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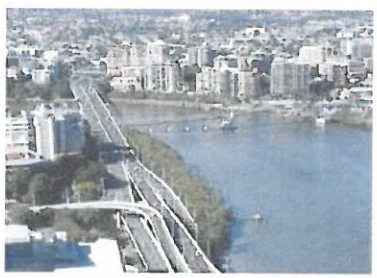
Air Noise Environment
Environmental Monitoring and Assessment

Hazelwood Mine Fire Inquiry -

Statement of Ms Claire Richardson

29 May 2014





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Brisbane Office

A: Unit 3, 4 Tombo Street,

Capalaba, QLD 4157

T: +61 7 3245 7808

E: qld@ane.com.au

Sydney Office

A: Level 6, 69 Reservoir Street

Surry Hills, NSW 2010

T: +61 2 9680 8599

E: nsw@ane.com.au

Townsville Office

A: Level 1, 25 Sturt Street,

Townsville, QLD 4810

T: +61 7 3245 7808

E: qld@ane.com.au

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Declaration

I, Claire Marie Richardson, confirm that

(i) I have received and read copy a of the Supreme Court (General Civil Procedure) Rules 2005 – Form 44A and agree to be bound by the Expert Witness Code of Conduct.

(ii) I understand that an expert witness is not an advocate for a party.

(iii) I have not been given or accepted to adopt or reject any particular opinion in preparing this report.

Furthermore, I, Claire Marie Richardson confirm that:

(i) The factual matters stated in the report are, as far as I know, true and correct;

(ii) I have made all enquiries that I consider desirable and appropriate with respect to the matters considered in this report;

(iii) I genuinely hold the opinions stated in this report; and

(iv) This report contains references to all matters that I consider relevant with respect to the matters considered in this report. Furthermore, there are no matters of significance which I believe to be relevant to matters considered in this report, that have been withheld from the Hazelwood Mine Fire Board of Inquiry.

Signature:

Claire Richardson

Date: 29 May 2014

Table of Contents

	Declaration	4
1	Matters Considered	6
1.1	Request from Hazelwood Mine Inquiry	6
1.2	Qualifications and Experience	7
2	Items 1 and 2 - Standards	8
2.1	Item 1 - Australian Standards	8
2.2	Item 2 - Basis for Air Quality Standards and Possible Impacts	12
3	Items 3 and 4 - $PM_{2.5}$ Standards and Exposure	19
3.1	Item 3 - Effects of Exposure to $PM_{2.5}$	19
3.2	Health Impact of Recorded $PM_{2.5}$ Levels	20
3.3	Gaps in Knowledge	23
4	Items 5 and 6 - Fly Ash	25
4.1	Description of Fly Ash	25
4.2	Characterisation of Ash from Hazelwood Fire	25
4.3	Potential Impacts of Inhalation and Ingestion	26
	Appendix A - Curriculum Vitae of Claire Richardson	27

1 Matters Considered

1.1 Request from Hazelwood Mine Inquiry

1. The Hazelwood Mine Fire Inquiry, on 14 May 2014, requested a written report that addresses the following matters:
    - Item 1: Identify the relevant Australian Standard in relation to ambient air quality for:
        a) carbon monoxide
        b) sulfur dioxide
        c) nitrogen dioxide
        d) fine particles as PM_{10}
        e) fine particles as $PM_{2.5}$
        f) photochemical oxidants
        g) lead
        h) volatile organic compounds including benzene, propene, napthalene and toluene; and
        i) any other substance that adversely affected the air quality in the Latrobe Valley during the fires at the Mine in February and March 2014.
    - Item 2: In relation to the standard applied for each of these substances, explain the scientific basis for the standard, with particular reference to the known effects, both short and long term, of exposure to the substance on human health and wellbeing.
    - Item 3: Outline the current state of knowledge in relation to the short and long term effects on human health and well-being of exposure to fine particulates as $PM_{2.5}$ at the levels recorded between 9 February and 27 March 2014 over that duration. Identify key studies.
    - Item 4: Identify any gap in the scientific understanding of the effects on human health and well being of exposure to fine particulates as $PM_{2.5}$ at the levels recorded between 9 February and 27 March over that duration?
    - Item 5: What is "fly ash"? Is exposure to and ingestion or inhalation of fly ash hazardous to human health.
    - Item 6: Can the ash from the fires at the Mine that fell around Morwell during February and March 2014 be characterised as fly ash? If not, why not?
2. This statement presents my response and opinions with respect to these matters.

1.2 Qualifications and Experience

3. My relevant qualifications and experience are as follows:
    - Bachelor of Science (Hons) from London University.
    - Post Graduate Diploma in Air Pollution Control (awarded by UK Royal Society of Health).
    - Post Graduate Diploma in Acoustics and Noise Control (awarded by UK Institute of Acoustics).
    - Member of the Clean Air Society of Australia and New Zealand since 1996, prior to that a Member of the UK Royal Society of Health and the UK Clean Air Society from 1989.
    - I have practised in the fields of Air Pollution and Acoustics since 1988. During this time I have completed an extensive range of air quality monitoring studies and assessments for a broad range of industries and operations in Australia and Europe. Since 1999 I have directed three research studies investigating particulate emissions from Australian open cut coal mines (PM_{10} and/or $PM_{2.5}$), and have also completed research into the risk of impacts associated with coal rail transport and the benefits of mitigation measures.
    - I am currently the Principal Consultant of Air Noise Environment Pty Ltd, a Company I founded in 1998. Prior to that, I was employed as an Environmental Scientist by ERM (Australia and UK) and Travers Morgan (UK).
4. A copy of my curriculum vitae is presented in Appendix A.
5. My particular expertise in the air quality field relates to air quality monitoring and assessment against air quality criteria. Where this Statement makes reference to the potential health impacts of exposure to air quality and to health based air quality criteria, the commentary is based on review of published studies where epidemiological data has been reviewed, and conclusions drawn, by national and international health experts or teams of health experts.

2 Items 1 and 2 – Standards

- Item 1: Identify the relevant Australian Standard in relation to ambient air quality for:
  a) carbon monoxide
  b) sulfur dioxide
  c) nitrogen dioxide
  d) fine particles as PM_{10}
  e) fine particles as $PM_{2.5}$
  f) photochemical oxidants
  g) lead
  h) volatile organic compounds including benzene, propene, napthalene and toluene; and
  i) any other substance that adversely affected the air quality in the Latrobe Valley during the fires at the Mine in February and March 2014.
- Item 2: In relation to the standard applied for each of these substances, explain the scientific basis for the standard, with particular reference to the known effects, both short and long term, of exposure to the substance on human health and wellbeing.

