observed when analysing the distribution across the sample area.

It is recommended that longer term monitoring be undertaken to account for longer term meteorological variability and to establish long term regional trends. Additionally, further monitoring could be undertaken outside the study area to determine the background levels and composition of deposited dust in other areas of the State. Short term sampling and analysis is also recommended, with strategic collection of samples upwind and downwind of sources to identify significant contributors.

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1.0 Introduction

1.1 Background

The Newcastle Community Consultative Committee on the Environment (NCCCE) administered by the New South Wales (NSW) Environment Protection Authority (EPA) was commissioned in 2011 by the NSW Minister for the Environment. The NCCCE works with community groups in the Newcastle Local Government Area (LGA) to identify environmental and amenity issues associated with local industrial activities.

Through the NCCCE, the community, both groups and individuals, have raised concerns about the level of visible black dust deposited around residences in the Newcastle area. In response to the community concerns, the EPA, at the request of the NCCCE, initiated the Lower Hunter Dust Deposition Project (LHDDP) and formed a project reference group for the study. The Lower Hunter Dust Deposition Project Reference Group (LHDDPRG) is comprised of eight members including EPA staff, community and industrial representatives as well as technical advisors.

After a competitive tender process AECOM Australia Pty Limited (AECOM) was commissioned by the EPA to undertake the LHDDP and worked in conjunction with the LHDDPRG throughout the project. The study included a twelve month monitoring program conducted between October 2014 and October 2015 with the aim of examining the quantity and composition of deposited dust in areas of the Lower Hunter.

1.2 What is Deposited Dust?

Deposited dust is dust from the air that settles onto the ground, or similar surface. The LHDDPRG agreed that for the purpose of this study, the term black dust (as stated in the project scope) refers to the total dust deposited and observed on surfaces around households and collected in the sampling program for analysis to identify particle constituents. Typically deposited dust is primarily comprised of larger, heavier particles (originating from nearby sources) but does also include smaller particles which may have travelled by wind from sources further away. Measured in the units of g/m^2.month, or grams per square metre (of ground) per month, deposited dust is typically considered an amenity or nuisance issue rather than a direct heath concern. Deposited dust may originate from many different sources, including both natural and man-made and monitoring deposited dust is a cost effective method to provide an indication of air quality in an area.

1.3 Community Involvement

The LHDDPRG comprises eight members: two community representatives, two industry representatives, two independent technical experts and two EPA staff. The reference group acts as a conduit between the broader community and the EPA regarding the study, and advises and guides the EPA on project design and delivery.

Through the LHDDPRG expressions of interest were sent out to the community requesting locations for dust monitoring for a one year period. Responses to the request were collated and those sites within the LHDDP defined area were reviewed for appropriateness with relevant Australian Standard siting guidelines. Representative sites were then selected and approved in coordination with the LHDDPRG. A copy of the expression of interest is provided in **Appendix A**.

The LHDDPRG and its community representatives were integral in the planning of the project scope, methodology and required outcomes. Through face to face meetings between the field study team and the LHDDPRG, a defined scope of work was agreed to, locations for monitoring selected and the form of analysis identified. The study design also included a peer review of the methodology paper by an independent expert. Progress meetings were conducted throughout the project to ensure the project was being undertaken in accordance with the aims of the LHDDPRG. The LHDDPRG agreed that for the purpose of this study, the term black dust refers to the total dust deposited and observed on surfaces around households and collected in sampling program for analysis to identify particle constituents.

1.4 Objective of the Report

The objective of this report is to document the scope, methodology and findings of the air quality monitoring program established as part of the LHDDP and provide an assessment of the dust composition and deposition rates in the LGA. The initial brief highlighted a number of research questions that the study should address. The objective of the study was to:

- Provide an assessment of dust deposition rates against the relevant criteria;
- Describe the composition of deposited dust at monitoring locations;
- Assess the geographical and spatial distribution of dust deposition in the LGA;
- Observe the potential relationship between distribution rates of total dust and black particles and the potential sources of this dust;
- Provide a response to each of the research questions (**Section 6.1.3**)
    - What is the association between proximity to potential sources, such as the rail corridor, and rate of dust deposition?
    - What is the level of dust deposition that is representative of specific areas in the Lower Hunter, including the rail corridor?
    - How do measured dust deposition rates compare with international dust deposition criteria and NSW criteria? - What is the composition of deposited dust?
    - Is coal dust deposited at residential properties and/or other locations within the study area?
    - What is the composition of the 'black dust' identified at residential properties within the study area?
    - What are the potential attributable sources of deposited dust/black dust?
    - Are there geographical or spatial variations in dust deposition/black dust?
- Discuss weather conditions throughout the study period as well as any other observations.

1.5 Scope of Works

The scope of works for the study is as follows:

- Provide a description of the LHDDP and purpose of this report;
- Describe the study area including;
    - Potential dust sources within the study area;
    - Air quality complaints data collected by the EPA;
    - Local meteorology during the monitoring period including wind speed and wind direction.
- Define the relevant NSW EPA criteria for dust deposition;
- Provide a description of the monitoring methodologies including the use of DDGs, Petri dish and brush sampling techniques;
- Provide a description of the methodologies used to analyse dust samples;
- Discuss the results of the monitoring and provide an assessment of the deposition rates of total dust and black particles in the LGA; and
- Provide recommendations and conclusion.

1.6 Structure of this Report

Table 1 outlines the structure of this report and provides a description of each section.

Table 1 Report Structure

Section	Description
Section 1.0	Provides a description of the Lower Hunter Dust Deposition Project and outlines the scope of works undertaken for this study.
Section 2.0	Provides a description of the study area, identifies potential sources of dust, provides a classification for deposited dust, the location of complaints data and provides a description of local meteorology.
Section 3.0	Outlines the EPA impact assessment criterion for dust deposition.
Section 4.0	Describes the dust monitoring methodology for dust deposition gauges, Petri dish and brush sampling as well as laboratory analysis.
Section 5.0	Summarises the results of the dust deposition monitoring and results of the additional identification analyses undertaken including the results from the stereomicroscopy, stereo electron microscopy and energy dispersive x-ray spectroscopy.
Section 6.0	Provides a discussion of the results presented in **Section 5.0** and recommendations for further assessment.
Section 7.0	Conclusion of the report.
Section 8.0	References.
Appendix A	Community Flyer.
Appendix B	Provides a comparison of meteorological data from NSW Office of Environment from Carrington, Mayfield, Newcastle and Stockton monitoring stations.
Appendix C	Provides figures for wind conditions during the time of sampling overlayed onto sampling locations.
Appendix D	DDG Field Sheets.
Appendix E	Laboratory certificates of analysis for dust deposition.
Appendix F	Laboratory reports for the stereomicroscopy analysis, scanning electron microscopy and energy dispersive x-ray spectroscopy analysis.
Appendix G	Detailed Summary of Identification Analysis Results.

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2.0 Project Location and Description

2.1 Study Area

The primary focus of the study area within the Newcastle LGA was determined by the distribution of dust complaints data received by the EPA between 1 January 2011 and 31 March 2014 as discussed in **Section 2.3.1**. Locations for dust monitoring were selected on the basis of historical complaints data and feedback from the Lower Hunter Dust Deposition Project Reference Group (LHDDPRG). **Figure 13** shows the locations of the DDGs and identifies the general study area, along with the location of the rail network in the study area.

2.2 Dust Sources and Dust Composition

2.2.1 Potential Regional Dust Sources

There are a number of potential sources of particulate matter in the Hunter Valley including both point and diffuse sources. These include:

- Windblown dust from unsealed surfaces;
- Sea salt;
- Coal mining, coal trains and associated stockpiles;
- Industrial emissions;
- Farming;
- Bushfires and hazard reduction burns;
- Electricity generation;
- Motor vehicle emissions; and
- Shipping.

Specifically in the study area, potential sources of industrially generated dust are concentrated around the suburbs of Mayfield, Mayfield East, Waratah, Carrington, Kooragang Island, Islington and Wickham. These suburbs form a central hub for industrial manufacturing facilities and include the Port of Newcastle and the rail line delivering coal to Newcastle's coal terminals.

2.2.2 Dust Composition

The purpose of this report is to provide an assessment of dust deposition rates and composition in the LGA. Dust composition varies depending on the locality of the sample and the locally contributing sources of dust. For the purpose of this study the following constituents that make up local dust deposits have been examined:

- Inorganic materials and minerals including:
  - Soil and rock particles;
  - Salts; and
  - Alumina.
- Black particulates including:
  - Coal;
  - Soot; and
  - Rubber;
- Slime and fungus;
- Insect and plant debris;
- Miscellaneous fibres; and
- Paint.

2.2.3 History of Dust Deposition in the Newcastle Region

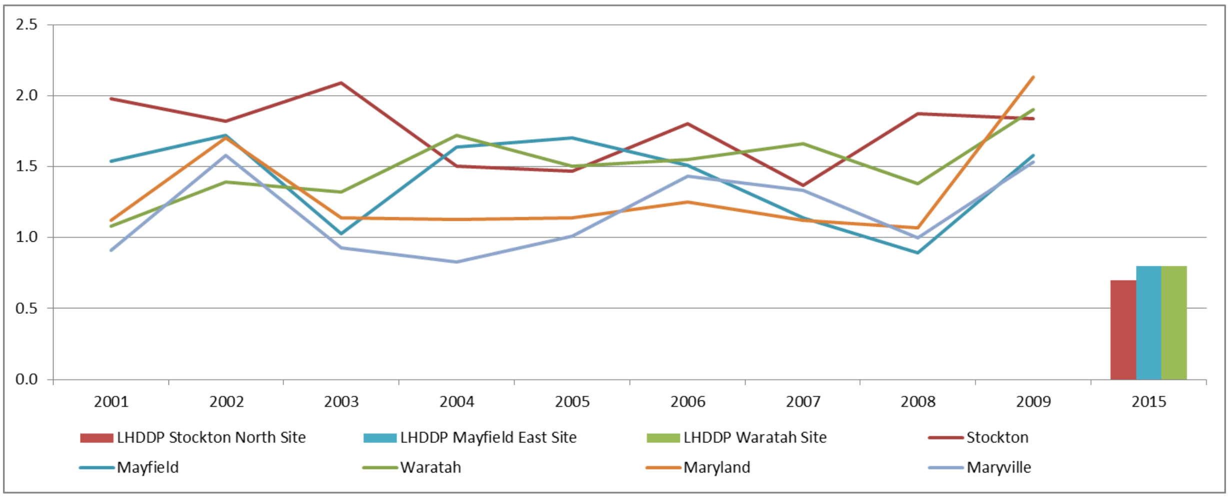
Dust deposition has been monitored in the Newcastle region for many years by various organisations including the NSW Government, Newcastle City Council and industries. Dust deposition rates have decreased significantly over the last 70 years as heavy industry in the area has decreased and dust control measures and practices have improved. **Table 2** presents indicative dust deposition rates for Sydney, Newcastle and Wollongong to provide an indication of historical dust deposition rates. Source: Bridgman, H.A. (2015) for 2001-2009 data

Figure 7 presents annual average deposition rates for five monitoring locations in the Newcastle Region for the period 2001 to 2009 (monitoring performed by Newcastle City Council) to provide a more recent indication of deposition rates in the study area. Included in this figure are DDG results for the LHDDP locations of Stockton North, Mayfield East and Waratah in order to provide a general comparison to recent levels where monitoring data is available for suburbs included in the LHDDP.

Table 2 Historical NSW dust deposition rates (1950 – 1980)

Decade	Dust Deposition (g/m^2.month)		
	Sydney	Newcastle	Wollongong
1950	9	**34**	13
1960	8	**24**	11
1970	4	**9**	8
1980	2	**2**	2

Source: Ferrari, L., (2015, 2000)



Source: Bridgman, H.A. (2015) for 2001-2009 data

Figure 7 Historical Newcastle region dust deposition rates (2001 – 2009)

2.2.4 Other Dust Deposition Composition Studies

A number of recent studies in Queensland coal mining areas have been conducted by the Queensland Government to identify the composition of locally deposited dust and specifically the contribution of coal. These include the *Tennyson Dust Monitoring Investigation* (Queensland Government 2012) and the *Western – Metropolitan Rail Systems Coal Dust Monitoring Program* (Queensland Government 2013).

The Tennyson Dust Monitoring Investigation was conducted over a one month period and found that:

- The major component of dust samples from Tennyson monitoring sties was soil and rock dust comprising 40 percent (%) or more of the total deposited dust collected;
- Coal was found to comprise between 10 to 20% of total deposited dust;
- Black rubber dust on average comprised 10% of deposited dust; and
- Plant and insect debris was also found in the dust samples.

The Western-Metropolitan Rail Systems Coal Dust Monitoring Program was conducted over a four month period and concluded that:

- The major component of deposited dust samples was mineral dust (soil and rock dust) comprising 50 to 90% of total deposited dust;
- Coal was consistently detected at monitoring sites along the rail corridor used by coal trains;
- Only trace amounts of coal were observed in one sample and the background monitoring site located on a section of rail not used by coal trains;
- Coal was found to comprise on average 10% of total deposited dust with levels as high as 20% observed in some samples; and
- Black rubber dust on average comprised 10% of deposited dust.

2.3 Complaints Data

2.3.1 Complaints Data pre Monitoring Period

Between 1 January 2011 and 31 March 2014 the NSW EPA's Environmental Line received 174 community complaints in the Newcastle LGA regarding dust and particulate matter including smoke. The issues reported varied considerably and included smoke, general black dust, dust from coal, fertiliser and grain, with spatial and temporal variations in the reports. Suburbs that registered an above average number of dust complaints over this period included:

- Carrington
- Hexham
- Kooragang
- Maryville
- Mayfield East
- Newcastle
- Newcastle East
- Shortland
- Stockton
- Tighes Hill
- Wickham

Of the 174 community complaints, the majority of complaints registered were black dust (29%), coal dust (18%), smoke (17%) and grain dust (10%). Black dust and coal dust accounted for almost half of the complaints, initiating further investigation into potential dust sources, as well as identifying composition and deposition levels in the Newcastle LGA.

2.3.2 Complaints Data during Monitoring Period

During the study period between October 2014 and October 2015 the NSW EPA's Environmental Line received 26 community complaints regarding air emissions in the Newcastle LGA. As recorded in previous years (refer to **Section 2.3.1**) the complaints varied considerably with nominated sources comprising:

- Industry stack emissions (14);
- Shipping activities (4);
- Coal trains and coal mining (3);
- Track and road maintenance work (2); and
- Other activities (3).

Of the 26 community complaints recorded during the monitoring period, 14 were related to dust deposition or smoke particulate matter. Of the 14 dust complaints only 6 reports were specifically related to black dust or black smoke, with 3 reports related to coal mining and coal trains and 3 reports relating to smoke from industrial emissions. Suburbs which registered black dust complaints were Beresfield, Wickham, Hexham, Sandgate and Kooragang Island.

Dust complaints received during the monitoring period were found to be less than half the annual average received over the 1 January 2011 to 31 March 2014 record period (refer to **Section 2.3.1**). Potential variables which may have contributed to a decrease in complaints over the study period are; meteorological conditions (wind, rainfall, temperature and other factors), industrial/mining operations and production rates as well as dust mitigation measures and practices.

2.4 Meteorology

Meteorology in the Newcastle area is affected by several factors with wind speed and direction largely affected by topography at the small scale, while factors such as synoptic scale winds affect wind speed and direction on the larger scale. Wind speed and direction as well as rainfall are important variables in assessing air quality, as they dictate the direction and distance air pollutants travel and are key factors for dust lift-off from area sources such as agricultural land and coal stockpiles. Wind speed/direction and rainfall are summarised in **Sections 2.4.1** and **2.4.2** respectively with the influence of meteorology on the sampling locations discussed in **Section 4.1.3**.

2.4.1 Wind Speed and Direction

The NSW Office of Environment and Heritage (OEH) record wind speed and wind direction at four air quality monitoring stations located within the study area. OEH monitoring stations are located at Carrington, Stockton, Mayfield West and Newcastle. The Carrington monitoring station is located within the centre of the study area and following data analysis is considered representative of local meteorological conditions within the study area. Little variation was observed between Carrington and the other monitoring sites in terms of wind direction and a comparison of this data is presented in **Appendix B**.

