IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of an application for resource consent by Fulton Hogan to establish Roydon Quarry

STATEMENT OF LOUISE FLEUR WICKHAM (AIR QUALITY)

CALLED BY CANTERBURY DISTRICT HEALTH BOARD

17 October 2019

EXECUTIVE SUMMARY

1. This statement addresses the potential health impacts of discharges to air from the proposed Roydon quarry. The key contaminants to be discharged to air are from the proposed activity are:

   (i) Particulate matter less than 10 micrometres in diameter (**PM_{10}**); and

   (ii) Respirable crystalline silica (**RCS**) measured in the respirable fraction, which is particulate less than 4 micrometres in diameter (**PM_4**).

2. I am sensitive to the widespread concern in the community over potential discharges to air from the proposed activity. It is therefore important to note up front that I agree with Mr Cudmore that discharges of PM_{10} and RCS from the proposed quarry are unlikely to present significant adverse health issues at distances greater than 700 metres (i.e. within the Templeton township). This is because, at these distances, even worst-case industrial residual air emissions (**IRAEs**) would be significantly diluted.

3. It is also important to note that the application has been significantly improved with respect to best practice emissions control and overall design, compared with that assessed in 2018. I concur with the statement of Mr Cudmore that the proposed controls are representative of best practice and will significantly mitigate the potential impacts of discharges to air.

4. However, I do not agree that the proposal is not likely to trigger the "significance threshold" in Regulation 17 of the *Resource Management (National Environmental Standards for Air Quality) Regulations 2004* (**NES-AQ**). Specifically, I consider the proposal is likely to result in concentrations greater than 5% of the NES for PM_{10} (2.5 µg/m^3 as a 24-hour average) in the adjacent polluted Christchurch airshed. Regulation 17 prohibits granting of consent for significant new discharges of PM_{10} in a polluted airshed unless the new discharges are offset (i.e. by taking out PM_{10} elsewhere because the airshed is already overallocated).

5. It is also relevant to note that the existing, background levels of PM_{10} in the Canterbury rural environment are relatively high (maximum 45 µg/m^3) compared with the NES for PM_{10} (50 µg/m^3 as a 24-hour average). This leaves little 'room' for new discharges in the rural environment – irrespective of the adjacent polluted Christchurch airshed. It also means that the "significance threshold" of 5% of the NES for PM_{10} in Regulation 17 has merit for this application.

6. Unfortunately, I consider the applicant's approach for assessing air quality, specifically PM_{10}, is inadequate and inaccurate;

   (i) Inadequate - quantification and dispersion modelling of discharges to air is routinely carried out in Australia and New Zealand for industry with significant discharges to air. In Australia discharges to air from mines and quarries are routinely modelled. This has not been the case to date in New Zealand but, until now, no quarry has been proposed adjacent to a polluted airshed. Mr Cudmore has stated that reliable emissions factors are not valid for New Zealand.[1] I note there are now sufficient monitoring data available to enable calibration of dispersion modelling of existing sources to validate these emissions factors.

   (ii) Inaccurate – the applicant's air quality assessment excluded significant amounts of data from the Yaldhurst Qir Quality Monitoring Study. The applicant's assumptions regarding wind directions further significantly underestimate potential downwind impacts. The assumption of a 10-fold reduction in impact from the existing Yaldhurst quarries is not based in science and unverifiable. This has led to inaccuracies in the overall assessment.

7. In my view, even with the good design and best practice mitigation proposed, it is reasonable to anticipate significant increases (i.e. > 5% of the NES for PM_{10}) within a few hundred (200 – 300) metres of the boundary of the

[1] Statement of Mr Roger Cudmore on behalf of Fulton Hogan dated 23 September 2019. At [88]

proposed quarry. Whilst maximum increases would likely be limited to adverse meteorology (dry, windy weather), non-permanent sources (e.g. bund construction) and IRAEs, the sheer size and scale of the proposed activity means that ongoing, significant increases in daily PM_{10} will be likely in some locations. Should consent be granted, I have recommended additional mitigation and monitoring as conditions of consent to assist with overall compliance and to improve the public's level of trust.

8. In the absence of a quantified assessment, I have recommended a default 500 metre buffer distance between the mobile crushing plant and sensitive receptors. This is primarily to address IRAEs. I have also provided comment on the application of separation distances in the Canterbury context.

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1.0 INTRODUCTION

9. My full name is Louise Fleur Wickham. I am a Director and Senior Air Quality Specialist at Emission Impossible Ltd. I joined Emission Impossible Ltd in April 2011 and became a Director in July 2016.

10. I am subcontracted by the Institute of Environmental Science and Research (**ESR**) to provide independent air quality advice to the Ministry of Health and Public Health Services. Canterbury District Health Board (**CDHB**), in turn, have engaged me through ESR to provide independent air quality advice on the proposed Roydon Quarry.

1.1 Qualifications and Experience

11. I hold the academic qualifications of Bachelor of Chemical and Materials Engineering from the University of Auckland and a Master of Environmental Law from the University of Sydney. I am a certified Resource Management Act decision maker and am in my second term of appointment to Auckland Council's panel of independent commissioners. I am a member of the Resource Management Law Association and the Clean Air Society of Australia and New Zealand.

12. I have over 25 years' experience in air quality gained in New Zealand, Australia and the United Kingdom in both the private and public sectors. From 2004 to 2011, I was the Ministry for the Environment's senior adviser on air quality. During this time, I was the Ministry's technical lead on air quality matters and played a key role in the introduction, implementation and review of the *Resource Management (National Environmental Standards for Air Quality) Regulations 2004*. I represented the Ministry for the Environment in a number of domestic and international air quality and technical forums.[2] I have also

[2] For example: Environment Protection and Heritage Council (of Australia & New Zealand) Air Quality Working Group, Standards Australia/Standards New Zealand technical committee for wood burners (CS-62; 2004 - 2011), Expert Group on Best Available Techniques /Best Environmental Practices for Stockholm Convention (2006 and 2007), New Zealand National Air Quality Working Group.

chaired and represented the Ministry in a number of national and Australasian research forums relating to air quality.[3]

13. Since 2011, I have provided technical air quality advice to both government and private clients and published articles on air quality issues.[4] I have also continued to author, and co-author, a number of national good practice air quality guidance documents.[5]

14. I am an accredited decision maker under the Resource Management Act 1991 and have acted as a commissioner for Auckland Council and Hawke's Bay Regional Council. These consent decisions were primarily on applications for resource consents with discharges to air, including Brookby Quarry in Auckland. I have also provided expert evidence for the Public and Population Health Unit of Northland District Health Board on, *inter alia*, the use of separation distances (buffers) in the proposed Regional Plan for Northland, a quarry application for land use consent and two appeals of the Whangarei District Plan relating to quarries and air quality.

15. I have visited many quarries over the years, most recently the Winstones and Road Metals quarries in Yaldhurst, Canterbury (2017/2018 – more on this below), the Winstones quarry in Otaika, Northland (2017) and the Brookby Quarry in Auckland (2016).

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[3] For example: (Chair, New Zealand) National Environmental Standards Research Advisory Group, (NZ representative) *Multicity Mortality and Morbidity Study* Research Advisory Group.

[4] For example:

Wickham L., (2017). New Zealand air quality case law review: what stinks and why. *Resource Management Journal*. April.

[5] For example:

Ministry for the Environment (MfE), (2016). *Good Practice Guide for Assessing Discharges to Air from Industry*. (Co-author). Wellington. November.

MfE, (2016b). *Good Practice Guide for Assessing and Managing Odour*. (Lead author). Wellington. November.

MfE, (2016c). *Good Practice Guide for Assessing and Managing Dust*. (Co-author). Wellington. November.

MfE, (2005). *Updated Users Guide to Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins and Other Toxics) Regulations 2004 (Including Amendments 2005) (second draft)*. Wellington. October.

16. Between November 2017 and April 2018, I was engaged as a subcontractor to Mote who, in turn were engaged by Environment Canterbury, to undertake an ambient air quality monitoring study in and around multiple quarries in Yaldhurst. I provided advice on the design of the Yaldhurst Air Quality Monitoring Study, hereafter referred to as the **Yaldhurst Study** (EIL and Mote, 2018)[6], assisted with liaison regarding monitoring locations, and provided peer review of subsequent air quality monitoring reports (Mote, 2018).[7]

17. In addition to this, in 2018 I provided independent air quality advice to the Yaldhurst Environment Association (a community group) for an appeal of consent granted to Road Metals Company Ltd to expand their quarry located at 394 West Coast Road, Yaldhurst. This appeal was successfully settled following mediation.

18. Further (brief) details of my qualifications and relevant experience are contained in **Attachment A**. A full CV is available upon request.

1.2 Code of Conduct

19. I confirm that I have read the Expert Witness Code of Conduct set out in the Environment Court's Practice Note 2014. I have complied with the Code of Conduct in preparing this submission, and I agree to comply with it while appearing before the Hearing Panel. Except where I state that I am relying on the statements of another person, this statement is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed in this submission.

20. I further confirm that I have read the Code of Ethics and Professional Conduct for members of the Clean Air Society of Australia and New Zealand. This requires me inter alia to remain objective and truthful in all statements or

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[6] Emission Impossible Ltd and Mote, (2018). *Yaldhurst Air Quality Monitoring Programme Design Recommendations*. Prepared for Environment Canterbury. Auckland. 12 January.

[7] Mote, (2018). *Yaldhurst Air Quality Monitoring Summary Report: 22 December 2017 – 21 April 2018*. Prepared for Environment Canterbury. Auckland. 19 June. Available at: www.ecan.govt.nz A total of four monthly monitoring reports were also prepared in addition to this summary report.

testimony and to uphold the safety and health of the community above private or business interests in the performance of my professional duties. I have complied with the Code of Ethics in preparing this submission, and I agree to comply with it while appearing before the Hearing Panel.

1.3 Reference Documents

21. In preparing this statement I reviewed the following documents:

(i) Golders, (2018).[8] Resource Consent Application to Establish 'Roydon Quarry', Templeton. Prepared by Golder Associates (NZ) Ltd for Fulton Hogan Ltd and submission to Environment Canterbury and Selwyn District Council. Dated November 2018.

(ii) Golders, (2019). Roydon Quarry Proposal - Response to Request for Further Information. Prepared by Golder Associates (NZ) Ltd for Fulton Hogan Ltd and submission to Environment Canterbury and Selwyn District Council. Dated March 2019.

(iii) Mote, (2018). Yaldhurst Air Quality Monitoring Summary Report: 22 December 2017 – 21 April 2018. Prepared for Environment Canterbury. Auckland. 19 June.

(iv) Statement of Mr Roger Cudmore of Golders Associates (New Zealand) on behalf of Fulton Hogan Ltd dated 23 September 2019.

(v) Statement of Mr Bruce Dawson of Golders Associates (Australia) on behalf of Fulton Hogan Ltd dated 23 September 2019.

(vi) Statement of Ms Audrey Wagenaar of Golder Associates (Canada) on behalf of Fulton Hogan Ltd dated 23 September 2019.

[8] NB: Main body of report and Appendix D (Air Quality Assessment and Draft Dust Management Plan) only

22. I have further utilised the ambient air quality data collected by Mote in the Yaldhurst area between December 2017 and April 2018, made available courtesy of Environment Canterbury.

1.4 Scope of Statement

23. My submission will address:

(i) Proposed activity and discharges to air
(ii) Regulatory context
(iii) Characterisation of existing receiving environment;
(iv) Impact of Yaldhurst quarries
(v) Assessment of proposed Roydon quarry
(vi) Recommendations

2.0 PROPOSED ACTIVITY AND DISCHARGES TO AIR

24. The proposal is to quarry a large (170 ha) site bound by Curraghs Road, Dawsons Road, Maddisons Road, and Jones Road on the outskirts of Templeton, Christchurch. Quarrying of the entire site, except for setbacks, will be undertaken to a depth of 10 metres below ground level. Consent is sought for a period of 35 years.

25. Key activities with discharges to air are:

- Site preparation, establishment of plant and equipment, formation of internal roads and bunding;
- Extraction of aggregate using two front end loaders;
- Maximum of up to 1,500 trucks per day accessing the site;
- Transport of unprocessed aggregate using (unspecified number) five tonne trucks to processing plants;
- Transport of unprocessed aggregate (unspecified rate) using a conveyor to a fixed processing plant;
- Storage of unprocessed aggregate in stockpiles;

- Crushing and screening up to 250 tonnes per hour of aggregate at a fixed plant in the centre of the site;
- Crushing and screening (unspecified amount and rate) of aggregate at a mobile plant >250 m from the site boundary;
- Production of 400,000 cubic metres of aggregate per year;
- Storage of processed aggregate in stockpiles;
- Transport of processed aggregate to market from the proposed Roydon Quarry site in (unspecified number) five tonne trucks;
- Transport, storage and disposal of clean fill from elsewhere in Canterbury to the proposed Roydon Quarry site in (unspecified number) five tonne trucks; and
- Site rehabilitation.

26. The application has been significantly improved with respect to best practice emissions control and overall design compared with that assessed in 2018. The active working quarry area has been reduced from 40 ha to 26 ha.

27. Whilst nuisance dust is an amenity issue that can impact on people's general health and wellbeing, this statement focusses primarily on potential adverse health effects arising from proposed discharges to air. The key contaminants to be discharged to air, with respect to potential adverse health effects, from the proposed activity are:

- Particulate matter less than 10 micrometres in diameter (**PM_{10}**); and
- Respirable crystalline silica (**RCS**) measured in the respirable fraction, which is particulate less than 4 micrometres in diameter (PM_4).

28. With respect to particulate matter, the World Health Organization (WHO) notes there is scientific consensus that exposure to particulate pollution causes predominantly respiratory and cardiovascular effects, ranging from subclinical functional changes (e.g. reduced lung function) to symptoms (increased cough, exacerbated asthma) and impaired activities (e.g. school or work absenteeism) through to doctors' or emergency room visits, hospital

admissions and death (WHO, 2006).[9] The effects, in terms of escalating severity, are described as increased visits to doctors for many individuals, hospital admission for some individuals and death for a few individuals. The exposure-response relationship is essentially linear and there is no 'safe' threshold; adverse health effects are observed at all measured levels (WHO, 2013).[10]

29. In 2013, the International Agency for Research on Cancer (IARC) classified particulate matter (as a component of outdoor pollution) as carcinogenic based on an increased risk of lung cancer (IARC, 2013).[11] New research further indicates particulate matter is associated with artherosclerosis, adverse birth outcomes, childhood respiratory disease (WHO, 2013)[12] as well as Alzheimer's disease and other neurological endpoints, cognitive impairment, diabetes, systemic inflammation and aging (WHO, 2016).[13]

30. With respect to RCS, WHO notes that inhalation of these particles may cause cancer of the lung, trachea and bronchus, and also non-malignant respiratory diseases such as silicosis (WHO, 2002).[14] However, the focus has primarily been on occupational exposure where concentrations and associated exposure have typically been elevated, and characterised by long latency periods. Typical levels for non-occupational exposure are rare, one US study

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[9] WHO, (2006). *Air Quality Guidelines Global Update 2005*. *Particulate matter, ozone, nitrogen dioxide and sulfur dioxide.* Copenhagen: WHO Regional Office for Europe. pp. 217-280.

[10] WHO, (2013). *Review of evidence on health aspects of air pollution – REVIHAAP Project*. Technical Report. Copenhagen: WHO Regional Office for Europe. pp. 38-40.

[11] IARC, (2013). *IARC: Outdoor air pollution a leading environmental cause of cancer deaths*. [online] Available at: www.iarc.fr/en/media-centre/pr/2013/pdfs/pr221_E.pdf Accessed 21 Aug. 2018.

[12] WHO, (2013). p.6.

[13] WHO, (2016). *WHO Expert Consultation: Available evidence for the future update of the WHO Global Air Quality Guidelines*. Meeting report Bonn, Germany 29 September – 1 October 2015. Copenhagen: WHO Regional Office for Europe. p.16.

[14] WHO, (2002). *The World Health Report 2002. Reducing Risks, Promoting Healthy Life.*

found ambient inhalable silica ranged from 0 – 16 µg/m^3 (not stated but assumed to be PM_{30} as a 24-hour average) (Davis *et al.,* 1984).[15]

3.0 REGULATORY CONTEXT

3.1 Land Use and Discharges to Air

31. National guidance recommends the use of separation distances as follows (MfE, 2016) (my emphasis added):[16]

> *Separation distances (buffers) are primarily intended to manage:*
>
> - *the potential effects of unintended or accidental discharges*
> - *the adverse effects of activities that cannot always be internalised without a separation distance, even with the adoption of best practice (**for example, large quarries** or landfills)*
> - *reverse sensitivity effects*
>
> ***Separation distances** are not intended as an alternative to source control but **are implemented in addition to pollution controls consistent with the best practicable option**.*

32. This is consistent with the approach taken by the Australian State of Victoria Environmental Protection Authority (**Vic EPA**), where unintentional or accidental discharges to air are referred to as industrial residual air emissions (**IRAEs**). I will continue to refer to IRAEs for ease of comparison with the statement of Mr Dawson. This is why good practice is to use separation distances *in addition to* good practice air pollution mitigation.

33. The applicant has proposed a 250 metre separation distance between the mobile processing site and the site boundary. This is significantly less than the

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[15] Davis BL, Johnson LR, Stevens RK, Courtney WJ, Safriet DW (1984). The quartz content and elemental composition of aerosols from selected sites of the EPA inhalable particulate network. *Atm Env.* 18(4):771-782.

[16] MfE, (2016). At s3.9.4.

500 metres recommended by the Vic EPA for quarrying with aggregate containing crystalline silica.

34. As noted by Mr Dawson, the separation distance should be measured from the activity boundary. This means that the crusher, at the mobile crushing plant, is the activity to which the 500 metre separation distance should apply.

35. Mr Dawson, supported by Mr Cudmore, has outlined that the Vic EPA does not intend this separation to be an absolute requirement, rather it is a trigger for additional site-specific assessment. I concur but note that no quantified, site-specific assessment has been provided by the applicant.

36. In the absence of any robust quantification and modelling of discharges to air, I recommend requiring a default separation distance of 500 metres between the mobile processing plant and sensitive receptors. In doing so I make no distinction between sensitive receptors (people/residences) within this distance who give their approval to the proposal and those who do not. This is for the following reasons;

(i) The RMA exclusion of consideration of effects on people who have provided written approval (s104(3)(a)(ii)) applies only to "a person", singular, "who has given written approval to the application". It may not therefore, address adverse effects on other family members or people visiting that location who have not provided written consent;

(ii) Importantly, this exclusion does not require informed consent which means that people may not understand the potential impacts of what they are consenting to;

(iii) Irrespective of the above, my concern is that the proposal does not result in any adverse health effects. This is because should people who have provided consent suffer adverse health effects as a result of discharges to air then Canterbury District Health Board will be still required to treat them.

37. It may be helpful to note that my recommended default separation distance of 500 metres is consistent with a joint request from Environment Canterbury, Christchurch City Council, Selwyn District Council and Canterbury District Health Board for national setbacks for quarries to the Ministry for the Environment (ECan, 2018).[17]

3.2 Regional Plan Requirements

38. Schedule 1 of the Canterbury Air Regional Plan requires an assessment of FIDOL factors, these being frequency, intensity, duration, offensiveness and location.

39. The proposed site is adjacent to the Christchurch airshed as shown in **Figure 1**. The AEE includes a meteorological dataset for the proposed site to assess the frequency of wind directions and wind speeds and the data appear robust and representative (Golders, 2018). However, Mr Cudmore appears to have limited his assessment to only wind directions from the south west and west (combined total frequency 11.6%) as potentially impacting on the adjacent Christchurch airshed, stating that winds from the north west and south are rare.[18] My review of the meteorology shows that winds from the north west and south are not rare; combined winds from these directions comprise 12.1% of all winds (refer **Attachment B** for further details).

40. **Figure 2** shows that, depending on the stage of operations, the adjacent airshed may be impacted by winds from the south right through (clockwise) to the north west. These wind directions combined to a total of 42.5% of all wind direction frequencies.

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[17] Letter from Environment Canterbury Chair Steve Lowndes, Christchurch Mayor Lianne Dalziel, Selwyn Mayor Sam Broughton and Canterbury District Health Board Chief Executive David Meates to Hon David Parker, Minister for the Environment dated 18 June 2018. This notes: "*Internationally a setback distance of between 250m to 500m has been used effectively for different elements of quarrying activities*".

[18] Statement of Mr Roger Cudmore at [122].