2.1 Item 1 – Australian Standards

6. Ambient (external) air quality standards in Australia are defined by the Commonwealth and individual States to provide for the protection of the general population. In Victoria, the Commonwealth and State ambient air quality goals are applicable.

7. Table 1a presents the Commonwealth Air Quality Goals for Ambient Air as defined in the National Environmental Protection Measure for Ambient Air Quality (NEPM AAQ)[1]. These are National air quality goals that provide for the adequate protection of human health and well-being. Table 1b presents the NEPM AAQ advisory reporting standard for $PM_{2.5}$. The Advisory Reporting standard was introduced in 2003 to collect additional information on $PM_{2.5}$ before considering a compliance standard, and to give jurisdictions flexibility about the timing and extent of monitoring to complete.

8. Table 1c presents the monitoring investigation thresholds for the NEPM Air Toxics[2]. When the Air Toxics NEPM was made, it was concluded that there were insufficient data to set either compliance standards or advisory reporting standards for the pollutants covered by the NEPM. Monitoring investigation levels protective of human health were developed instead.

9. National occupational air quality standards (for workplaces, internal and external) are also

1 National Environmental Protection (Ambient Air Quality) Measure, 1998 as varied in 2003.

2 National Environmental Protection (Air Toxics) Measure, 2004 as varied 2011.

defined, and these are applicable for the workplaces and the working population. The occupational air quality standards are less stringent than the ambient air quality goals and standards defined for the general population. This is because the intent of the occupational exposure thresholds is to provide for protection based an a working life exposure duration (typically standardised to an 8 hour day, 5 day week over a working lifetime) and individuals that are of working age[3,4].

Table 1a: NEPM Ambient Air Quality - Standards and Goals

Pollutant	Averaging Period	Maximum Concentration	Goal within 10 years Maximum Allowable Exceedances
Carbon Monoxide	8 hours	9.0 ppm	1 day a year
Sulfur Dioxide	1 hour 1 day 1 year	0.20 ppm 0.08 ppm 0.02 ppm	1 day a year 1 day a year none
Nitrogen Dioxide	1 hour 1 year	0.12 ppm 0.03 ppm	1 day a year none
Particulates as PM_{10}	1 day	50 µg/m^3	5 days a year
Photochemical oxidants (as ozone)	1 hour 4 hours	0.10 ppm 0.08 ppm	1 day a year 1 day a year
Lead	1 year	0.50 µg/m^3	none

3 National Exposure Standards. NOHSC:1003 (1995). Exposure Standards for Atmospheric Contaminants in the Occupational Environment.

4 Guidance on the Interpretation of Workplace Exposure Standards for Airborne Contaminants. Safe Work Australia. 2012.

Table 1b: NEPM Ambient Air Quality - $PM_{2.5}$ Advisory Reporting Standard

Pollutant	Averaging Period	Advisory Reporting Standard	Goal
Particulates as $PM_{2.5}$	1 day 1 year	25 µg/m^3 8 µg/m^3	Goal is to gather sufficient data nationally to facilitate a review of the Advisory Reporting Standards as part of the review of this Measure scheduled to commence in 2005

Table 1c: NEPM Air Toxics - Monitoring Investigation Levels

Pollutant	Averaging Period	Monitoring Investigation Levels	Goal
Benzene	Annual average	0.003ppm	8-year goal is to gather sufficient data nationally to facilitate development of a standard.
Toluene	24 hours Annual average	1 ppm 0.1 ppm	8-year goal is to gather sufficient data nationally to facilitate development of a standard.
Benzo(a)pyrene as a marker for Polycyclic Aromatic Hydrocarbons	Annual average	0.3ng/m^3	8-year goal is to gather sufficient data nationally to facilitate development of a standard.
Formaldehyde	24 Hours	0.04 ppm	8-year goal is to gather sufficient data nationally to facilitate development of a standard.
Xylenes (as total of ortho, meta and para isomers)	24 hours Annual average	0.25ppm 0.2 ppm	8-year goal is to gather sufficient data nationally to facilitate development of a standard.

10. The Victorian State Environmental Protection Policy Ambient Air Quality (SEPP AAQ)[5] incorporates the NEPM Ambient Air Quality goals and additional ambient air quality objectives relevant to Victoria. Table 2 presents these air quality goals and objectives. These are the ambient air quality goals that apply throughout the State. Compliance with these air quality

5 State Environmental Protection Policy (Ambient Air Quality), Victorian Government Gazette, 9 February 1999.

goals is measured continuously in accordance with the monitoring requirements defined in the NEPM AAQ. These monitoring requirements include sampling methodologies and the number and location of monitoring stations.

Table 2: VIC SEPP AAQ - Environmental Quality Objectives

Environmental Indicator	Averaging Period	Environmental Quality Objectives	Goal within 10 years maximum allowable exceedances
Carbon Monoxide (maximum concentration)	8 hours	9 ppm	1 day a year
Sulfur Dioxide (maximum concentration)	1 hour 1 day 1 year	0.20 ppm 0.08 ppm 0.02 ppm	1 day a year 1 day a year none
Nitrogen Dioxide (maximum concentration)	1 hour 1 year	0.12 ppm 0.03 ppm	1 day a year none
Particulates as PM_{10} (maximum concentration)	1 day	50 µg/m³	5 days a year
Photochemical oxidants (as ozone) (maximum concentration)	1 hour 4 hours 8 hours 8 hours	0.10 0.08 0.05 0.08	1 day a year 1 day a year 3 days a year none
Lead (maximum concentration)	1 year	0.50 µg/m³	None
Visibility reducing particles (minimum visual distance)	1 hour	20 km	3 days a year

11. In the case of air emissions from coal combustion, the US EPA[6] define the following substances as being of primary significance:
    - particulate matter;
    - sulphur oxides;
    - nitrogen oxides;
    - carbon monoxide;
    - organic compounds including volatile organic compounds (VOC), polynuclear aromatic hydrocarbons (PAH), dioxins and furans (PCDD/PCDF);
    - trace metals.
12. Whilst the Commonwealth and Victorian State air quality goals and criteria consider the key pollutants identified as being released during coal combustion, some of the pollutant emissions are not addressed by the State air quality goals. In such circumstances, reference is made to other reliable and up to date sources of ambient air quality goals developed in other jurisdictions, national or international. This is the case for specific components of the coal combustion emissions that may have occurred during the Hazelwood Mine fire. I understand from the Statement prepared by Dr Paul Torre (VIC EPA Team Leader, Analysis and Predictions) that, in this instance, reference was made to criteria developed by the United States Agency for Toxic Substances and Disease Registry and the US Texas Commission on Environmental Quality based on advice from the Victorian Department of Health.
13. The databases maintained by the United States Agency for Toxic Substances and Disease Registry and the US Texas Commission on Environmental Quality provide guidance on appropriate exposure thresholds for a range of toxic substances. These exposure thresholds are intended to protect the general population from health impacts. The databases were most recently updated in 2013, hence are expected to reflect recent research on the substances for which guidance is provided.