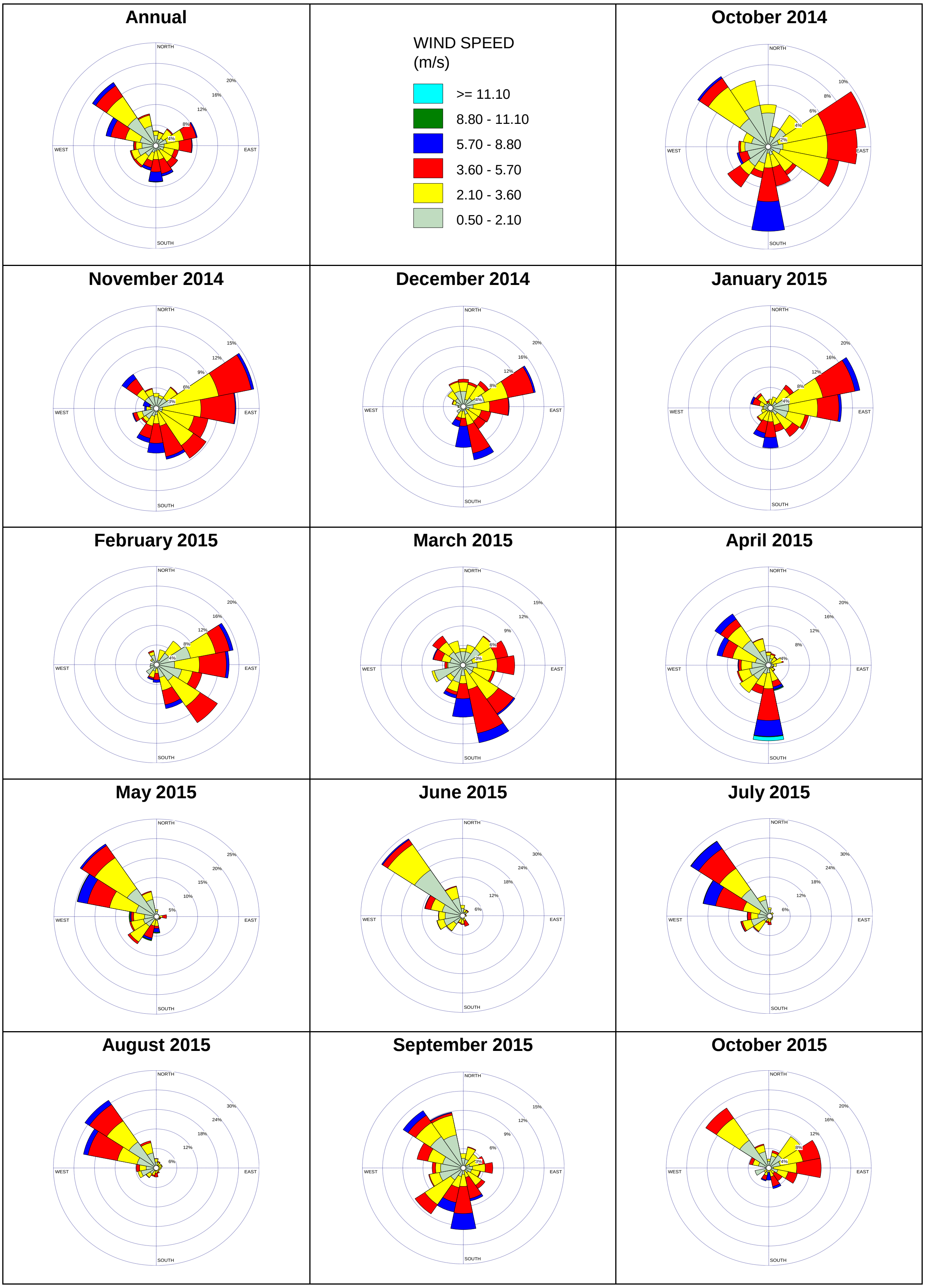
A wind speed frequency distribution and annual and seasonal wind roses for the Carrington OEH site for the study period between October 2014 and October 2015 are presented in **Table 3** and **Figure 8** respectively. It can be seen from **Table 3** and **Figure 8** that on an annual basis the dominant wind direction is from the west northwest to northwest; occurring for 25% of the time. The annual average wind speed was found to be 2.7 metres per second (m/s) which is a light to moderate wind speed. Calms (<0.5m/s) were found to occur for just over one percent of the monitoring period.

On a monthly basis the average wind speed ranged from 2.0 m/s to 3.1 m/s. June 2015 had the highest wind speed while the lowest average wind speed was observed in November 2014. In mid to late October 2014 no dominant wind direction was observed with winds frequenting from the east, south and northwest. From November 2014 to February 2015 the dominant wind direction was from the east northeast and a higher portion of southeast to southerly winds were observed in March and April 2015. From May 2015 to mid-October 2015 the predominant wind direction was from the northwest, similar to the annual trend observed.

Table 3 Wind Speed Frequency Distribution of OEH Carrington Meteorology Station - Oct 2014 to Oct 2015 data (%)

Wind Direction	Wind Speed Class (m/s)						
	0.5-2.1	2.1-3.6	3.6-5.7	5.7-8.8	8.8-11.1	≥11.1	Total
N	2.0	0.8	0.1	<0.1	<0.1	<0.1	2.9
NNE	1.3	1.3	0.1	<0.1	<0.1	<0.1	2.7
NE	1.7	2.0	0.2	<0.1	<0.1	<0.1	4.0
ENE	2.2	3.3	2.4	0.2	<0.1	<0.1	8.2
E	1.6	2.9	2.4	0.1	<0.1	<0.1	7.1
ESE	1.6	2.1	0.8	<0.1	<0.1	<0.1	4.5
SE	1.1	2.7	1.3	<0.1	<0.1	<0.1	5.1
SSE	0.9	1.9	2.8	0.5	<0.1	<0.1	6.0
S	1.0	1.7	2.4	1.9	<0.1	0.1	7.1
SSW	1.3	1.7	1.3	0.5	<0.1	<0.1	4.9
SW	2.4	2.2	0.4	<0.1	<0.1	<0.1	5.0
WSW	3.5	1.3	0.2	<0.1	<0.1	<0.1	5.1
W	2.7	1.2	0.4	0.1	<0.1	<0.1	4.3
WNW	3.1	2.9	2.9	0.9	<0.1	<0.1	9.8
NW	6.6	4.9	2.5	0.8	<0.1	<0.1	14.7
NNW	3.9	2.1	0.3	<0.1	<0.1	<0.1	6.3
Sub-Total	36.9	35.0	20.6	5.0	0.1	0.1	97.7
Annual (15 Oct 2014 to 15 Oct, 2015). Total periods = 8,784; Valid periods = 8,703; Calm wind periods = 123; Calm winds: 1.4%							

Figure 8 Annual and Monthly Wind Roses at OEH Carrington Monitoring Station between 15 October 2014 and 15 October 2015



2.4.2 Rainfall

In the absence of rainfall being measured at the OEH monitoring stations, data has been obtained from Bureau of Meteorology stations located at Nobbys Head (Station ID 061055) and Newcastle University (Station ID 061390). Rainfall influences dust deposition by both wetting surface material and thereby reducing the potential for dust becoming airborne, as well as having a scrubbing effect on the atmosphere, potentially reducing wind-blown dust entering the study area as well as removing dust from the air closer to local sources. **Figure 9** presents both historical rainfall data as well as data for the study period as a comparison. Historical average rainfalls are compared graphically to the project period rainfall in **Figure 10**.

Bureau of Meteorology - Nobbys Head Rainfall Data

	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Annual
Historical rainfall mean (mm)	72.2	71.4	80.9	87.9	108.1	118.9	117.2	117	116.9	93.4	73.4	72.3	**1130**
Project Period Rainfall (mm)	33	31.6	115.4	81.2	39.4	49.2	295.2	123.6	92	35.4	23	103	**1022**
Historical mean days > 1mm	7.8	7.9	7.6	8.2	8.2	9.1	9.2	9	9.1	8.2	7.4	7.2	**98.9**
Project period days > 1mm	3	4	10	9	8	6	12	10	9	7	3	15	**96**

Historical data 1862 to 2015

Bureau of Meteorology - Newcastle University Rainfall Data

	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Annual
Historical rainfall mean (mm)	59.4	119.3	74.3	71.9	145.3	117	140.2	100.9	124	59.2	62.6	69.3	**1143**
Project Period Rainfall (mm)	52	45.7	125.2	149.2	88.7	70.4	355.3	133.9	85.5	25.6	26.6	127.8	**1286**
Historical mean days > 1mm	6.5	10.6	7.9	7.8	10.3	8.9	9.4	8.3	8.7	7.5	6.3	5.8	**98.0**
Project period days > 1mm	5	5	11	12	14	10	9	9	9	7	4	12	**107**

Historical Data 1998 to 2015

Figure 9 Bureau of Meteorology Rainfall Data

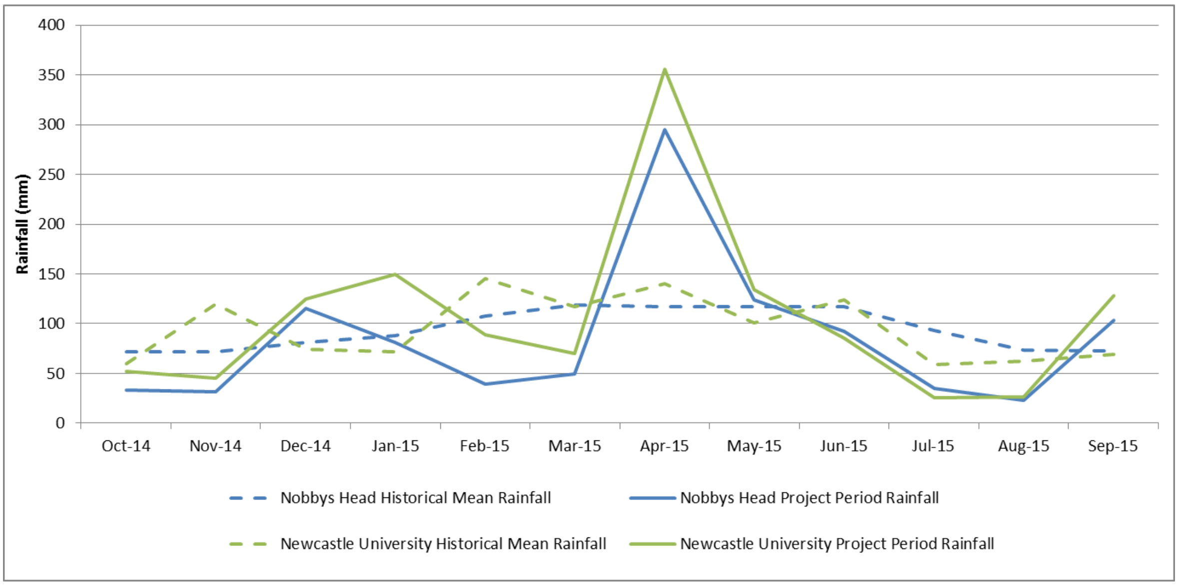


Figure 10 Comparison of Historical Rainfall and Project Period Rainfall

Comparison with historical data indicates that although the annual average for the study period was similar to long term annual averages, some monthly rainfall figures varied significantly from long term averages. Most notably, April 2015 recorded rainfall well in excess of what is typical for this month. The effect of such a large amount of rainfall may be long lasting, with natural ground potentially staying wet for some time after such an event. The months of October, November, February and March along with the three winter months experienced below average rainfall during the study period while December, April, May and September experienced above average rainfall. Rainfall data for January varied significantly between the Nobbys Head and Newcastle University locations.

The average rainfall for each DDG monitoring period (calculated from the estimated volume of rainwater collected in the DDG samples) is also provided in **Table 11**. It should be recognised that while DDG monitoring periods are identified by month, the actual sampling periods are not necessarily calendar months e.g. The November DDG monitoring period ran from 14 November 2014 to 12 December 2014.

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3.0 Impact Assessment Criteria

The assessment criteria applicable in NSW for the assessment of deposited dust are specified in the EPA's *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (DEC, 2005b), and is shown in **Table 4**. The criterion of 4g/m^2.month refers to the total maximum dust deposition rate.

A literature review was conducted of international dust deposition criteria and guideline documents. Findings of the literature review indicated that the NSW EPA total maximum criterion of 4g/m^2.month is a conservative value (generally lower than international standards) when compared to international deposition rate guidelines as listed in **Table 5**.

Table 4 Ambient Air Quality Assessment Criteria (DEC 2005b)

Pollutant	Averaging Period	Criterion	Units
Dust deposition as insoluble solids	Annual	4 (total maximum)	g/m^2.month

The dust deposition criterion discussed in **Table 4** of this report has been used to assess the dust deposition rates measured at the DDG monitoring network set up as part of the LHDDP as discussed in **Section 4.1.1** and **Section 4.1.2**.

Table 5 International Impact Assessment Criteria – Deposited Dust

Source	Averaging Period	Concentration	
		g/m^2.month	mg/m^2.day
NSW EPA	Annual	2 (maximum increase)	67*
		4 (maximum total)	133*-
NZ Ministry for the Environment	Not specified	4 (as an increase above background concentrations)	133*-
German Federal Environment Agency[2]	Annual	10.5 *	350
UK 'unofficial' nuisance[3]	Annual mean	6*	200
Vallack, H. W. & Shillito, D. E. (1998)4	Monthly mean	Open Country 3* (complaints possible), 4.2* (complaints likely)	100 (complaints possible), 140 (complaints likely)
		Residential 4.5* (complaints possible), 6* (complaints likely)	150 (complaints possible), 200 (complaints likely)
		Commercial centres 6* (complaints possible), 7.8* (complaints likely)	200 (complaints possible), 260 (complaints likely)
West Australia Nuisance Standard	Monthly mean	4*	133 (First loss of amenity)
		10*	333 (Unacceptable reduction in air quality)
West Germany Nuisance Standard	Monthly mean	10.5*	350 (Possible nuisance)
		19.5*	650 (Very likely nuisance)
Malaysia Air Quality Standard		4*	133

[2] Federal Ministry for Environment, Nature Conservation and Nuclear Safety (2002) Determination and Evaluation of Ambient Air Quality - Manual of Ambient Air Monitoring in Germany
[3] Quality of Urban Air Research Group. (1996) "Airborne Particulate Matter in the United Kingdom: Third Report of the Quality of Urban Air Review Group", prepared at the request of the Department of the Environment. University of Birmingham, Birmingham.
[4] Vallack, H. W. & Shillito, D. E. (1998), "Suggested guidelines for deposited ambient dust", Atmospheric Environment, Vol.32, pp.2737-2744

Source	Averaging Period	Concentration	
		g/m^2.month	mg/m^2.day
* Converted from g/m^2.day to g/m^2/month for comparison with NSW EPA Standard (assumes 30 days per month)			

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4.0 Methodology

4.1 Dust Monitoring Methods

The air quality monitoring comprised of 12 dust deposition gauges (DDGs) installed by AECOM in general accordance with the Australian Standard AS/NZS 3580.1.1:2007. Samples were collected and analysed for insoluble solids and ash residue in general accordance with the Australian Standard AS/NZS 3580.10.1:2003(R2014) and the EPA (DEC 2005a) guidelines.

AECOM's Newcastle Office is National Association of Testing Authorities (NATA) accredited (Accreditation Number 2778 [14391]) for the installation and collection of DDGs.

The following sections outline the monitoring undertaken for the study. Sampling methods were chosen to establish long-term trends (dust gauges), undertake short-term spot checks (Petri dishes) and identify long term composition (swab/brush samples).The monitoring program is summarised in **Table 6** with laboratory analysis detailed in the form of a flow chart in **Figure 11**.

Table 6 Monitoring Program Frequency by Analysis Counts

Sample Type	Analysis Type	Samples per Quarter	Samples per Year
Dust gauges	Standard suite (Insoluble matter, combustible matter, ash)	36	144
	Stereomicroscopy and Scanning Electron Microscopy/Energy Dispersive X-Ray Spectroscopy[1]	3	12
	Image	3	12
Petri dish	Stereomicroscopy and Scanning Electron Microscopy/Energy Dispersive X-Ray Spectroscopy	9	36
	Image	9	36
Brush samples	Stereomicroscopy and Scanning Electron Microscopy/Energy Dispersive X-Ray Spectroscopy	6	24
	Image	6	24

[1] X-ray diffraction analysis was also originally included in the monitoring program however sufficient material was not collected in the DDG's to enable these analyses to be undertaken; as such, they have not been included in the monitoring.