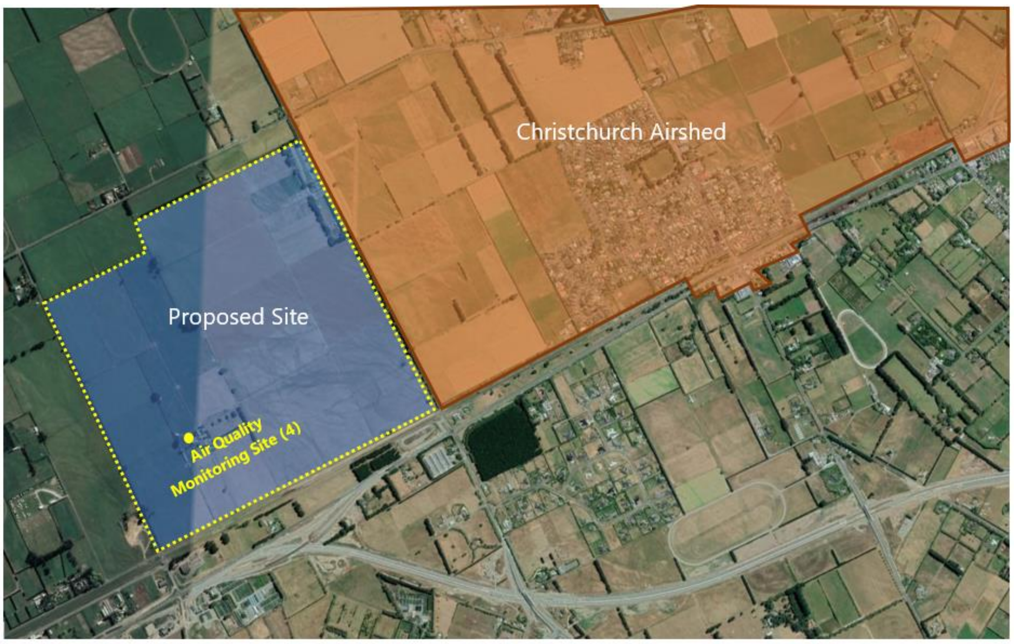

Figure 1 Location of proposed site and (background) air quality monitoring station (Site 4 in Yaldhurst Study, Dec 2017 – Apr 2018).

Figure 2 Wind directions potentially impacting on Christchurch Airshed (wind rose generated from Golders met set with filtered values <180 (S) and > 315° (NW)).

41. Similarly, the applicant has assessed only wind speeds greater than 7 m/s on the basis that large increments in PM_{10} are not seen until wind speeds exceed 7 m/s.[19] This is inconsistent with good practice guidance which states that wind pick-up of dust from exposed areas commences when winds are above 5 m/s (MfE, 2016c). More importantly, this exclusion is directly at odds with the Yaldhurst Study data which recorded six (BAM-equivalent) exceedances of the NES for PM_{10} on days where the maximum wind speed measured was 4.4 m/s (further details in **Attachment B**).[20]

42. I conclude the applicant's approach has led to serious inaccuracies in their FIDOL assessment.

4.0 CHARACTERISATION OF EXISTING RECEIVING ENVIRONMENT

4.1 Wind direction and Wind Speed

43. As noted above, the applicant has considered only very high winds, (speeds >7 m/s) and excluded winds from directions that I consider may impact on the adjacent Christchurch airshed. **Figure 3** presents a wind rose that I have prepared with the applicant's meteorological data generated for the Roydon Quarry site. This shows that Mr Cudmore is correct that the most frequent winds are from the north east.

44. However, winds from directions that may impact on the adjacent Christchurch airshed (south through north west combined) are cumulatively significant in total (42.5%), even when only considering wind speeds above 5 m/s (27.4%) as shown in **Figure 4** (data tabulated in Attachment B).

[19] Golders, (2018). At section 5.1.3 page 26.

[20] NB: The Yaldhurst Study employed a 2-metre high met mast which reads at around 2 m/s less than a standard (10-metre high) met mast. This means the maximum wind speed of 4.4 m/s (measured at 2 m above ground level) would be around 6.4 m/s (measured at 10 m above ground level).

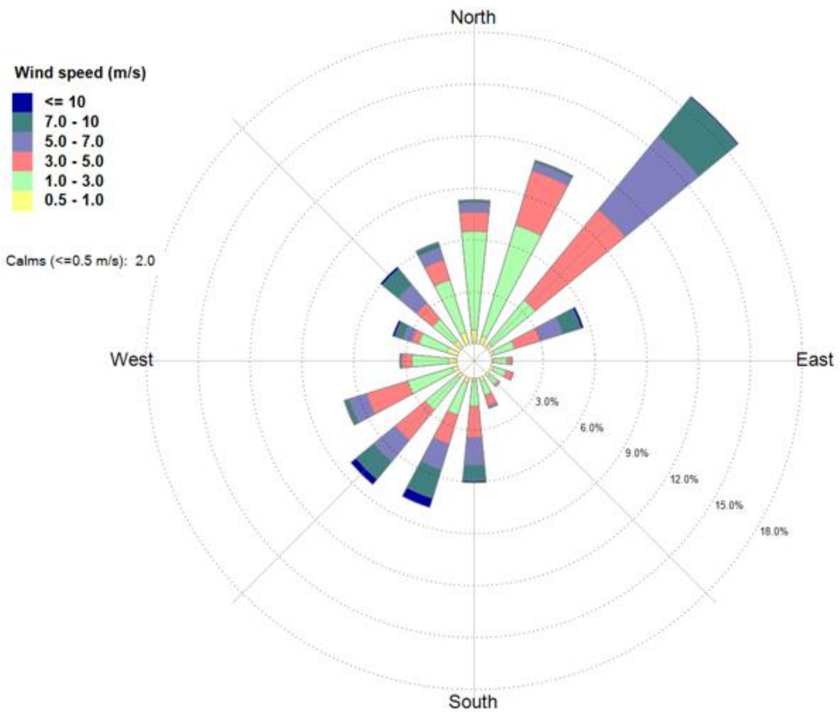

Figure 3 Wind rose showing (1-hour average) wind speed and wind direction predicted for Roydon Quarry site in year 2006 [Source: Golders]

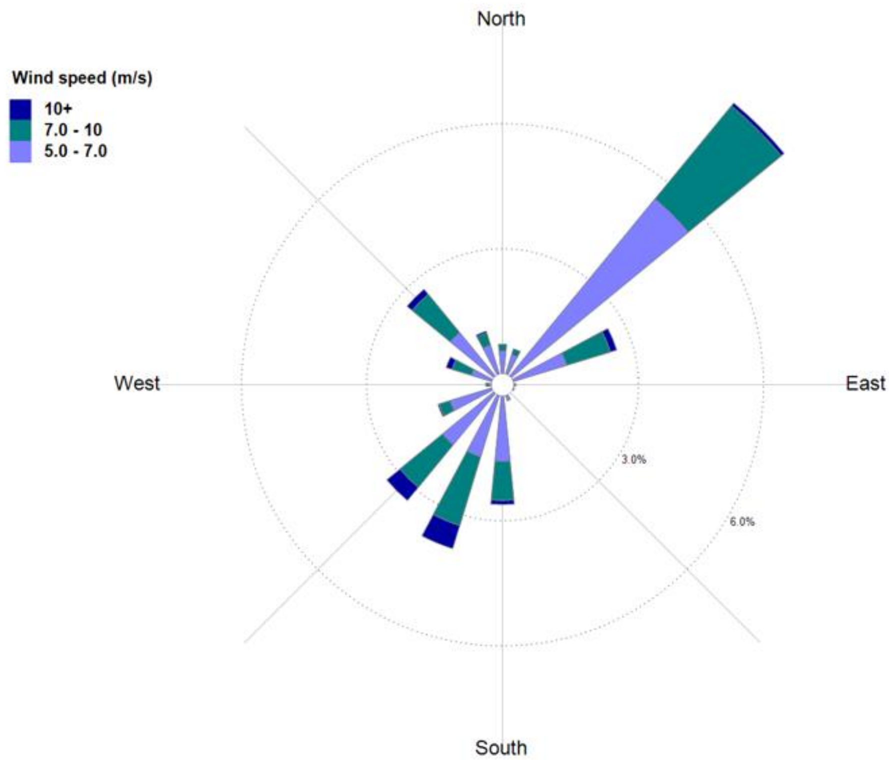

Figure 4 Wind rose showing (1-hour average) wind speed (>5 m/s only) and wind direction predicted for Roydon Quarry site in year 2006 [Source: Golders]

4.2 NESAQ and Requirement for Offsets

45. Schedule 1 of the *Resource Management (National Environmental Standards for Air Quality) Regulations 2004* (**NESAQ**) includes an ambient air quality standard for PM_{10} (**NES for PM_{10}**) of 50 micrograms per cubic metre (**$\mu g/m^3$**) as a 24-hour average with one permitted exceedance in a 12-month period.

46. From 1 September 2012, Regulation 17(4) of the NESAQ provides that an airshed is "polluted" if, for the immediately prior 5-year period, the average number of exceedances of the NES for PM_{10} was more than 1 per year. As at 1 January 2019, the Christchurch airshed had 8.2 exceedances per year of the NES for PM_{10} as a 5-year (2014 – 2018) average.[21] The Christchurch airshed is therefore, a polluted airshed for the purposes of Regulation 17.

47. Regulation 17(1) of the NESAQ states:

> *A consent authority must decline an application for a resource consent (the proposed consent) to discharge PM_{10} if the discharge to be expressly allowed by the consent would be likely, at any time, to increase the concentration of PM_{10} (calculated as a 24-hour mean under Schedule 1) by more than 2.5 micrograms per cubic metre in any part of a polluted airshed other than the site on which the consent would be exercised.*

48. However, Regulation 17(3) of the NESAQ also provides:

> *Subclause (1) also does not apply if—*
>
> *(a) The consent authority is satisfied that the applicant can reduce the PM_{10} discharged from another source or sources into each polluted airshed to which subclause (1) applies by the same or a greater amount than the amount likely to be discharged into the relevant airshed by the discharge to be expressly allowed by the proposed consent; and*
>
> *(b) The consent authority, if it intends to grant the proposed consent, includes conditions in the consent that require the reduction or*

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[21] Generated from Environment Canterbury data available online: https://ecan.govt.nz/reporting-back/improving-air-quality/ [Accessed 1 July 2019]

reductions to take effect within 12 months after the consent is granted and to then be effective for the remaining duration of the consent.

49. In simple terms, Regulation 17 requires new industry to offset discharges of PM_{10} into any polluted airshed if the new discharges are "significant", where significance is determined by the likelihood of the discharge causing an increase in daily PM_{10} of more than 2.5 µg/m^3 (or 5% of the NES for PM_{10}). Based on the size and scope of the proposal, and my experience monitoring quarries in the Canterbury region, I consider that discharges of PM_{10} are very likely to result in an increase in daily PM_{10} of more than 2.5 µg/m^3 in the Christchurch airshed.

50. My indicative (order of magnitude) estimate suggests PM_{10} emissions would be around 6-8 tonnes per year (refer **Attachment D**). However, less than half (42.5%) of these discharges would be directed towards the adjacent Christchurch airshed (refer Section 4.1).

51. For comparison, Christchurch industry *in total* emits around 550 tonnes of PM_{10} per year. Similarly, Auckland industry *in total* emits around 300 tonnes of PM_{10} per year (Auckland Council, 2018).[22] This estimate agrees with Mr Cudmore's estimate that site discharges would tally to around 1% of Christchurch's total emissions. However, I disagree that the estimate is conservative as it does not include *inter alia* PM_{10} discharges to air from:

- Bund formation;
- Formation/processing/wind pickup from all stockpiles;
- Truck movement on sealed roads (up to 1,500 / day)

52. In any case, it is a substantial sum. In order to grant the proposed consent Regulation 17(3) requires the applicant to reduce PM_{10} discharged from another source in the Christchurch airshed. Ms Ryan has noted that the

[22] Auckland Council, (2018). *Auckland Air Emissions Inventory 2016. Industry.* Auckland. August. Available at www.aucklandcouncil.govt.nz

applicant may offset discharges from an existing quarry in Pound Road.[23] I do not know the term of consent for the Pound Road Quarry, but this may impact on the term of consent for the proposed Roydon Quarry. Relevant guidance on offsets for the purposes of the NESAQ has been published by the Bay of Plenty Regional Council and I recommend this to the Commissioners for drafting conditions of consent (BOPRC, 2014)[24]. I further understand Environment Canterbury has experience in drafting conditions of consents for PM_{10} offsets.[25]

53. In the absence of any conditions of consent requiring offsets, Regulation 17(1) requires Commissioners to decline the application for consent.

4.3 PM_{10}

54. Detailed PM_{10} data for the proposed Roydon Quarry site are provided in **Attachment B** and discussed in brief here:

(i) **The maximum daily PM_{10} measured at the proposed site was 45 µg/m^3 which is close to the NES for PM_{10} of 50 µg/m^3 as a 24-hour average**.[26] This was not a one-off high, daily levels of PM_{10} exceeded the alert threshold of 33 µg/m^3 (66% of the NES for PM_{10} MfE, 2009)[27] on four occasions during the 4-month study period ending 21 April 2018.

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[23] S42A Report of Ms Deborah Ryan. At [82]

[24] Bay of Plenty Regional Council, (2014). *Offsets Guidance for the Rotorua Airshed*. Whakatane. October. Available at: https://www.boprc.govt.nz

[25] Specifically, New Zealand Dairies Ltd in Waimate. In this consent the applicant removed 36 open fires and older burners to allow for a new coal-fired boiler. The fires were replaced with either heat pumps or pellet burners. The consent further includes conditions requiring in-house monitoring (real-life testing) of five pellet fires, every five years, to ensure the offsets are real and measurable. MfE, (2009). *2008 Report on progress: National Environmental Standards for Air Quality*. Wellington. Available at www.mfe.govt.nz. At Section 6.2.

[26] Value quoted is for BAM data (refer Attachment B).

[27] MfE, (2009). *Good Practice Guide for Air Quality Monitoring and Data Management.* Wellington. April. Available at www.mfe.govt.nz Section 9.4 at page 78.

For comparison, the maximum daily concentration of PM_{10} measured in Patumahoe, Auckland during the same period was 39 μg/m^3. This was a one-off event, with daily PM_{10} levels remaining below the alert threshold of 33 μg/m^3 (66% of the NES for PM_{10}) for the remainder of the study monitoring period.

For the 10 years 2003 – 2013 maximum daily PM_{10} concentrations measured in Pongakawa, Bay of Plenty - another rural area of New Zealand – between late December through late April ranged between 17 – 32 μg/m^3.[28] These were all within the acceptable threshold (33 – 66% of the NES for PM_{10}).

Similarly, a review of 10 years of PM_{10} monitoring, during the study period December through April, from Pongakawa show maximum daily concentrations range from 23 – 45 μg/m^3 with only 4 exceedances of the alert threshold in total (in the 10 years).

(ii) **The 4-month average concentration of PM_{10} measured at the proposed site was 16 μg/m^3**.

For comparison, the 4-month average concentration of PM_{10} measured in Patumahoe, Auckland was 14 μg/m^3 for the same monitoring period. This was a high year for Patumahoe, the 4-month average PM_{10} concentration ranged from 11 – 14 μg/m^3 (during the study monitoring period) between 2008 and 2018.

Also for comparison, the 4-month average concentration of PM_{10} measured in Pongakawa, Bay of Plenty, between late December through late April ranged between 8 – 12 μg/m^3 for the 10 years 2003 – 2013.

[28] NB: The Pongakawa PM_{10} data was measured with a (reference method) Partisol on a one-day-in-six schedule (so not as comprehensive at the Patumahoe data).

55. **I conclude that background concentrations of PM_{10} at the proposed site are relatively high compared with some rural areas in New Zealand, and can be elevated on occasion when compared with the NES for PM_{10}.**

56. This suggests that existing Canterbury rural air quality is somewhat degraded, with limited 'room' for significant new discharges of PM_{10}, particularly if they are to impact on short-term (daily) concentrations of PM_{10}.

57. There are insufficient data from the 4-month monitoring study to make robust conclusions about long-term concentrations. However, it is notable that the summertime PM_{10} levels are elevated when compared with other rural areas.

58. I consider that caution is needed when characterising background concentrations of daily PM_{10} in terms of wind direction as suggested by the applicant.[29] This is because wind direction is meaningless when presented as a 24-hour average, and daily concentrations are also impacted by *inter alia* wind speed. Further detail is provided in **Attachment B**.

59. However, the data clearly show that elevated short-term (1-minute, 1-hour and daily) PM_{10} concentrations do mirror the frequency of winds, with more elevated daily levels coinciding with more frequent wind directions as shown in **Figure 5**.

[29] Mr Cudmore at Table 1.

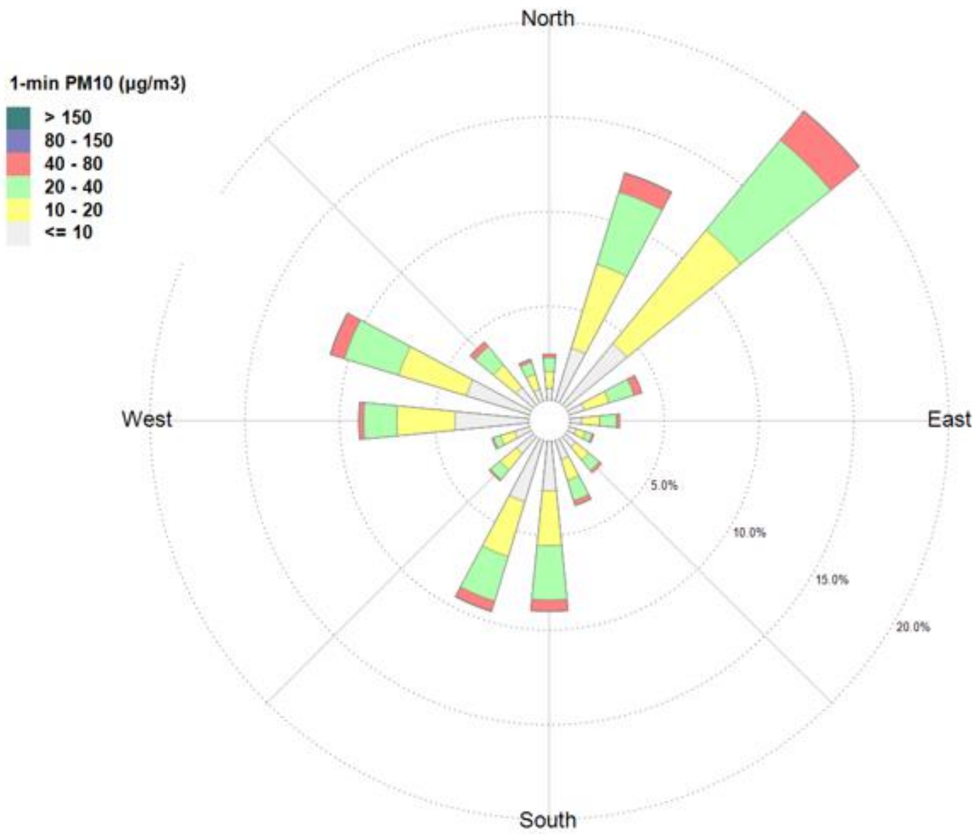

Figure 5 Pollution rose showing PM_{10} ($\mu g/m^3$, 1-minute average) measured at proposed Roydon Quarry site and wind direction (1-minue average) measured at Yaldhurst Study Site 2 for period 21 Dec 2017 – 21 Apr 2018 [Source: Mote, (2018)]

4.4 $PM_{2.5}$

60. By contrast, indicative monitoring at the proposed site for $PM_{2.5}$ for the monitoring study period suggests ambient levels of $PM_{2.5}$ in the rural environment were reasonably low:[30]

(i) The maximum daily $PM_{2.5}$ measured at the proposed site was 11 $\mu g/m^3$. This is less than half of the World Health Organisation global ambient air quality guideline of 25 $\mu g/m^3$ as a 24-hour average.[31]

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[30] Monitoring for $PM_{2.5}$ utilised a nephelometer, which is not a reference method. In the absence of any calibration or correction to BAM equivalency, the $PM_{2.5}$ measurements may only be regarded as indicative.

[31] WHO, (2006).

This compares well with the maximum daily $PM_{2.5}$ measured at another rural site, Patumahoe in Auckland; also 11 μg/m^3 during the same period.

(ii) Daily levels of $PM_{2.5}$ measured at the proposed site were "good" or "excellent" (<33% of the WHO guideline) more than 95% of the time with the remainder being "acceptable" (33-66% of the WHO guideline).

This compares well with daily $PM_{2.5}$ measured at Patumahoe, which were also "good" or "excellent" more than 95% of the time with the remainder being "acceptable".

The 4-month average $PM_{2.5}$ measured at the proposed site was 4.3 μg/m^3. This also compares well with the 4-month average $PM_{2.5}$ measured at Patumahoe; 3.8 μg/m^3 for the same period.