2.2 Item 2 – Basis for Air Quality Standards and Possible Impacts

- Item 2: In relation to the standard applied for each of these substances, explain the scientific basis for the standard, with particular reference to the known effects, both short and long term, of exposure to the substance on human health and wellbeing.

14. The air quality standards and goals adopted in Australia are primarily based on epidemiological research. These studies include investigations that seek to identify the response of individuals to inhalation exposure to specific doses of pollutants, controlled human exposure studies and toxicological studies. The World Health Organisation (WHO)

6 United States Environmental Protection Agency. AP 42 - Volume 1, Chapter 1.7 Lignite Coal Combustion.

defines epidemiology as the study of the causes and distribution of health-related states or events (including disease), and the application of this study to the control of diseases and other health problems.

15. The NEPM AAQ sought to provide protection of the most sensitive groups within the population. The process for development of the 1995 NEPM AAQ included:
    - an independent review to assess the health effects of the six pollutants covered by the NEPM, and to identify adverse health impacts on both the general population and on any susceptible subgroup;
    - an exposure assessment;
    - an examination of the air quality management or control options and their associated costs for achieving the proposed standards;
    - consideration of the benefits, typically in terms of avoided health costs, associated with each of the standards;
    - as a general principle, uncertainty (or safety) factors were not used in developing AAQ NEPM standards, except where there was uncertainty about the existence of a health effects threshold.
16. In developing the NEPM AAQ, the NEPC identified the groups as being particularly susceptible to effects of the criteria air pollutants as follows:
    - older adults;
    - children;
    - asthmatics and people with existing respiratory and cardiovascular disease;
    - diabetics;
    - foetuses;
    - low socio-economic groups; and
    - potentially, people who work or exercise outdoors due to increased exposure.
17. The current basis for developing air quality standards in Australia was documented by the National Environmental Protection and Health Council (NEPHC)[7] in 2011. This methodology was developed with the intent of providing a consistent approach to development of air quality standards and goals in Australia. The methodology also provides guidance with respect to adjusting air quality criteria to allow consideration of different time based exposure scenarios (e.g., short term, longer term, chronic).
18. Development of international and overseas air quality standards generally follows a similar process, however there are some overseas authorities (e.g., the World Health Organisation) that do not specifically account for cost-benefits and socio-economic factors when defining air quality goals and criteria.

7 Methodology for setting air quality standards in Australia Part A, National Environmental Protection Council, February 2011

19. One of the difficulties when completing epidemiological studies is that the effect of exposure to individual pollutants is confounded by the range of pollutants involved. The interaction of complex mixtures of pollutants makes it problematic to determine the specific dose response relationship for an individual pollutant. Furthermore, there is potential for some mixtures of pollutants to have synergistic effects. An example is exposure to elevated concentrations of particulates and sulphur dioxide[8].

20. Research into the effects of inhalation of pollutants is an on-going area of investigation. As new research becomes available, existing air quality goals may be adjusted, and air quality goals for individual pollutants where a national or state based standard did not previously exist, may be adopted.

21. A review of the Commonwealth NEPM AAQ and Air Toxics was completed in 2011[9]. The review included consideration of recent epidemiological data from Australia and overseas. The existing national air quality goals were considered in the context of the latest research, and a total of 23 recommendations were made including:

    - Revise the desired environmental outcome of the NEPM to 'minimise the risk from adverse health impacts from exposure to air pollution for all people wherever they may live'.
    - Revise the standards for all air pollutants in Schedule 1 of the NEPM to take into account new evidence around the health effects of air pollution.
    - Introduce compliance standards for $PM_{2.5}$.
    - Remove allowable exceedances from Schedule 2 and introduce a natural events rule.
    - Initiate research into the composition of particles in Australia and associated health impacts.
    - Monitor and report coarse particle fraction.

22. On 29 April 2014, Ministers signalled their intention to vary the National Environment Protection (Ambient Air Quality) Measure for particles reflecting the latest scientific understanding on health risks arising from particle pollution. The variation seeks to establish a more stringent reporting standard for particulate pollution ($PM_{2.5}$ and PM_{10})[10].

23. The pollutants that are associated with coal combustion processes and are considered to be of relevance for the Hazelwood Mine fire include:

    - particulates;
    - carbon monoxide;

8 Air Quality Guidelines for Europe, World Health Organisation, 1987.

9 National Environmental Protection (Ambient Air Quality) Measure Review, Review Report, prepared for the National Environmental Protection Council, May 2011.

10 Commonwealth of Australia, Government Gazette, 13 May 2014 - Notice of Intention to Vary the National Environmental Protection (Ambient Air Quality) Measure.

- nitrogen dioxide;
- sulphur dioxide;
- dioxin and furans;
- metals (in particular, magnesium, manganese, mercury, zinc)
- polycyclic aromatic hydrocarbons (PAH);
- volatile organic compounds.

24. Based on literature sources, a summary of the potential human health effects of short and long term exposure to these pollutants is presented in Table 3.