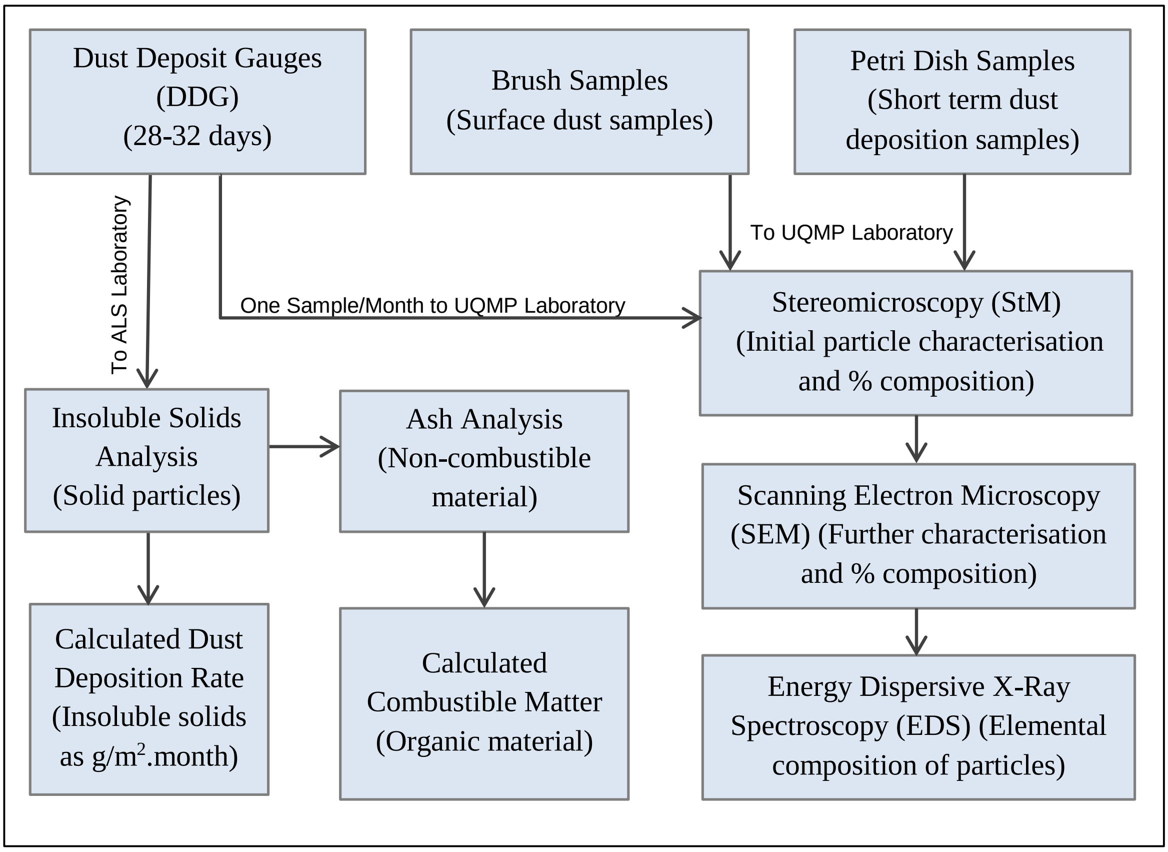

Figure 11 Sample Analysis Flow Chart

4.1.1 Dust Deposition Gauges (DDGs)

Dust deposition monitoring is a long-term monitoring strategy used to identify trends in local dust levels, primarily to provide an indication of the potential nuisance effects of dust fallout. Results are used to determine compliance with the EPA guideline (which requires at least 12 months of data to establish an annual average), and to identify long-term dust deposition trends. Monitoring is typically undertaken for periods of at least 12 months in order to account for seasonal factors

DDGs are collected every 30 ± 2 days and analysed in accordance with the requirements of AS/NZS 3580.10.1:2003(R2014) (Methods for sampling and analysis of ambient air - Determination of particulate matter - Deposited matter - Gravimetric method) and the NSW EPA Approved Methods (DEC 2005b). Samples were analysed for the following parameters:

- Insoluble solids (required for regulatory compliance);
- Combustible material; and
- Ash content (non-combustible portion).

Each month following the collection of DDG samples, wind conditions for the monitoring period were analysed in conjunction with the locations of potential dust sources and the sampling locations, with one appropriate DDG sample selected for particle characterisation analysis by the University of Queensland Materials Performance (UQMP) laboratory. Efforts were made to vary the sample chosen for additional analysis with samples from 11 of the 12 DDG sites selected for particle characterisation. These samples were analysed using the following analytical techniques:

- Stereomicroscopy;
- Scanning electron microscopy (SEM); and
- Energy dispersive x-ray spectroscopy (EDS).

The dates for the dust deposition sampling undertaken between October 2014 and October 2015 are shown in **Table 7**.

Table 7 Deposited Dust Samples Collection Dates

Sampling Period	Exposure Date	Collection Date	Sample Duration (days)
October 2014	- 17 October 2014 (Carrington and Newcastle) - 16 October 2014 (All other sites)	14 November 2014 (All sites)	28 days Carrington and Newcastle 29 days all other sites
November 2014	14 November 2014	12 December 2014	28
December 2014	12 December 2014	9 January 2015	28
January 2015	9 January 2015	6 February 2015	28
February 2015	6 February 2015	6 March 2015	28
March 2015	6 March 2015	7 April 2015	32
April 2015	7 April 2015	5 May 2015	28
May 2015	5 May 2015	2 June 2015	28
June 2015	2 June 2015	3 July 2015	31
July 2015	3 July 2015	3 August 2015	31
August 2015	3 August 2015	3 September 2015	31
September 2015	3 September 2015	2 October 2015	29

4.1.2 Dust Deposition Gauge Monitoring locations

The requirements for the monitoring locations are specified by the Australian Standard for siting monitoring instruments AS/NZS 3580.1.1 2007[5]; the requirements are reproduced in **Figure 12**.

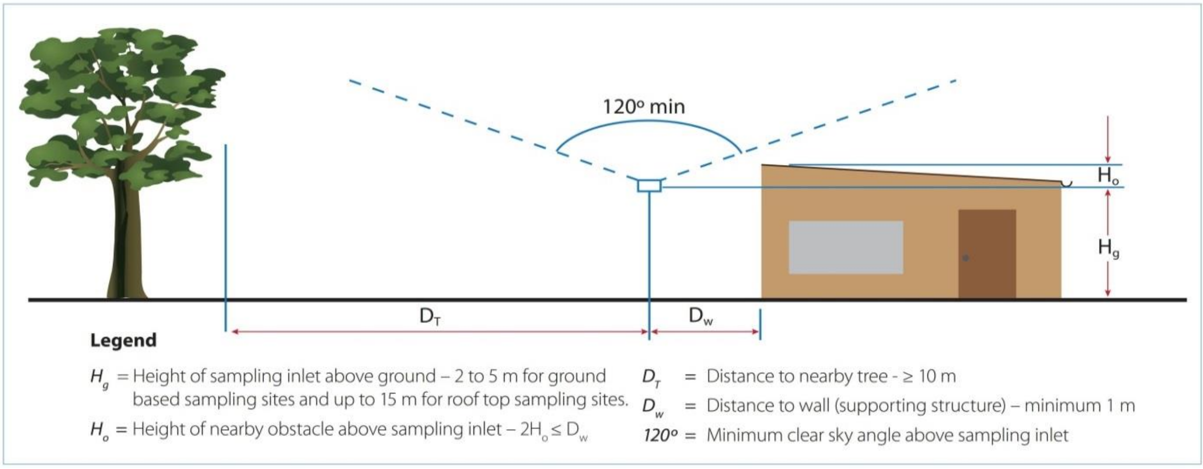

Figure 12 Ground Level Monitoring Locations from AS/NZS 3580.1.1 2007 (Reproduced with permission from SAI Global Ltd under Licence 1408-C007)

[5] Australian Standard AS/NZS 3580.1.1 2007, Methods for sampling and analysis of ambient air – Guide to siting air monitoring equipment

Suburbs included in the monitoring program were chosen based on the history of complaints made to the EPA, and sampling locations were selected in consultation with relevant community groups and residents. Efforts were made to select sampling locations at residential properties that were compliant with the siting requirements. Additional sampling locations were chosen to spatially represent the greater region, provide additional data from sites near to rail lines, and to provide comparative data from locations not near to rail lines. Best efforts were made to choose locations which generally meet the following standards however given the built up environment in which the study was performed, some locations are not entirely compliant with the following siting requirements:

- Australian Standard AS/NZS 3580.1.1 2007, Methods for sampling and analysis of ambient air – Guide to siting air monitoring equipment; and
- Australian Standard AS/NZS 3580.10.1 2003(R2014), Methods for sampling and analysis of ambient air – Method 10.1: Determination of particulate matter - deposited dust – gravimetric method.

The locations of the monitoring sites are summarised in **Table 8** and shown in **Figure 13**. A dust gauge was located at each site and was sampled on a monthly basis. An example location of a DDG monitor is presented in **Figure 14**.

Table 8 Monitoring Locations and Details

Suburb	Location	Selection Reason
Mayfield West	OEH Monitoring Station	Proximity to Industrial Drive
Mayfield East	Public School	Complaints
Waratah	Community Centre	Proximity to rail line
Islington	Private Residence	Proximity to rail line
Tighes Hill	Private Residence	Complaints
Carrington	OEH Monitoring Station	Complaints
Wickham	Private Residence	Proximity to rail line
Hamilton	Retirement Village	Proximity to rail line
Newcastle	OEH Monitoring Station	Complaints
Stockton North*	OEH Monitoring Station	Complaints
Stockton South*	Private Residence	Complaints
Newcastle East	Foreshore Park	Complaints
*For the purpose of monitoring the suburb of Stockton has been divided into two locations; Stockton North and Stockton South		

Figure 13 Dust Deposition Monitoring Locations (DDG's)

Figure 14 Example DDG location (Waratah)

4.1.3 Petri Dish Sampling

The Petri dishes used in this study were cleaned and did not contain growth media as they were used to collect dust fall rather than to grow bacteria. The purpose of the sampling is to collect specimens for analysis to identify dust composition. Petri dish monitoring is a good method for collecting dust in areas where high dust loadings are likely to occur (but that are not suitable for the installation of a DDG) or in response to dust complaints. Such areas can include window sills or ledges located in proximity to dust sources. Short term sampling (< 5 days) was conducted, with sampling sites chosen based on potential sources and the meteorological conditions at the time of sampling. For the purpose of this study, Petri dish sampling was not used to calculate dust deposition rates, rather to simply collect dust for particle characterisation analysis.

Petri dish samples were periodically collected at spatially variant locations as outlined in **Table 9**. For the first two months, limited Petri dish samples were collected and analysed in order to provide a general understanding of the likely composition of dust in the area. The required Petri dish exposure time in order to collect sufficient sample material for analysis was also determined in these two months. This information was used to help guide the future sampling events.

Efforts were made to sample during periods of higher winds, with locations chosen such that likely sources of dust were upwind of the sampling locations. The sampling duration for this portion of work was largely dependent on weather conditions. Efforts were made to avoid rainfall during the sampling periods so that dry samples were collected, and efforts were made to avoid high variability in wind direction where possible.

Petri dish monitoring is a passive method, which relies on the natural deposition of dust onto the surface of the dish. The Petri dish needs to remain in the monitoring location until sufficient dust has accumulated to enable analysis to be undertaken. In the absence of a relevant Australian Standard, the required duration of exposure varies depending on the deposition rate and the type of analysis required. Initial monitoring and analysis determined that exposure for 1 - 2 days typically provided a sufficient dust sample for the required laboratory analysis. Sampling protocols related to quality control and chain of custody procedures were similar to AS/NZS 3580.10.1:2003(R2014).

36 Petri dish samples were collected between October 2014 and October 2015. An example Petri dish sampling location is shown in **Figure 15** with a map showing all locations of all samples provided as **Figure 16**. Details of meteorology conditions during each sampling period are provided in **Table 9** with wind roses for each sampling period overlayed onto sampling locations provided in **Appendix C**.

Figure 15 An Example Petri Dish Sample

Table 9 Petri Dish Sample Meteorology Conditions

Sample ID	Labor-atory ID	Date Exposed	Date Collected	Sample Location	Dominant Wind Direction(s)	Average Wind Speed (m/s)	Estimated Rainfall
P1	13080	14/11/2014	15/11/2014	Tighes Hill (DDG site)	South, East Northeast	3.5	<1mm
P2	13144	17/12/2014	18/12/2015	Carrington (DDG site)	South (variable)	3.7	<1mm
P3	13145	17/12/2014	18/12/2014	Mayfield East (DDG site)	South (variable)	3.7	<1mm
P4	13296	18/02/2015	20/02/2015	Mayfield West (DDG site)	East	2.3	<1mm
P5	13297	18/02/2015	20/02/2015	Ferndale St, Tighes Hill	East	2.3	<1mm
P6	13298	18/02/2015	20/02/2015	Waratah (DDG site)	East	2.3	<1mm
P7	13299	18/02/2015	20/02/2015	Islington (DDG site)	East	2.3	<1mm
P8	13300	5/03/2015	6/03/2015	Kerr St, Mayfield	South Southeast, North Northwest	3.8	No rain
P9	13301	5/03/2015	6/03/2015	Selwyn St, Tighes Hill	South Southeast, North Northwest	3.8	No rain
P10	13399	8/04/2015	8/04/2015	Warabrook Blvde, Warabrook	North Northwest	6.8	No rain
P11	13400	8/04/2015	8/04/2015	Stockton South (DDG site)	North Northwest	6.8	No rain
P12	13401	8/04/2015	8/04/2015	Stockton North (DDG site)	North Northwest	6.8	No rain
P13	13470	11/05/2015	13/05/2015	Newcastle East (DDG site)	North Northwest	4.4	<1mm
P14	13471	11/05/2015	13/05/2015	Stockton North (DDG site)	North Northwest	4.4	No rain
P15	13472	11/05/2015	13/05/2015	Punt Rd, Stockton	North Northwest	4.4	No rain
P16	13473	11/05/2015	13/05/2015	Taylor Rd, Fern Bay	North Northwest	4.4	No rain
P17	13556	3/07/2015	7/07/2015	Stockton South (DDG site)	Northwest	2.8	No rain
P18	13557	3/07/2015	7/07/2015	Stockton North (DDG site)	Northwest	2.8	No rain
P19	13558	3/07/2015	7/07/2015	Carrington (DDG site)	Northwest	2.8	No rain
P20	13559	3/07/2015	7/07/2015	Tighes Hill (DDG site)	Northwest	2.8	No rain
P21	13560	3/07/2015	7/07/2015	Hamilton (DDG site)	Northwest	2.8	No rain
P22	13633	3/08/2015	6/08/2015	Mayfield West (DDG Site)	North Northwest	3.3	No rain
P23	13634	3/08/2015	6/08/2015	Stockton North (DDG site)	North Northwest	3.3	No rain

Sample ID	Labor-atory ID	Date Exposed	Date Collected	Sample Location	Dominant Wind Direction(s)	Average Wind Speed (m/s)	Estimated Rainfall
P24	13635	3/08/2015	6/08/2015	Carrington (DDG site)	North Northwest	3.3	No rain
P25	13636	3/08/2015	6/08/2015	Newcastle East (DDG site)	North Northwest	3.3	No rain
P26	13747	17/08/2015	3/09/2015	Stockton South (DDG site)	Northwest	2.0	No rain
P27	13748	17/08/2015	20/08/2015	Stockton North (DDG site)	Northwest	2.0	No rain
P28	13749	28/08/2015	31/08/2015	Bourke St, Carrington	Northwest	2.6	No rain
P29	13750	28/08/2015	31/08/2015	Wright Ln, Honeysuckle	Northwest	2.6	No rain
P30	13751	17/08/2015	20/08/2015	Stockton South (DDG site)	North Northwest	3.9	No rain
P31	13765	9/09/2015	11/09/2015	Mayfield East (DDG site)	South (variable)	2.2	1mm
P32	13766	9/09/2015	11/09/2015	Waratah (DDG site)	South (variable)	2.2	1mm
P33	13767	2/10/2015	6/10/2015	Carrington (DDG site)	Northwest	2.3	No rain
P34	13768	2/10/2015	6/10/2015	Newcastle (DDG site)	Northwest	2.3	No rain
P35	13769	2/10/2015	6/10/2015	Broadmeadow (train station)	Northwest	2.3	No rain
P36	13770	2/10/2015	6/10/2015	Eucalyptus Cct, Warabrook	Northwest	2.3	No rain

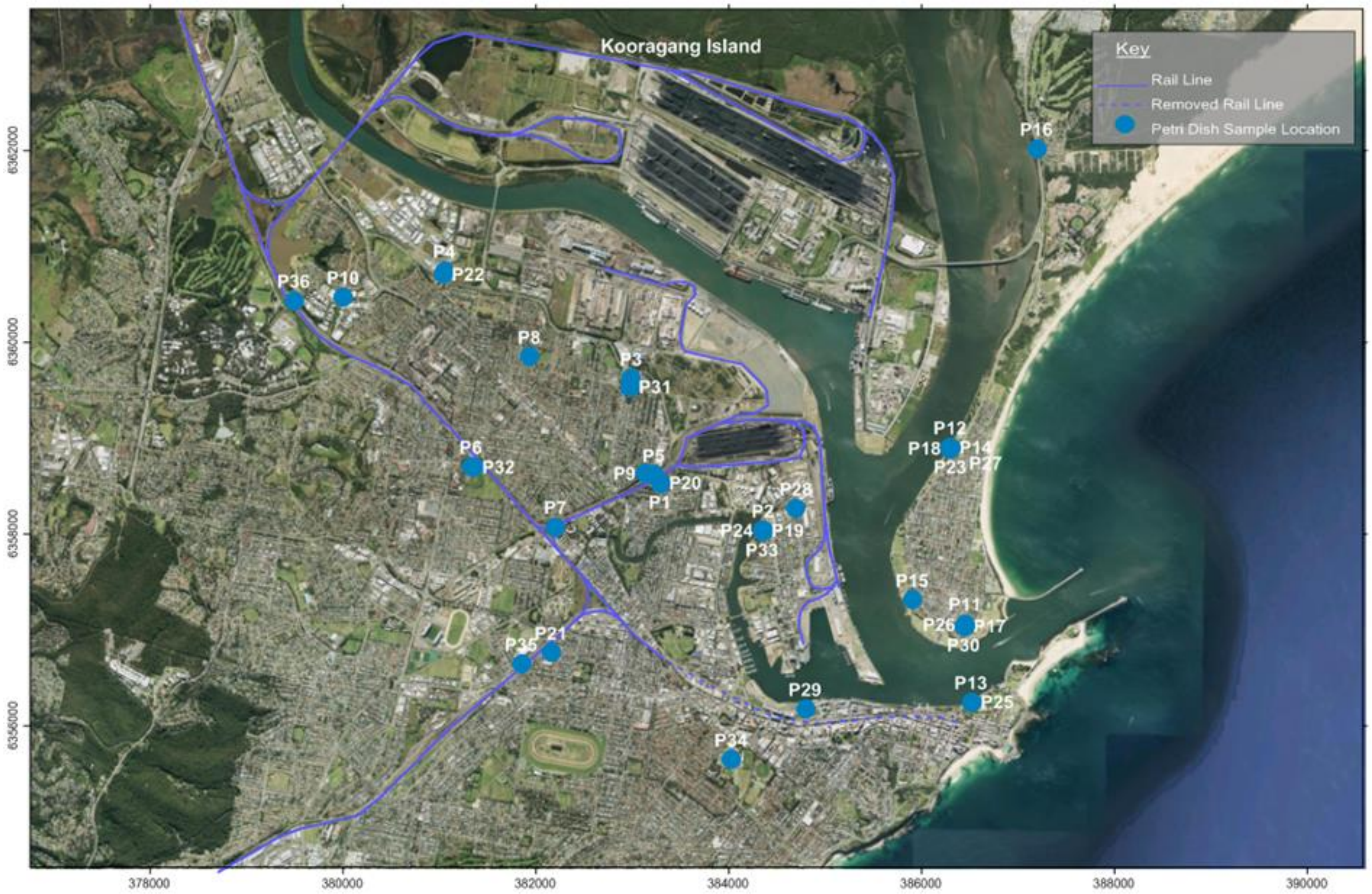

Figure 16 **Petri Dish Sampling Locations**

4.1.4 Brush Samples

Brush sampling is an active method for deposited dust collection, where the dust from a target surface is brushed into a clean Petri dish. Similar to the Petri dish sampling described above, the purpose of brush sampling is to collect a sample in order to analyse the composition of the dust. Brush sampling is a good method for assessing the composition of dust which has accumulated over time, such as occurs on window sills or under structures.