61. The typically low $PM_{2.5}$ concentrations and parity with $PM_{2.5}$ concentrations measured in another rural area suggest the relatively elevated levels of PM_{10} are predominantly in the coarse fraction of particulate (i.e. $PM_{2.5-10}$). This is reasonable as the anticipated key sources of PM_{10} in a rural environment are of natural or agricultural origin which are in the coarse fraction.

62. I conclude that $PM_{2.5}$ levels in the existing environment are low and similar to other rural areas in New Zealand reflecting the lack of significant sources of $PM_{2.5}$ in the Canterbury rural environment.

4.5 RCS

63. Three monthly samples were collected at the proposed site and analysed by x-ray diffraction for RCS. All three samples were below the limit of detection (0.2 μg/m^3 as a monthly average). It should be noted that RCS is measured in the fraction of particulate matter that is less than 4 micrometres in diameter (PM_4) for comparison with the (California) Office of Environmental Health Hazard Assessment (OEHHA) annual guideline of 3 μg/m^3.

64. I conclude that RCS levels in the existing environment are low, reflecting the lack of significant sources of RCS (as measured in PM_4) in the Canterbury rural environment.

4.6 Location of People

65. The applicant has comprehensively detailed existing houses where people live and activities sensitive to proposed discharges to air (sensitive receptors) near the proposed quarry.[32] There are 32 residential properties within 500 metres of the proposed quarry, of which 14 are located within 250 metres.[33] Importantly, two of these residential properties will be located within 19 metres and 90 metres of proposed quarrying activities.

5.0 IMPACT OF YALDHURST QUARRIES

5.1 PM_{10}

66. Environment Canterbury undertook air quality monitoring between 22 December 2017 and 21 April 2018 around five quarries on West Coast Road in Yaldhurst in the Yaldhurst Air Quality Monitoring Study (hereafter referred to as the **Yaldhurst Study**, Mote (2018). **Figure 6** shows the locations of the Yaldhurst Study monitoring stations, all of which had nephelometers with two also co-locating Beta Attenuation Monitors (**BAMs**), and one containing a meteorological station. The Yaldhurst Study also located a monitoring location at the proposed Roydon quarry site (refer **Figure 1**) to serve as a 'background' monitoring location.

[32] Golders, (2018). Air Quality AEE. Appendix D. At page 30.

[33] This includes a temple, temple/accommodation lodge, and motor caravan park.

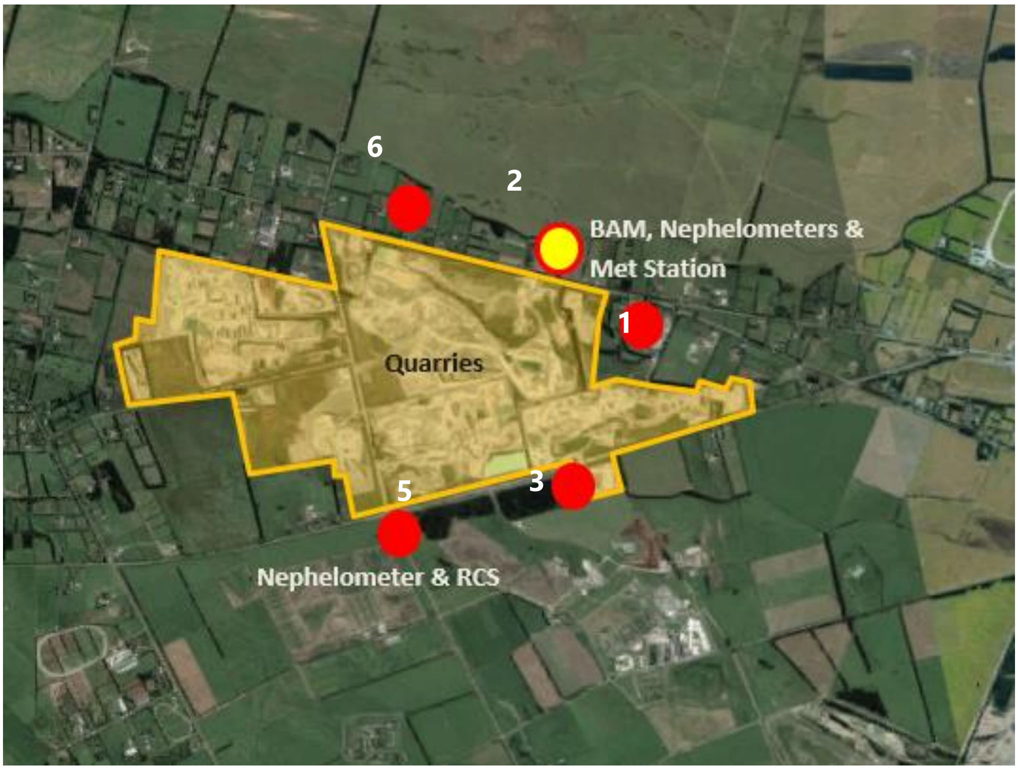

Figure 6 Yaldhurst Study monitoring site locations (NB: Background site (4) not shown – refer Figure 1).

67. The co-location of nephelometers with BAMs enabled the development of "BAM-equivalent" PM_{10} data. BAM-equivalent PM_{10} are the concentrations of PM_{10} measured by a (non-reference method) nephelometer that are corrected to be equivalent to concentrations of PM_{10} that would be measured by a (reference method) BAM if a BAM were present at that location. **Attachment B** contains more details.

68. The BAM-equivalent PM_{10} data from the Yaldhurst Study indicate ambient concentrations of PM_{10} in the vicinity of the quarries would have exceeded the NES for PM_{10} at 3 monitoring locations on 6 days (i.e. 6 exceedances) throughout the 4-month Yaldhurst Study.

69. The monitoring locations where these exceedances occurred were all within 100 m of the Yaldhurst quarry boundaries. However, it is notable that two other locations within 200 m of the quarry boundaries also recorded daily BAM-equivalent PM_{10} concentrations of 50 μg/m^3 as a 24-hour average. The

concentration must exceed 50.5 μg/m^3 to be counted as an exceedance of the NES for PM_{10} (MfE, 2009).[34]

70. The Yaldhurst Study period was a particularly wet summer and I consider that ambient levels of PM_{10} may have been lower during the study period than during other years. This means the any conclusions drawn from the Yaldhurst Study are not likely to be conservative.

71. **I conclude that exceedances of the NES for PM_{10} are likely within 100 m, and may also occur within 200 m, of the existing Yaldhurst quarry boundaries.**

5.2 $PM_{2.5}$

72. Indicative monitoring for $PM_{2.5}$ at two sites in the Yaldhurst Study suggests ambient levels of $PM_{2.5}$ were relatively low: [35]

    (i) The maximum daily $PM_{2.5}$ measured in the Yaldhurst Study was 13 μg/m^3 (Site 2). This is just over half of the World Health Organisation global ambient air quality guideline of 25 μg/m^3 as a 24-hour average.[36]

    This is slightly higher than the maximum daily $PM_{2.5}$ measured at another rural site, Patumahoe in Auckland; also 11 μg/m^3 during the same period.

    (ii) Daily levels of $PM_{2.5}$ at Site 2 were "good" or "excellent" (<33% of the WHO guideline) 93% of the time with the remainder being "acceptable" (33-66% of the WHO guideline at Site 2).

[34] MfE, (2009). Section 9.3 at page 76.

[35] Monitoring for $PM_{2.5}$ utilised a nephelometer, which is not a reference method. In the absence of any calibration or correction to BAM equivalency, the $PM_{2.5}$ measurements may only be regarded as indicative.

[36] WHO, (2006).

This compares well with daily $PM_{2.5}$ measured at Patumahoe, which were "good" or "excellent" more than 95% of the time with the remainder being "acceptable".

The 4-month average $PM_{2.5}$ measured in the Yaldhurst Study was 3.9 μg/m^3 (Site 2). This also compares well with the 4-month average $PM_{2.5}$ measured at Patumahoe; 3.8 μg/m^3 for the same period.

73. The typically low $PM_{2.5}$ concentrations and parity with $PM_{2.5}$ concentrations measured in another rural area suggest the relatively elevated levels of PM_{10} measured in the Yaldhurst Study are predominantly in the coarse fraction (i.e. $PM_{2.5\text{-}10}$). This is reasonable as quarries are the key source of PM_{10} in Yaldhurst, and these particulate discharges are known to be in the coarse fraction.

74. **I conclude that the Yaldhurst quarries do not have substantial discharges of $PM_{2.5}$ and do not consider this contaminant further.**

5.3 RCS

75. Three monthly samples were collected at five sites around the (West Coast Road) Yaldhurst quarries and analysed by x-ray diffraction for RCS during the Yaldhurst Study. All samples were below the limit of detection (0.2 μg/m^3 as a 1-month average) except two samples collected at Site 3 (< 100 m from the quarries) which measured 0.3 μg/m^3 (Jan/Feb) and 0.8 μg/m^3 (Mar/Apr) as a 1-month average. These measurements have an estimated accuracy of +/- 23% (Mote, 2018).

76. These monthly levels of RCS may be conservatively compared with the (California) OEHHA annual guideline of 3 μg/m^3. The ambient RCS monitoring data shows that, when monitored in January - April 2018, *ambient* levels of RCS were low in all areas monitored (even the locations which measured exceedances of the NES for PM_{10}).

77. However, *personal* exposure RCS monitoring undertaken in August 2017,[37] January 2018[38] and March 2018[39] by Environment Canterbury shows that some Yaldhurst residents were being exposed to short-term (i.e. 8-hours) elevated levels of RCS compared with background rural levels in Canterbury. This monitoring was separate to the Yaldhurst Study (Mote, 2018) and I understand it included residents located in the wider Yaldhurst area (i.e. not just those near the quarries on West Coast Road). Summary details of the personal monitoring are provided in **Attachment C**.

78. To maintain residents' privacy, I only have redacted copies of these reports and this has limited my ability to interpret the data. However, I do note that measured exposures for two residents in August 2017 equalled the proposed Australian workplace exposure standard time weighted average of 20 μg/m^3 as an 8-hour average.[40] Workplace exposure standards are not designed to protect the general population.

79. **I conclude that long-term (annual) levels of RCS in Yaldhurst should be below the OEHHA criterion. However, short-term (hourly/daily) levels of RCS *may* be elevated in some Yaldhurst locations compared with background**.

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[37] Chemsafety, (2017). *Quarry Dust Residential Exposure Assessment. 1 – 25 August 2017.* Prepared for Environment Canterbury by Bridgett Jennings and Sam McGee. Christchurch. October. Report 10 version 1 Public copy.

[38] Chemsafety, (2018). *Quarry Dust Residential Exposure Assessment – Post Cleaning. 25 & 27 January 2018.* Prepared for Environment Canterbury by Bridgett Jennings and Sam McGee. Christchurch. March. Report 5 version 2 Public copy.

[39] Chemsafety, (2018b). *Quarry Dust Residential Exposure Assessment 9 – 27 March 2018.* Prepared for Environment Canterbury by Bridgett Jennings and Sam McGee. Christchurch. May. Report 9 version 2 Public copy.

[40] Worksafe, (2019). *Special note in regards to Silica – crystalline (all forms)*. Available at: https://worksafe.govt.nz/laws-and-regulations/consultations/workplace-exposure-standards-changes-2019/open/ [Accessed 8 Oct 2019]

6.0 ASSESSMENT OF PROPOSED QUARRY

6.1 PM_{10}

80. The applicant has stated (Golders, 2019):[41]

> *The magnitude of increased PM_{10} levels beyond the boundary of the Yaldhurst quarrying area (due to the multiple quarry sites) would be significantly higher than impacts from the smaller Roydon Quarry site. The exposed quarrying area at Yaldhurst is approximately 230 ha compared to a maximum of 40 ha for the Roydon Quarry (6:1) ratio. Secondly the Yaldhurst site has multiple fixed processing sites (four) that are relatively close to their respective site boundaries where the ambient monitors are located (approximately 200 m – 300 m). By comparison, the Roydon Quarry has one central processing site which would be situated 500 m from the site boundary with any mobile plant to be located at least 250 m from the site boundary.*

81. The applicant goes on to estimate the incremental increase in the 95%ile *hourly* PM_{10} between selected sites in the Yaldhurst Study during working hours only, and south westerly winds only. The intent of this approach is to assess potential contributions of the Yaldhurst quarries to *daily* PM_{10} concentrations in the north east (of Yaldhurst quarries) because the Christchurch airshed is located to the north east of the proposed site.

82. This approach significantly underestimates the potential impact of the proposal for the following reasons.

    (i) The applicant's approach excludes the impact of the Yaldhurst quarries in other wind directions. This is important because:

    - The most significant impact of the Yaldhurst quarries was measured to the south east (i.e. when winds were blowing from the north west

[41] Golders, (2019). At page 9.

which would potentially impact on the adjacent Christchurch airshed) which the applicant excluded from consideration; and

- There are sensitive receptors located at all points of the compass around the proposed site.

(ii) By excluding an (unstated) number of non-working hours, the applicant has neglected consideration of discharges of PM_{10} that occur outside these hours. For example, wind pickup of exposed ground. These discharges can, and do, occur after working hours which comprise more than 50% of the time and can be a significant contribution to daily PM_{10} (particularly in the absence of staff onsite to control and reduce discharges to air).

My analysis of *hourly* PM_{10} from the Yaldhurst Study is provided in **Attachment B**. The data show that there were prolonged periods of elevated, hourly PM_{10} outside working hours that contributed to breaches of the NES for PM_{10} (e.g. refer Figure B9 in Attachment B). These prolonged periods of elevated hourly PM_{10} would not be included in the applicant's assessment because it only considered working hours.

(iii) By considering only the 95th percentile of data, the applicant has excluded the top 5% of measured hourly PM_{10} concentrations. For 2,904 hours of monitored data this equates to removing 145 hours which is just over 6 days. The applicant states that "*higher percentiles are more likely to report unrealistic extreme values that can be expected from instrument variability*".[42] However, there is a reasonable chance that some of these 145 hours, or 6 days, of data are real and their exclusion would significantly underestimate the potential increase (and impacts) in daily PM_{10} attributable to the Yaldhurst quarries.

[42] Golders, (2019). At page 10.

(iv) Finally, I am further unclear how the applicant estimated the potential increment in *daily* PM_{10} from an estimate of incremental increase in *hourly* PM_{10} (during working hours only from only some wind quadrants).

83. A more robust approach is to look at the overall difference between *daily* PM_{10} at all points on the compass around the Yaldhurst quarries and *daily* PM_{10} at the background site. This was, after all, the purpose of the background site – to provide an understanding of the difference between monitoring locations close to the Yaldhurst quarries and the typical Canterbury rural environment. The development of BAM-equivalent PM_{10} data provides a robust method for this comparison at all points on the compass.[43]

84. A detailed review of the incremental difference between daily BAM-equivalent PM_{10} measured at each Yaldhurst Study monitoring site and background (i.e. daily BAM-equivalent PM_{10} measured at the applicant's proposed site) is provided in **Attachment B**. This data shows that on days when daily BAM-equivalent PM_{10} at Yaldhurst was *higher* than at the background site:

(i) The 99^{th} percentile *increase* ranged from 21 – 37 µg/m^3 at monitoring sites within 100 m of the Yaldhurst quarry boundaries; and

(ii) The 99^{th} percentile *increase* ranged from 15 – 21 µg/m^3 at monitoring sites 150 – 200 m of the Yaldhurst quarry boundaries.

85. Similarly, a straight comparison between daily PM_{10} measured by BAM at Site 2 (Yaldhurst) and Site 4 (proposed Roydon Quarry) reveals significantly higher concentrations measured in Yaldhurst, as shown in **Table 1**. Notably Table 1 also shows a big drop between the 99^{th} percentile and the 95^{th} percentile at Site 2 (Yaldhurst) compared with Site 4 (proposed Roydon Quarry). This

[43] This too being the purpose of co-locating reference and non-reference monitoring methods.

indicates that daily PM_{10} at Site 4 (background) was consistently lower than daily PM_{10} at Site 2.

Table B-1 Summary daily PM_{10} measured by BAM from Yaldhurst Study: 22 Dec 2017 – 21 Apr 2018

Site ID / Distance from quarries	**Site 2 150 – 200 m (North)**	**Site 4 5 km (Proposed Roydon Quarry Site)**
	($\mu g/m^3$, 24-hour average)	
Maximum daily PM_{10}	47	45
99%ile daily PM_{10}	45	40
95%ile daily PM_{10}	36	29
4-month average PM_{10}	21	16
Standard Deviation	8	7
No. days >50.5 $\mu g/m^3$	0	0

86. The key difference between the Yaldhurst Study sites and the background (proposed Roydon Quarry) site is the presence of five large quarries. The above data suggest that the Yaldhurst quarries can contribute at least 15 $\mu g/m^3$ to 99th percentile daily PM_{10} within 200 metres.

87. This may be compared with the significance threshold of 2.5 $\mu g/m^3$ PM_{10} as a 24-hour average in Regulation 17 of the NESAQ. **I conclude that the discharges from the Yaldhurst quarries are having a measurable, and significant, impact on daily concentrations of PM_{10} at locations close to (i.e. within 200 m of) the quarries.**

88. Given PM_{10} can travel hundreds of metres, it is further reasonable to conclude that discharges from the Yaldhurst quarries may exceed the significance threshold (i.e. increase background levels by more than 5% of the NES for PM_{10}) out to some distance.

89. The Yaldhurst Study also employed three transect monitoring locations (Sites 7, 8 and 9) at distances of <100 m, 250 m and 350 m from the nearest site activities for the period 10 February – 21 April 2018. A review of this data is

provided in **Attachment B**. The transect data suggest that PM_{10} discharges from the Yaldhurst quarries provides significant, measurable increases in daily PM_{10} out to 350 metres as shown in **Figure 7**.

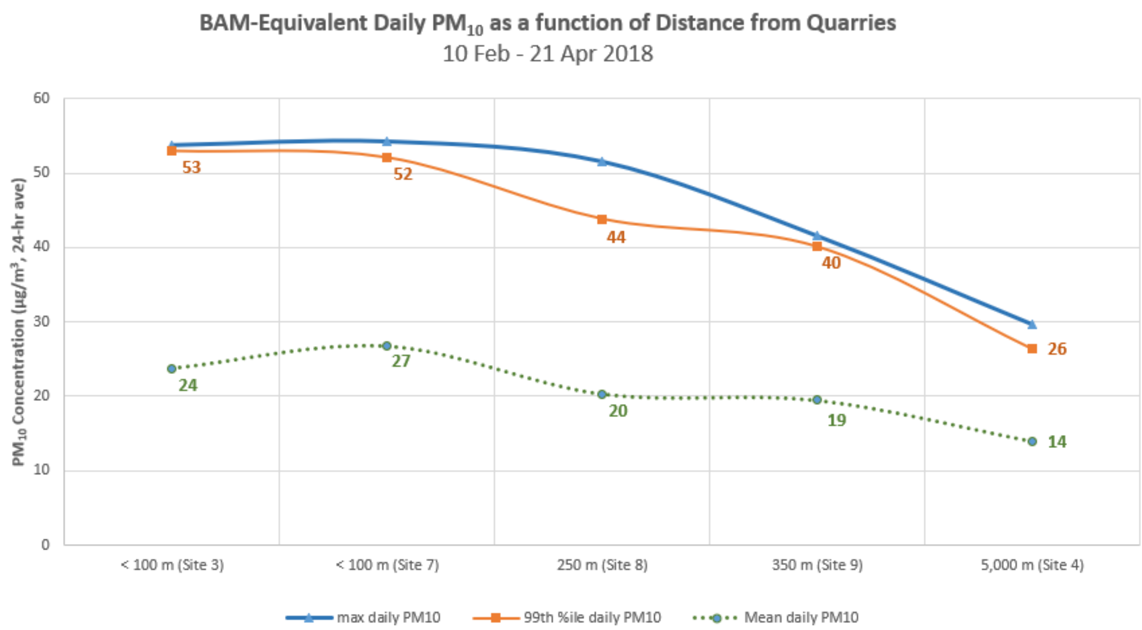

Figure 7 Daily (BAM-Equivalent) PM_{10} Concentrations as a function of distance from the Yaldhurst quarry boundaries [Source: Mote, (2018)]

90. The next issue to address is how to relate the findings of the Yaldhurst Study to the proposed application. The applicant has stated (Golders, 2018):

> *The factor by which Yaldhurst monitoring data needs to be reduced so it is more relevant to the Roydon Quarry site should account for all the above factors and the benefits of implementing best practice dust controls at the Roydon site. When accounting for the reduced area (6 times), operation of one processing site versus four, and the 500 m distance between the processing site and the boundary (cf 200-300m), then this reduction would be in the order of 10-fold.*

91. This approach has similarly been adopted by Mr Cudmore: [44]

> *In my view the of [sic] the proposed quarry (26 ha of active open area at any one time) and the design of the proposed quarry, combined with the proposed*

[44] Statement of Mr Roger Cudmore on behalf of Fulton Hogan dated 23 September 2019 at [110].

control/mitigation measures for control of dust discharges, would readily achieve a 10-fold reduction in the increase in ambient respirable particulate levels compared to that measured for the 230 ha Yaldhurst gravel quarry area.