Table 3: Potential Health Effects Associates with Exposure to Air Pollutants[11,12,13,14]

Pollutant	Health Effects	Reference
Nitrogen Dioxide	Hospital admissions for respiratory disease; decreases in lung function; cardiovascular disease	NEHPC 2010
Particulates	Mortality due to cardiovascular and respiratory diseases; hospital admissions due to respiratory and cardiovascular disease; decreases in lung function	NEPHC 2010
Carbon Monoxide	Mortality and increased hospital admissions due to heart diseases	NEPHC 2010
Sulphur Dioxide	Adverse effects on the respiratory system and lung functions. Irritation of the eyes. Inflammation of the respiratory tract causes coughing, mucus secretion, aggravation of asthma and chronic bronchitis, and makes people more prone to infections of the respiratory tract. Mortality and hospital admissions for cardiac disease increase on days with higher SO_2 levels	EEA 2013
Metals	Heavy metals do not break down in the environment, and some bioaccumulate, i.e. they gradually accumulate in plants and animals and cannot be excreted by them. This means that plants and animals can be poisoned by heavy metals over a long period of time through long-term exposure to even small amounts of heavy metals. Arsenic exposure is associated with increased risk of skin and lung cancer.	WHO 2007 & EEA 2013

11 Expansion of the Multi-City Mortality and Morbidity Study, Final Report, Environment Protection and Heritage Council, September 2010.

12 Air Quality in Europe - 2013 Report, European Environment Agency, Report No 9/2013.

13 Exposure to Dioxins and Dioxin-like Substances - A Major Public Health Concern, World Health Organisation, 2010.

14 Health risks of heavy metals from long-range transboundary air pollution, World Health Organisation, 2007.

Pollutant	Health Effects	Reference
	Cadmium is associated with kidney and bone damage and has also been identified as a potential human carcinogen, causing lung cancer. Lead exposure has developmental and neuro-behavioural effects on foetuses, infants and children, and can also elevate blood pressure in adults. Mercury is toxic in the elemental and inorganic forms, but the main concern is associated with mercury's organic compounds, especially methyl mercury. Methyl mercury accumulates in the food chain Nickel is a known carcinogen and also has other non-cancerous effects, for example on the endocrine system.	
Volatile Organic Compounds	Benzene is a carcinogenic pollutant. The most significant adverse effect from prolonged exposure is damage to the genetic material of cells. This damage can cause cancer. Chronic exposure can damage bone marrow and cause haematological effects such as decreased red and white blood cell counts.	EEA 2013
PAH	The International Agency for Research on Cancer (IARC) has identified Benzo-a-pyrene as a known carcinogen. While laboratory studies show that BaP is a known carcinogen in animals, epidemiological studies have only been able to assess the effect of a mixture of PAHs (including BaP) found in soot, tars and oils. Prenatal exposure to PAHs has been linked to significantly reduced birth weight in international studies, and it is suggested that pre-natal exposure also adversely affects cognitive development in young children.	WHO 2010
Dioxins and Furans	Short-term exposure to high levels of dioxins and dioxin-like substances in occupational settings or following industrial accidents may cause skin lesions known as chloracne, which is persistent. Longer-term environmental exposure causes a range of toxicity, including immunotoxicity, developmental and	WHO 2010

Pollutant	Health Effects	Reference
	neuro-developmental effects, and effects on thyroid and steroid hormones and reproductive function. The most sensitive life stage is considered to be the fetus or neonate. Guidance values have been based on reproductive and developmental effects. Experimental animal studies indicate carcinogenicity in a range of species with multiple sites of tumours. Epidemiological studies in occupational settings also indicate human carcinogenicity at multiple sites. The International Agency for Research on Cancer (IARC) classified TCDD in Group 1 (carcinogenic to humans) and some other dioxins in Group 3 (not classifiable as to their carcinogenicity to humans).	

3 Items 3 and 4 – $PM_{2.5}$ Standards and Exposure

- Item 3: Outline the current state of knowledge in relation to the short and long term effects on human health and well-being of exposure to fine particulates as $PM_{2.5}$ at the levels recorded between 9 February and 27 March 2014 over that duration. Identify key studies.
- Item 4: Identify any gap in the scientific understanding of the effects on human health and well being of exposure to fine particulates as $PM_{2.5}$ at the levels recorded between 9 February and 27 March over that duration?

3.1 Item 3 – Effects of Exposure to $PM_{2.5}$

25. In 2005 the World Health Organisation released guidelines relating to short and long term exposure to PM_{10} and $PM_{2.5}$. Since that time, research into the potential effects of exposure to $PM_{2.5}$ has increased significantly. There is now an extensive body of published research relating to the relationship between $PM_{2.5}$ exposure and adverse health impacts.
26. Reference to specific peer reviewed papers of relevance is beyond the scope of this statement. However, extensive reviews of relevant literature have been completed by panels of overseas experts and key recent studies include:
    - Air Quality Guidelines, Global Update 2005, World Health Organisation[15].
    - Integrated Science Assessment for Particulate Matter, United States Environmental Protection Authority, 2009[16].
    - REVIHAAP Project, World Health Organisation, 2013[17].
27. Aspects considered in these studies include the health risks associated with varying exposure periods, particulates from different sources, chemical characteristics of particulates and particle size and morphology.
28. The REVIHAAP project is a key recent study that provides detailed consideration of the issues associated with exposure to particulates. Based on consideration of a large body of new studies, the REVIHAAP project concludes that the current state of scientific knowledge, supported by an extensive body of literature, shows a wide range of adverse effects on health associated with exposure to $PM_{2.5}$ and PM_{10}. The data strongly suggest that these effects have no threshold within the ambient range studied; follow a mostly linear concentration-response function; and are likely to occur at fairly low levels, close to $PM_{2.5}$ background concentrations.

15 Air Quality Guidelines - Global Health Update 2005, Particulate Matter, Ozone, Nitrogen Dioxide and sulfur dioxide. World Health Organisation 2006

16 Integrated Science Assessment for Particulate Matter . United States Environmental Protection Agency, EPA/600/R-08/139F, December 2009

17 Review of evidence on health aspects of air pollution - REVIHAAP Project, World Health Organisation, 2013.

With respect to particulates, one of the conclusions of the REVIHAPP project is that there is a need to revise the current WHO air quality guidelines for PM_{10} (20 µg/m^3, annual average; and 50 µg/m^3, 24-hour average, 99th percentile) and $PM_{2.5}$ (10 µg/m^3, annual average; and 25 µg/m^3, 24-hour average, 99th percentile).

3.2 Health Impact of Recorded $PM_{2.5}$ Levels

29. $PM_{2.5}$ concentrations were recorded at Morwell East and Morwell South during the Hazelwood mine fire. The maximum concentrations were recorded at Morwell South. This is the monitoring position located on the southern outskirts of Morwell closest to the fire. Monitoring commenced at the Morwell East monitoring station on 13th February and Morwell South in the morning of 20th February 2014. The VIC EPA Traralgon monitoring station was in continuous operation throughout the mine fire, and of particular relevance are the PM_{10} data from this station.