As there is no time-dimension for the sample collected (that is, the dust has been landing on that area for an unknown time period), the sample cannot be compared against a criterion and cannot be linked to a specific source (as potential contributing sources may have been varied over the sample time). Sampling sites for this portion of the study were based on proximity to potential sources and areas of interest such as the rail corridor and around the port. Efforts were made to sample at residences in the community that expressed interest in taking part in the study.

24 brush samples were collected over the duration of this study with details of the samples provided in **Table 10**. An example of a typical brush sample location is shown in **Figure 17** with **Figure 18** presenting the locations of the brush samples collected.

Figure 17 A Typical Brush Sample Location

Table 10 Brush Samples

Sample Location	Sampling Date	Sampling Notes
Islington (DDG site)	12/12/2014	Top of meter box. Generally out of the rain. Appeared to be uncleaned for long period.
Stockton South (DDG site)	12/12/2014	Outdoor sink. Significant amount of hair or fabric fibre in the sample. Unknown source.
Stockton South (DDG site)	6/03/2015	Sample collected from window sill on back porch. Protected from the weather.
Roxburgh Street, South	6/03/2015	Sample collected from along a ledge below louvres on the back porch of the property.
Mayfield East (DDG site)	6/03/2015	Sample collected from the top of a fence - generally protected from the weather.
Ferndale St, Tighes Hill	6/03/2015	Sample collected from top of meter box on front porch. Porch faces the rail line with a large amount of brown dust collected.
Forbes St, Carrington	6/03/2015	Top of meter box on front porch. Protected from rain. Appeared to be uncleaned for long period. Large amount of loose brown coloured dust.
Wickham (DDG site)	6/03/2015	Outdoor window sill on back porch. Protected from the weather.
Phillips St, Hamilton North	6/03/2015	Sample collected from window sill in back porch area. Protected from the weather.
Tighes Hill (DDG site)	6/03/2015	Sample collected from small ledge below windows in the back porch area. Protected from the weather.
Islington (DDG site)	6/03/2015	Sample collected from bathroom window sill (inside house). The window is left slightly open at one end, with the sill left uncleaned for approximately 1 month before sample was taken. Small amount of dust collected.
Hamilton (DDG site)	2/06/2015	Sample collected from window sill on back porch.
Stockton South (DDG site)	2/06/2015	Sample collected from the top of the meter box (minimal dust) and fire hydrant box (significant amount of dust) situated under an eave. Surfaces were exposed to the direction of the rail line.
Wickham (1) (DDG site)	3/09/2015	Sample collected from meter box at the side of the house.
Wickham (2) (DDG site)	3/09/2015	Sample collected from rafters on the back porch.
Lott St, Carrington	8/09/2015	Sample collected from top of meter box on porch.
Bull St, Mayfield	8/09/2015	Sample collected from top of horizontal wooden beam structure on outer edge of verandah. Verandah only 1 year old.
Elcho St, Hamilton	8/09/2015	Sample collected from top of meter box under porch. Protected from the weather.
Kings Rd, Tighes Hill	8/09/2015	Sample collected from top of meter box under porch. Protected from the weather.
Neville St, Mayfield	8/09/2015	Sample collected from top of meter box under porch. Protected from the weather.
Hargrave St, Carrington	8/09/2015	Sample collected from top of air conditioner under porch. Protected from the weather.
Bourke St, Mayfield	8/09/2015	Sample collected from top of air conditioner. Air conditioner is partially protected from the weather by the eave of the house. Sample taken from closer to the house wall where undisturbed.
Stevenson Pl, Newcastle	9/09/2015	Sample taken from front porch window sill facing North (towards harbour mouth). Protected from Rain.
Gregson St, Mayfield West	9/09/2015	Sample taken from meter box on front porch. Meter box quite close to the roof but exposed to the direction of Industrial Drive. Protected from rain. No signs of recent cleaning. Large amount of loose brown dust.

Figure 18 Brush Sampling Locations

4.2 Laboratory Analysis

The standard DDG analyses were performed by ALS, a NATA-accredited and registered laboratory for standard dust gauge sample analysis. When particle characterisation analyses were required, a small known volume of the DDG samples was collected prior to analysis and sent to University of Queensland Materials Performance (UQMP). The calculated dust deposition rate for samples sent to UQMP accounts for the removed portion of sample.

Petri dish and brush samples collected for dust composition analysis were analysed by UQMP.

- The following analysis was conducted:
  - Standard dust gauge sample analysis conducted by Australian Laboratory Services (ALS) Environmental Laboratory, a NATA-accredited and registered laboratory for standard dust gauge sample analysis (NATA accreditation number 825); and
  - Stereomicroscopy, scanning electron microscopy (SEM) and energy dispersive x-ray spectroscopy (EDS) of selected samples by the University of Queensland Materials Performance (UQMP) laboratory.

4.2.1 Standard Depositional Dust Suite

The standard dust suite involved analysing samples for insoluble solids, ash content and combustible material. Insoluble solids are the total filterable material within each sample. Once filtered, the remaining filtered portion (solid portion) of the sample is dried and weighed, and the material is burned in a furnace at approximately 850 °C. Combustible materials, such as vegetative matter, coal and insects are lost in the process, and the remaining non-combustible material is weighed and reported as ash. Although combustible matter is typically used as an indicator of contamination due to insects and vegetation, coal fines are also combusted in this process. Should a sample contain a high percentage of coal, the percentage of combustible material would also be expected to be high. The resultant ash residue provides an indication of the 'inorganic' or non-combustible sample contents. As the purpose of this study was to investigate black dust observed on surfaces around residential properties, the soluble portions of the samples were not analysed.

Following the standard dust deposition analysis, the gravimetric weight of the solid portion of the sample is known, allowing the deposition rate to be determined (g/m^2.month). The percentage of combustible material within the sample is also known, allowing the percentage of organic material to be identified (vegetation, insects, coal, soot, rubber). The non-combustible portion of the sample (represented as ash, following the combustion process) is also identified and includes mineral and rock particles along with other non-combustibles.

4.2.2 Stereomicroscopy (StM)

Stereomicroscopes have characteristics that are valuable in situations where three-dimensional observation and perception of depth and contrast is critical to the interpretation of specimen structure. The wide field of view and variable magnification displayed by stereomicroscopes makes it a useful tool for many tasks.

Stereomicroscopy is the first stage of the identification analyses for dust samples and combines microscopes with digital cameras so that high magnification digital photos can be obtained. This method enables individual dust particles to be identified through visual analysis. This method is satisfactory for the preliminary identification of coarser dust particles. It should be noted that the percentages reported as a result of the sample composition analysis are best estimates and do not take into account the particle density or the very small sample field analysed under the microscope. Stereomicroscopy relies on the experienced operator to determine the sample composition. Results of the stereomicroscopy assist to provide a percentage contribution for each of the deposited dust components identified in **Section 2.2.2.**

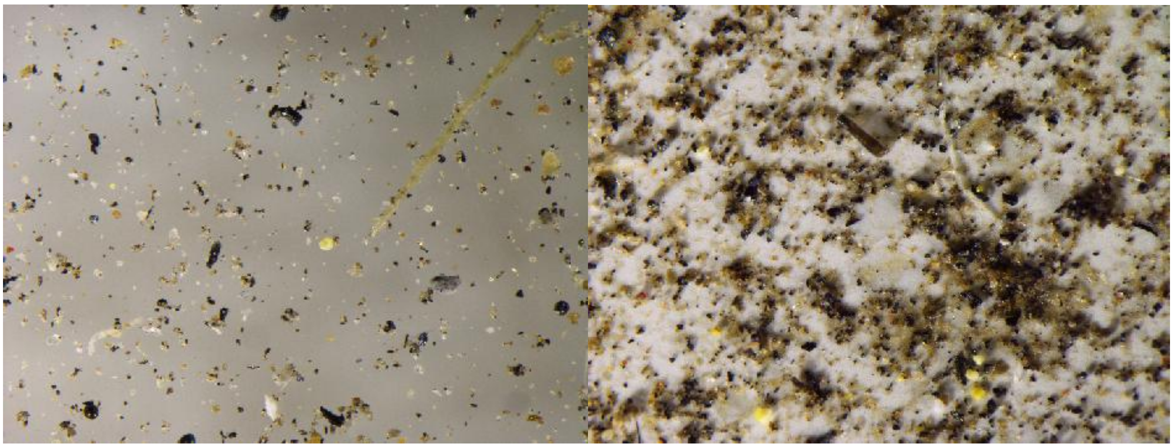

Figure 19 Example StM Images

4.2.3 Scanning Electron Microscopy (SEM)

Scanning electron microscopy (SEM) is a method for high-resolution and long-depth-of-field imaging of the sample surface and near-surface. The SEM uses a focused beam of high-energy electrons (produced at the top of the microscope by an electron gun) to generate a variety of signals at the surface of solid specimens. The electron beam follows a vertical path through the microscope, which is held within a vacuum. The beam travels through electromagnetic fields and lenses, which focus the beam down toward the sample. Once the beam hits the sample, electrons and X-rays are ejected from the sample. Detectors collect these X-rays, backscattered electrons and secondary electrons and convert them into a signal that is sent to a screen similar to a television screen.

The signals that derive from electron-sample interactions reveal information about the sample including external morphology (texture), chemical composition, and crystalline structure and orientation of materials making up the sample.

SEM is used when fine dust particles need more detailed investigation and characterisation and when semi-quantitative and qualitative information is needed on the composition of the dust. The additional magnification allows the particle geometry and structure to be observed further assisting in identifying dust particles and confirming the findings of the StM analysis.

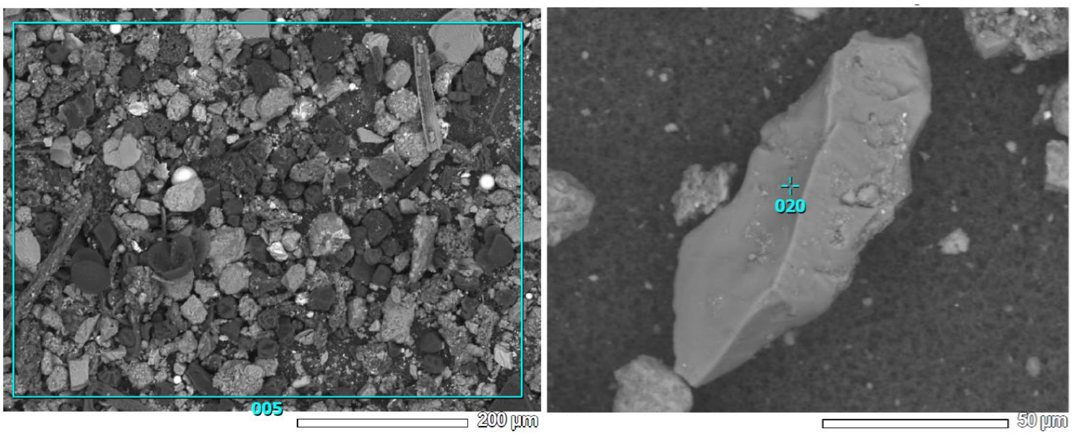

Figure 20 Example SEM images for multiple particles (left) and a single particle (right).

4.2.4 Energy Dispersive X-Ray Spectroscopy (EDS)

Energy Dispersive X-Ray Spectroscopy (EDS) systems are attachments to Electron Microscopy instruments (SEM or Transmission Electron Microscopy (TEM)) where the imaging capability of the microscope identifies the specimen of interest. The data generated by EDS analysis consist of spectra showing peaks corresponding to the elements making up the true composition of the sample being analysed. Elemental mapping of a sample and image analysis are also possible.

When combined with other imaging tools as discussed, EDS can provide elemental analysis on areas as small as nanometres in diameter. EDS was used in combination with SEM to further confirm the composition of both multiple particles and individual particles. The EDS scan area can be seen by the blue box (multiple particles) and crosshair (single particle) in **Figure 20** above, with the elemental composition of these scans shown in **Figure 20**.

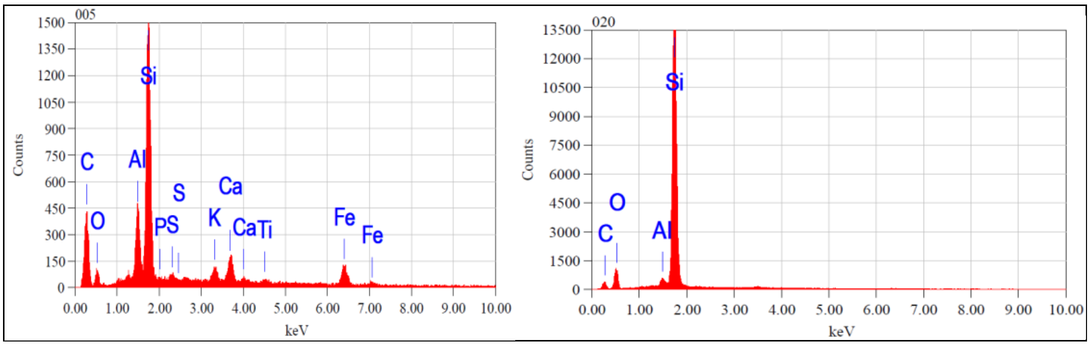

Figure 21 Example EDS scans of the two SEM images above in Figure 20.

In order to undertake the EDS analytical process, sampled particulate material is collected on a carbon-based backing tape for analysis. Ideally the coverage of the particles on this tape would be sufficient such that there is no backing tape showing during the analysis. In some instances, small sample sizes, particularly for Petri dish samples meant that often achieving a complete uniform coverage of particles on the backing tape was not possible. The result of this is that the carbon backing tape is visible to the EDS analysis, resulting in an elevated reading for carbon. Although affecting the EDS spectrum, this interference does not affect the percentages of each particle type reported in the stereomicroscopy analysis (**Section 5.2.1**) and throughout this report. Samples which have experienced this interference have been identified in the results section below.

4.2.5 Chain of Custody Protocols

Chain of Custody (CoC) procedures were followed to maintain and document sample possession from the time of collection to handover to the laboratory for analysis. CoC records accompanied samples at all times once the samples were collected. When transferring possession of the samples, the individuals relinquishing and receiving the samples signed, dated, and noted the time of transfer on the CoC record. The CoCs also included any field notes that may assist with analysis.

AECOM field staff reviewed all CoC documentation prior to dispatch of the samples to the laboratory. Appropriately signed CoC records were sent from the laboratory to AECOM via email to confirm sample delivery.

5.0 Monitoring Results

The results of the monitoring undertaken between October 2014 and October 2015 are summarised in the following sections. Field sheets relating to DDG sample collections are provided in **Appendix D**. The results of the standard dust deposition analyses are discussed in **Section 5.1** and laboratory analysis certificates for the standard dust suite undertaken by ALS Environmental are presented in **Appendix E**. The results of the composition identification analyses undertaken, including the results from the stereomicroscopy, scanning electron microscopy and energy dispersive x-ray spectroscopy analysis are discussed in **Section 5.2**. Laboratory test reports for the identification analyses undertaken by UQMP are presented in **Appendix F**.

5.1 Standard Dust Deposition Analyses

The levels of insoluble solids captured in the deposited dust are summarised in **Table 11** and presented graphically in **Figure 22**. Annual average dust deposition rates recorded during the monitoring period were below the EPA 4g/m^2.month maximum dust deposition criterion for all sites. The highest annual average dust deposition rate was found to occur at Islington (1.1g/m^2.month) and the lowest annual dust deposition rate occurred at Newcastle (0.5g/m^2.month). All other sites were found to have relatively similar dust deposition rates ranging from 0.7 to 0.9 g/m^2.month resulting in an overall annual average of 0.8 g/m^2.month for the study period.