92. There is no science to support the assumption of a 10-fold reduction. Whilst it is true that the emissions from exposed areas are directly proportional to the amount of area exposed, a reduction factor in concentrations measured at multiple locations downwind of multiple quarries cannot be robustly estimated by comparing the total area exposed and the number of processing sites and separation distances. Such a comparison ignores:

(i) The volume of material being excavated, handled, stored, processed and transported (existing vs proposed).

(ii) Existing site operations during the monitoring period compared with those proposed (no information on operations was provided by the quarries for the monitoring study period).

(iii) Existing site mitigation employed during the monitoring period compared with those proposed. (Dust mitigation was employed by the Yaldhurst quarries during the period of monitoring, however, as noted above no details were made available).

93. I further note that the actual impact measured at a specific site is primarily influenced by the site operations and activities being undertaken closest to each site. This reflects the physics of PM_{10} discharges to air from quarries being:

(i) largely in the coarse fraction ($PM_{2.5-10}$);
(ii) discharged at ambient temperature; and
(iii) discharged close to the ground.

94. For example, based on our observations during the Yaldhurst Study, myself and my colleague Mr Paul Baynham of Mote Ltd, consider that the primary sources of PM_{10} measured at Site 3 (< 100 m of the quarry boundaries) were

trucks entering and exiting the adjacent Road Metals quarry site and site works at a smaller adjacent site with exposed ground. Consent documents for Road Metals indicate they process around 200,000 cubic metres per year of aggregate at this site.[45] There is also a concrete batching plant at this site.

95. It is also worth noting:

(i) There are two processing sites proposed (compared with four existing processing sites in Yaldhurst);

(ii) The proposed separation distance is only 250 m from the mobile processing site to the boundary. This is less than the distance (~350 m) between the existing Road Metals processing site and the monitoring station located at Site 3 (which measured the largest *incremental* increase in daily BAM-equivalent PM_{10} concentrations during the Yaldhurst Study);

(iii) There will be a maximum of 1,500 trucks per day entering and exiting the proposed Roydon quarry. I could not find data on trucks accessing the Road Metals site, however, given it processes half the throughput of the proposed Roydon Quarry the number of trucks is likely to be significantly less than 1,500 per day.[46]

96. The only way to robustly estimate the impact that the proposed quarry will have on the surrounding environment would be to quantify all discharges to air and undertake atmospheric dispersion modelling to predict downwind concentrations. This approach is routinely adopted in New Zealand for industry with significant discharges to air. In Australia discharges to air from mines and quarries are routinely modelled. This has not been the case to date

[45] Road Metals, (2014). Assessment of Environmental Effects in support of application for resource consents (CRC153827 CRC153828 CRC153829 CRC153830). 21 November 2014. https://api.ecan.govt.nz/TrimPublicAPI/documents/download/2213028

[46] Personal comms. Jana Hayes. RMO II Compliance Monitoring. Environment Canterbury. 7 Oct 2019.

in New Zealand but, until now, no quarry has been proposed adjacent to a polluted airshed.

97. Mr Cudmore has stated that published emissions factors are not valid for New Zealand. I note there are now sufficient monitoring data available (and much of it local) to enable calibration of emission factors for application in New Zealand. Such an approach would enable development of a robust estimate of the required offset for Regulation 17 of the NES-AQ.

98. The applicant has elected instead to focus on mitigation and proposed separation distances. Background air quality monitoring indicates that PM_{10} concentrations in the existing environment are relatively degraded, with limited 'room' for significant new discharges of PM_{10}. This offers Commissioners little assurance that the NES for PM_{10} will not be breached.

99. **I am not confident that, even with application of best practice dust control, the proposal will not on occasion breach the NES for PM_{10}.** This should not reflect badly on the applicant, rather it reflects the scale and size of the activities being proposed.

100. Further discussion on mitigation and recommendations follows in Section 7.

6.2 RCS

101. The *personal* sampling has three (only) samples for which RCS comprised less than 5% of PM_4 (refer **Attachment C**). This suggests that if PM_{10} levels are maintained below the PM_{10} annual guideline (20 μg/m^3) then RCS may similarly be maintained below the RCS annual guideline (3 μg/m^3). Provided the good practice controls recommended by Mr Cudmore are implemented, this should be achievable.

102. **I therefore, consider that with application of best practice dust control discharges of RCS from the proposed quarry should remain below the OEHHA annual criterion offsite.**

103. With respect to short-term (hourly, daily) concentrations of RCS it is impossible to draw firm conclusions in the absence of robust data. If we assume that:

(i) daily PM_{10} is maintained below the NES of 50 $\mu g/m^3$; and

(ii) in the absence of data on PM_{10}:PM_4 ratios in the locations tested during the personal sampling that RCS comprises at most 5% of PM_{10}; then

concentrations of RCS would be <2.5 $\mu g/m^3$ as a 24-hour average. This is less than background levels measured in the personal sampling (for which the minimum detection level was 3 $\mu g/m^3$ as an 8-hour average).

104. However, given the NES for PM_{10} may be breached offsite, I recommend monitoring for short-term RCS on a precautionary basis.

105. I note Mr Cudmore has estimated maximum *hourly* RCS for some sites in the Yaldhurst Study (Sites 2, 3 and 4) based on measured ratios of $PM_{2.5}$ to PM_4.[47] These estimates cannot be valid, or robust, for a 1-hour average because PM_4 measurements were only made at monthly intervals, with only three months of data (i.e. three datapoints) at each site.

106. I also note Ms Wagenaar, a toxicologist engaged by Fulton Hogan Ltd, recommends the use of the Texas Commission on Environmental Quality (TCEQ) criterion of 47 $\mu g/m^3$ as a 1-hour average for respirable silica less than or equal to 10 micrometres in diameter (PM_{10}).[48] I am not a toxicologist but this criterion seems at odds with *workplace* exposure standards for respirable silica as PM_4 currently under consideration in New Zealand and Australia (50 and 20 $\mu g/m^3$ as an 8-hour average respectively). Good practice guidance in

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[47] Statement of Mr Roger Cudmore on behalf of Fulton Hogan dated 23 September 2019 at [114]

[48] Statement of Ms Audrey Wagenaar on behalf of Fulton Hogan Ltd dated 23 September 2019. At [35]

New Z7ealand does not typically recommend the use of TCEQ air quality criteria (MfE, 2016).[49]

7.0 RECOMMENDATIONS

107. The applicant has proposed a range of measures (e.g. fully sealed road to central processing area, water sprays, etc.) that are consistent with good practice (MfE, 2016) and I support their inclusion.

108. I also support the recommendations of Ms Ryan, [50] called by Environment Canterbury, and the applicant,[51] for a reduced dust trigger threshold of 60-65 µg/m^3 as a 1-hour average. This is based on my review of the hourly data from the Yaldhurst Study, for which elevated offsite levels were not well correlated with the higher MfE suggested dust nuisance threshold (refer **Attachment B** for further details).

109. I consider additional monitoring and more stringent trigger limits are required to assist with compliance with health-based air quality criteria. Specifically, I recommend:

(i) The trigger wind speed be set to reflect good practice guidance (5 m/s, not 7 m/s as proposed by the applicant);

(ii) Meteorological monitoring be carried out at 10 metres above ground level and sited, as far as practicable, in accordance with AS/NZS 3580.1.1:2016;

(iii) Continuous, monitoring for PM_{10} using a reference method on the site boundary adjacent to the Christchurch airshed for the entire consent duration.

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[49] MfE, (2016). At section 4.6.

[50] S42A Report of Ms Deborah Ryan. At [24]

[51] Golders, (2018). Appendix D. At section 7.3.2

(iv) Continuous, long-term (monthly) monitoring for RCS at the boundary adjacent to the Christchurch airshed for the entire consent duration.

(v) Continuous monitoring for PM_{10} at the boundary near houses located within 100 metres of site activities. This monitoring should be coordinated with staged operations (i.e. timed to coincide with site activities occurring within 500 metres).

(vi) Continuous monitoring for PM_{10} at the boundary closest (but greater than 100 metres) to the nearest two residential receptors to site activities.

(vii) If using non-reference methods for monitoring PM_{10}, the data be calibrated carefully using co-location of non-reference instruments with reference instruments to provide robust data for the purposes of demonstrating compliance with the NES for PM_{10}.

(viii) Continuous, long-term (monthly) monitoring for RCS at the boundary near houses located within 100 metres of site activities. This monitoring should be coordinated with staged operations (i.e. timed to coincide with site activities occurring within 500 metres).

(ix) Intermittent, short-term (24-hour) monitoring for RCS at the boundary near houses located within 100 metres of site activities on a precautionary basis. This monitoring should be coordinated with staged operations (i.e. timed to coincide with site activities occurring within 500 metres) that are likely to give rise to elevated PM_{10} concentrations.

(x) In the absence of any further information, a default separation distance of 500 metres for the mobile crushing plant and the nearest boundary.

8.0 CONCLUSIONS

110. Available monitoring data for the proposed Roydon Quarry site indicates that the existing air quality is already somewhat degraded with little room for new discharges of PM_{10}.

111. In my view, even with the good design and best practice mitigation proposed, it is reasonable to anticipate significant increases (i.e. > 5% of the NES for PM_{10}) within a few hundred (200 – 300) metres of the boundary of the proposed quarry and possibly further. If consent were to be granted, Regulation 17 of the NESAQ requires offsets.

112. Whilst maximum increases would likely be limited to adverse meteorology (dry, windy weather), non-permanent sources (e.g. bund construction) and IRAEs, the sheer size and scale of the proposed activity (400,000 cubic metres of aggregate per year, up to 1,500 trucks per day) means that ongoing, significant increases in daily PM_{10} will be likely in some locations. Should consent be granted, I have recommended additional mitigation and monitoring as conditions of consent to assist with overall compliance and to improve the public's level of trust.

113. In the absence of information on the type of crusher, or a quantified assessment, my recommendations include the provision of a default 500 metre buffer distance between the mobile crushing plant and sensitive receptors. This is primarily to address IRAEs.

114. I consider that should PM_{10} remain below the annual guideline then RCS should similarly be well below the annual OEHHA criterion. However, I cannot draw any firm conclusions about short-term RCS levels downwind. I have proposed additional (short-term) RCS monitoring as a condition of consent on a precautionary basis.

Louise Wickham

17 October 2019

ATTACHMENT A   CURRICUM VITAE

July 2019

With degrees in both chemical engineering and environmental law, Louise is an air quality expert with a comprehensive understanding of both applied science and resource management. Louise has 25 years' experience working for both private and public sectors in New Zealand, Australia and the United Kingdom on all aspects of air quality management including:

- *Local, regional and national air quality policy and regulation*
- *Techniques and best practice for assessing the effects of discharges to air*
- *Air pollution control*
- *Odour control and assessment*

Louise is an experienced presenter and has acted as an expert witness, Commissioner and Chair in numerous public hearings under the Resource Management Act 1991.

Current Position

Director and Senior Air Quality Specialist, Emission Impossible Ltd (since 2011)

Qualifications

Master of Environmental Law, University of Sydney, Australia, 2003
Bachelor of Chemical and Materials Engineering, University of Auckland, New Zealand, 1993
Certified decision maker under Resource Management Act 1991 (current until 31 Dec 2020)

Academic and Employment History

Senior Analyst, Ministry for the Environment, New Zealand (8 years)
Senior Policy & Programmes Officer, NSW Environment Protection Authority, Australia (2 years)
Senior Engineer - Air Quality, URS Australia Pty Ltd, Australia (4 years)
(Contract) **Environmental Engineer,** Environment Protection Authority Victoria, Australia (3 months)
Business Area Manager – Air Quality, RSK Environment Ltd, United Kingdom (2 years)
(Contract) **Project Manager**, Dames & Moore, United Kingdom (3 months)
Environmental Engineer, Woodward-Clyde NZ Ltd, New Zealand (3 years)
Undergraduate Engineer, Tasman Pulp & Paper, New Zealand (9 months)

Professional and Other Involvement

Member, Resource Management Law Association
Member, Clean Air Society of Australia and New Zealand
Approved Commissioner, Auckland Council Independent Panel

ATTACHMENT B YALDHURST AIR QUALITY MONITORING STUDY DATA

B1. Introduction

In November 2017 Environment Canterbury engaged Mote (who subcontracted Emission Impossible Ltd) to undertake ambient air quality monitoring around five quarries in Yaldhurst, near Christchurch. This was the Yaldhurst Air Quality Monitoring Study, hereafter referred to as the Yaldhurst Study.

Following consultation with the local community, ambient air quality monitoring was undertaken between 22 December 2017 and 21 April 2018 as follows:

- Five sites measured PM_{10} for four months within 200 metres (**m**) of quarry boundaries in Yaldhurst. One site (Site 2) co-located a beta attenuation monitor (**BAM**) with twin nephelometers to measure PM_{10} and $PM_{2.5}$. This site also employed a meteorological station.
- Five sites measured respirable crystalline silica (RCS) for three months ending 20 April 2018. These sites employed a modified NIOSH sampling method with monthly filter collection and analyses.
- A sixth "background" site (Site 4) measured PM_{10} using a co-located BAM and nephelometer for four months. This monitoring location also measured $PM_{2.5}$ using a nephelometer and RCS using a modified NIOSH sampling method with monthly filter collection. The background site was located on the applicant's proposed site for the Roydon Quarry (refer **Figure 1**).

The location of the monitoring sites remains inexact to preserve resident's privacy however, the general locations are provided in **Figure B1**.

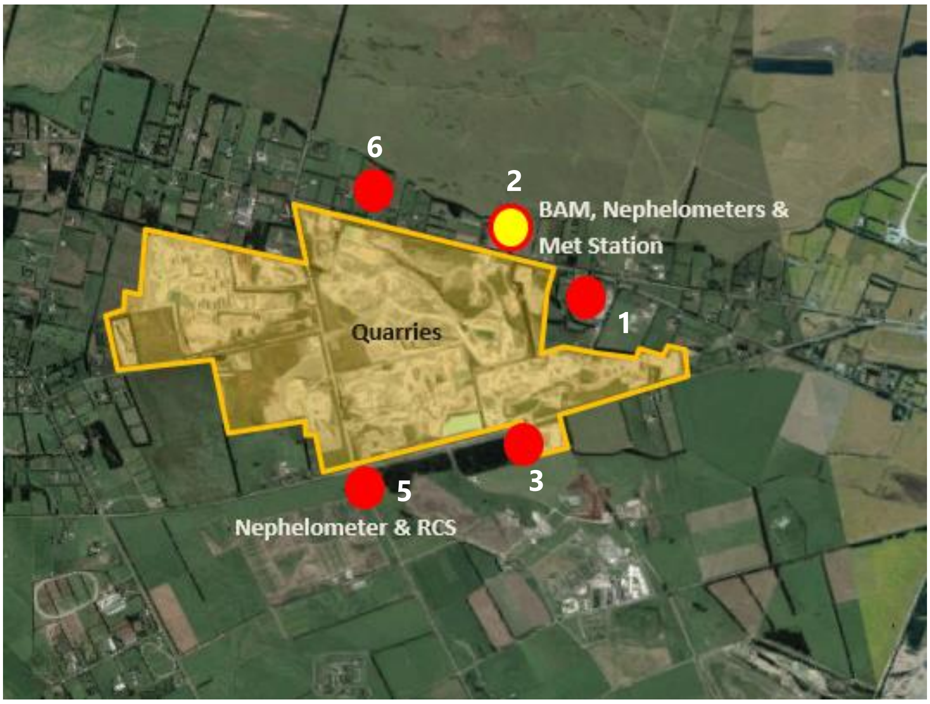

Figure B1. Yaldhurst Study monitoring site locations (NB: Background site (Site 4, Proposed Roydon Quarry site not shown – refer Figure 1). [Source: Mote, (2018)]

B2. Meteorology

The predominant wind direction during the study period was from the north east as shown in **Figure B2**. Winds measured at Christchurch Airport during the study period are presented for comparison in **Figure B3**.

Meteorology measured at Site 2 during the Yaldhurst Study was generally consistent with meteorological data collected at Christchurch. However, the lower wind speeds and high percentage of calms (at Site 2 in the Yaldhurst Study) reflect the presence of large trees and the reduced (2 metre) height of the meteorological tower (10 metres is standard) employed during the study.

It is important to note that the monitoring study period was unusually wet, receiving 386 mm of rain compared with a 10-year average of 205 mm for the same four-month period. The applicant has stated that the elevated rainfall was "principally due to three isolated events where the daily rainfall exceeded 40 mm" and that "the effect does not persist much beyond the rain event itself, with warm daily maximum temperatures facilitating drying of exposed surfaces".[52]

Research I have undertaken into PM_{10} from unsealed roads indicates that some effective mitigation (i.e. reduction in daily PM_{10}) is provided by rain on days with more than 1 millimetre (**mm**) of rain (EIL, 2019).[53] There were 23 days of >1 mm rain during the monitoring study period. This may be compared with a 10-year average of 25 days of >1 mm rain for Christchurch for this period (min 19, max 33, Mote Ltd).

However, it is also notable that the average soil moisture content during the study period as measured in Broadfield, Lincoln was 22.3% compared with the 10-year average of 17.9% for the same four-month period.

Considering the elevated rainfall and the elevated average soil moisture content, I conclude that levels of particulate and RCS measured during the study monitoring period may be lower than during other years.

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[52] Golders, (2018). Appendix D at page 19.

[53] Emission Impossible Ltd, (2019). *Health Impacts of PM_{10} from Unsealed Roads in Northland*. Prepared for Ministry of Health. Auckland. July. Available at www.moh.govt.nz

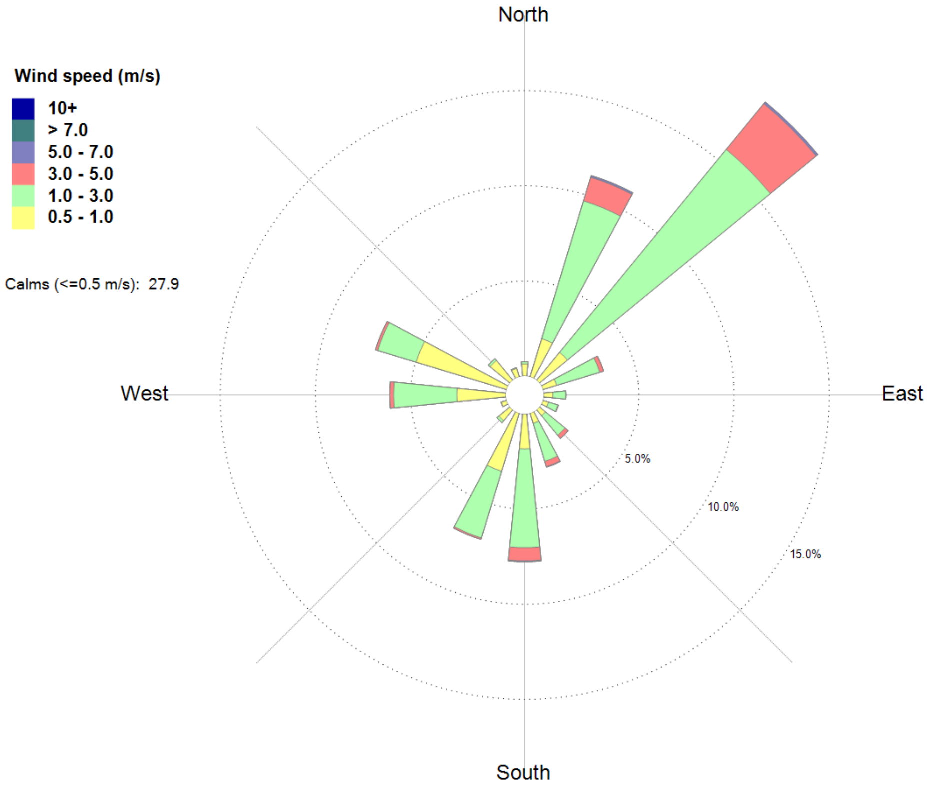

Figure B2 Wind direction and wind speed (1-minute average) measured at Yaldhurst Study Site 2 for period 22 Dec - 21 Apr 2018 [Source: Mote, (2018)]

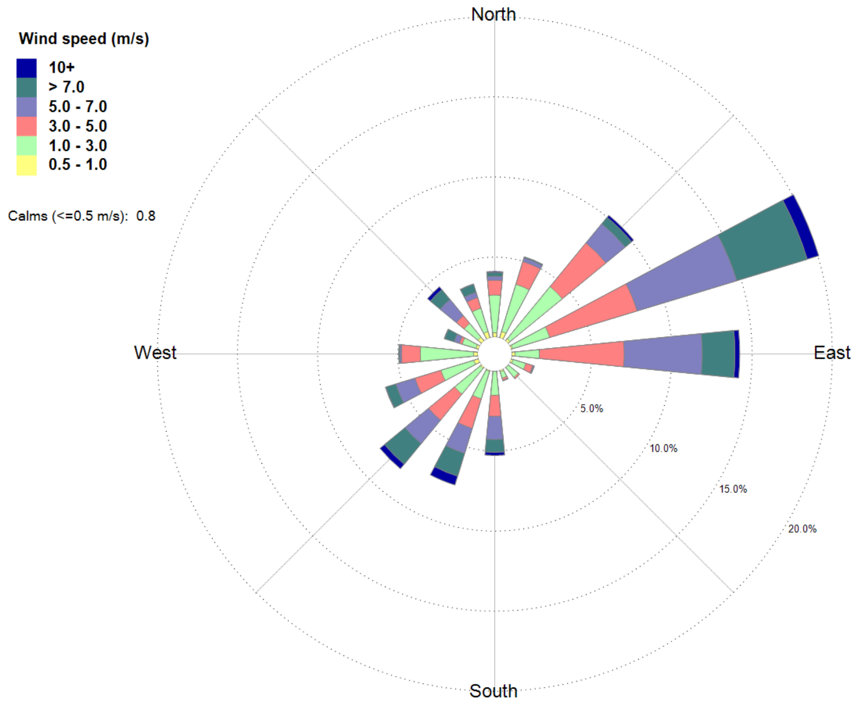

Figure B3 Wind direction and wind speed (1-hour average) measured at Christchurch Airport for period 22 Dec - 21 Apr 2018 [Source: MetService]

B3. Daily PM_{10}

The proposed site for the Roydon Quarry was used as a 'background' monitoring location in the Yaldhurst Study (i.e. Site 4 in Mote, 2018). There were two residential houses within 80 metres of the air quality monitoring station, however, these were not occupied during the period of monitoring. This means that there was no potential inference with discharges of PM_{10} from solid fuel combustion for domestic heating. During the period of monitoring some construction was underway for a bypass on State Highway 1 around 600 m to the south of the monitoring location (refer **Figure 1**). There were no other sources of PM_{10} that I am aware of during the monitoring study other than typical rural activities (e.g. cropping) and natural sources (e.g. wind pick-up of dust from exposed areas).