30. Based on the results of the VIC EPA monitoring, the maximum 24 hour rolling average $PM_{2.5}$ concentration recorded at the Morwell South monitoring station was 501 µg/m^3 on 22nd February. The average measured $PM_{2.5}$ concentration at the Morwell South monitoring station over the period 20th February to 25th March was 68 µg/m^3.

31. The levels recorded at the Morwell South monitoring station are considered representative of the maximum $PM_{2.5}$ concentrations that are likely to have affected the populated areas of Morwell during the period for which the monitoring data is available. Higher concentrations could have affected individual properties located between the monitoring station and Hazelwood Mine. Some preliminary monitoring was completed at Morwell South using nephelometry techniques during the period 13th February to 19th February. As this monitoring technique only provides an estimate of $PM_{2.5}$ concentrations, these ~~date~~ data are considered to be indicative only.

32. Significantly lower maximum $PM_{2.5}$ concentrations were measured at the Morwell East monitoring location, with a maximum 24 hour rolling average concentration of 92 µg/m^3 on 23rd February and an overall average concentration of 21 µg/m^3 over the period 13th February to 25th March 2014.

33. The question of whether initial $PM_{2.5}$ concentrations during the period 9th February to 13th February could have been higher than the data recorded at the Morwell South or Morwell East monitoring stations is pertinent. The potential for this can be considered in the context of the available monitoring data.

34. The location of the Traralgon monitoring station relative to the two monitoring stations at Morwell that were in operation during the Hazelwood Mine fire is shown on Figure 1. During worst case wind conditions, south-westerlies, Traralgon monitoring station is downwind of Morwell and the two monitoring stations located in the town.

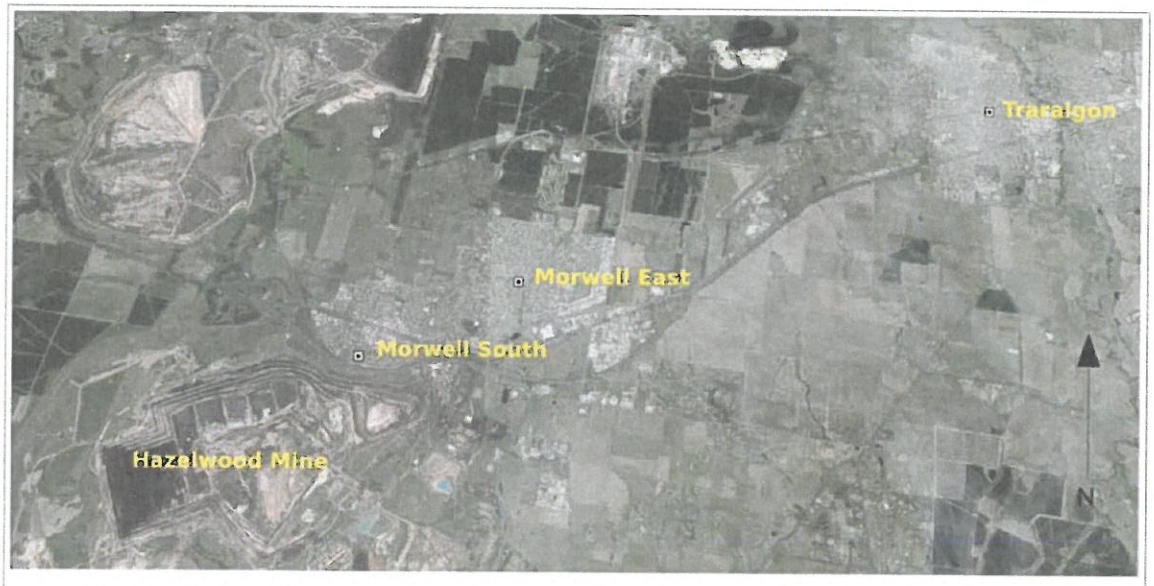

Figure 1: Location of EPA Monitoring Stations

35. The potential significance of the $PM_{2.5}$ concentrations occurring in Morwell during the period can be considered by review of the PM_{10} monitoring data from Traralgon. Figure 2 shows a graph of the PM_{10} from Traralgon and $PM_{2.5}$ from Morwell South and East.