It can be seen from **Table 11** and **Figure 22** that the highest monthly dust deposition rate (2.7g/m^2.month) occurred at Stockton South in the February 2015 monitoring period (6 February to 6 March 2015). During this period dust deposition rates were found to be generally higher across the study area with the maximum monthly dust deposition rate recorded for the sampling locations of Mayfield West, Mayfield East, Waratah, Islington, Tighes Hill and Stockton South. Elevated dust deposition levels were also recorded at Carrington, Wickham and Newcastle during the February 2015 monitoring period. This period returned an average deposition rate of 1.5g/m^2.month against an overall average for the study of 0.8g/m^2.month.

Meteorology data for February indicates winds were predominantly from the East quadrant, with the majority of deposition gauges collecting in the order of 45mm of rainwater over this monitoring period. While there is an increase in deposition rates measured during the February monitoring period, results remained below the EPA annual average criterion.

Dust deposition was also above the study average for the October 2014 and November 2014 monitoring periods with monthly maximums recorded at Carrington, Wickham, Newcastle and Stockton North.

Upon collection, DDG samples were assessed for water level (rainwater), colour, turbidity and decomposing organic matter. These field notes are vital in determining whether a sample may be contaminated.

A sample may be deemed to be contaminated if it is either highly turbid or discoloured, shows visual evidence of organic contamination (e.g. bird droppings, insects, vegetation) or appears to have been impacted by localised dust generation (e.g. earthworks).

Several DDG samples have been deemed to be contaminated and these are identified in **Table 11**.

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Table 11 Deposited Dust – Insoluble Solids (g/m².month)

Site	Monthly Dust Deposition Rates (g/m².month)												Annual Average (g/m².month)
	Oct 14	Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15	
Mayfield West	0.6	1.3	0.7	0.8	2.2	0.4	0.2	0.3	1.4c	0.4	0.8	0.5	0.7
Mayfield East	2.6c	12.0c	3.3c	0.9	1.5	0.8	0.7	0.3	0.8	0.8	1.2	0.5	0.8
Waratah	1.1	0.9	0.5	0.6	1.4	1.0	0.5	0.2	1.2	1.4	0.6	0.5	0.8
Islington	1.9	1.3	1.4	0.8	2.0	0.9	0.6	0.6	0.9	1.3	1.3	0.4	1.1
Tighes Hill	1.6	1.3	1.4	0.5	2.2	0.7	0.3	0.5	0.8	0.7	1.0	0.3	0.9
Carrington	1.1	1.2	0.8	0.6	1.1	0.8	0.2	0.3	0.9	1.0	0.9	1.0	0.8
Wickham	1.2	1.4	1.2	0.5	1.3	0.6	0.3	0.6	0.9	0.8	0.9	0.4	0.8
Hamilton	1.3	1.1	0.8	0.3	1.1	0.8	1.3c	0.6	0.6	0.5	1.0	0.5	0.8
Newcastle	0.8	1.6	0.5	0.4	1.0	0.2	0.3	0.2	0.3	0.3	0.5	0.4	0.5
Stockton North	0.9	1.2	0.4	0.5	0.5	0.6	0.3	0.7	0.8	0.8	0.9	0.5	0.7
Stockton South	1.6	1.4	0.6	0.4	2.7	0.7	0.4	0.3	0.5	0.6	0.6	0.4	0.9
Newcastle East	0.7	1.1	0.9	1.4	0.7	0.9	0.8	0.5	0.5	0.8	0.3	0.6	0.8
Average Deposition	1.2	1.3	0.8	0.6	1.5	0.7	0.4	0.4	0.7	0.8	0.8	0.5	0.8
Average Rainfall (mm)	30	110	25	175	50	160	>235*	70	95	20	30	145	NA

c = contaminated sample

* Samples full due to very high rainfall

Note 1: Samples collected at Mayfield East in October, November and December 2014 were considered to be contaminated due to the presence of beetles in the samples. The April 2015 sample collected at Hamilton was found to contain a high percentage of organic material (vegetation), and the sample collected at Mayfield West in June 2015 contained glass fragments due to the stem of the funnel breaking. Sample data deemed to be contaminated have been excluded from the annual average and plot for the relevant site.

Note 2: Average rainfall has been calculated from the estimated volume of rainwater collected in the DDG samples for each period. This should be considered indicative only.

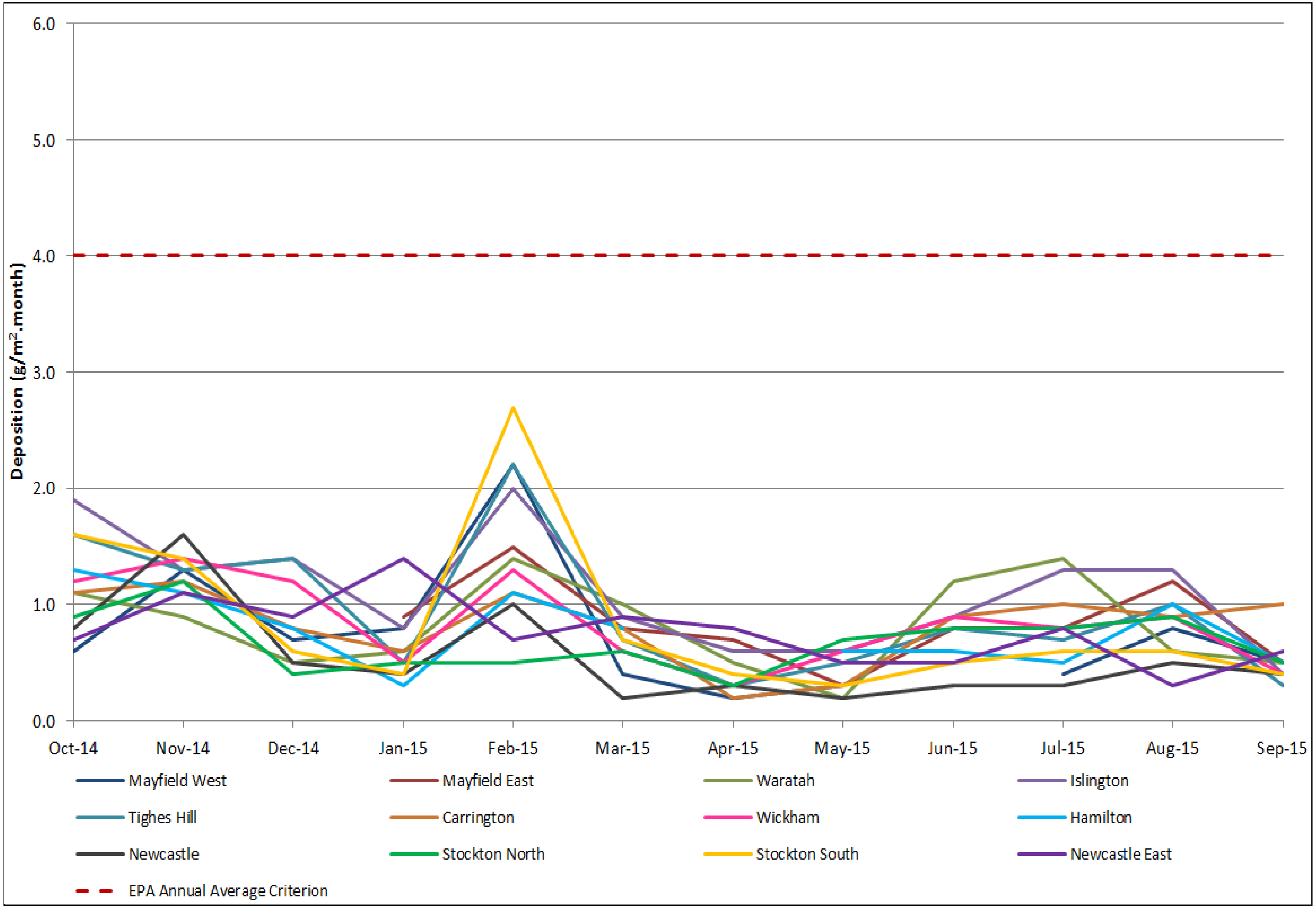
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Deposition (g/m².month)
Oct-14
Nov-14
Dec-14
Jan-15
Feb-15
Mar-15
Apr-15
May-15
Jun-15
Jul-15
Aug-15
Sep-15
Mayfield West
Mayfield East
Waratah
Islington
Tighes Hill
Carrington
Wickham
Hamilton
Newcastle
Stockton North
Stockton South
Newcastle East
EPA Annual Average Criterion

Figure 22 Dust Deposition Monthly Results Plot

5.2 Identification Analyses

The following subsections discuss the results of the stereomicroscopy, SEM and EDS analysis. A total of 24 brush samples, 12 DDG samples and 36 Petri dish samples underwent particle identification analysis at UQMP. Results of the stereomicroscopy (used to classify dust particles through visual analysis) are presented in **Section 5.2.1**. The SEM (used to characterise fine dust particles by their texture, chemical composition and crystalline structure) and EDS (used to identify the elemental spectra of the sample materials) are presented in **Section 5.2.2**. As noted in **Section 1.3**, the LHDDPRG agreed that for the purpose of this study, the term black dust would refer to the total dust deposited and observed on surfaces around households and collected during the sampling program for analysis to identify particle constituents. The laboratory analysis identified that the dust samples typically contained predominantly brown inorganic material consisting of rock and soil particles and darker particles such as coal, soot and rubber particles (identified as black particles).

Laboratory reports for the stereomicroscopy, SEM and EDS analysis undertaken by UQMP are presented in .

5.2.1 Stereomicroscopy

Results of the stereomicroscopy provide a percentage contribution for each of the deposited dust components identified in **Section 2.2.2**. The percentages quoted are best estimates and do not take into account the particle density or the very small sample field analysed under the microscope and rely on the experienced operator to determine the sample composition. The average percentage contribution of components of deposited dust across all samples that underwent composition analysis is presented in **Figure 23**. It can be seen in **Figure 23** that the primary source of deposited dust is soil and rock particles, on average making up 69% of deposited dust. Other sources of deposited dust, on average are coal (10%), rubber (4%) and soot (3%), with salt and other (including insects and vegetation) accounting for 14% of the composition.

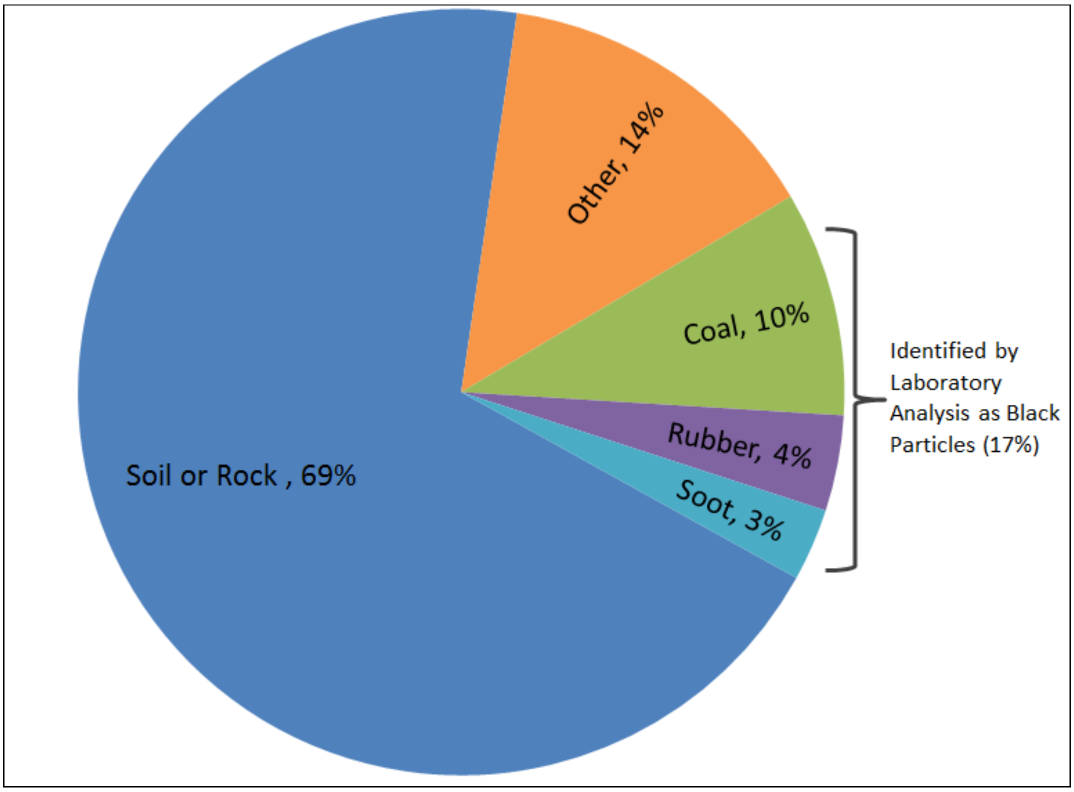

Figure 23 Average Percentage Composition of Deposited Dust Samples (all samples)

A summary of the results of the stereomicroscopy analysis for each sampling technique are presented in **Table 12** to **Table 14**. **Table 12** to **Table 14** provide a breakdown of the dust sample composition for brush, DDG and Petri dish samples, including those identified as black particles (coal, soot and rubber). The percentage composition of rock dust, other organics, inorganics and other materials are also shown in **Table 12** to **Table 14**. A more detailed summary of the results which provide a breakdown of the organic, inorganic and other constituents is presented in **Appendix G**. Examples of images taken from the stereomicroscopy analysis are presented in **Figure 24** and are indicative of the wide range of particulates found within the dust samples collected.

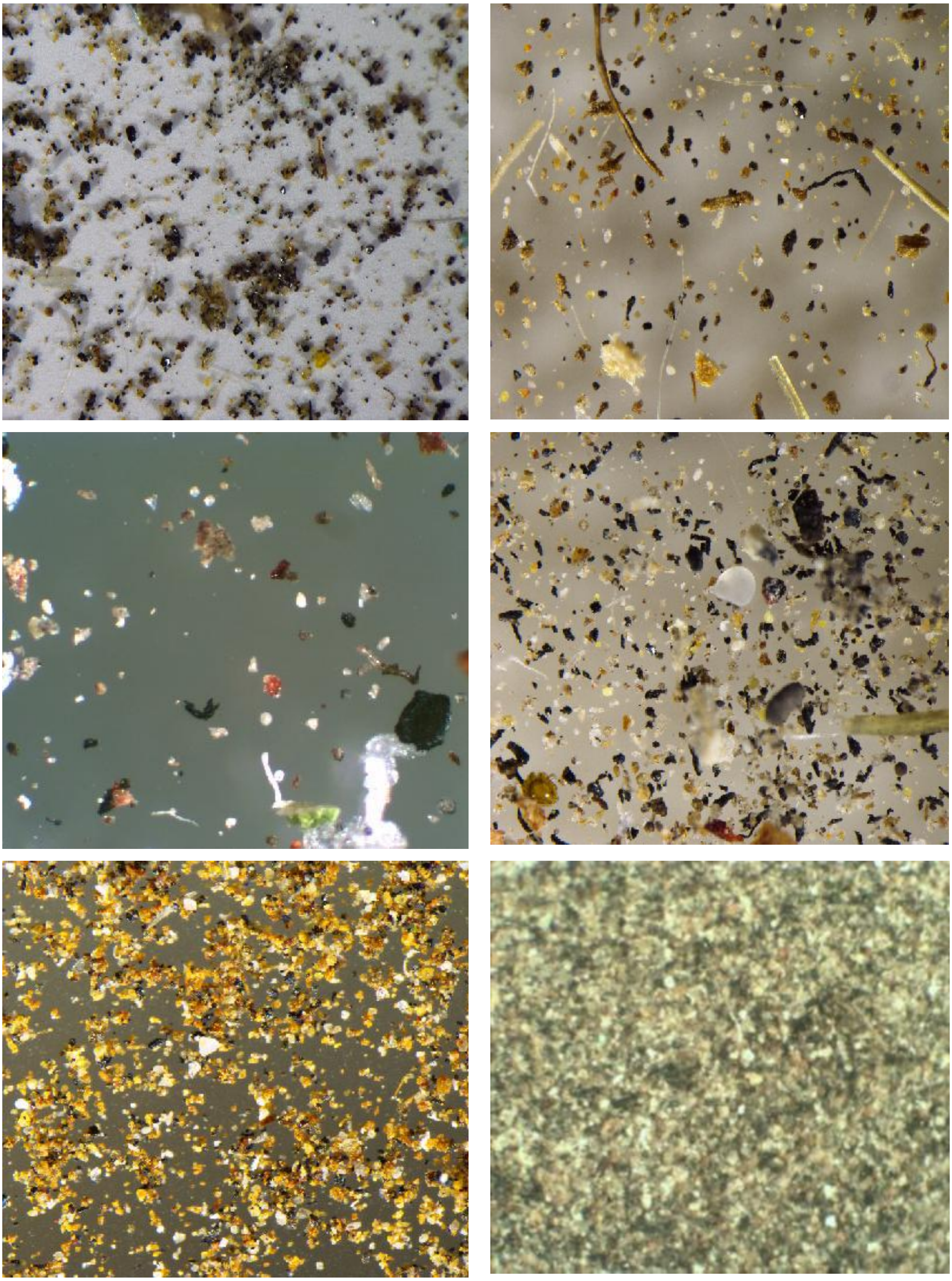

Figure 24 General Examples of Stereomicroscopy Images

5.2.1.1 Brush Sample Results

24 brush samples were collected as part of the study in order to analyse the composition and patterns of long term dust accumulation. Based on the visual analysis shown in **Table 12**, brush samples indicate that long term deposited dust was primarily composed of soil or rock making up 45 to 95% of the samples examined with an average of 74%.

