Before Independent Commissioners Appointed by the Canterbury Regional Council and Selwyn District Council

In the matter of	The Resource Management Act 1991
And	
In the matter of	Applications by **Fulton Hogan Limited** for all resource consents necessary to establish, operate, maintain and close an aggregate quarry (**Roydon Quarry**) between Curraghs, Dawsons, Maddisons and Jones Roads, Templeton

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SUPPLEMENTARY REBUTTAL EVIDENCE OF ROGER STEVEN CUDMORE ON BEHALF OF FULTON HOGAN LIMITED

AIR QUALITY – LOUISE WICKHAM EVIDENCE

DATED: 6 NOVEMBER 2019

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Introduction

1. My full name is Roger Steven Cudmore. I am a Principal of Golder Associates (NZ) Limited (Golder) and am the National Technical Leader for Golder's Environmental Services.

2. I have previously provided a written brief of evidence in relation to the Roydon Quarry Proposal ('the Proposal'). That evidence is dated 23 September 2019. I confirm my qualifications and experience as set out in paragraphs 4 to 8 of that evidence.

3. I have also previously provided rebuttal evidence dated 21 October 2019 addressing the evidence of the following witnesses:

   (a) Mr Charles Kirkby

   (b) Rhys Boswell

   (c) Devin Westley

   (d) Gareth James Mitchell

   (e) Brian John Reddington

   (f) Jane Caroline Cartwright

4. I confirm I have read and agree to comply with those parts of the Environment Court Practice Note that bear on my role as an expert witness, in accordance with paragraphs 4 to 8 of my earlier evidence.

Scope

5. In this rebuttal evidence I address the evidence of Ms Louise Wickham on behalf of the Canterbury District Health Board.

6. I identify and expand on areas of disagreement between us. I will also identify matters not discussed in my primary evidence, but which are raised by Ms Wickham and with which I agree.

Ms Wickham's Evidence

7. I provide a summary of the key positions/points of view presented in Ms Wickham's evidence regarding; the potential air quality effects of the Proposal, the supporting assessment of air quality effects prepared by

Golder, and my own evidence on this matter. Subsequent to this, I provide my general responses to Ms Wickham's criticisms and concerns.

8. Ms Wickham's evidence (Executive Summary, Para 3) agrees with my evidence that the proposed emission controls represent best practice and will significantly mitigate the potential impacts of discharges to air. She also states that the proposed quarry is unlikely to present significant health issues at the Templeton township. I would go further and state the Proposal is likely to present negligible health issues for residents of Templeton. On all other aspects Ms Wickham disagrees with my evidence on the air quality effects of the Proposal.

9. Ms Wickham's evidence (Executive Summary, Para 4) disagrees with my own finding that the Proposal is likely to comply with the National Environmental Standards for Air Quality (NESAQ) for PM_{10} (i.e. 50 $\mu g/m^3$ 24 hour average, only to be exceeded once per year). I do not accept Ms Wickham's reasons for this view and will discuss this later in this evidence.

10. Ms Wickham also disagrees with my finding that the Proposal can meet the requirements of the "significance test" under Regulation 17 of the NESAQ for new air discharges adjacent to polluted airsheds (i.e. increase in PM_{10} of 2.5 $\mu g/m^3$ 24 hour average anywhere in a polluted airshed). I do not accept Ms Wickham's reasons for this, which I will also discuss later (and which is discussed to some extent in paragraphs 10 to 18 of my rebuttal evidence dated 21 October 2019, in response to Mr Kirkby and others evidence).

11. In paragraph 79, Ms Wickham concludes that annual exposure levels of respirable crystalline silica (RCS) in Yaldhurst should be below relevant health guideline criteria, but short-term levels may be elevated in some Yaldhurst locations compared with background. In my view, her evidence on this point does not form a basis for recommending continuous monitoring of RCS at the boundary of the proposed Roydon quarry. Furthermore, I consider any potential increase in RCS due to the Proposal will be of negligible effect. I will discuss Ms Wickham's assessment of the Yaldhurst study in regard to RCS exposures later in this evidence.