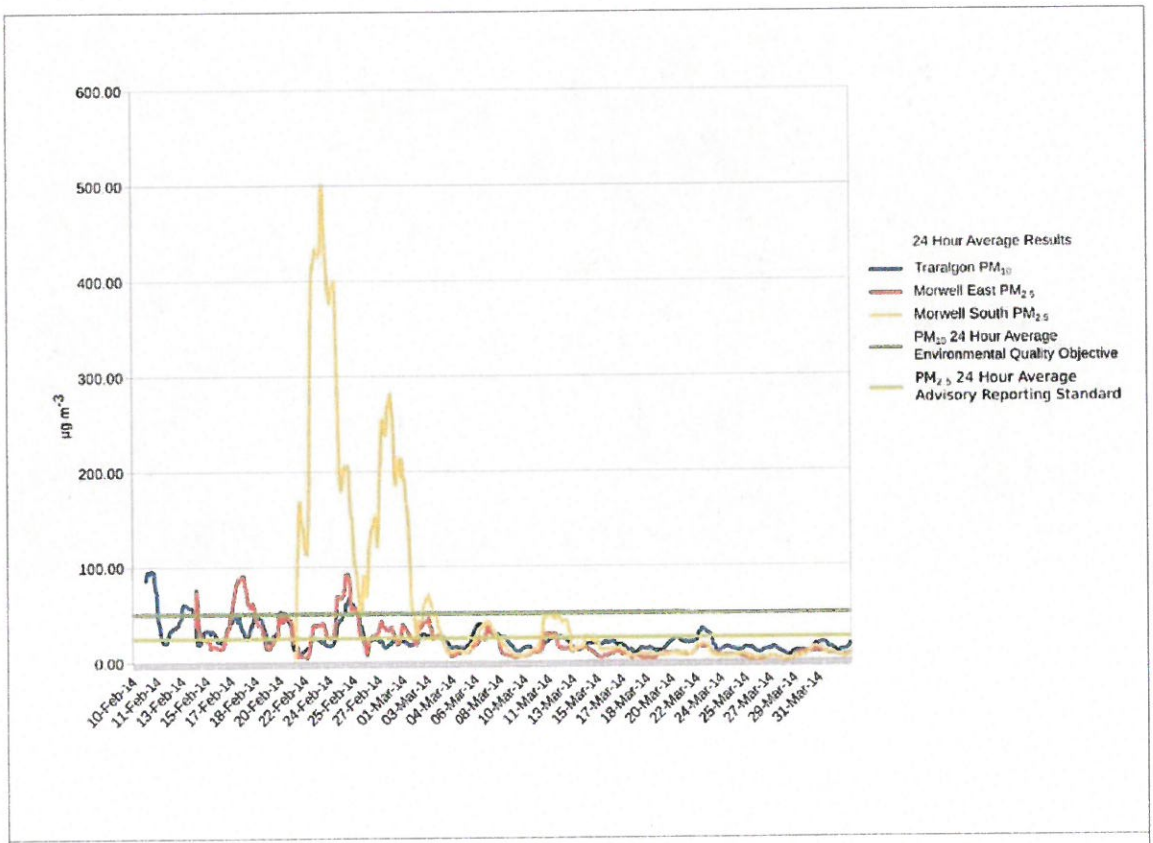

Figure 2 – Comparison of PM_{10} and $PM_{2.5}$ Data Trends (24 hour rolling averages)

36. The $PM_{2.5}$ concentrations at Morwell East and South tend to peak at similar times to the PM_{10} concentrations at Traralgon. This suggests a correlation between the concentrations experienced at Morwell and Traralgon. The data in Figure 2 confirm that the highest PM_{10} concentrations measured at Traralgon during the fire were on the 9th February. Therefore, it is likely that higher concentrations would have been recorded at Morwell East and South on 9th February than later in the fire, had monitoring been in place at the time. It is possible that the magnitude of the particulate concentrations at Morwell South prior to the installation of the fixed monitoring station could be estimated based on the relationships with data from the other monitoring stations and other available data sources.

37. Turning to the question of the potential health impacts of exposure to these concentrations, elevated particulate concentrations (usually measured as TSP or PM_{10}) over extended time periods are regularly experienced in developing countries[18], and can also occur in more developed countries from time to time (e.g., Harbin, China 2013 and London, April 2014). The

18 Health Effects of Outdoor Air Pollution in Developing Countries of Asia: A Literature Review, Health Effects Institute, Special Report 15, April 2004.

literature relating to elevated particulate exposures and the relevance of the available studies in terms of potential health impacts for the Hazelwood Mine fire is a matter for detailed consideration by the health experts advising the Commission of Inquiry. Based on my understanding of the health based criteria and standards adopted in Australia, it is clear that the concentrations of $PM_{2.5}$ experienced in the Latrobe Valley during the Hazelwood Mine fire could have resulted in short-term health impacts. This could have affected both those most at risk of health impacts, as well as normally healthy individuals.

3.3 Gaps in Knowledge

- Item 4: Identify any gap in the scientific understanding of the effects on human health and well being of exposure to fine particulates as $PM_{2.5}$ at the levels recorded between 9 February and 27 March over that duration?

38. With respect to the gaps in scientific understanding relating to $PM_{2.5}$ exposure, these issues have been documented both by Australian and overseas experts. Common themes in terms of gaps in scientific knowledge, and areas where further research is considered necessary, include investigation of:

    - Health effects resulting from different particulate size fractions, including ultra-fine particulates.
    - Health effects resulting from the different chemical composition of particulate matter.
    - Relationship between particulate matter and specific health outcomes, including asthma.
    - Toxic mechanisms that trigger biological processes in response to inhalation of particulate matter.
    - Susceptible populations that are at greater risk of exposure to particulate matter.

39. In Australia, the NEPM AAQ Review[19] provided recommendations for future research and research relating to emerging issues, to inform scientific knowledge relating to air pollution. The recommendations relating to research and emerging emissions are as follows:

    - Recommendation 20 – Evaluate the options to assess ozone and secondary particle precursors.
    - Recommendation 21 – Initiate research into the composition of particles in Australia and associated health impacts.
    - Recommendation 22 – Initiate health research on the impact (in particular, particles) in regional areas.
    - Recommendation 23 – Monitor and report coarse particle fraction ($PM_{2.5-10}$).

19 National Environmental Protection (Ambient Air Quality) Measure Review, Review Report, prepared for the National Environmental Protection Council, May 2011.

40. Based on my review of the information and data relating to the Hazelwood Mine fire, further gaps in scientific knowledge that are pertinent to the specific circumstances associated with this incident include:

    - The potential community health impacts associated with the $PM_{2.5}$ exposure periods that occurred. The majority of published studies consider health impacts in terms of short term exposure (24 hours) and long term exposure (a year). In the case of the Hazelwood Fire, the community was exposed to particulate concentrations that were elevated above normal background concentrations for periods of weeks, interspersed with periods of exposure to acute concentrations many times higher than the 24 hour exposure during unfavourable meteorological conditions.
    - The appropriate $PM_{2.5}$ exposure thresholds for integration into a community response and alert framework, in circumstances where elevated pollution concentrations occur over extended periods of time.
    - Whether there is a significant difference in the air emissions profile from a coal fire that is being quenched by fire water, when compared to more typical mine coal fires arising as a result of spontaneous combustion and to normal emissions from combustion processes in the Latrobe Valley.
    - The air exchange rate of the housing stock in Morwell, and how this influenced internal concentrations of pollutants when members of the community were advised to remain indoors.

4 Items 5 and 6 – Fly Ash

- Item 5: What is "fly ash"? Is exposure to and ingestion or inhalation of fly ash hazardous to human health?
- Item 6: Can the ash from the fires at the Mine that fell around Morwell during February and March 2014 be characterised as fly ash? If not, why not?

4.1 Description of Fly Ash

41. Ash is the residual material from combustion processes. Bottom ash is the term used to describe the coarser residual that remains in the grate or combustion chamber once combustion has ceased. Fly ash is the term used to describe finer material that is entrained in the combustion emission gas stream. The finer ash material is subsequently captured when the exhaust gas stream passes through the pollution control system. Depending on the efficiency of capture of this material in the pollution control system, a small fraction of the fly ash is released to atmosphere following venting of the flue gases via a stack.