The black particles (coal, soot and rubber) observed in brush samples was found to be between 0 and 30%, averaging 14% and was detected in 21 of the 24 samples. Of these, the major constituent of was found to be coal (9% on average) in most cases with smaller contributions of soot (3% on average) and rubber (2% on average). The highest percentages of black particles were recorded at Stockton South (sample B13), Wickham (B14) and Newcastle East (B23), recording 30% of coal, soot and rubber combined within these samples. The contribution of black particles at Stockton was found to be highly variable ranging from 7 to 30%, while the contribution black particles at Wickham was relatively consistent ranging between 22 and 30% of the sample. Only one brush sample was collected at Newcastle East which contained traces of coal, soot and rubber. No notable black particles were recorded in brush samples for Mayfield East (B5), Hamilton North (B9), or one of two Tighes Hill samples (B10).

When reviewing the breakdown of black particles (coal, soot and rubber) at each site, the following was noted (refer to **Table 12**):

- The highest levels of coal within brush samples were observed at Wickham and Stockton South (20%), with above average levels (15%) observed at Newcastle, Tighes Hill, Mayfield and Carrington;
- The highest levels of soot within brush samples were observed at Stockton South with two samples yielding 10% soot. All other samples were comprised of equal to or less than 5% soot; and
- The highest levels of rubber within brush samples were observed at Hamilton, Stockton South, Wickham and Newcastle East (10%). All other samples were comprised of equal to or less than 5% rubber.

As there is no time-dimension for the brush samples collected (that is, the dust has been landing on that area for an unknown time period), the results cannot be compared against a criterion and cannot be linked to a specific source (as potential contributing sources may have been varied over the sample time).

Table 12 Stereomicroscopy Results for Brush Samples: Visual Composition Identification Analysis

Sample ID	Analysis ID	Date Collected	Sampling site	Coal, Soot and Rubber (%)	Percentage of Sample (%)						
					Coal	Soot	Black Rubber	Soil or Rock	Other Inorganics and Minerals	General Organic	Other
B1	13146	12/12/2014	Islington (DDG site)	5	5	0	0	95	0	0	0
B2	13147	12/12/2014	Stockton South (DDG site)	15	5	10	0	50	0	5	30
B3	13287	6/03/2015	Stockton South (DDG site)	7	5	2	0	68	0	20	5
B4	13288	6/03/2015	Roxburgh Street, South Stockton	20	10	10	0	65	0	5	10
B5	13289	6/03/2015	Mayfield East (DDG site)	0	0	0	0	95	5	0	0
B6	13290	6/03/2015	Ferndale St, Tighes Hill	5	5	0	0	80	5	5	5
B7	13291	6/03/2015	Forbes St, Carrington	5	5	0	0	90	5	0	0
B8	13292	6/03/2015	Wickham (DDG site)	22	20	2	0	73	0	5	0
B9	13293	6/03/2015	Phillips St, Hamilton North	0	0	0	0	80	10	10	0
B10	13294	6/03/2015	Tighes Hill (DDG site)	0	0	0	0	90	0	10	0
B11	13295	6/03/2015	Islington (DDG site)	15	10	5	0	55	0	30	0
B12	13497	2/06/2015	Hamilton (DDG site)	20	10	0	10	70	0	10	0
B13	13498	2/06/2015	Stockton South (DDG site)	30	20	0	10	65	5	0	0
B14	13752	3/09/2015	Wickham (1) (DDG site)	30	15	5	10	70	0	0	0
B15	13753	3/09/2015	Wickham (2) (DDG site)	20	10	5	5	65	0	15	0
B16	13754	8/09/2015	Lott St, Carrington	15	5	5	5	50	35	0	0

Sample ID	Analysis ID	Date Collected	Sampling site	Coal, Soot and Rubber (%)	Percentage of Sample (%)						
					Coal	Soot	Black Rubber	Soil or Rock	Other Inorganics and Minerals	General Organic	Other
B17	13755	8/09/2015	Bull St, Mayfield	15	5	5	5	60	25	0	0
B18	13756	8/09/2015	Elcho St, Hamilton	5	5	0	0	95	0	0	0
B19	13757	8/09/2015	Kings Rd, Tighes Hill	15	15	0	0	85	0	0	0
B20	13758	8/09/2015	Neville St, Mayfield	15	15	0	0	75	10	0	0
B21	13759	8/09/2015	Hargrave St, Carrington	15	15	0	0	75	10	0	0
B22	13760	8/09/2015	Bourke St, Mayfield	10	5	5	0	90	0	0	0
B23	13761	9/09/2015	Stevenson Pl, Newcastle East	30	15	5	10	45	10	15	0
B24	13762	9/09/2015	Gregson St, Mayfield West	15	10	5	0	85	0	0	0

Note: For the purpose of this report, results reported by UQMP as “trace” or “no result” have been assumed to be 0%.

5.2.1.2 DDG Sample Results

Visual analysis of the 12 DDG samples presented in **Table 13** was performed in order to gain an understanding of the likely composition of monthly dust deposits at DDG monitoring locations. Similar to the brush sample results, the analysis shows that the major constituents of deposited dust were generally soil and rock, making up 50 to 95% of the sample[6] with an average of 70%.

The combined percentages of coal, soot and rubber within samples was found to range between 0 and 35%, averaging 18% and was observed at greater than trace levels within 10[7] of the 12 samples. On average coal was found to be the largest contributor of black particles within DDG samples (12%) with smaller fractions of soot (4%) and rubber (2%). The highest percentage of black particles within DDG samples was found at the Stockton North DDG location; with both samples analysed for particle composition from this location consisting of over 30% black particles, largely including coal and moderate traces of soot. Notable portions of black particles were also recorded at Wickham, Hamilton (mainly coal) and Carrington (coal, soot and rubber). No notable black particles were recorded at Stockton South in the single DDG sample analysed from this location.

When reviewing the percentages of coal, soot and rubber in each of the DDG samples presented in **Table 13** the following was noted:

- The highest levels of coal were observed at Wickham, Stockton North and Hamilton (20%), with above average levels also observed at Newcastle East (15%).
- The highest levels of soot were observed at Stockton North with two samples yielding 10% soot. All other samples were comprised of equal to or less than 5% soot; and
- All samples were comprised of equal to or less than 5 % rubber.

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[6] The sample taken at Mayfield East was deemed to be contaminated and was comprised of 18% soil and rock due to the sample containing high fractions of copper sludge, slime and insect and plant debris.
[7] Trace amounts of black particles were found in the other two samples.

Table 13 Stereomicroscopy Results for DDG Samples: Visual Composition Identification Analysis

Sample ID	Analysis ID	Date Exposed	Date Collected	Sampling site	Coal, Soot and Rubber (%)	Percentage of Sample (%)						
						Coal	Soot	Black Rubber	Soil or Rock	Other Inorganics and Minerals	General Organic	Other
D1	13079	17/10/2014	14/11/2014	Carrington	20	10	5	5	75	0	5	0
D2	13143	12/12/2014	9/01/2015	Islington	5	5	0	0	95	0	0	0
D3	13173	12/12/2014	9/01/2015	Mayfield East	12c	10c	2c	0c	18c	0c	40c	30c
D4	13239	9/01/2015	6/02/2015	Mayfield West	5	5	0	0	95	0	0	0
D5	13286	6/02/2015	6/03/2015	Tighes Hill	0c	0c	0c	0c	50c	0c	30c	20c
D6	13398	6/03/2015	7/04/2015	Waratah	15	5	5	5	75	0	10	0
D7	13469	7/04/1945	5/05/2015	Stockton South	0	0	0	0	65	0	30	5
D8	13496	5/05/2015	2/06/2015	Stockton North	32	20	10	2	63	0	5	0
D9	13555	2/06/2015	3/07/2015	Stockton North	35	20	10	5	60	0	5	0
D10	13632	3/07/2015	3/08/2015	Newcastle East	17	15	2	0	73	0	10	0
D11	13746	3/08/2015	3/09/2015	Wickham	25	20	0	5	50	0	25	0
D12	13764	3/09/2015	2/10/2015	Hamilton	25	20	5	0	50	0	25	0

Note: For the purpose of this report, results reported by UQMP as “trace” or “no result” have been assumed to be 0%.

c = Contaminated (visual analysis). Sample D2 and D5 were encased in a polysaccharide slime and copper sludge preventing accurate visual analysis from being undertaken. Contaminated D2 and D5 have been excluded from reported composition averages.

5.2.1.3 Petri Dish Sample Results

36 Petri dish samples were collected as part of the study to analyse short term deposited dust composition within the study area. Results from the Petri dish samples presented in **Table 14,** like the DDGs and Brush samples, show the majority of deposited dust is soil and rock particles, making up 40 to 95% of the samples.

Coal, soot and rubber were found to make up 0 to 45% of the samples, averaging 18% and were found to be present in 31[8] of 36 samples. Constituent fractions on average were found to be 9% for coal, 3% for soot and 6% for rubber. The coal and soot fractions were found to be comparative to both DDG and brush samples, but a higher fraction of rubber dust was found within the Petri dish samples on average. The highest percentage of black particles was found to occur at the Stockton South DDG site, comprising 45% of a sample from this location (sample P30), largely including coal and soot with lower levels of rubber. Notable portions of black particles were also recorded at a number of other sites with 21 of the samples containing 20% or higher fractions of coal, soot and rubber combined. No black particles were recorded in samples taken at Carrington and Mayfield East between 17 and 18 December 2014 (P2 and P3) or at Mayfield between 5 and 6 March 2015 (P8).

When reviewing the percentage coal, soot and rubber in each of the samples presented in **Table 14** the following was noted:

- The highest level of coal within Petri dish samples was observed at Stockton South (25%), with above average levels observed at Stockton North, Fern Bay, Tighes Hill and Hamilton (15 to 20%).
- The highest levels of soot within Petri dish samples were observed at Stockton South with one sample yielding 20% soot. Above average levels of soot were also observed at Carrington (15%) and Stockton North (10%).
- The highest levels of rubber recorded in Petri dish samples were 20% recorded at Newcastle East, Carrington, Honeysuckle, Mayfield East and Waratah. Above average levels of 10 to 15% rubber dust were also recorded at Tighes Hill, Mayfield West, Newcastle, Broadmeadow and Warabrook.

[8] Trace amounts of black particles were found in the remaining five samples.

Table 14 Stereomicroscopy Results for Petri Dish Samples: Visual Composition Identification Analysis

Sample ID	Analysis ID	Date Exposed	Date Collected	Sampling site	Coal, Soot and Rubber (%)	Percentage of Sample (%)						
						Coal	Soot	Black Rubber	Soil or Rock	Other Inorganics and Minerals	General Organic	Other
P1	13080	14/11/2014	15/11/2014	Tighes Hill (DDG site)	5	5	0	0	90	0	5	0
P2	13144	17/12/2014	18/12/2015	Carrington (DDG site)	0	0	0	0	90	10	0	0
P3	13145	17/12/2014	18/12/2014	Mayfield East (DDG site)	0	0	0	0	95	5	0	0
P4	13296	18/02/2015	20/02/2015	Mayfield West (DDG site)	5	5	0	0	75	0	20	0
P5	13297	18/02/2015	20/02/2015	Ferndale St, Tighes Hill	15	10	5	0	65	0	20	0
P6	13298	18/02/2015	20/02/2015	Waratah (DDG site)	10	10	0	0	60	20	10	0
P7	13299	18/02/2015	20/02/2015	Islington (DDG site)	5	5	0	0	90	5	0	0
P8	13300	5/03/2015	6/03/2015	Kerr St, Mayfield	0	0	0	0	70	20	10	0
P9	13301	5/03/2015	6/03/2015	Selwyn St, Tighes Hill	20	10	0	10	50	20	10	0
P10	13399	8/04/2015	8/04/2015	Warabrook Blvde, Warabrook	10	10	0	0	50	0	40	0
P11	13400	8/04/2015	8/04/2015	Stockton South (DDG site)	20	15	5	0	65	0	15	0
P12	13401	8/04/2015	8/04/2015	Stockton North (DDG site)	20	10	10	0	60	0	20	0
P13	13470	11/05/2015	13/05/2015	Newcastle East (DDG site)	10	10	0	0	85	0	5	0
P14	13471	11/05/2015	13/05/2015	Stockton North (DDG site)	20	20	0	0	75	0	5	0
P15	13472	11/05/2015	13/05/2015	Punt Rd, Stockton	8	5	3	0	87	0	5	0

Sample ID	Analysis ID	Date Exposed	Date Collected	Sampling site	Coal, Soot and Rubber (%)	Percentage of Sample (%)						
						Coal	Soot	Black Rubber	Soil or Rock	Other Inorganics and Minerals	General Organic	Other
P16	13473	11/05/2015	13/05/2015	Taylor Rd, Fern Bay	25	20	0	5	75	0	0	0
P17	13556	3/07/2015	7/07/2015	Stockton South (DDG site)	30	10	20	0	65	0	5	0
P18	13557	3/07/2015	7/07/2015	Stockton North (DDG site)	25	20	5	0	75	0	0	0
P19	13558	3/07/2015	7/07/2015	Carrington (DDG site)	20	10	5	5	75	0	5	0
P20	13559	3/07/2015	7/07/2015	Tighes Hill (DDG site)	25	20	0	5	75	0	0	0
P21	13560	3/07/2015	7/07/2015	Hamilton (DDG site)	25	20	0	5	75	0	0	0
P22	13633	3/08/2015	6/08/2015	Mayfield West (DDG Site)	10	0	0	10	70	0	20	0
P23	13634	3/08/2015	6/08/2015	Stockton North (DDG site)	15	10	5	0	75	0	10	0
P24	13635	3/08/2015	6/08/2015	Carrington (DDG site)	15	5	5	5	75	0	10	0
P25	13636	3/08/2015	6/08/2015	Newcastle East (DDG site)	25	5	0	20	65	0	10	0
P26	13747	17/08/2015	3/09/2015	Stockton South (DDG site)	15	10	0	5	55	0	30	0
P27	13748	17/08/2015	20/08/2015	Stockton North (DDG site)	20	15	0	5	75	5	0	0
P28	13749	28/08/2015	31/08/2015	Bourke St, Carrington	30	10	0	20	40	0	30	0
P29	13750	28/08/2015	31/08/2015	Wright Ln, Honeysuckle	25	5	0	20	45	0	30	0
P30	13751	17/08/2015	20/08/2015	Stockton South (DDG site)	45	25	15	5	55	0	0	0

Sample ID	Analysis ID	Date Exposed	Date Collected	Sampling site	Coal, Soot and Rubber (%)	Percentage of Sample (%)						
						Coal	Soot	Black Rubber	Soil or Rock	Other Inorganics and Minerals	General Organic	Other
P31	13765	9/09/2015	11/09/2015	Mayfield East (DDG site)	25	5	0	20	45	0	25	5
P32	13766	9/09/2015	11/09/2015	Waratah (DDG site)	25	0	5	20	45	0	25	5
P33	13767	2/10/2015	6/10/2015	Carrington (DDG site)	35	10	15	10	55	0	10	0
P34	13768	2/10/2015	6/10/2015	Newcastle (DDG site)	25	5	5	15	40	10	25	0
P35	13769	2/10/2015	6/10/2015	Broadmeadow (train station)	25	10	5	10	40	5	30	0
P36	13770	2/10/2015	6/10/2015	Eucalyptus Cct, Warabrook	20	5	5	10	50	10	20	0

Note: For the purpose of this report, results reported by UQMP as “trace” or “no result” have been assumed to be 0%.

5.2.2 Scanning Electron Microscopy and Energy Dispersive X-Ray Spectroscopy

Scanning electron microscopy (SEM) was used to identify fine particulates and to provide a more detailed investigation and characterisation of each sample as well as to support the results of the stereomicroscopy analysis. The energy dispersive x-ray spectroscopy (EDS) was then used to identify the elemental composition of dust particles within the samples.

A summary of the results of the SEM and EDS are presented in **Table 15** to **Table 17**.
Table 15 to **Table 17** provides a summary of the major elements found in each sample as well as the major and minor particle types in each dust sample. Details of this analysis can be found in the UQMP laboratory reports presented in **Appendix F**. A selection of images from the scanning electron microscopy analysis are presented in **Figure 25** and are indicative of the wide range of particulates found within the dust samples collected.