Air quality monitoring at the proposed site was undertaken for the following pollutants:

(i) PM_{10} using co-located nephelometer and beta attenuation monitor (**BAM**);

(ii) Particulate matter less than 2.5 micrometres in diameter (**$PM_{2.5}$**) using a nephelometer; and

(iii) RCS using a modified NIOSH method with monthly collection and analyses by x-ray diffraction.

A nephelometer is a light scattering method, i.e. it uses visual properties of the dust present in the air sample to determine the mass of pollutant present. This is a non-reference method of measurement for particulate matter for the purposes of the NESAQ. The nephelometers used in the Yaldhurst Study were very precise (i.e. fast response time) but not highly accurate (i.e. over-read concentrations by more than 5%). As such, daily values from nephelometers required careful calibration to improve accuracy.

A BAM has equivalency with reference gravimetric methods for measuring particulate matter for the purpose of the NES-AQ. BAMs are, however, slow to respond with reference status only applicable to daily values (i.e. concentrations expressed as a 24-hour average) and not hourly concentrations.

A straight-line correlation $y = 0.8182x + 1.774$ ($R^2 = 0.89$) was determined between PM_{10} measured using a nephelometer and a BAM co-located at a monitoring site located just under 200 metres from the Yaldhurst quarry boundaries (Site 2). This correlation is shown in **Figure B4**.

A straight-line correlation $y = 0.7863x + 2.0298$ ($R^2 = 0.93$) was determined between PM_{10} measured using a nephelometer and a BAM co-located at a monitoring location at the proposed Roydon Quarry site (Site 4, refer Figure1). This correlation is shown in **Figure B5**. These correlated PM_{10} data are hereafter referred to as "BAM-equivalent".

Table B-1 presents summary daily PM_{10} concentrations measured using both BAMs and (BAM-equivalent) nephelometers at Site 2 and Site 4 (proposed Roydon Quarry site) during the Yaldhurst Study. These were calculated using the correlations in Figures B4 and B5.

Table B-2 presents summary daily (BAM-equivalent) PM_{10} concentrations measured using nephelometers around the Yaldhurst quarries in the Yaldhurst Study. The BAM-equivalent data in Table B-2 were calculated using the correlation in Figure B4 (i.e. Site 2 correlation).

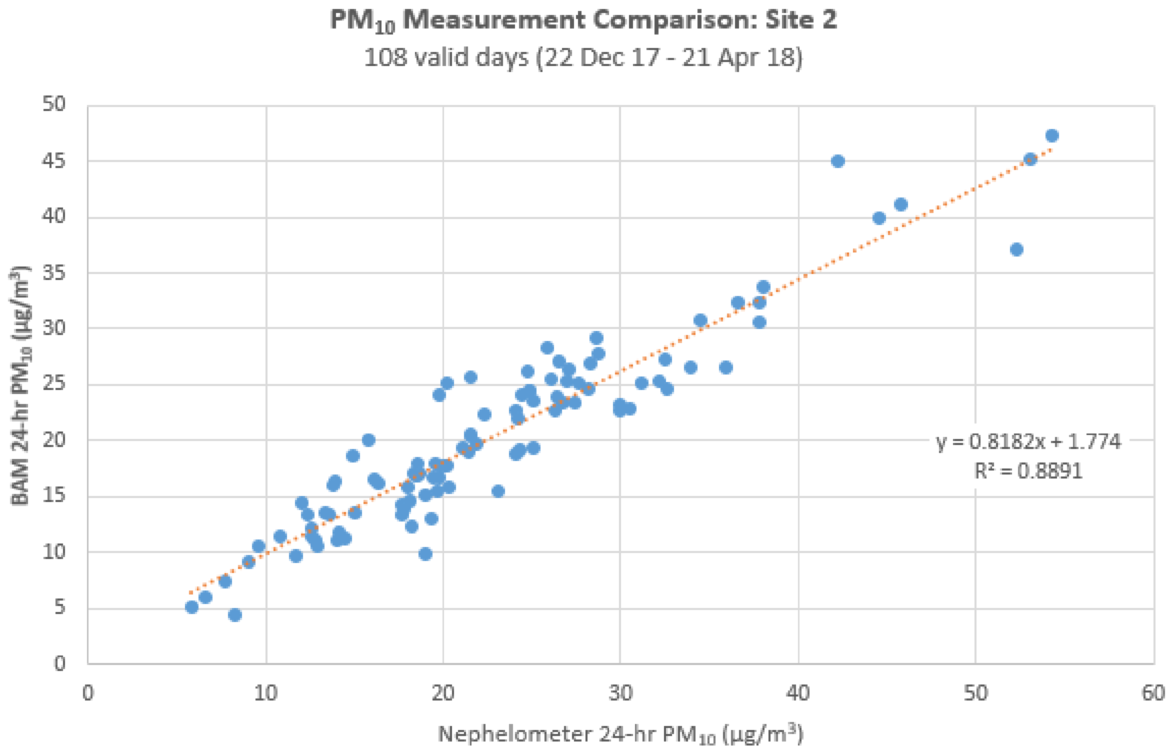

Figure B4. Daily PM_{10} as measured by BAM (x-axis) and nephelometer (y-axis) at Yaldhurst Study Site 2 for period 22 Dec - 21 Apr 2018. [Source: Mote, (2018)]

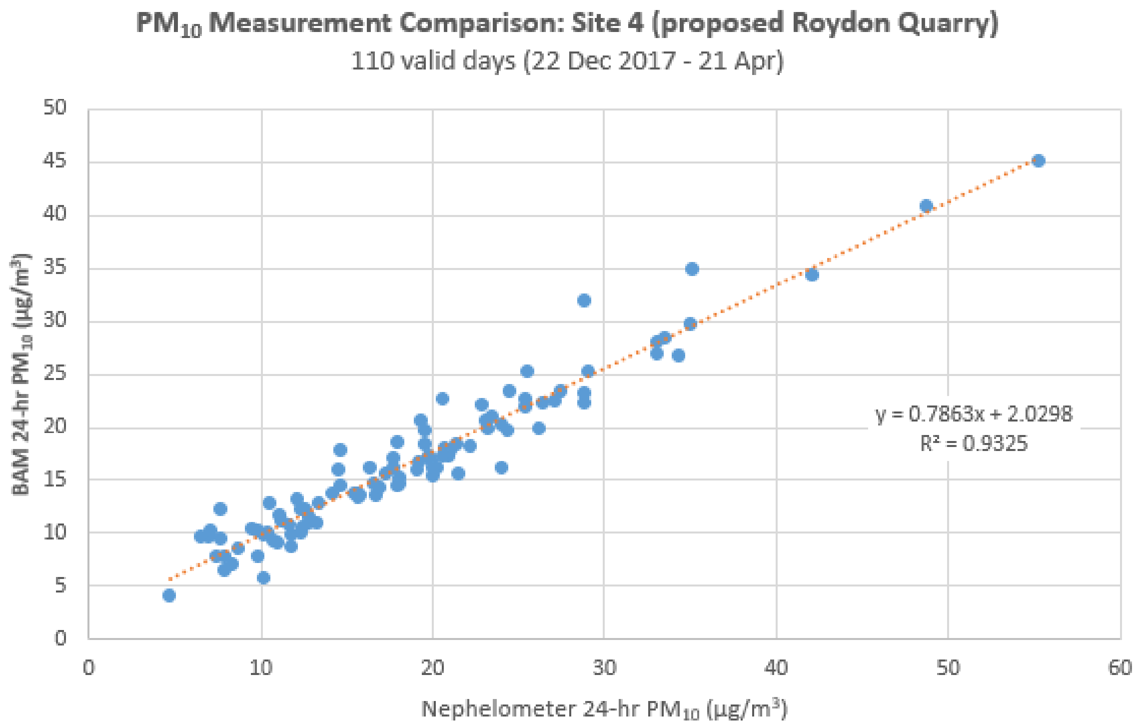

Figure B5. Daily PM_{10} as measured by BAM (x-axis) and nephelometer (y-axis) at Yaldhurst Study Site 4 (Proposed Roydon Quarry Site) for period 22 Dec - 21 Apr 2018. [Source: Mote, (2018)]

Table B-1 Summary daily (BAM and BAM-equivalent) PM_{10} from Yaldhurst Study: 22 Dec 2017 – 21 Apr 2018

Site ID / **Distance from quarries**	Site 2 **150 – 200 m (N)**		Site 4 **5 km (Proposed Roydon Quarry Site)**	
	BAM	**BAM-Equivalent**	**BAM**	**BAM-Equivalent**
	(µg/m³)			
Maximum daily PM_{10}	47	50	**45**	**47**
99%ile daily PM_{10}	45	46	**40**	**44**
95%ile daily PM_{10}	36	36	**29**	**30**
4-month average PM_{10}	21	20	**16**	**17**
STD DEV daily PM_{10}	8	8	**7**	**7**
No. days >50.5 µg/m³	0	0	**0**	**0**

Table B-2 Summary daily (BAM-equivalent) PM_{10} from Yaldhurst Study: 22 Dec 17 – 21 Apr 18

Site ID / **Distance from quarries**	Site 3 **< 100 m (SE)**	Site 5 **< 100 m (SW)**	Site 1 **< 100 m (E)**	Site 6 **150 – 200 m (NW)**
	(µg/m³)			
Maximum daily PM_{10}	54	55	53	47
99%ile daily PM_{10}	53	50	48	44
95%ile daily PM_{10}	44	39	38	35
4-month average PM_{10}	24	23	21	19
STD DEV daily PM_{10}	11	9	9	8
No. days >50.5 µg/m³	5	2	1	0

What is notable, in Table B-1 and Table B-2, are the significant increases in PM_{10} concentrations measured in and around Yaldhurst (Sites 1 – 3 and 5 – 6) compared with those measured at the background (Site 4, proposed Roydon Quarry) site.

B4. Hourly PM_{10}

The Ministry for the Environment suggested trigger threshold for nuisance dust is 150 µg/m^3 as a 1-hour average. **Figure B6** compares maximum hourly PM_{10} measured at the Yaldhurst Study monitoring sites < 100 m from the quarry boundaries with those measured at the proposed Roydon Quarry site (Site 4). **Figure B7** compares maximum hourly PM_{10} measured at the Yaldhurst Study sites 150 - 200 m from the quarry boundaries, with the background (proposed Roydon Quarry) site.

Table B-3 presents summary hourly data for each site. **It is very clear from Table B-3 that maximum hourly levels of PM_{10} measured around Yaldhurst were significantly higher (maximum increase ranged from 47-183 µg/m^3) than those measured at the background site.**

There were 10 exceedances of the suggested trigger threshold throughout the four-month monitoring period. Three of these trigger threshold exceedances coincided with days of exceedance of the NES for PM_{10}. These coincidental exceedances all occurred at a site within 100 m of the quarries (Site 3) on two days as follows:

- 1 February 2018: daily (BAM-equivalent) PM_{10} concentration of 51 µg/m^3 coincided with hourly PM_{10} concentration of 284 µg/m^3 measured between midday and 1 pm.
- 19 April 2018: daily (BAM-equivalent) PM_{10} concentration of 54 µg/m^3 coincided with hourly PM_{10} concentrations of 153 and 156 µg/m^3 measured between 6 am and 8 am.

There were an additional three days when the NES for PM_{10} was exceeded at this monitoring site, but the suggested hourly trigger threshold was not exceeded:

- 9 January 2018: daily BAM-equivalent PM_{10} concentration of 51 µg/m^3 only recorded a maximum PM_{10} hourly concentration of 86 µg/m^3;
- 16 January 2018: daily BAM-equivalent PM_{10} concentration of 54 µg/m^3 only recorded a maximum PM_{10} hourly concentration of 81 µg/m^3; and
- 17 April 2018: daily BAM-equivalent PM_{10} concentration of 53 µg/m^3 only recorded a maximum PM_{10} hourly concentration of 136 µg/m^3.

Similarly, on 5 April 2018 another monitoring site within 100 m of the quarries had a daily BAM-equivalent PM_{10} concentration of 53 µg/m^3 but only recorded a maximum hourly PM_{10} concentration of 86 µg/m^3.

On these four days when the ambient air quality standard for PM_{10} was exceeded, but the trigger threshold was not, it is notable that the hourly concentration was consistently above 50 µg/m^3. This is best illustrated by comparing **Figure B8** (exceedance of both NES for PM_{10} and suggested trigger threshold) with **Figure B9** (exceedance of NES for PM_{10} but no exceedance of suggested trigger threshold).

Also of interest are days when the suggested trigger threshold was exceeded, in some cases by some margin, but the daily NES for PM_{10} was not. An example is shown in **Figure B10**.

Table B-3 Summary hourly (nephelometer) PM_{10} from Yaldhurst Study: 22 Dec 2017 – 21 Apr 2018

Site ID:	Site 3	Site 5	Site 1	Site 2	Site 6	Site 4
Distance from quarries	**< 100 m (SE)**	**< 100 m (SW)**	**< 100 m (E)**	**150 – 200 m (N)**	**150 – 200 m (NW)**	**5 km (Background/ Proposed Site)**
	(µg/m³)					
Maximum hourly PM_{10}	284	205	208	183	147	**99**
99%ile hourly PM_{10}	95	87	73	75	66	**64**
95%ile hourly PM_{10}	65	58	54	55	48	**44**
STD DEV hourly PM_{10}	20	18	16	16	14	**13**
No. hours > 150 µg/m³	7	3	2	1	0	**0**

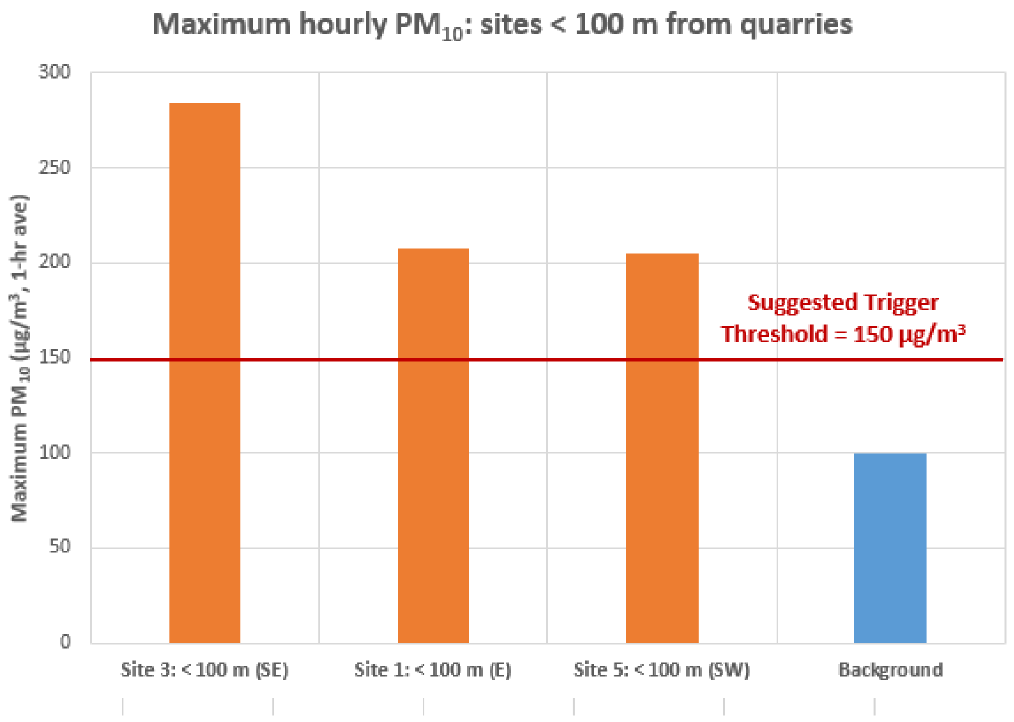

Figure B6. Maximum hourly (nephelometer) PM_{10} measured at sites < 100 m from Yaldhurst quarry boundaries compared with the background (proposed Roydon Quarry) site 22 Dec 2017 – 22 Apr 2018. [Source: Mote, (2018)]

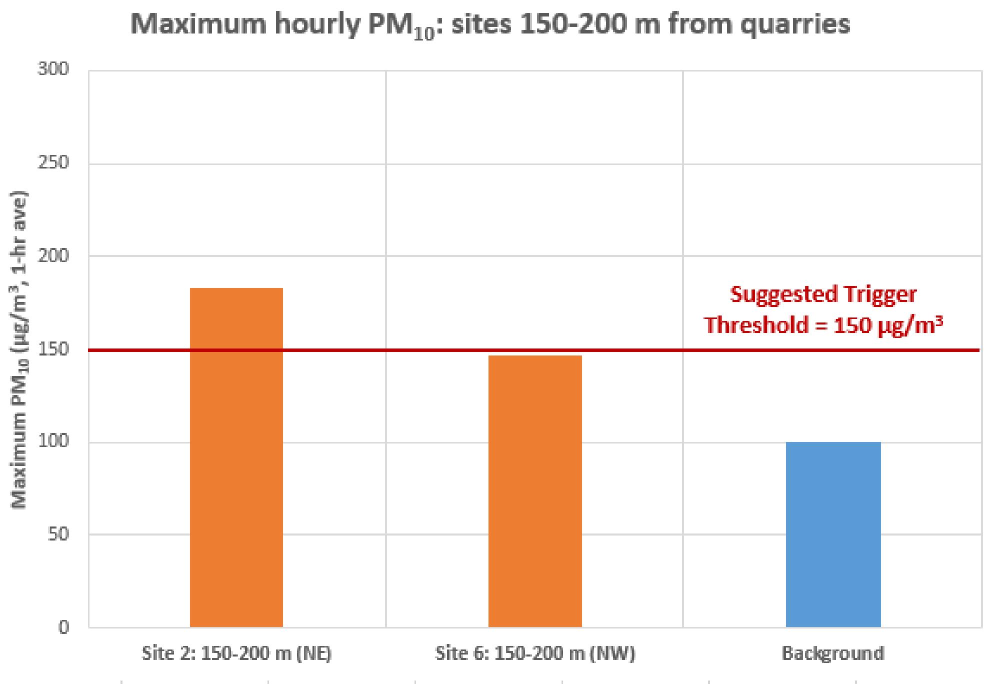

Figure B7. Maximum hourly (nephelometer) PM_{10} measured at sites 150 - 200 m from Yaldhurst quarry boundaries compared with the background (proposed Roydon Quarry) site 22 Dec 2017 – 22 Apr 2018. [Source: Mote, (2018)]