12. In paragraph 109 of Ms Wickham's evidence there are recommendations for monitoring of ambient effects of the Proposal. In my opinion many of these recommended monitoring measures would be met by Conditions 4, 5, 9(x), 20, 21, and 22 as proposed by the Applicant.

13. However, the recommendations for a substantial amount of long term and short-term RCS monitoring that are listed in Paragraphs 109 (iv), 109 (viii), and 109 (ix) of Ms Wickham's evidence are not necessary in my view. The results of the Yaldhurst and related RCS exposure studies do not justify this onerous monitoring for the proposed Roydon quarry, which is likely to cause significantly lower levels of ambient RCS than that measured downwind of the Yaldhurst quarries.

14. Paragraph 108 (i) and 109 (ii) of Ms Wickham's evidence respectively recommend dust and wind speed trigger levels that are far more stringent than those proposed by the Applicant, in conditions 24 and 23 respectively. In my view, these lower threshold levels are not supported by robust science.

15. I consider the approach/rationale used by Ms Wickham to justify the lower ambient PM_{10} trigger limit of 60 to 65 μg/m^3 (1 hour) is not logical. The background levels at the proposed Roydon quarry can be this high (see Figure 9, Golder (2018). The trigger limit is not related to NESAQ compliance but instead dust nuisance, and the location of monitoring is not where the NESAQ is relevant to apply.

Quantification and Dispersion Modelling

16. Ms Wickham's evidence criticises the assessment of air quality effects prepared by Golder (2018).[1] In paragraph 6, Executive Summary, of her evidence, it is concluded that the Applicant's approach for assessing PM_{10} effects was inadequate and inaccurate. The reasons given for this view are summarised in paragraph 6(i) and 6(ii) of Ms Wickham's evidence. It is apparent Ms Wickham considers a modelling-based assessment should have been undertaken. Ms Wickham contends that no quarry has been proposed adjacent to a polluted airshed and that there is now sufficient monitoring data available to enable a calibration of dispersion modelling of existing sources to validate particulate emissions factors. Both these statements are incorrect in my view.

17. There is to date, no publicly available data in New Zealand (including that collated for the Yaldhurst study) that allows for reliable quarry particulate emission factors to be developed, which could then be used to assess air quality effects from the Proposal. Paragraph 92 of Ms Wickham's evidence supports my view as to why the Yaldhurst study results cannot be used to

[1] Golder (2018) Assessment of Air Quality Effects – Proposed 'Roydon Quarry', Templeton. Appendix D of Application Document.

derive reliable particulate emission factors that relate to wind erosion, process plant and truck movements. I am not aware of any other publicly available datasets in New Zealand that allow for this either. This aside, the Yaldhurst study does provide a comprehensive data base of ambient particulate impacts that has allowed me to assess the likely air quality effects of the Proposal.

18. I am aware of the typical processing capacities of the various quarry sites at Yaldhurst (a total in the order of 2 million tonnes production/year) and difference in technology use, for example use of haul trucks versus conveyors for half of the annual production. However, there are too many variables across the sites to develop robust emission factors, irrespective of the comprehensive ambient monitoring data the Yaldhurst study generated.

19. I agree with Ms Wickham that air discharges from quarries are not routinely modelled in New Zealand. However, even in Australia, monitoring and management plans for managing dust effects from quarries is often given primary consideration as modelling is seen to be unreliable. As such the primary approach for assessing dust emissions from proposed quarries or expansions in both countries, is to consider the necessary mitigation measures that are likely to achieve compliance with ambient and nuisance guidelines.

20. Therefore, reliable assessments of fugitive dust from quarries relies on expertise and experience with the effectiveness of various dust mitigation/control measures. The more traditional tool of dispersion modelling - that is, for example, typically applied to industrial point source (stack) emissions to air - is not reliable when applied to residual fugitive emissions from quarries. This is supported by the MfE dust guideline (MfE, 2017) which notes in Section 4.4 that:

    (a) Modelling of dust emissions from area and fugitive sources is not generally recommended.

    (b) In situations where good quality data is not available it may be more appropriate to focus on methods to control the dust at source instead.