42. Fly ash is characterised by the non-flammable mineral elements contained in the raw fuel. The final composition and the particle size distribution of the fly ash depends on a range of factors. These include the coal type, the temperature of combustion, availability of oxygen, the type of combustion process and whether the coal is pre-treated prior to combustion (e.g., pulverised coal)[20].

4.2 Characterisation of Ash from Hazelwood Fire

43. A relevant issue with respect to the Hazelwood coal mine fire is whether the smoke and particulate matter can be characterised as fly ash.

44. Based on the available data, there are a range of factors that would result in the smoke and particulate material from the Hazelwood coal mine differing from fly ash including:

    - additional sources of smoke and particulates from biomass burning (bush fires) that were occurring at the same time as the Hazelwood coal mine fire;
    - coal combustion in the open air as opposed to within a controlled environment such as a combustion chamber;
    - the temperature of combustion, and the variation in temperature of combustion spatially and temporally as the fire progressed;
    - the use of water and fire fighting foam to quench the fire. This would have changed the combustion characteristics and provided an additional source of chemical constituents (e.g., from the additives used in fire fighting foam).

20 Size Distribution and Trace Elements Contents of Coal Fly Ash from Pulverized Boilers Katarzyna Juda-Rezler, Dominik Kowalczyk. Pol. J. Environ. Stud. Vol. 22, No. 1 (2013), 25-40.

45. The composition of ash samples collected and analysed by the Victorian Environment Protection Authority (VIC EPA) has been reviewed. A particular difference that has been identified is the particle size distribution and carbon content. The power station fly ash has a significantly larger fraction of $PM_{2.5}$ and a significantly lower proportion of carbonaceous material than the ash samples collected from areas affected by the Hazelwood Coal Mine Fire.

46. Overall, based on consideration of the combustion conditions and the available analytical data, it appears that ash from the Hazelwood Coal Fire is likely to differ from fly ash for some key characteristics.

4.3 Potential Impacts of Inhalation and Ingestion

47. The potential for human health impacts of ingestion of fly ash is not within my area of expertise, hence I am not able to provide detailed comment on this issue. However, I understand that a health risk analysis of exposure to environmental pollutants during and subsequent to the Hazelwood fire would include consideration of ingestion as a potential exposure pathway, along with inhalation and dermal exposure.

48. The inhalation of fly ash at concentrations above air quality guidelines has the potential to cause human health impacts. In common with particulate matter in general, the potential for human health impacts of inhalation of fly ash relate are primarily related to:

    - the overall concentration of particulate matter inhaled;
    - the particle size distribution; and
    - the chemical composition of the particulate matter.

49. The analysis results of the ash collected by the EPA confirms that a range of metals and organic compounds were present. When breathed in, and the exposure concentration exceeds health guidelines for the particulate matter and any compounds it contains, then there is potential for human health impacts. The VIC EPA has completed sampling and analysis of a range of inorganic and organic atmospheric pollutants that were present during the Hazelwood Mine coal fire. These analyses have included metals, VOC's, PAH's and dioxins. These data are available to inform detailed health risk analyses of the community health outcomes associated with the Hazelwood Mine fire.

Appendix A – Curriculum Vitae of Claire Richardson

Air Noise Environment Pty Ltd

Curriculum Vitae

Claire Richardson

Title	Managing Director and Principal Consultant
Academic Background	Bachelor of Science (Hons), University of London, 1987 Post Graduate Diploma in Air Pollution Control, 1989 Post Graduate Diploma in Acoustics and Noise Control, 1990 Certificate of Competence in Workplace Noise Assessment, 1994 Company Directors Diploma, 2010
Professional Affiliations	Member of the Clean Air Society of Australia and New Zealand Member of the Australian Acoustical Society
General Description of Experience	An Environmental Scientist with key expertise in the fields of air quality and acoustics, Claire has been involved in technical assessments, auditing, environmental monitoring, environmental modelling and policy studies throughout her career both in Australia and overseas. Claire is regularly called upon to provide Expert Advice and Expert Evidence with respect to Planning and Environment Court related matters, and has completed a number of research projects on behalf of industry and government.
Gas and Particulates Research, Measurement and Prediction	▪ Research project to determine emission rates of $PM_{2.5}$ particulates from emission sources at open cut coal mines. ▪ Investigation of the risk of impacts associated with particulate emissions during coal transport by rail, including analysis of the potential health impacts and the benefits of control solutions such as veneering. ▪ Fine particulate research project on behalf of the Australian Coal Industry (ACARP) assessing emissions and fate of particulates from open cut coal mining. ▪ NPI particulate emission factor validation research projects for open cut mines to refine and improve emission datasets for open cut mining activities. The studies included assessment of watering as a control mechanism. ▪ Particulate investigation study at Mt Coo-tha Quarry over a 12 month period. This project including auditing emission sources at the quarry, completing particulate measurements in the quarry and surrounding community for 12 months, and investigating and recommending control solutions. ▪ Occupational exposure sampling at Darwin International Airport. ▪ Suspended and deposited particulate monitoring and investigation, including chemical analysis of composition of particulates at a metal recycling facility, identification of control solutions, auditing compliance, community liaison. ▪ Ambient particulate sampling during the construction of Beenleigh Road, Beenleigh over a twelve month period. ▪ Continuous monitoring of nitrogen oxides and carbon monoxide within warehouse structure during fitout of a major retailing distribution centre in Brisbane for a 9 month period.

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- Measurement and assessment of ambient particulate deposition rates for Newcrest mining.
- Suspended particulate and aerosol sampling and analysis for mass, PAHs and dioxin content for a proposed incinerator site.
- Analysis and assessment of particulate emissions from a proposed quarry for a P&E Appeal in North Queensland.
- Suspended and deposited particulate measurement for an existing concrete batching plant operation to determine appropriate control strategies for a proposed new plant on the Sunshine Coast.
- Measurement and prediction of dust emissions from a range of extractive and construction sources both in Australia and overseas, including projects for British Coal, Blue Circle, ARC, MIM, BHP, Newcrest Mining and others.
- Nitrogen oxide monitoring at a proposed residential development site adjacent to the Gateway Motorway for a 2 month period to determine existing exposure levels.
- Occupational monitoring for a range of compounds using real time and static sampling methodologies.