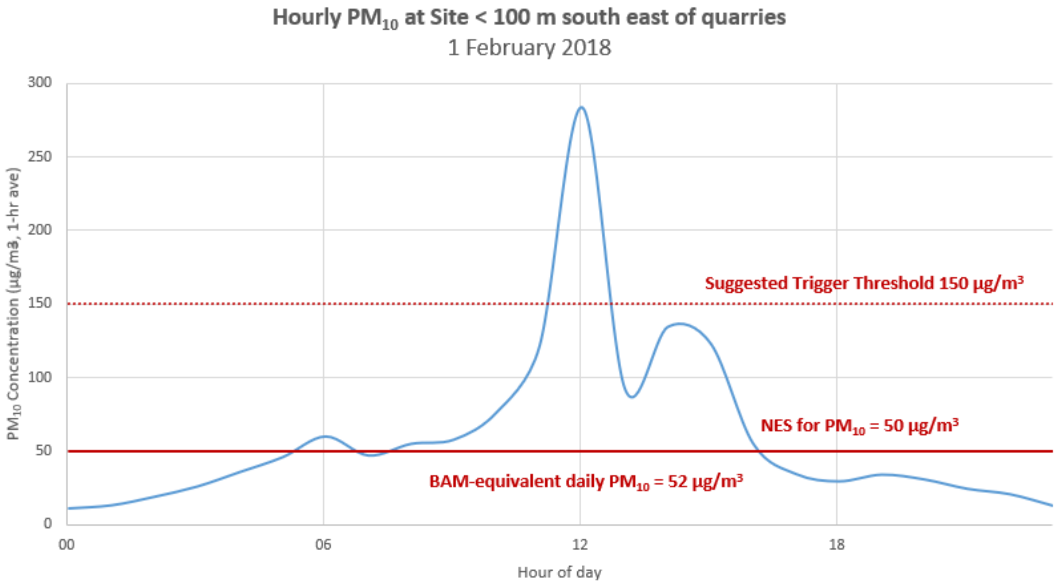

Figure B8. Coincidental exceedances of (hourly) MfE suggested dust nuisance trigger threshold and (daily) NES for PM_{10}. In this example, high hourly concentrations resulted in an elevated daily average. [Source: Mote, (2018)]

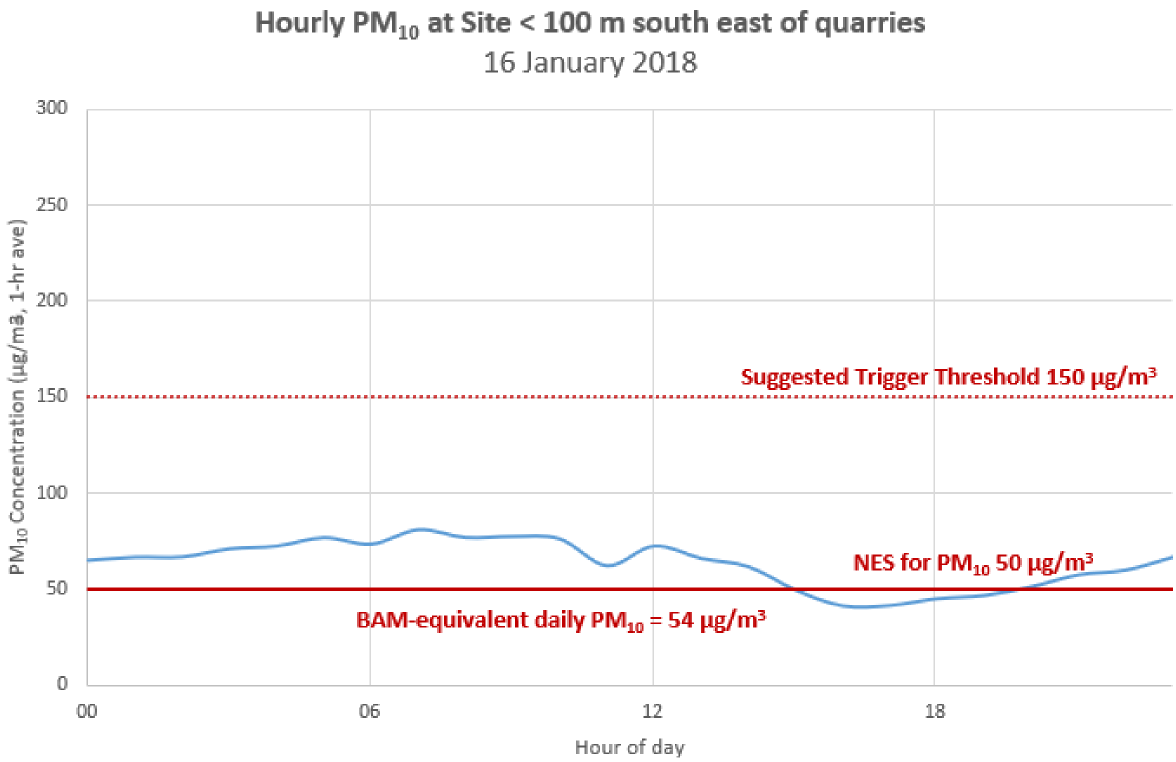

Figure B9. Exceedance of (daily) NES for PM_{10} not coinciding with exceedance of (hourly) MfE suggested dust nuisance trigger threshold. In this example, repeated, moderate hourly concentrations resulted in an elevated daily average. [Source: Mote, (2018)]

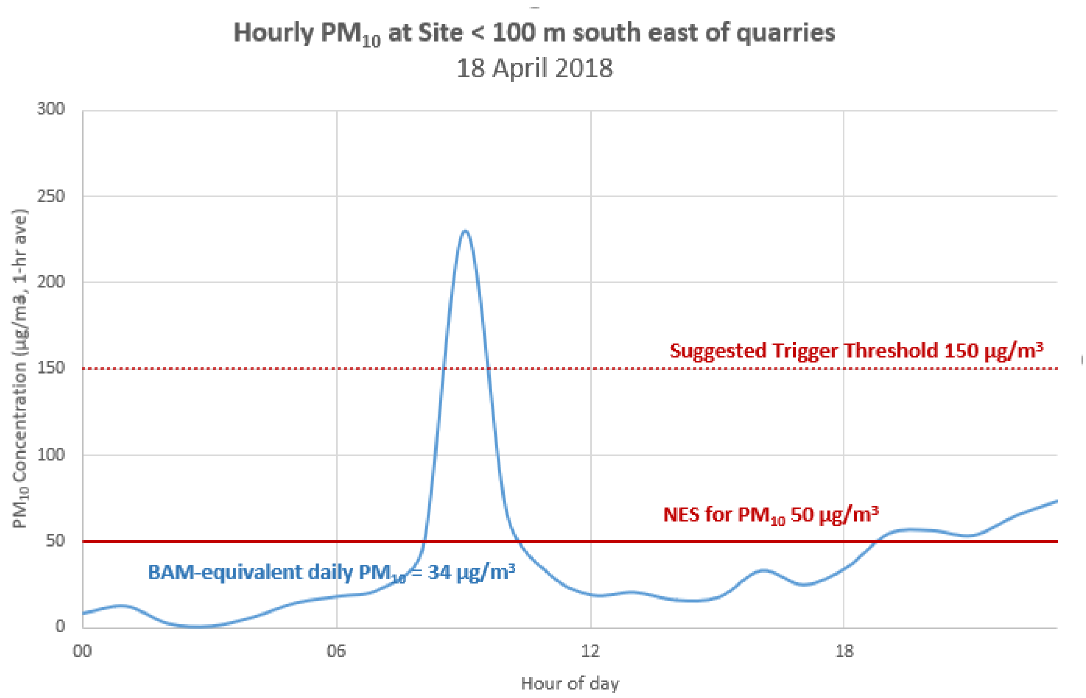

Figure B10. Exceedance of (hourly) MfE suggested dust nuisance trigger threshold not coinciding with exceedance of (daily) NES for PM_{10}. In this example, a few high hourly concentrations did not result in an elevated daily average. [Source: Mote, (2018)]

The focus of my statement is on potential adverse health effects which relate to 24-hour (daily) average concentrations of PM_{10}.

My review of the hourly data suggests that the MfE suggested (hourly) dust nuisance trigger threshold is set too high to be used as a pro-active tool to maintain concentrations below the (daily) NES for PM_{10}. I concur with the proposed lowering of the trigger threshold as suggested by Ms Ryan in the s42A report.

B5. Impact of Yaldhurst Quarries on Daily PM_{10}

The following graphs show how daily BAM-equivalent PM_{10} at each Yaldhurst Study monitoring site compares with daily BAM-equivalent PM_{10} at the background monitoring location (also the proposed site):

- **Figure B11**, daily BAM-equivalent PM_{10} at site (3) <100 m south east of quarries compared with background;
- **Figure B12**, daily BAM-equivalent PM_{10} at site (5) <100 m south west of quarries compared with background;
- **Figure B13** daily BAM-equivalent PM_{10} at site (1) <100 m east of quarries compared with background;
- **Figure B14**, daily BAM-equivalent PM_{10} at site (6) <150-200 m north west of quarries compared with background; and
- **Figure B15**, daily BAM-equivalent PM_{10} at site (2) <150-200 m north east of quarries compared with background.
- **Figure B16** also compares daily PM_{10} measured with a BAM at site (2) <150-200 m north east of quarries, with daily PM_{10} measured with a BAM at the background location (also the proposed site).

Summary statistics for each site are presented below in **Table B-4** (increase in BAM-equivalent PM_{10} above background) and **Table B-5** (decrease in BAM-equivalent PM_{10} from background).

For completeness, **Table B-6** summarises the incremental change in daily PM_{10} measured by the BAM at Site 2 compared with daily PM_{10} measured by the BAM at the background location (proposed Roydon Quarry site).

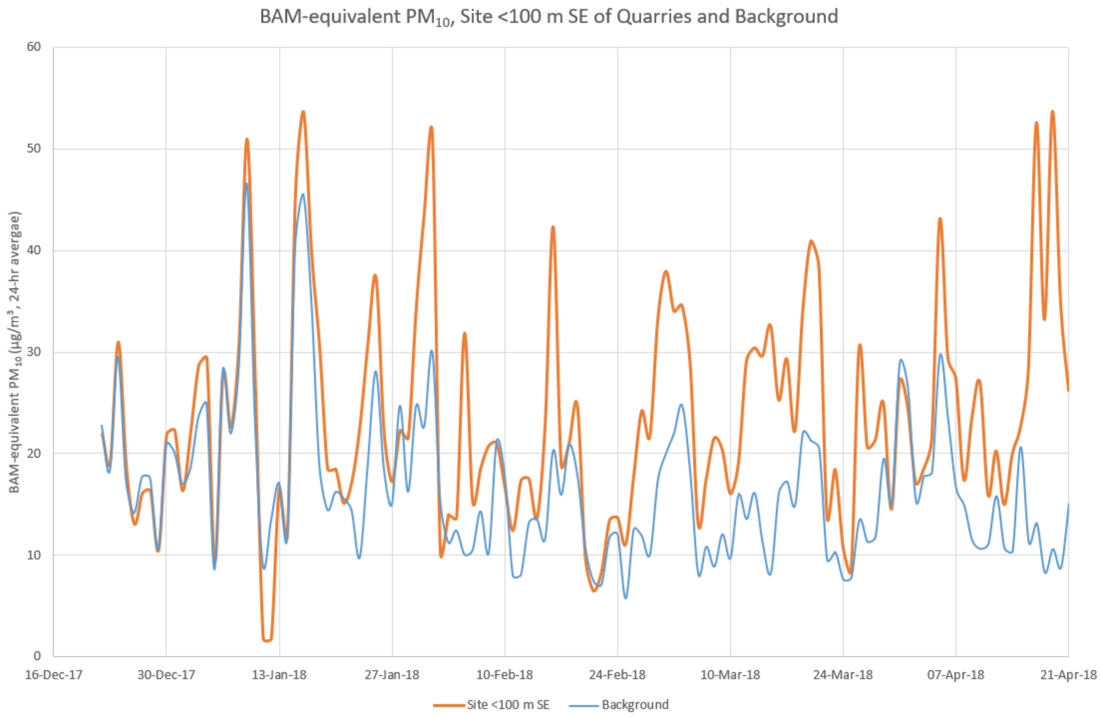

Figure B11. Comparison of daily BAM-equivalent PM_{10} measured at Site <100 m south east of Yaldhurst quarry boundaries (Site 3, orange) with daily BAM-equivalent PM_{10} measured at background monitoring location (Site 4, Proposed Roydon Quarry site, blue) during Yaldhurst Study. [Source: Mote, (2018)]

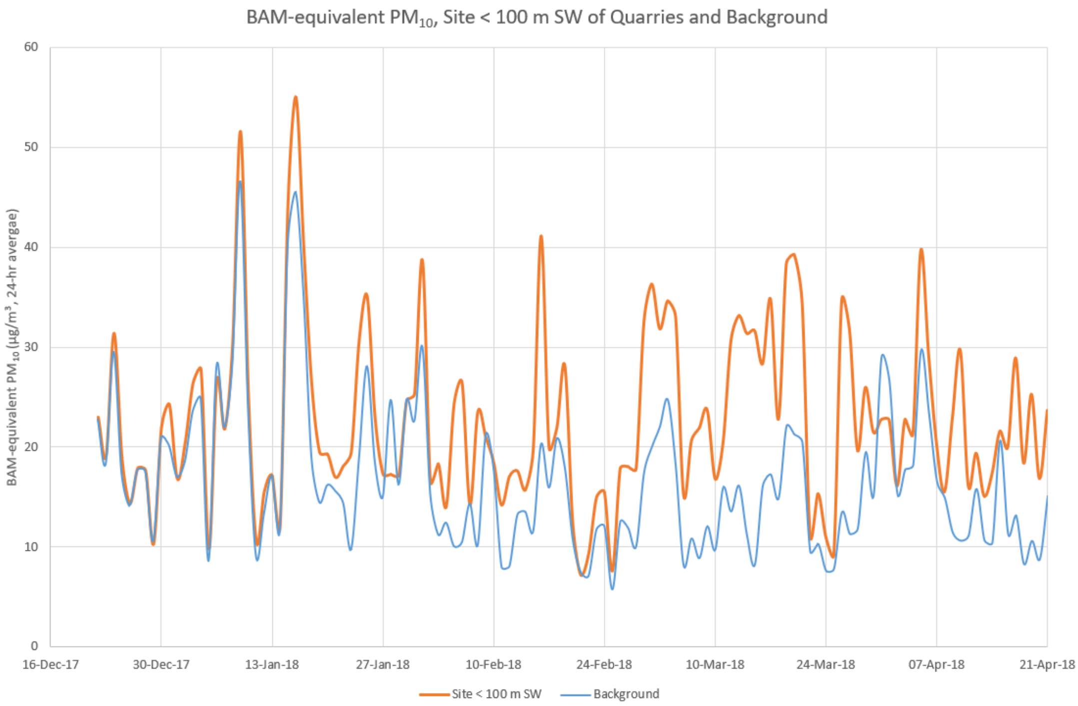

Figure B12. Comparison of daily BAM-equivalent PM_{10} measured at Site <100 m south west of Yaldhurst Quarry boundaries (Site 5, orange) with daily BAM-equivalent PM_{10} measured at background monitoring location (Site 4, Proposed Roydon Quarry site, blue) during Yaldhurst Study. [Source: Mote, (2018)]

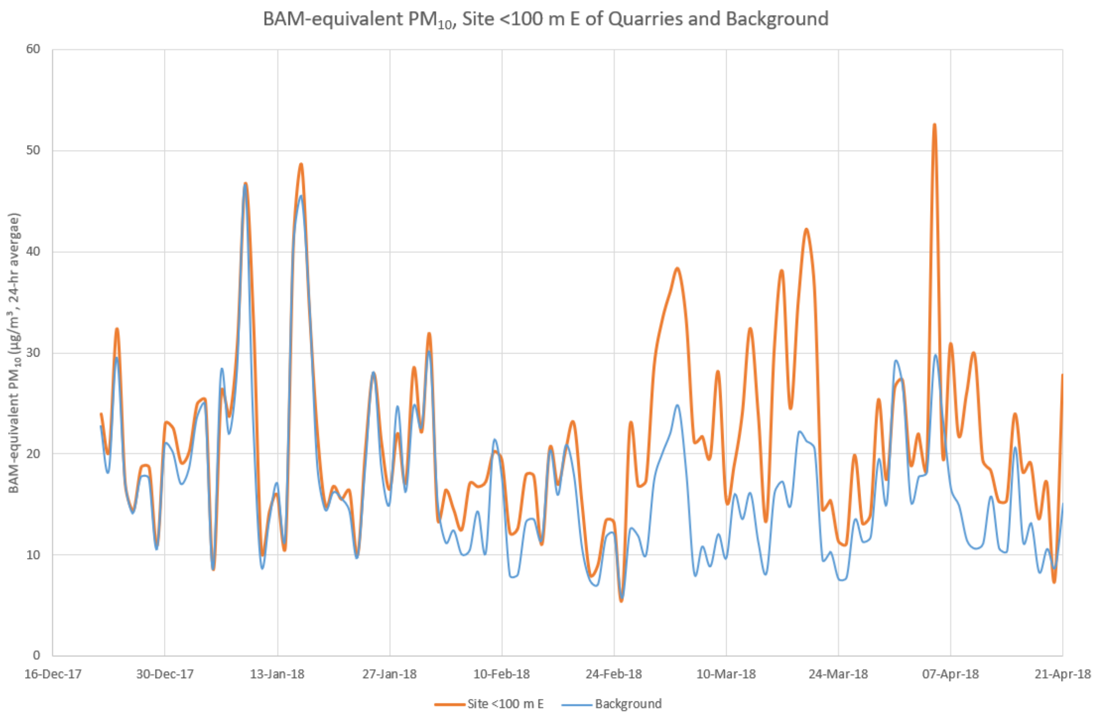

Figure B13. Comparison of daily BAM-equivalent PM_{10} measured at Site <100 m east of Yaldhurst Quarry boundaries (Site 1, orange) with daily BAM-equivalent PM_{10} measured at background monitoring location (Site 4, Proposed Roydon Quarry site, blue) during Yaldhurst Study. [Source: Mote, (2018)]

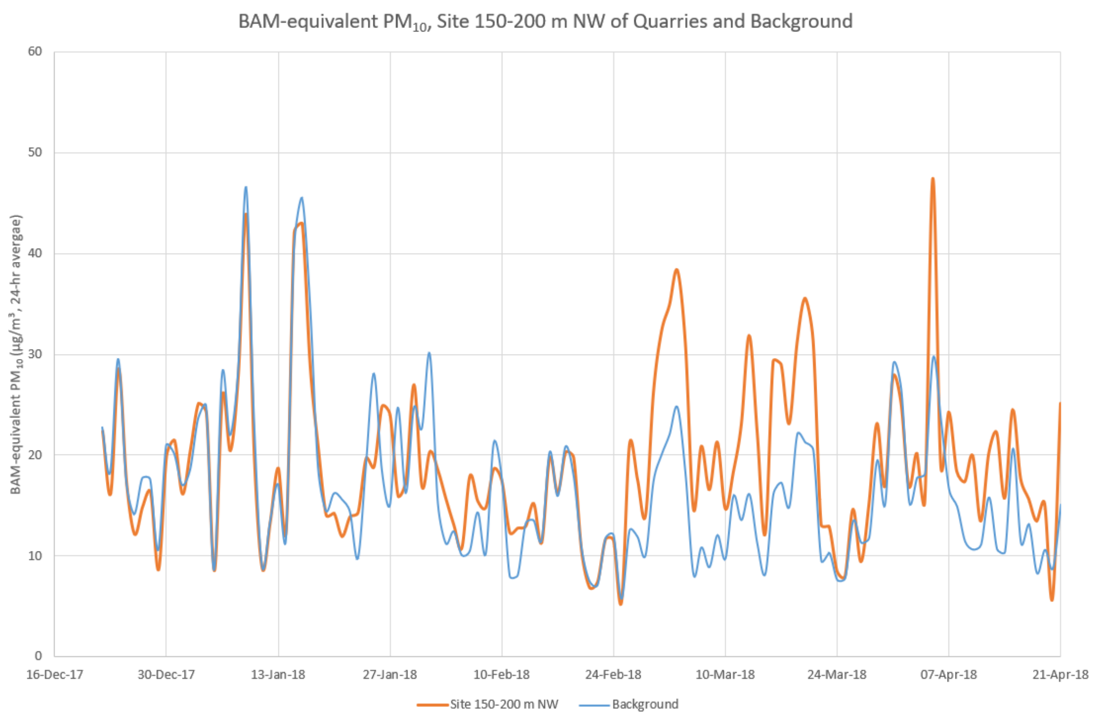

Figure B14. Comparison of daily BAM-equivalent PM_{10} measured at Site 150-200 m north west of Yaldhurst quarry boundaries (Site 6, orange) with daily BAM-equivalent PM_{10} measured at background monitoring location (Site 4, Proposed Roydon Quarry site, blue) during Yaldhurst Study. [Source: Mote, (2018)]