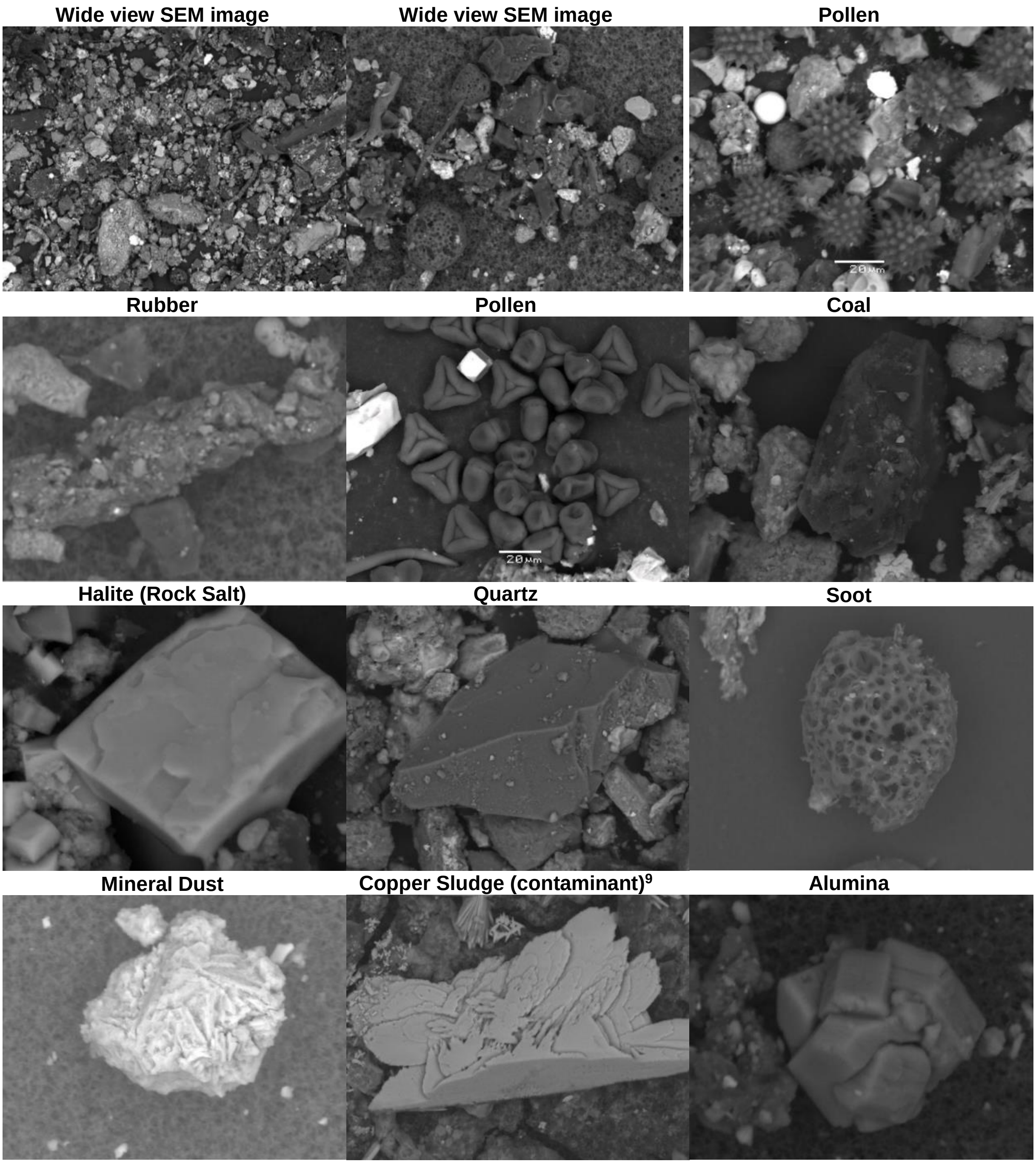

Figure 25 Example of Scanning Electron Microscopy Images (black and white)

[9] DDG's are dosed with Copper Sulphate to prevent organic growth as per the standard methodology.

5.2.2.1 Brush Samples – SEM and EDS Analysis

SEM and EDS analysis of samples of long term dust deposits showed the major contributor to brush samples was aluminosilicate mineral dust. EDS analysis identified that the primary elements within the brush samples were aluminium (Al) and silicon (Si). Other major elements included carbon (C), chlorine (Cl), oxygen (O), iron (Fe) and zinc (Zn). A few brush samples were found to have carbon tape interference from the analytical process due to the non-uniform sample coverage over the analysis area resulting in elevated readings of carbon in the EDS analysis.

The results of the SEM and EDS analysis support the results of the Stereomicroscopy analysis, which identified the major component of most samples as soil or rock and identified the presence of minor amounts of black particles, with coal, soot and rubber detected in most samples.

Table 15 Energy Dispersive X-Ray Spectroscopy and Scanning Electron Microscopy Results for Brush Samples

Sample ID	Analysis ID	Major Elements in Sample	Carbon Tape Interference	Dust Particle Composition	
				Major Constituents	Minor Constituents
B1	13146	Si, Al, C, O	No	- Aluminosilicate mineral dust	- Halite (sodium chloride) - Calcium sulphate - Zinc rich mineral dust
B2	13147	Si, C, Al, O	No	- Aluminosilicate mineral dust - Fibres	No data
B3	13287	No analysis (insufficient sample)			
B4	13288	Si, C, Cl, Al	No	- Aluminosilicate mineral dust	- Coal and soot - Insect debris - Fibres
B5	13289	Si, C, Cl, Al	No	- Aluminosilicate mineral dust	- Coal, soot and rubber dust - Halite (sodium chloride) - Alumina - Fibres - Paint
B6	13290	Si, C, Al, O	No	- Aluminosilicate mineral dust	- Coal, soot and rubber dust - Fibres - Paint
B7	13291	Si, Al, C, Cl, O	No	- Aluminosilicate mineral dust - Halite (sodium chloride)	- Coal - Fibres - Paint
B8	13292	C, Si	Yes	- Aluminosilicate mineral dust	- Coal and soot - Plant debris - Wood dust
B9	13293	Si, Cl, C, Al	No	- Aluminosilicate mineral dust	- Coal and soot - Plant and insect debris - Wood dust - Fibres
B10	13294	C, Si	Yes	- Aluminosilicate mineral dust	- Coal, soot and rubber dust

Sample ID	Analysis ID	Major Elements in Sample	Carbon Tape Interference	Dust Particle Composition	
				Major Constituents	Minor Constituents
					- Iron rich particles - Alumina - Wood dust - Fibres
B11	13295	Si, C, Al, O	No	- Organic particles including coal, soot, plant and insect debris	- Soil and rock dust
B12	13497	Si, C, Fe, Al	No	- Mineral dust	- Coal and rubber dust - Plant and insect debris - Iron oxide - Fibres - Paint
B13	13498	Si, Cl, C,	No	- Aluminosilicate mineral dust - Halite (sodium chloride)	- Coal, soot and rubber dust - Plant and insect debris
B14	13752	Si, Al	No	- Aluminosilicate mineral dust	- Coal, soot and rubber dust - Plant and insect debris
B15	13753	Si, Al, C	No	- Aluminosilicate mineral dust	- Coal, soot and rubber dust - Plant and insect debris
B16	13754	Si, Al	No	- Aluminosilicate mineral dust - Alumina	- Coal, soot and rubber dust - Plant and insect debris
B17	13755	Si, Al	No	- Aluminosilicate mineral dust - Alumina	- Coal, soot and rubber dust - Plant and insect debris
B18	13756	Si, Al	No	- Aluminosilicate mineral dust	- Coal, soot and rubber dust - Plant and insect debris
B19	13757	Si, Al	No	- Aluminosilicate mineral dust	- Coal, soot and rubber dust - Plant and insect debris
B20	13758	Si, Al	No	- Aluminosilicate mineral dust - Alumina	- Coal and soot
B21	13759	Si, Al	No	- Aluminosilicate mineral dust - Alumina - Zinc	- Coal and soot

Sample ID	Analysis ID	Major Elements in Sample	Carbon Tape Interference	Dust Particle Composition	
				Major Constituents	Minor Constituents
B22	13760	Si, Zn, Al	No	- Aluminosilicate mineral dust - Alumina - Zinc	- Coal and soot
B23	13761	Si, Al	No	- Aluminosilicate mineral dust	- Coal, soot and rubber dust - Plant and insect debris
B24	13762	Si, Al	No	- Aluminosilicate mineral dust	- Coal and soot - Plant debris - Fibres

5.2.2.2 DDG Samples – SEM and EDS Analysis

EDS analysis from DDG samples showed the major elements within samples were aluminium (Al), silicon (Si), carbon (C) and oxygen (O). Due to the relatively small sample sizes, the fraction of carbon observed in most DDG samples has been over estimated due to the presence of exposed carbon tape, which interfered with sample readings. Although affecting the EDS spectrum, this interference does not affect the percentages of each particle type reported in the stereomicroscopy analysis (**Section 5.2.1**).

Scanning electron microscopy analysis revealed the major components of dust within the DDG samples was aluminosilicate which is consistent with both the findings of the energy dispersive x-ray spectroscopy which also identified the major elements as silicon and aluminium and the stereomicroscopy which identified the major component of most samples as soil or rock. The results of the SEM/EDS analysis also identified the presence of coal, soot and rubber in most samples similar to the findings of the stereomicroscopy.

Table 16 Energy Dispersive X-Ray Spectroscopy and Scanning Electron Microscopy Results for DDG Samples

Sample ID	Analysis ID	Major Elements in Sample	Carbon Tape Interference	Dust Particle Composition	
				Major Constituents	Minor Constituents
D1	13079	C, Si, Al,	No	- Mineral dust	- Coal, soot and rubber dust - Plant and insect debris - Copper sludge (contaminant)
D2	13143	C, Si, O	Yes	- Aluminosilicate mineral dust	- Coal, soot and rubber dust - Plant and insect debris - Fibres
D3	13173	Sample contaminated			
D4	13239	C, O	Yes	- Aluminosilicate mineral dust	- Coal, soot and rubber dust - Plant and insect debris
D5	13286	Sample contaminated			
D6	13398	C, O, Si, Al	Yes	- Mineral dust	- Coal and rubber dust - Plant and insect debris
D7	13469	No analysis (insufficient particles)			
D8	13496	C, Si, O, Al	Yes	- Aluminosilicate mineral dust	- Coal, soot and rubber dust - Plant and insect debris - Paint
D9	13555	C, Si, Al, O, S	Yes	- Aluminosilicate mineral dust	- Coal, soot and rubber dust - Plant and insect debris - Fibres
D10	13632	C, Si, Al, O	Possible	- Aluminosilicate mineral dust	- Coal, soot and rubber dust - Plant and insect debris
D11	13746	Si, C, Al	Yes	- Aluminosilicate mineral dust	- Coal, soot and rubber dust - Plant and insect debris - Fibres
D12	13079	C, Si	Yes	- Aluminosilicate mineral dust	- Coal and soot - Plant and insect debris

Note: Samples D3 and D5 were contaminated. Contaminated samples were encased in a polysaccharide slime and copper sludge.

5.2.2.3 Petri Dish Samples – SEM and EDS Analysis

EDS analysis from short term Petri dish samples showed the major elements within the Petri dish samples were aluminium (Al), silicon (Si), carbon (C), oxygen (O) and sodium (Na). Due to the small sample sizes, the fraction of carbon observed in most Petri dish samples has been over estimated due to the presence of exposed carbon tape, which interfered with sample readings. Some samples contained insufficient particles resulting in EDS analysis unable to be undertaken.

SEM analysis revealed the major components of dust within the samples was aluminosilicate mineral dust which is consistent with both the findings of the EDS (which identified the major elements as silicon and aluminium) and the stereomicroscopy which identified the major component of most samples as soil or rock. The results of the SEM and EDS analysis confirm the presence of black particles including coal, soot and rubber in most samples which supports the findings of the stereomicroscopy.

Table 17 Energy Dispersive X-Ray Spectroscopy and Scanning Electron Microscopy Results for Petri Dish Samples

Sample ID	Analysis ID	Major Elements in Sample	Carbon Tape Interference	Dust Particle Composition	
				Major Constituents	Minor Constituents
P1	13080	C, Si, Al,	No	- Aluminosilicate mineral dust	- Coal, soot and rubber dust - Plant and insect debris
P2	13144	Si, Al, Cl, C, O	No	- Aluminosilicate mineral dust	- Coal and soot - Halite (sodium chloride) - Calcium sulphate - Plant and insect debris
P3	13145	Si, Cl, Al, Na, O	No	- Aluminosilicate mineral dust	- Coal and rubber dust - Halite (sodium chloride) - Calcium sulphate - Plant and insect debris
P4	13296	SEM only (insufficient particles)			
P5	13297	C, Cl	Yes	- Aluminosilicate mineral dust	- Coal, soot and rubber dust - Plant and insect debris - Paint
P6	13298	C, Cl, Si, Na	Yes	- Aluminosilicate mineral dust - Halite (sodium chloride)	- Coal, soot and rubber dust - Plant and insect debris - Fibres
P7	13299	C, Cl, Si, Na	Yes	- Aluminosilicate mineral dust - Halite (sodium chloride)	- Coal, soot and rubber dust - Fibres
P8	13300	C, Si, Cl	Yes	- Aluminosilicate mineral dust - Halite (sodium chloride)	- Coal and soot - Plant and insect debris - Fibres
P9	13301	Si, Cl, C, Na	No	- Aluminosilicate mineral dust - Halite (sodium chloride)	- Coal, soot and rubber dust - Plant and insect debris
P10	13399	C, O, Si, Na, Cl	Yes	- Mineral dust	- Coal and rubber dust - Plant and insect debris
P11	13400	C, Si, O, Al, S	Yes	- Mineral dust	- Coal and rubber dust - Plant and insect debris

Sample ID	Analysis ID	Major Elements in Sample	Carbon Tape Interference	Dust Particle Composition	
				Major Constituents	Minor Constituents
P12	13401	C	Yes	- Mineral dust	- Coal and soot - Plant debris
P13	13470	C, O, Si, Cl, S	Yes	- Mineral dust	- Coal, soot and rubber dust - Plant debris
P14	13471	C, Si, Al, O	Yes	- Mineral dust	- Coal and soot - Plant debris - Fibres
P15	13472	C, O, Si	Yes	- Mineral dust	- Coal and soot - Plant debris - Fibres
P16	13473	C, Si, O, Al, S	Yes	- Mineral dust	- Coal, soot and rubber dust - Plant and insect debris
P17	13556	C, Si, Al, O, Ca	Yes	- Aluminosilicate mineral dust	- Coal, soot and rubber dust - Plant and insect debris - Fibres
P18	13557	C, Si, O, Al	Yes	- Mineral dust	- Coal and soot - Plant and insect debris
P19	13558	SEM only (insufficient particles)			
P20	13559	SEM only (insufficient particles)			
P21	13560	SEM only (insufficient particles)			
P22	13633	SEM only (insufficient particles)			
P23	13634	SEM only (insufficient particles)			
P24	13635	SEM only (insufficient particles)			
P25	13636	C, Si, Al, O	Yes	- Aluminosilicate mineral dust	- Coal, soot and rubber dust - Plant and insect debris
P26	13747	Si, C, Al	No	- Aluminosilicate mineral dust	- Coal, soot and rubber dust - Plant and insect debris

Sample ID	Analysis ID	Major Elements in Sample	Carbon Tape Interference	Dust Particle Composition	
				Major Constituents	Minor Constituents
					- Fibres
P27	13748	C, Al, Si	Yes	- Mineral dust	- Coal, soot and rubber dust - Plant and insect debris - Fibres
P28	13749	C, Si, Al	Yes	- Mineral dust	- Coal, soot and rubber dust - Plant and insect debris
P29	13750	Si, C, Al	Yes	- Organic - coal, rubber, soot, plant (mostly pollen), insects	- Mineral dust
P30	13751	Si, Al, C	Yes	- Mineral dust	- Coal, soot and rubber dust - Plant and insect debris
P31	13765	C, Si, Al	Yes	- Organic matter including coal, rubber, plant and insect debris and fibres	- Aluminosilicate mineral dust
P32	13766	C, Si	Yes	- Aluminosilicate mineral dust	- Coal, soot and rubber dust - Plant and insect debris
P33	13767	Si, C, Al	Yes	- Aluminosilicate mineral dust	- Coal, soot and rubber dust - Plant and insect debris
P34	13768	C, Si, Al	Yes	- Aluminosilicate mineral dust	- Coal, soot and rubber dust - Plant and insect debris
P35	13769	Si, C, Al	Yes	- Aluminosilicate mineral dust	- Coal, soot and rubber dust - Plant and insect debris
P36	13770	Si, C, Al	No	- Aluminosilicate mineral dust	- Organic material (unspecified)

6.0 Discussion and Recommendations

The following section provides a discussion of the results presented in **Section 5.0** and recommendations for further assessment.

6.1 Discussion of Results

6.1.1 Total Dust Deposition

Annual average dust deposition recorded in the study area was found to be below the EPA 4g/m^2.month maximum dust deposition criterion for all sites (refer to **Section 5.2**). The highest annual average dust deposition rate was recorded at Islington at 1.1 g/m^2.month. Little variation was observed between the remaining sites with deposition rates varying between 0.7 to 0.9 g/m^2.month with the exception of Newcastle which recorded a deposition rate of 0.5 g/m^2.month. The average annual average across all 12 DDG sites was found to be 0.8g/m^2.month for the study period.