Air Quality Modelling:

- Air Quality assessment for proposed power generation plant for CSG operations, on behalf of QGC.
- Project Director for air quality assessment for CSG operations near Dalby.
- Airport Link and Northern Busway Project, Brisbane. Air quality modelling and assessment of the potential impacts of the final project design on behalf of the PBAJV/TJH. Supply and installation of particulate sampling network for the construction phase including completion of staff training.
- Clem 7, Brisbane: EIS phase, peer review of the air quality modelling, liaison role with the community consultation and air quality steering group.
- Waterview Connection, Auckland. Project director and technical review for the air quality modelling completed for a range of project options for this project.
- Eastlink Motorway, Melbourne. Project Director and in-house technical review of the mathematical modelling of the final detailed design for the tunnel and surface roads for this major project.
- Victoria Park Tunnel, Auckland – Peer review of the air quality assessment completed by Holmes Air Sciences.
- Cross City Tunnel, Sydney (Downer Engineering). Mathematical modelling of emissions from the stack, community consultation and input to the selection of compliance monitoring stations.
- Quay Street Underpass, Auckland. Air dispersion modelling of emissions from the portals of this extended underpass in Auckland City.
- M5 Motorway Tunnel, Sydney (Hyder Consulting). Modelling and assessment of the potential for air quality impacts as a result of atmospheric emissions from the tunnel portals and stack.
- Mathematical modelling of urban renewal areas in inner suburbs of Brisbane. These complex projects include auditing and emission inventories of remnant

3/4 Tombo Street • Capalaba • QLD 4157
Phone: 07 3245 7808 • Fax 07 3245 7809 • Email claire.richardson@ane.com.au

industry in areas earmarked for residential development, followed by detailed computational modelling using Ausplume and Calpuff.

- Industrial point source emission modelling including power stations, hazardous waste incinerators, manufacturing industry through to fugitive sources such as mines and ponds.
- Road traffic air quality modelling using Caline4 and CAL3QHC for a range of projects.

Expert Witness:

- P&E Appeal 3354/10 & 3764/2010 – particulate emissions from proposed expansion of an open cut sand and gravel extraction operation and associated processing facility.
- Land Court matter – particulate emissions from expansion of a proposed open cut coal mine (2014)
- P&E Appeal 3370/2012 – Odour and noise impacts from a proposed abattoir expansion.
- P&E Appeal 19/2012 – Odour and noise impacts associated with a proposed poultry breeder rearer farm.
- P&E Appeal 700/2012 – Odour impacts from a proposed major poultry farming development located in the Southern Downs Regional Council area.
- P&E Appeal 5172/2011 & 5174/2011 – The impact of existing industrial emissions on a proposed major housing development.
- P&E Appeal 5192/2011 – Air quality and noise emissions from a proposed poultry litter fired power station in Redland City.
- P&E Appeal 3587/2010 & 411/2011 – Noise and dust impacts from an existing scrap metal yard operation seeking a material change of use to formalise existing operations.
- P&E Appeal 510/2010 – Air and noise impacts from existing sandstone rock quarry on proposed subdivision, Warwick.
- P&E Appeal 129/2009 – Air quality impacts from existing industrial estate on proposed new high rise retirement development on the Gold Coast.
- P&E Appeal 12/2009 – Reverse amenity impacts from an existing abattoir with respect to a proposed small lot residential subdivision.
- P&E Appeal 2186/2009: Expert advice regarding noise impacts from a proposed vehicle workshop at an existing car salesyard, on behalf of Brisbane City Council.
- P&E Appeal 3664/2007: Expert advice with respect to odours, noise and dust relating to a proposed cattle saleyard at Roma (on behalf of co-respondents, instructed by King & Co).
- P & E Appeal BD940/2007 – Poultry Farm at Tramway Road, Tabooba – Odour and noise issues, on behalf of Gary Pemberton (Co-respondent), instructed by Clayton Utz.
- P & E Appeal 2526/2005 – Proposed childcare centre at Delathin Road – Air quality and noise issues on behalf of Brisbane City Council.

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- P & E Appeal 2801/2004 – Proposed childcare centre at Maundrell Terrace – Air quality and noise issues on behalf of Brisbane City Council.
- P & E Appeal 2260/2004 – Proposed childcare centre at Lucy St, Albion – Air quality and noise issues on behalf of Brisbane City Council.
- NSW P & E Court matter 10729/2004 Proposed cherry fumigation operation at Griffith – Air quality issues, Court Appointed Expert.
- P & E Appeal 4703/2005 – Proposed Poultry Farm at Coominya, Odour, noise and dust issues, on behalf of Esk Shire Council.
- Proposed residential development at Holland Park, P & E Appeal, Odour issues (on behalf of Australian Property Developments).
- Proposed concrete batching plant at Cooloola, P & E Appeal, dust issues (on behalf of Readymix Holdings, Appellant).
- Proposed concrete batching plant at Kawana, P & E Appeal noise and dust issues (on behalf of Readymix Holdings).

Papers and Publications:

- *Development of $PM_{2.5}$ Emission Factors for the Open Cut Coal Industry*, Claire Richardson, Clean Air Society of Australia and New Zealand, National Clean Air Conference, September 2013.
- *The Historical and Current Challenge of Environmental Nuisance*, Claire Richardson, Environmental Institute of Australia and New Zealand, National Conference, October 2012.
- *The Clem7 Motorway Tunnel: Mechanical and Electrical Plant Acoustic Design and Performance*, Claire Richardson and Beau Weyers, Proceedings of Acoustics 2011, November 2011.
- *Environmental Monitoring – Science or Black Art?* Claire Richardson, Queensland Environment Law Society Annual Conference 2011.
- *Environmentally Friendly Surface Coatings – Friend or Foe?* Claire Richardson and Craig Beyers, Clean Air Conference 2007.
- *Noise and Air Quality Policy – Issues and Risks for the Industry, Claire Richardson, presented at the Cement, Concrete and Aggregate Australia Conference 2005*
- *Particulate Emission Estimation Techniques – Field Validation for Area Sources*, Claire Richardson, Craig Beyers and Ramses Zietek, Clean Air Conference 2002
- *The Brisbane River Management Plan*, Claire Richardson, Proceedings of Acoustics 1998.
- *A Comprehensive Noise Management Strategy for the an Urbanised River Catchment*, A L Brown & C M Richardson, Journal of Environmental Planning and Management, 41(3), 299-312, 1998.
- *Pop Concert Noise Control – A UK Perspective*, Claire Richardson, Proceedings of Acoustics 1995.
- *Bio-Technology for Odour Control*, Claire Richardson, Institute of Water and Waste Management (UK), 1991.

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