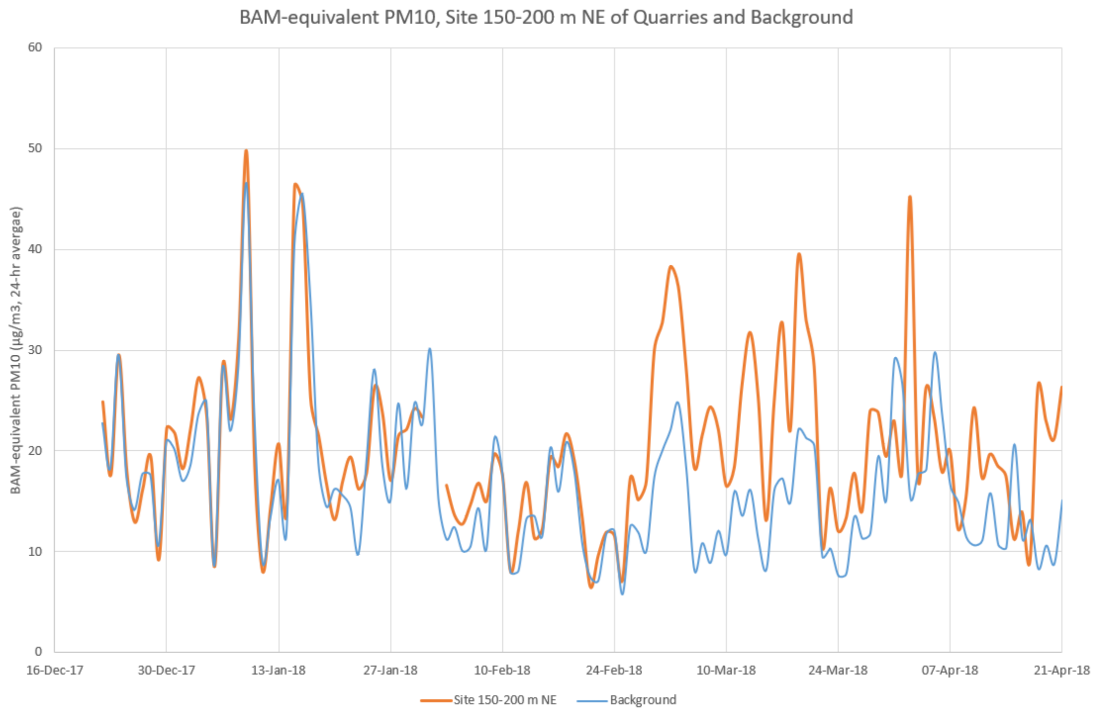

Figure B15. Comparison of daily BAM-equivalent PM_{10} measured at Site 150-200 m north east of Yaldhurst quarry boundaries (Site 2, orange) with daily BAM-equivalent PM_{10} measured at background monitoring location (Site 4, Proposed Roydon Quarry site, blue) during Yaldhurst Study. [Source: Mote, (2018)]

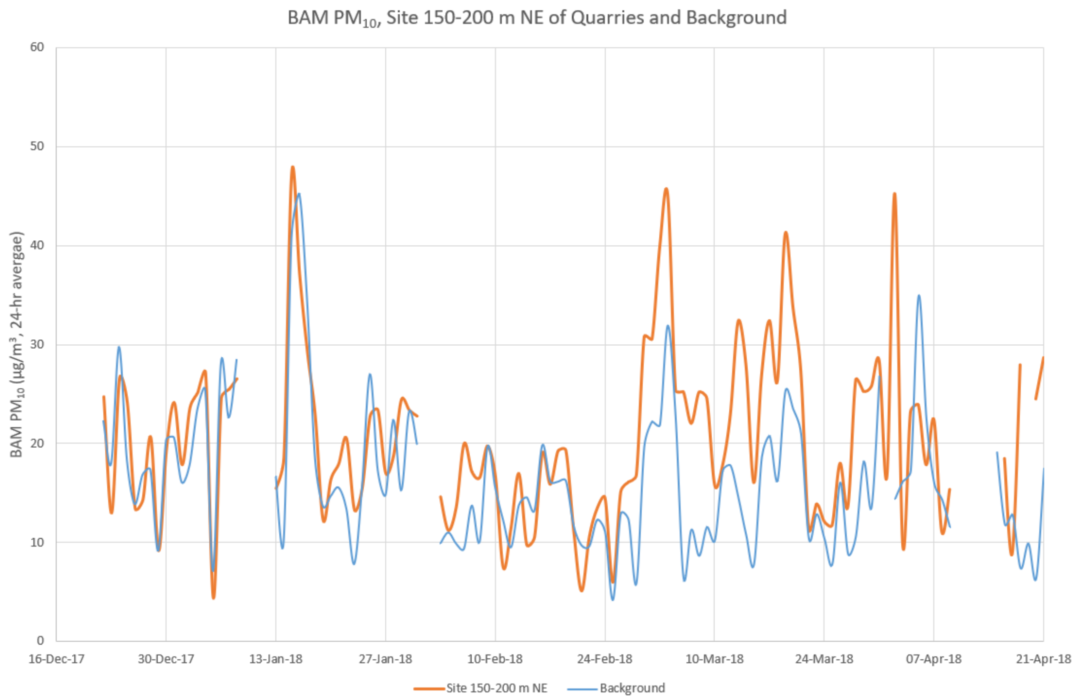

Figure B16. Comparison of daily PM_{10} (BAM) measured at Site 150-200 m north east of Yaldhurst quarry boundaries (Site 2, orange) with daily PM_{10} (BAM) measured at background monitoring location (Site 4, Proposed Roydon Quarry site, blue) during Yaldhurst Study. [Source: Mote, (2018)]

Table B-4 Increase in daily BAM-equivalent PM_{10} as measured at five sites around quarries in Yaldhurst compared with background during Yaldhurst Study

Increase in daily PM_{10} from background	**Site 1 <100m (E)**	**Site 3 <100m (SE)**	**Site 5 <100m (SW)**	**Site 2 150-200m (NE)**	**Site 6 150-200m (NW)**
	(µg/m^3, 24-hour average)				
Maximum	23	43	23	30	18
99th Percentile	21	39	21	19	16
95th Percentile	16	22	19	16	13
Std Dev	5	8	6	5	4
Mean	6	9	7	6	6

Table B-5 Decrease in daily BAM-equivalent PM_{10} as measured at five sites around quarries in Yaldhurst compared with background during Yaldhurst Study

Decrease in daily PM_{10} from background	**Site 1 <100m (E)**	**Site 3 <100m (SE)**	**Site 5 <100m (SW)**	**Site 2 150-200m (NE)**	**Site 6 150-200m (NW)**
	(µg/m^3, 24-hour average)				
Maximum	3	12	7	10	10
99th Percentile	3	11	7	10	9
95th Percentile	3	7	7	9	8
Std Dev	1	3	3	3	2
Mean	1	2	2	3	2

Table B-6 Incremental difference in BAM daily PM_{10} measured at Site (2) 150-200 m north of Yaldhurst quarry boundaries compared with background (Site 4, Roydon Quarry) during Yaldhurst Study

Incremental difference in daily PM_{10} compared with background	**Increase**	**Decrease**
	(µg/m^3, 24-hour average)	
Maximum	31	11
99th Percentile	23	10
95th Percentile	18	8
Std Dev	6	3
Mean	7	3

B6. Wind Direction Analysis

Mr Cudmore has presented daily concentrations of PM_{10} by wind direction. I am concerned that this characterisation is not valid and potentially misleading because wind direction is meaningless as a 24-hour average.

For example, **Figure B17** presents the 1-minute average PM_{10} concentrations on the day that maximum daily PM_{10} (47 µg/m^3) was measured at the Roydon quarry (16 January 2018). Also presented in Figure B17 is the 1-minute average wind direction (measured in Yaldhurst).

Figure B17 shows that whilst the 24-hour average wind direction was north east, the maximum concentrations that contributed to the overall daily concentration of PM_{10} actually occurred between midnight and 6 am when the wind was from the west through north directions. Figure B17 shows that PM_{10} levels *reduced* when the wind shifted towards the north east, even though wind speed during this time picked up (refer **Figure B18**).

NB: The 1-minute PM_{10} data, whilst precise, are indicative only being uncorrected for equivalency and included here for illustrative purposes.

Further, Mr Cudmore has relied on hourly data from the BAM instruments, which are known to be slow to respond to changes in concentrations and are only a reference method for daily time averages. The difference between the hourly BAM data and hourly (uncorrected) nephelometer data is apparent as shown in **Figure B19**.

Table B-7 summarises the frequency of wind directions from the (Golders generated) meteorological dataset prepared for the proposed Roydon Quarry site.

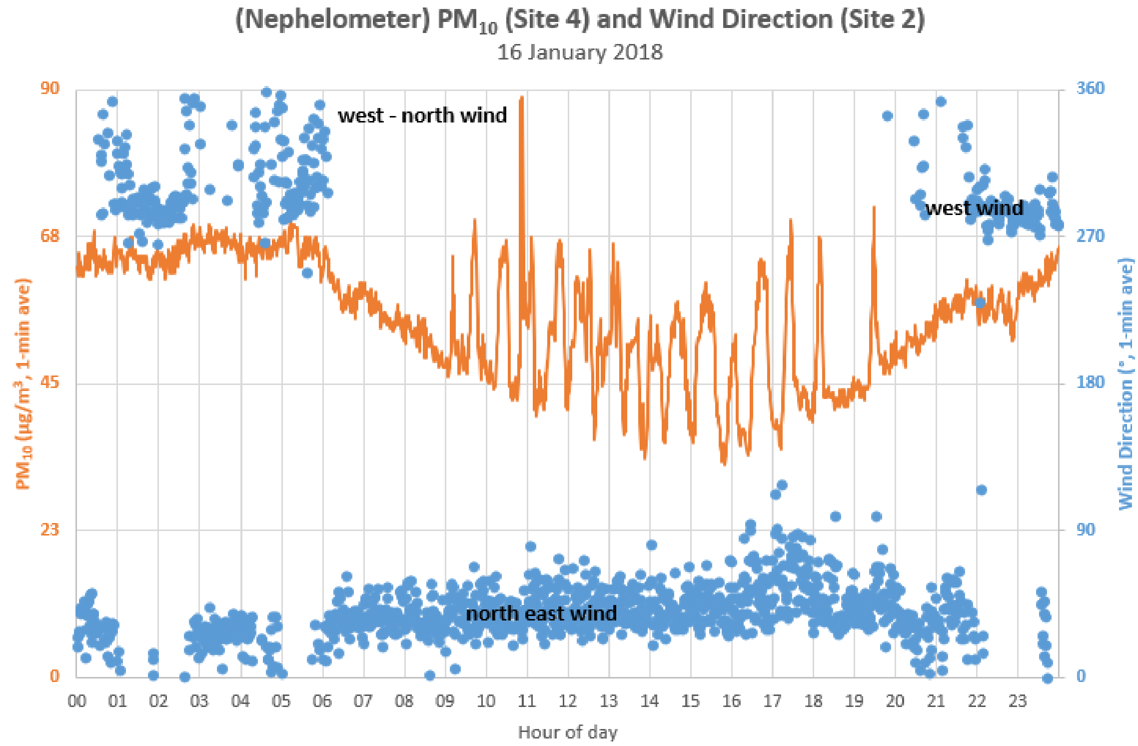

Figure B17. 1-min PM_{10} (measured at Proposed Roydon Quarry site) and 1-min wind direction (measured at site 150-200 m north east of Yaldhurst quarry boundaries, Site 2) on day of maximum daily PM_{10} at proposed Roydon quarry (16 January 2018, daily BAM PM_{10} 47 µg/m³).

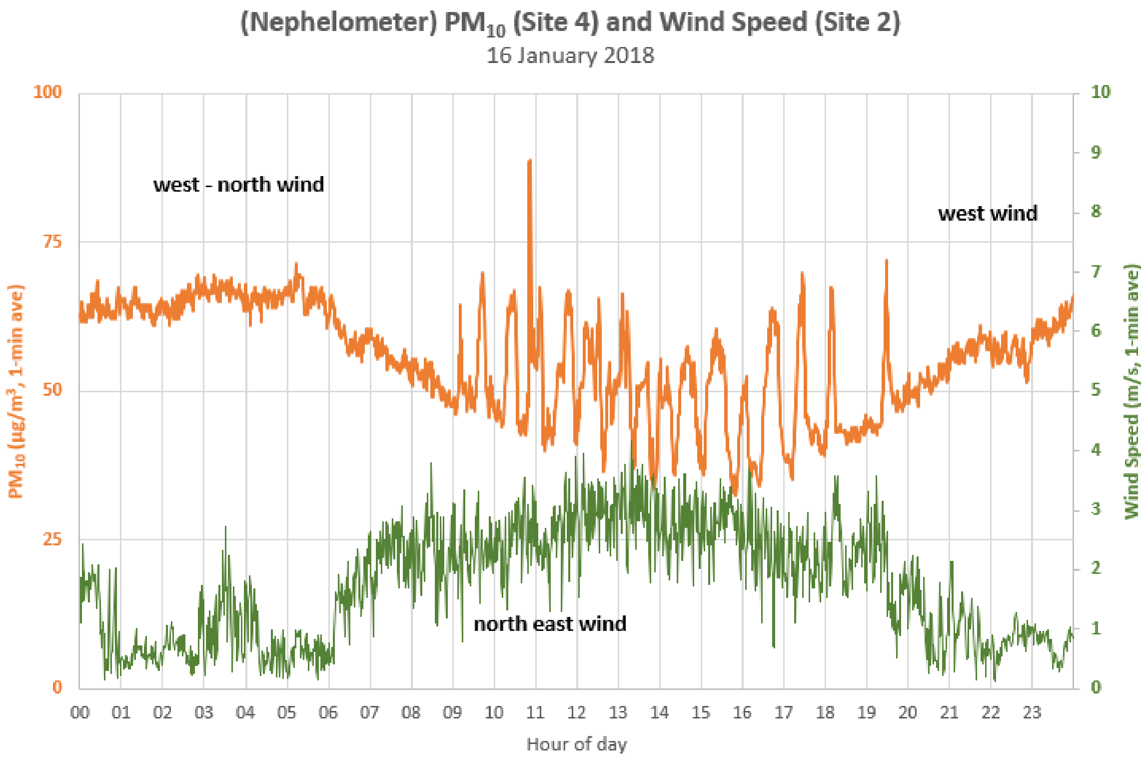

Figure B18. 1-min PM_{10} (measured at Roydon Quarry site) and 1-min wind speed (measured at site 150-200 m north east of Yaldhurst quarry boundaries, Site 2) on day of maximum daily PM_{10} at proposed Roydon quarry (16 January 2018, daily BAM PM_{10} 47 µg/m³).

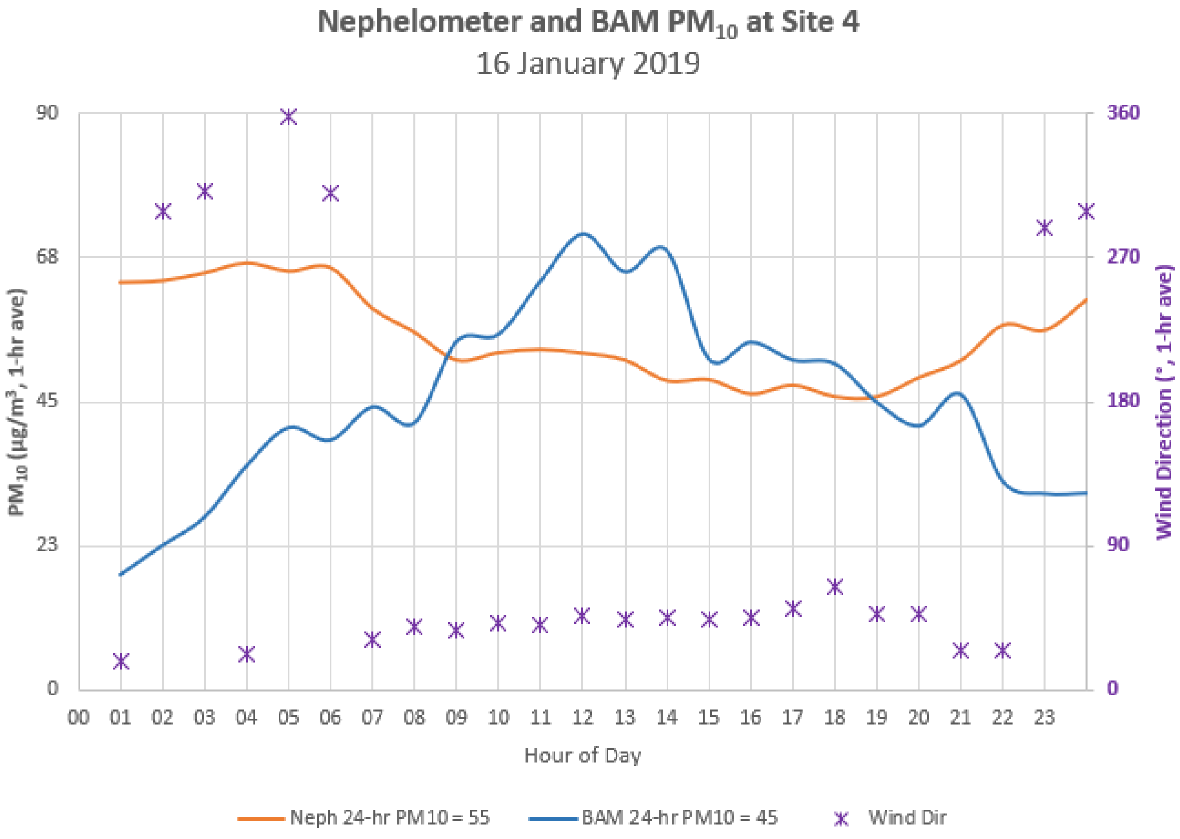

Figure B19. 1-hr average nephelometer PM_{10} (orange line) and BAM PM_{10} (blue line) measured at Roydon Quarry, with 1-hour average wind direction (measured at site 150-200 m north east of Yaldhurst quarry boundaries, Site 2) on day of maximum daily PM_{10} at Roydon quarry (16 January 2018, daily BAM PM_{10} 47 µg/m^3).

Table B-7 Frequency of wind directions predicted for Proposed Roydon Quarry Site in 2006 [Source: Golders]

Wind Direction*		**Frequency (%)**
North	N	8.3
North north east	NNE	11.1
North east	NE	18.8
East north east	ENE	5.6
East	E	1.2
East South east	ESE	1.4
South east	SE	0.9
South south east	SSE	1.9
South	S	6.1
South south west	SSW	7.9
South west	SW	8.3
West south west	WSW	6.9
West	W	3.3
West north west	WNW	4.0
North west	NW	6.1
North north west	NNW	6.2
Calms		2.0
Total		100%

*Winds potentially impacting adjacent Christchurch airshed in grey highlight

B7. Wind Speed Analysis

The applicant has excluded winds less than 7 m/s from their FIDOL assessment in the AEE. This is at odds with data from the Yaldhurst Study that showed that elevated levels of PM_{10} were not correlated well with high wind speeds.

Table B-8 shows the six days when BAM-equivalent exceedances of the NES for PM_{10} were measured and maximum wind speed measured on these days.

Table B-8 Days of Elevated BAM-equivalent PM_{10} and Maximum Measured Wind Speed measured during Yaldhurst Study

Date	**Site 1**	**Site 3**	**Site 5**	**Max Wind Speed**
	PM_{10} (µg/m^3, 24-hr ave)			(m/s)
9 Jan 2018	47	**51**	**52**	2.3
16 Jan 2018	49	**54**	**55**	3.0
1 Feb 2018	32	**51**	39	(4.4)*
5 Apr 2018	**53**	43	40	3.3
17 Apr 2018	19	**53**	29	1.9
19 Apr 2018	17	**54**	25	1.6
NES for PM_{10} = 50 µg/m^3 (24-hr ave)				

* 12 hrs of data only – wind blew down met tower

B8. Transect Analysis

The Yaldhurst Study also employed three transect monitoring locations (Sites 7, 8 and 9) at distances of <100 m, 250 m and 350 m downwind of the nearest site activities for the period 10 February – 21 April 2018. The three additional monitoring locations are shown in **Figure B20**.