Results of the identification analysis determined soil or rock (primarily aluminosilicate) as the primary source of deposited dust averaging 69% of all samples[10]. This is consistent with the findings of the deposited dust composition studies conducted by the Queensland Government (refer to **Section 2.2.4**) which found the major deposited dust to be soil and rock dust.

The remaining portion was largely found to be organic materials such as plant and insect debris, fibres, halite and black particles from coal, soot and rubber (refer to **Section 5.2.1**, **Section 5.2.2** and **Appendix G**). The proportion of black particles in deposited dust samples is discussed below in **Section 6.1.2**.

Dust deposition monitoring is a long-term monitoring strategy used to identify trends in local dust levels, primarily fallout. Monitoring was conducted over a twelve month period between October 2014 and October 2015 in accordance with the EPA guideline however, longer term monitoring may account for additional seasonal factors and potential variability in the collection method, as well as aid in establishing long term regional trends.

6.1.2 Deposition of Black Particles (Coal, Soot and Rubber)

The identification analysis undertaken for brush, DDG and Petri dish samples found that on average, deposited dust within the region contained 17% black particles (refer to **Section 5.2.1**, **Section 5.2.2** and **Appendix G**). When accounting for the annual average deposition rates observed from the DDG monitoring network (refer to **Section 5.2** and **Section 6.1.1**) the average dust deposition rate for coal, soot and rubber combined would be in the order of 0.09 to 0.19 g/m^2.month.

Black particles within the study area was largely comprised of coal; accounting for approximately 10% of deposited dust on average across all samples based on the stereomicroscopy analysis. This is similar to the results of the Tennyson Dust Monitoring Investigation and Metropolitan Rail Systems Coal Dust Monitoring Program (refer to **Section 2.2.4**) which both observed an average 10% contribution from coal to total deposited dust. Smaller fractions of soot and rubber dust were also observed accounting for approximately 3% and 4% on average across all samples. The contribution of rubber dust in the Queensland Government 2012 and 2013 studies both found higher fractions of rubber at 10%, while only trace amounts of soot were observed in the studies. No regional background samples were taken as part of the LHDDP for comparison with the Metropolitan Rail Systems Coal Dust Monitoring Program.

The following subsections provide a discussion of black particle contributions at each location and the meteorological conditions and potential upwind sources at the time of sampling with regards to coal (**Section 6.1.2.1**), soot (**Section 6.1.2.2**) and rubber (**Section 6.1.2.3**) dust deposition. Brush samples were collected as part of the study to provide an analysis of long term dust accumulation patterns and hence are not discussed in terms of associated meteorological data. For the monthly DDG samples and short term Petri dish samples, associated meteorological conditions are discussed below. Figures pertaining to sample locations and wind roses of each monitoring period for DDG and Petri dish samples are presented in **Appendix C**.

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[10] Including brush samples, DDG samples and petri dish samples.

6.1.2.1 Coal

Primary sources of coal within the study area include coal trains and three coal export facilities; two located at Kooragang and a third located at Carrington.

Of the brush samples, the highest portion of coal was found to be 20% recorded at both Stockton South and Wickham. Results of 15% (above the brush sample average of 9%) were also recorded at Newcastle, Tighes Hill, Mayfield and Carrington. Samples recorded at Stockton South, Tighes Hill, Mayfield and Carrington were found to have varying fractions of deposited coal with long term samples of 5% or lower also recorded in the area. Samples at Wickham were found to be slightly more consistent with between 10 and 20% coal recorded from samples collected. Only one sample was recorded at Newcastle as such no variability could be observed between samples.

Similar to the brush samples analysed, DDG samples at Wickham (20%) and Newcastle East (15%) were found to have an above average portion of coal. Higher than average coal fractions were also observed at Stockton North (20%) and Hamilton (20%). During the monitoring periods for samples at Stockton North, Newcastle East and Wickham, north-westerly winds were dominant (refer to **Appendix C**). Under these meteorological conditions, upwind sources include both the rail and coal terminals for the Stockton North and Newcastle East sampling locations, while only the rail was upwind of the Wickham location. At Hamilton, winds were more variable from the north to north east indicating the rail line as a possible source of coal dust. Other DDG samples were also found to be downwind of potential sources of coal during the sample periods but were found to contain 10% or less coal.

Higher levels of deposited coal were recorded in similar locations to the brush and Petri samples with 25% observed at Stockton South and 15 to 20% at Stockton North, Tighes Hill and Hamilton. Additionally one sample was taken at Fern Bay which yielded a result of 20% of the dust deposition. Above average coal deposits recorded at Stockton South, Stockton North and Fern Bay are likely attributed to both rail and coal stockpiling at terminals in conjunction with northwest to north north-westerly winds (refer to **Appendix C**). Above average coal deposition samples at Tighes Hill and Hamilton are downwind of the rail line under these meteorological conditions. Deposited coal, while varied, was generally present at Tighes Hill and Stockton South at not less than 5% while not less than 10% at Stockton North under north westerly winds. Only one sample at Hamilton was taken, as such variability at this location could not be determined. All other locations were found to contain 10% or less deposited coal and were generally downwind of some potential sources of coal dust during the sampling period.

6.1.2.2 Soot

Potential sources of soot within the study area are most likely to include local industry primarily located in the suburbs of Mayfield West, Mayfield East, Carrington and Kooragang Island as well as ships in the Port of Newcastle, diesel train locomotives and vehicle exhaust emissions. Industry stack emissions and exhaust emissions from ships were logged as the cause of 18 community complaints lodged with the EPA during the monitoring period and is discussed in **Section 2.3.2**.

Two brush samples taken at Stockton South were found to have the highest fraction of soot (10%) within the long term deposited dust samples. However two additional brush samples taken at Stockton South were found to have soot at 2% or less. All other samples were comprised of equal to or less than 5% soot.

DDG samples collected for identification analysis showed two samples with 10% soot content. These were both recorded at Stockton North. During both periods meteorological conditions were characterised by dominant winds from the northwest. Directly upwind of this location are industrial areas at Kooragang Island, Mayfield East and Mayfield West as well as shipping activities which may have attributed to the elevated soot deposition. All other samples were comprised of equal to or less than 5% soot; and all samples with the exception to those recorded at Wickham and Hamilton were downwind of industrial and shipping sources for part of the monitoring period.

Stockton South was observed to have the highest contribution (20%) of deposited soot within Petri dish samples, consistent with the findings of the two brush samples taken at Stockton South. Higher levels of deposited soot were also observed at Carrington (15%) and Stockton North (10%). These locations experienced northwest to north north-westerly winds during the sampling periods (refer to **Appendix C**) and were downwind of industrial and shipping activities with exception to the sample collected at Carrington which was largely only downwind from industrial sources. Of these locations, percentage contribution of deposited soot was found to vary between samples, with only trace amounts of carbon reported in some samples despite being downwind of industrial and/or shipping activities. All other samples were comprised of equal to or less than 5% soot.

6.1.2.3 Rubber

The most significant source of rubber dust within the LGA is most likely tyre degradation on local roadways. Over time the rubber tread on motor vehicles degrades generating rubber dust. This rubber dust both settles on the road and is blown away from the road by winds and air turbulence generated by passing motor vehicles.

From the brush samples the highest levels of rubber were observed at Hamilton, Stockton South, Wickham and Newcastle East (10%). Results were highly variable at Hamilton, Stockton South and Wickham with observed rubber content recorded as low as 0% or found only in trace amounts in other samples. Only one sample was taken at Newcastle East as such variability amongst samples at this location could not be observed. All other brush samples were comprised of equal to or less than 5% rubber.

All DDG samples were found to comprise of equal to or less than 5% rubber. Within the Petri dish samples the highest level of rubber dust recorded was 20% at Newcastle East, Carrington, Honeysuckle, Mayfield East and Waratah. Higher levels of 10 to 15% rubber dust were also recorded at Tighes Hill, Mayfield West, Newcastle, Broadmeadow and Warabrook. Similar to the brush samples, results were highly variable amongst samples and 69% of all Petri dish samples were found to contain 5% or less rubber dust.

The results did not indicate any trends where higher than average rubber dust concentrations may be occurring. This would be fairly typical given the level of urbanisation in the study area and number or arterial and local roads.

6.1.3 Summary of Findings

In summary, dust deposition was measured at 12 locations across the Newcastle LGA with annual average deposition rates for insoluble solids found to be between 0.5 and 1.1 g/m^2.month for the study period, below the EPA maximum dust deposition criteria of 4 g/m^2.month.

Examination of the dust composition results has shown that deposited dust within the study area was comprised of primarily soil and rock particles, averaging 69% for the study as a whole. Of the total dust deposited, approximately 17% was identified as black particles (coal, soot and rubber), equating to an annual average deposition rate in the order of 0.09 to 0.19 g/m^2.month for black particles alone.

Coal, on average, formed 10% of total deposited dust, equating to 57% of dust identified as black by laboratory analysis. Rubber dust made up 4% of total deposited dust, equating to approximately a quarter (24%) of black particles while soot made up 3% of total deposited dust accounting for approximately a fifth (19%) of black particles.

The highest levels of coal were generally observed in the east of the study area around Stockton and Newcastle East, and closer to the rail line around Wickham, Hamilton and Tighes Hill. Short term samples indicated higher concentrations downwind of the rail line and coal terminals; however the contribution of coal was highly variable with some samples yielding little coal when downwind of potential sources. More data would be required to establish any potential long term trends.

Analysis of both long term and short term soot contributions indicated higher deposition rates around Stockton. Short term sampling indicated a high contribution of soot in deposited dust downwind from the industrial areas of Mayfield, Carrington and Kooragang Island as well as the shipping channels and berths within the harbour though some variability was also present between samples. It is unclear whether industry or shipping activities pose the most significant contribution to deposited soot levels at this location, and further analysis would be required to estimate source contributions.

With regards to the distribution of rubber dust the results did not indicate any significant trends. This would be fairly typical given the level of urbanisation in the study area and number of arterial and local roads.

The project research questions are addressed below:

1) What is the association between proximity to potential sources, such as the rail corridor, and rate of dust deposition?

There was little association between the proximity to potential sources and the rate of dust deposition. The average dust deposition rate for the sampling period was 0.8 g/m^2.month. Of the locations in close proximity to the rail line the averages were:

a. Waratah 0.8 g/m^2.month

b. Islington 1.1 g/m^2.month

c. Tighes Hill 0.9 g/m^2.month

d. Hamilton 0.8 g/m^2.month.

Other potential sources such as industrial facilities in Waratah/Mayfield and coal handling facilities in Tighes Hill were also in proximity to these locations.

Newcastle received the lowest annual deposition rate of 0.5 g/m^2 month. It is noted that there is no industrial rail corridor or industry in this location.

2) What is the level of dust deposition that is representative of specific areas in the Lower Hunter, including the rail corridor?

Dust deposition was measured at 12 locations across the Newcastle LGA with annual average deposition rates for insoluble solids found to be between 0.5 and 1.1 g/m^2 month for the study period. **Table 10** gives the annual averages for each of the specific dust gauge locations.

3) How do measured dust deposition rates compare with international dust deposition criteria and NSW criteria? - What is the composition of deposited dust?

As part of this study dust deposition was measured at 12 locations for a 12 month period. Annual dust deposition rates for insoluble solids ranged between 0.5 and 1.1 g/m^2.month, below the NSW EPA maximum criteria of 4 g/m^2.month. The deposition rates were also below the international criteria listed in **Table 5** of **Section 3.0**. Analysis indicates that the dust is generally comprised of soil and rock particles with smaller fractions of coal, rubber and soot as well as inorganic matter such as insects and vegetation.

4) Is coal dust deposited at residential properties and/or other locations within the study area?

Coal dust was found in the majority of DDG, brush and Petri dish samples collected during this study. Samples were collected from both residential and non-residential areas within the Newcastle LGA. On average, coal accounted for 10% of the dust within samples analysed.

5) What is the composition of the 'black dust' identified at residential properties within the study area?

Noting that for the purpose of this study that 'black dust' was considered to be the total dust observed by residents on surfaces around their properties, the following was found. On average, samples were primarily comprised of soil and rock, accounting for 69% of the composition of samples. Following this, coal was the second largest contributor at 10%, with rubber (4%) and soot (3%) accounting for smaller portions. Particles identified as black by laboratory analysis (coal, soot and rubber) therefore on average accounted for 17% of the total deposited dust analysed.

6) What are the potential attributable sources of deposited dust/black dust?

Potential sources of deposited dust/black dust include natural ground (soil and rock dust). Such areas may include natural earth, beaches, farming operations, construction sites and mining operations. Potential sources of black particles (coal, soot and rubber) are likely to include coal handing operations, industrial activities, shipping and automobile traffic and tyre degradation.

7) Are there geographical or spatial variations in dust deposition/black dust?

While there is some variation between dust deposition annual averages across the 12 DDG monitoring locations selected for this study, it is relatively minimal. The Newcastle site returned the minimum annual average at 0.5 g/m^2.month with Islington recording the maximum of 1.1 g/m^2.month. The other 10 sites recorded annual averages ranging from 0.7 to 0.9 g/m^2.month resulting in overall average deposition rate of 0.8 g/m^2.month for the study area.

Black dust, or more specifically black particles did show some geographical variations. Coal was at times observed in higher concentrations when sampling was performed downwind of coal handling operations. However at other times, samples contained relatively low concentrations under these conditions downwind of coal handling. Generally the percentages of coal found were higher in those areas surrounding the port and coal handing areas.

Soot was also found in higher concentrations around and downwind of the port operations. Sources may include ships, trains and tucks as well as industry located around the port area.

No observable pattern was observed when analysing the distribution across the sample area.

6.2 Recommendations

The findings of the investigation discussed in **Section 6.1** observed some variability between samples, and longer term monitoring may account for variability in meteorology and potential variability in the collection and analytical methods, as well as aid in establishing long term regional trends, particularly with regards to dust deposition. Additionally, further monitoring could be undertaken outside the study area to determine the background levels and composition of deposited dust more widely in the Lower Hunter Region. Short term sampling and analysis is also recommended, with strategic collection of samples upwind and downwind of sources to identify significant contributors.

Although outside of the scope of the LHDDP, further monitoring could be undertaken with the aim of correlating results against regional influences including rail, road and port movements as well as coal handling throughput.

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7.0 Conclusion

After a competitive tender process, AECOM was commissioned by the EPA to undertake a twelve month monitoring program to assess the dust deposition rates and composition as well as to assess the geographical and spatial distribution of deposited dust and its constituents as part of the LHDDP.

Dust sampling was undertaken over the twelve months between October 2014 and October 2015 using dust deposition gauges, brush and Petri dish samples. All DDG samples underwent standard dust deposition analysis, while Petri dish, brush samples and a selection of DDGs samples underwent dust composition identification analysis using stereomicroscopy, SEM and EDS analysis. Results of the study found:

Annual average dust deposition was found to be below the EPA 4g/m2.month maximum dust deposition criterion for all sites, ranging from 0.5 g/m2.month at the Newcastle monitoring location to 1.1g/m2.month at the Islington location.

Results of the composition identification analysis identified:

a. Soil or rock (primarily aluminosilicate) as the primary source of deposited dust averaging 69% of all samples with a range of 40% to 90%;

b. Insect and plant debris accounted for an average of 10% of all samples with a range of 0% to 40%;

c. Coal on average formed 10% of total deposited dust with a range of 0% to 25%;

d. Rubber dust on average made up 4% of total deposited dust with a range of 0% to 20%;

e. Soot accounted for an average of 3% of all samples with a range of 0% to 20%; and

f. The remainder of the deposit dust was largely comprised of halite (salt), fly ash, alumina, paint and miscellaneous fibres.

g. Deposited dust within the study area is comprised of approximately:

   i. 69% soil and rock dust; equating to a deposition rate in in the order of 0.35 to 0.76 g/m^2.month;

   ii. 17% black particles (coal, soot and rubber); equating to a deposition rate in in the order of 0.09 to 0.19 g/m^2.month; and

   iii. 14% other material (including insects and vegetation); equating to a deposition rate ranging from 0.07 to 0.15 g/m^2.month.

The highest levels of coal deposition were generally observed in the east of the study area around Stockton and Newcastle East, and closer to the rail line around Wickham, Hamilton and Tighes Hill, near to the rail line and coal terminals. The contribution of coal however was highly variable with some samples yielding little coal when downwind of potential sources.

Analysis of soot contributions indicated higher deposition rates around Stockton when downwind from the industrial areas of Mayfield, Carrington and Kooragang Island as well as the shipping channels and berths within the harbour though some variability was also present between samples.

The rubber dust results did not indicate any significant trends; and would largely be attributed to tyre degradation along arterial and local roads.

It is recommended that longer term monitoring be undertaken to establish long term regional trends and account for variability in meteorology as well as variability in the collection and analytical methodologies. Additionally, further monitoring could be performed outside the study area to determine the background levels of dust deposition and black particles more widely in the Lower Hunter Region. Short term sampling and analysis is also recommended, with strategic collection of samples upwind and downwind of sources to identify significant contributors of dust deposition.

Although outside of the scope of the LHDDP, further monitoring could be undertaken with the aim of correlating results against regional influences including rail, road and port movements as well as coal handling throughput.

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