Days with less than 75% valid data, or obviously incorrect data (at even one location), were removed from the analysis. There were 68 days of valid data. Daily PM_{10} concentrations at Sites 7 – 9 were corrected to BAM-equivalency using the correlation for Site 2 (refer section B3).

Figure B21 shows how daily BAM-equivalent PM_{10} at each monitoring site compares with daily BAM-equivalent PM_{10} at the background monitoring location (also the proposed Roydon Quarry site)**.**

Table B-9 presents summary statistics for each monitoring site. **Table B-10** presents the <u>increase</u> in BAM-equivalent PM_{10} above background and **Table B-11** presents the <u>decrease</u> in BAM-equivalent PM_{10} compared with background.

Of interest were four days in April 2018 with a clear correlation with daily (BAM-Equivalent) PM_{10} and distance from the quarries. This is shown in **Figure B22**.

Figure B20 Locations of Yaldhurst Study transect monitoring sites

Table B-9 Summary daily BAM-equivalent PM_{10} from Transect Monitoring Locations for period 10 Feb – 21 Apr 2018

Site ID / **Distance from nearest quarry boundary**	Site 3 **<100 m**	Site 7 **<100 m**	Site 8 **250 m**	Site 9 **350 m**	**Site 4 Background**
	(µg/m^3)				
Maximum daily PM_{10}	54	54	52	42	**30**
99%ile daily PM_{10}	53	52	44	40	**26**
95%ile daily PM_{10}	42	49	36	38	**22**
Mean daily PM_{10}	24	27	20	19	**14**
STD DEV daily PM_{10}	10	11	9	9	**5**
No. days >50.5 µg/m^3	2	3	1	0	**0**

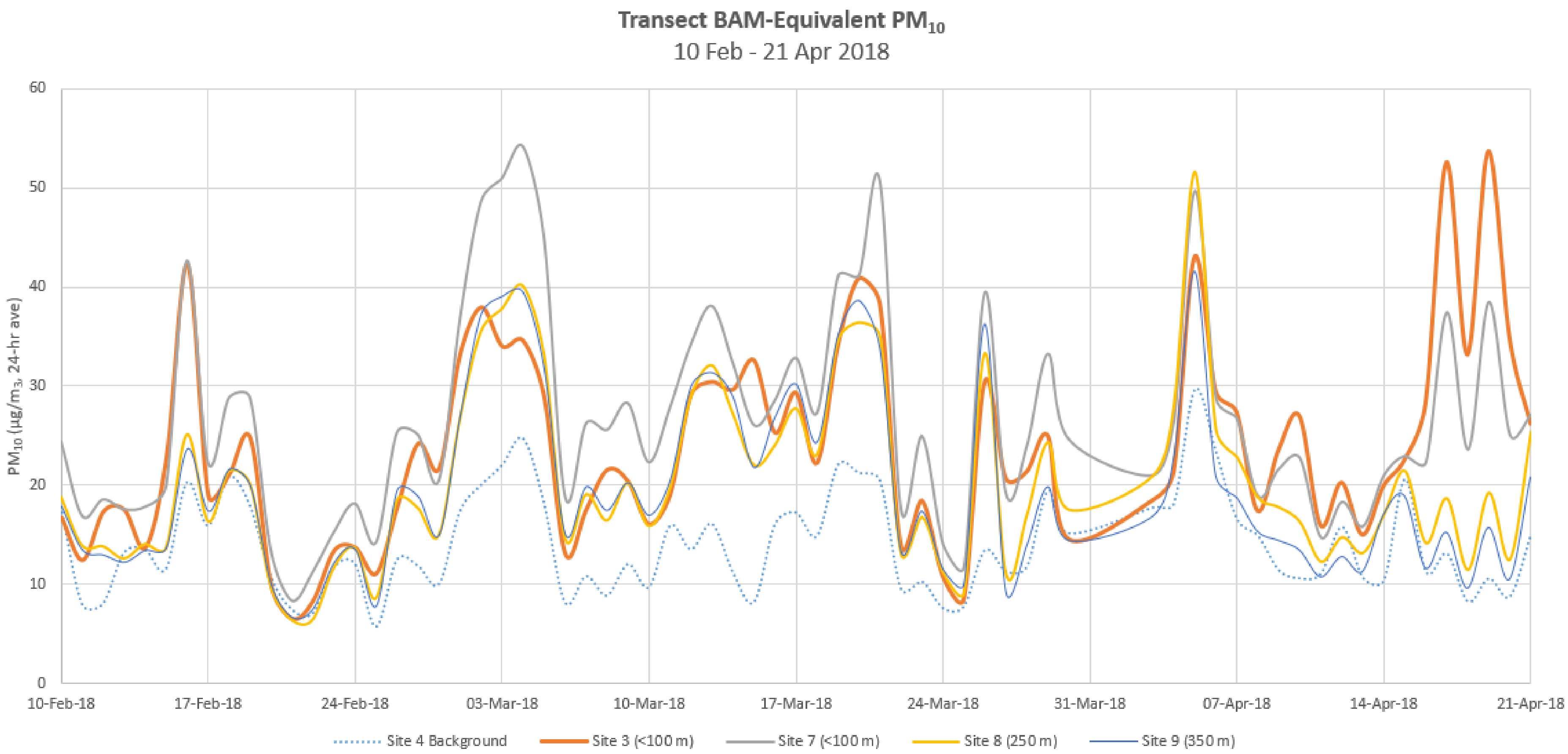

Figure B21 BAM-Equivalent (24-hr) PM_{10} Concentrations Measured at Site 3 (<100 m), Site 7 (<100 m), Site 8 (250 m) and Site 9 (350 m) from nearest site activities as compared with Site 4 (background) 10 Feb – 21 Apr 2018 [Source: Mote, (2018)]

Table B-10 Increase in daily BAM-equivalent PM_{10} as measured at Site 3 and three transects near quarries in Yaldhurst compared with background (10 Feb – 21 Apr 2018)

Increase in daily PM_{10} from background	**Site 3 <100m**	**Site 7 <100 m**	**Site 8 250 m**	**Site 9 350 m**
Maximum	43	30	22	23
99th Percentile	41	30	21	20
95th Percentile	25	28	16	17
Mean	10	13	7	7
Std Dev	9	8	5	6
No. days (n=)	64	68	61	57

Table B-11 Decrease in daily BAM-equivalent PM_{10} as measured at Site 3 and three transects near quarries in Yaldhurst compared with background (10 Feb – 21 Apr 2018)

Decrease in daily PM_{10} from background	**Site 3 <100m**	**Site 7 <100 m**	**Site 8 250 m**	**Site 9 350 m**
Maximum	1	0	1	3
99th Percentile	1	0	1	3
95th Percentile	1	0	1	3
Mean	1	0	1	1
Std Dev	0	0	0	1
No. days (n=)	4	0	7	11

It is clear from Table B-10 and Table B-11 that daily concentrations of PM_{10} measured at the Yaldhurst monitoring locations were significantly elevated compared with background.

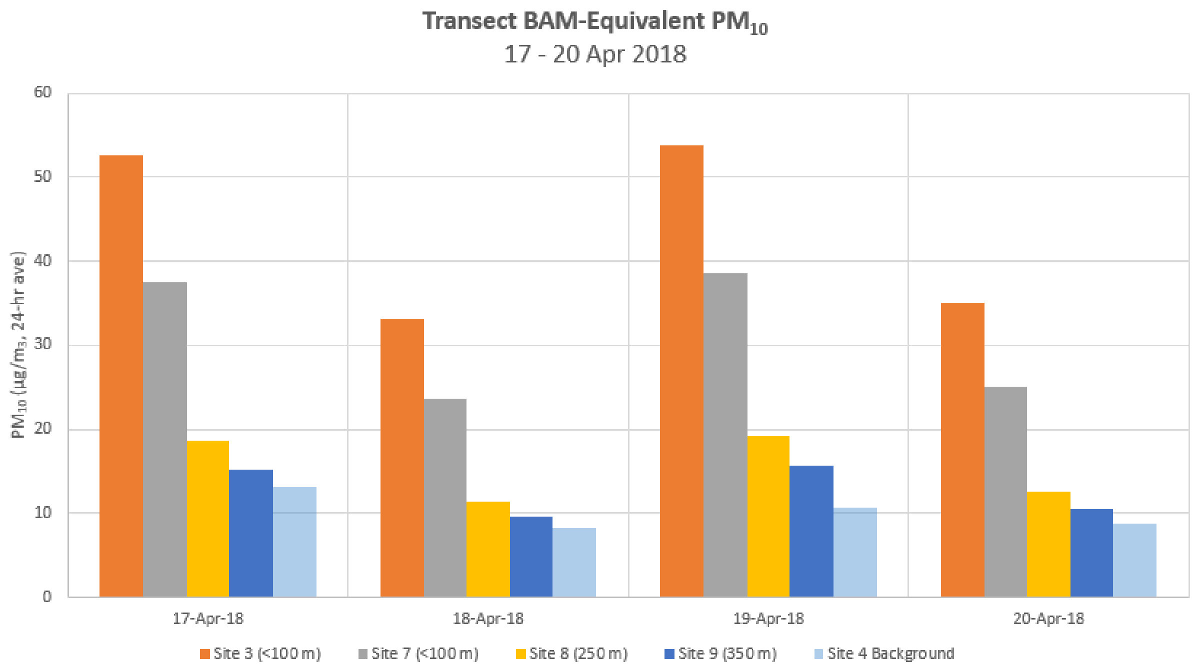

Figure B22 BAM-Equivalent (24-hr) PM_{10} Concentrations Measured at Site 3 (<100 m), Site 7 (<100 m), Site 8 (250 m) and Site 9 (350 m) from nearest site activities as compared with Site 4 (background) 17 – 20 Apr 2018 [Source: Mote, (2018)]

ATTACHMENT C RCS PERSONAL MONITORING

Guideline	PM_{100}	PM_4	RCS*
NZ WES-TWA (8 hr ave)	10,000	3,000	50
NZ WES-TWA/100 (1 hr ave)	100	30	0.5
Aus. WES-TWA (8 hr ave)	-	-	20
Aus. WES-TWA/100 (1 hr ave)	-	-	0.2

Person	Date	Inhalable PM_{100}	Respirable PM_4	RCS (PM_4)	PM_4:PM_{100}	RCS:PM_{100}	RCS:PM_4
		($\mu g/m^3$, **8-hour** average)					
A	Aug-17	270	-	20		7%	
B	Aug-17	263	<21	<3			
C	Aug-17	822	622	9	76%	1%	1%
E	Aug-17	207	<21	20		10%	
F	Aug-17	213	<21	<3			
G	Aug-17	325	26	<3	8%		
H - Control	Aug-17	302	<21	<3			
	LOD	5	21	3			
A	Jan-18	413	204	<3	49%		
C	Jan-18	186	26	<3	14%		
E	Jan-18	95	<21	<3			
	LOD	24	21	3			
A	Mar-18	1,828	169	7	9%	0.4%	4%
B	Mar-18	167	<21	<3			
C	Mar-18	515	73	<3	14%		
E	Mar-18	86	<20	<3			
F	Mar-18	121	<21	<3			
G	Mar-18	4,809	258	13	5%	0.3%	5%
H - Control	Mar-18	142	<21	<3			
	LOD	47	21	3			
	n =	17	7	**5**	7	**5**	**3**
	min	5	21	3	5%	0%	1%
	max	4,809	622	20	76%	10%	5%
	mean	568	158	11	25%	4%	4%
	geo mean	217	79	8	16%	2%	3%
	STDEV	1105	196	7	27%	4%	2%
	95%ile	2126	476	20	68%	9%	5%

* Proposed (Worksafe, 2019)

What the data show: Inhalable particulate (PM_{100})

- Personal monitoring for 6 Yaldhurst residents in August 2017 found inhalable particulate ranged from 213 - 822 μg/m^3 as an 8-hour average
- Following a house clean, follow-up personal monitoring in January 2018 for 3 residents found inhalable particulate levels of 95, 186 and 413 μg/m^3 as an 8-hour average
- Personal monitoring for 7 residents in March 2018 found inhalable particulate ranged from 86 - 4,809 μg/m^3 as an 8-hour average

What the data show: Respirable particulate (PM_4)

- Personal monitoring for 7 residents in August 2017 found respirable particulate ranged from below detection (<21) - 622 μg/m^3 as an 8-hour average
- Following a house clean, follow-up personal monitoring in January 2018 for 3 residents found respirable particulate levels below detection (<21), 26 and 204 μg/m^3 as an 8-hour average
- Personal monitoring for 7 residents in March 2018 found respirable particulate ranged from below detection (<21) at four locations and 73, 169 and 258 μg/m^3 as an 8-hour average at the remaining three locations

What the data show: RCS (PM_4)

- Personal monitoring in August 2017 detected RCS for 3 out of 6 Yaldhurst residents
    - The 8-hour RCS for the 3 residents was 9, 20 and 20 μg/m^3
    - A 7th background (control) resident in another location had no detected RCS
- Following a house clean, follow-up personal monitoring in January 2018 did not detect RCS for the 3 residents who had previously detected RCS
- Subsequent personal monitoring in March 2018 detected RCS for 2 out of 6 Yaldhurst residents
    - The 8-hour RCS for one residents (cleaned) house was 7 μg/m^3
    - The 8-hour RCS for another resident (who previously did not detect RCS) was 13 μg/m^3
    - A 7th background (control) resident in another location had no detected RCS
- The 8-hour RCS detection limit was 3 μg/m^3

ATTACHMENT D INDICATIVE PM_{10} EMISSIONS CALCULATIONS

The following estimates are based on US EPA AP-42 emission factors. NB: calculations exclude bund formation, formation/duration of all stockpiles, and all truck movement (up to 1,500/day) on sealed roads onsite. It may be considered an indicative, order of magnitude (but not conservative) estimate.

1.0 Site Preparation					
1.1 Topsoil removal	377	kg			
1.2 Loading of topsoil	69	kg			
1.3 Dumping of topsoil	69	kg			
2.0 Wind erosion					
2.1 Dust pickup	2,210	kg/yr			
3.0 Gravel loading/unloading					
3.1 Loading of gravel into trucks	71	kg/yr			
3.2 Unload of gravel from trucks	71	kg/yr			
4.0 Gravel processing					
4.1 Crushing (controlled)	108	kg/yr			
4.2 Screening (controlled)	148	kg/yr			
4.3 Conveyor transfers	2200	kg/yr			
4.4 Truck loading - conveyor crushed	20	kg/yr			
5.0 Trucks					
5.1 Trucks - first year only	1,400	kg/yr			
				cf:	
Total PM_{10} (first year)	**6.7**	**T/yr**	0.3%	*2,076*	*National construction dust (T/yr) (EIL, 2018)*
			1.2%	*550*	*Chch industrial inventory (T/yr)*
5.1 Trucks - subsequent years	3,499	kg/yr			
Total PM_{10} (subsequent years)	**8.3**	**T/yr**	0.4%		
			1.5%		

1.0 Site Preparation

1.1 Topsoil removal by scraper

	TSP	0.029	kg/Mg	AP-42 Table 11.9-4
	PM_{30}	0.029	kg/Mg	
	Assume	0.5	m deep	The gravel is overlain by a shallow layer of superficial soils, typically in the vicinity of 0.5 to 1.0 m depth (Golders, 2018). At section 3.5. Page 9.
First stage only		26	ha	
		260,000	m^2	
Topsoil to remove		130,000	m^3	
	Assume	1	Mg/m^3	
		130,000	Mg	
	PM_{30}	3,770	kg	
	Assume PM_{10}	10%	PM_{30}	
	PM_{10}	**377**	**kg**	

1.2 Loading of excavated material into trucks

Topsoil to load		130,000	Mg			
	PM_{10}	$k \times 0.0016 \times (U/2.2)^{1.2} / (M/2)^{1.4}$			kg/Mg	AP42 Section 13.2 Aggregate Handling
	k	0.35	AP42			
	U	mean wind speed				
	U	3.9	m/s	Annual average Golders met set		
	M	3.4	%	AP-42 Table 13.2.4-1 (exposed ground)		
	PM_{10}	0.00056	1.987789	2.10198	kg	
		0.00053	kg/Mg			
	PM_{10}	**69**	**kg**			

1.3 Truck dumping of topsoil

PM_{10}	$k \times 0.0016 \times (U/2.2)^{1.2} / (M/2)^{1.4}$		kg/Mg	AP42 Section 13.2 Aggregate Handling
PM_{10}	**69**	**kg**		

2.0 Wind erosion of exposed areas

2.1 Dust pickup

TSP	0.85	Mg/ha/yr	AP-42 Table 11.9-4
	26	ha	
	22.1	T/yr	
Assume PM_{10}	10%	PM_{30}	
PM_{10}	**2,210**	**kg/yr**	

3.0 Gravel loading/unloading

3.1 Loading of gravel into trucks

PM_{10}	$k \times 0.0016 \times (U/2.2)^{1.2} / (M/2)^{1.4}$		
k	0.35		AP42 13.2.4.1
U	mean wind speed		
U	3.9	m/s	Annual average Golders met set
M	7.4	%	Table 13.2.4-1 (sand)
PM_{10}	0.00056	1.987789	6.244281
	0.00018	kg/Mg	
	400,000	Mg/year	
PM_{10}	**71**	**kg/year**	

3.2 Unloading of gravel into trucks

PM_{10}	**71**	**kg/year**

4.0 Gravel processing

4.1 Crushing (controlled)

PM_{10}	0.00027	kg/Mg	AP-42 11.19.2
	400,000	Mg/year	
PM_{10}	**108**	**kg/year**	

4.2 Screening (controlled)

PM_{10}	0.00037	kg/Mg	AP-42 11.19.2
	400,000	Mg/year	
PM_{10}	**148**	**kg/year**	

4.3 Conveyor transfer points

PM_{10}	0.00055	kg/Mg	AP-42 11.19.2
Assume	10	transfer points	
	400,000	Mg/year	
PM_{10}	**2,200**	**kg/year**	

4.4 Truck loading - conveyor crushed

PM_{10}	0.00005	kg/Mg	AP-42 11.19.2
	400,000	Mg/year	
PM_{10}	**20**	**kg/year**	

5.0 Trucks on unsealed areas of site

5.1 Trucks - first year only

Assume 26 ha (open ground) excavated to 0.5 m

Topsoil to remove	130,000	m^3	
Truck capacity	5	m^3	
No. trucks	26,000	trucks/yr	

Assume these trucks travel 500 m each way over unsealed ground with watering @ 70% efficient emissions reduction

PM_{10}	$k \times (s/12)^a (W/3)^b$		lb/VMT
1 lb/VMT	281.9	g/VKT	
k	1.5	AP-42 Table 13.2.2-2	
a	0.9	AP-42 Table 13.2.2-2	
b	0.45	AP-42 Table 13.2.2-2	
s	Silt content		
s	4.8	AP-42 Table 13.2.2-1 Plant road, gravel processing	
W	mean vehicle weight (tons)		
W	5.0	tons	
Assume	5.5	tonnes	assumed average between empty (3) and full (8)
PM_{10}	0.8	lb/VMT	
	233	g/VKT	
	0.23	kg/VKT	
Assume each truck	1000	m travelled on unsealed ground on site (i.e. 500 m one way and 500 m back)	
	20,000	trucks/yr	
PM_{10}	4666	kg/yr	
Watering control reduction	70%		
PM_{10}	**1,400**	**kg/yr**	

5.1 Trucks - subsequent years

Trucks to mobile crushing site

Gravel to move	250,000	m^3
Truck capacity	5	m^3
No. trucks	50,000	trucks/yr

Assume these trucks travel 500 m each way over unsealed ground with watering @ 70% effective emissions reduction

PM_{10}	$k \times (s/12)^a (W/3)^b$		lb/VMT
1 lb/VMT	281.9	g/VKT	
k	1.5	AP-42 Table 13.2.2-2	
a	0.9	AP-42 Table 13.2.2-2	
b	0.45	AP-42 Table 13.2.2-2	
s	Silt content		
s	4.8	AP-42 Table 13.2.2-1 Plant road, gravel processing	
W	mean vehicle weight (tons)		

W	5.0	tons	
Assume	5.5	tonnes	assumed average between empty (3) and full (8)
PM_{10}	0.8	lb/VMT	
	233	g/VKT	
	0.23	kg/VKT	
Assume each truck	1,000	m travelled on unsealed ground on site (i.e. 500 m one way and 500 m back)	
	50,000	trucks/yr	
PM_{10}	11,664	kg/yr	
Watering control reduction	70%		
PM_{10}	**3,499**	**kg/yr**	