21. Therefore, I disagree that undertaking atmospheric dispersion modelling of quantified discharges is the only way to robustly estimate the impact of the proposed quarry via predicted downwind concentrations. The potential air

quality effects of fugitive dust discharges cannot be quantified with sufficient accuracy to enable a predictive modelling-based assessment.

22. To date there is no accurate set of equations that reliably predict particulate mass emission rates and size distribution as a function of ambient conditions and site operations. A mitigation-based assessment approach (i.e. methods of dust control) is the norm for such activities which is the approach taken in the Golder (2018) assessment of air quality effects and the further assessments which I have conducted.

23. Ms Wickham asserts (paragraph 6(i)) that no quarry has been proposed adjacent to a polluted airshed. However, there are multiple examples of new quarries and quarry expansions adjacent to and within the Christchurch gazetted airshed boundary.

24. Recent examples include quarries consented by Fulton Hogan and Waterloo Park at Roberts Road, Islington (both are within the airshed boundary), as well as the Fulton Hogan's Barters Road Quarry at Templeton, and expansions of the Yaldhurst Road Metals and Winstone Quarries, which have been approved directly adjacent to the airshed. These sites and their locations with respect to the airshed boundary, are shown in **Attachment A** to this evidence.

25. Ms Wickham further asserts (paragraphs 6(ii) and 81) that the Applicant's assumptions regarding wind directions significantly underestimate potential downwind impacts. As discussed later in this evidence, I do not consider Ms Wickham has portrayed my own assessment of wind information correctly and has misrepresented the assessment methodology employed. Suffice to say, I consider Ms Wickham's inference (paragraph 82 of her evidence) that my assessment understates potential impact of the proposal incorrect and likewise, her list of reasons, to be invalid.

Regulation 17(1) Compliance

26. The main difference in my view regarding compliance with Regulation 17 versus the counter view (summarised in Paragraph 4 of Ms Wickham's evidence) arises from our different assessments of the extent to which the Proposal is likely to achieve a lower level of ambient PM_{10} impact than measured at the Yaldhurst Quarries (i.e. the reduction factor or scale factor assessment).

27. We have also assessed the incremental PM_{10} impacts due to existing quarries (i.e. the monitoring data collected from the Yaldhurst Study) using different approaches, but as I explain below, I consider that we reach similar positions on this matter.

Incremental PM_{10} assessment – Yaldhurst Quarries

28. Ms Wickham is incorrect (at paragraph 39) to surmise that I have limited my assessment of PM_{10} impacts on the airshed, to south west and westerly wind conditions. I have analysed incremental PM_{10} impacts for all wind conditions. However, with reference to Figure 12 in the air quality assessment by Golder (2018), it is clear that north west winds only result in active areas of the quarry being directly upwind of the gazetted airshed boundary for limited periods of the quarry life-time. Most of the proposed quarry area including the processing plant, the mobile processing plant, the main site access/exit roads are not upwind of the airshed boundary during northwest winds at any stage of the quarry life cycle.

29. To a lesser extent, southerly winds also place a portion of future active quarry areas upwind of the airshed boundary. These winds place active quarry areas upwind of the airshed boundary at times when there would be a significant distance to that boundary. The converse is true for south westerly wind conditions, which will always place the active part of the quarry upwind of the gazetted airshed boundary. Furthermore, these winds are far more prevalent than north west or southerly winds

30. Ms Wickham also criticises the incremental PM_{10} assessment on the basis wind speeds less than 7m/s (and greater than 5m/s) should have been assessed (her paragraph 41). I consider Ms Wickham's recommended wind speed trigger of 5 m/s - for instigating increased dust management or ceasing operations - is too low. The proposed threshold of 7 m/s for dust erosion effects has been widely used and confirmed, from my own experience. Figure 14 of Golder's assessment of effects document (Golder, 2018) presents research that supports the hourly average wind speed limit of 7 m/s. I am not aware of any similar research that points to a lower threshold wind speed.

31. I note that Section 2.1.1 of the MfE Dust Management Guideline (MfE, 2017) presents a theoretical analysis of particle size versus settling velocity, which finds that PM_{10} can travel up to a kilometre before settling. Section 5.2.5 of the MfE guideline suggests that fine material stored in stockpiles can be

subject to erosion at winds above 5 m/s. However, for materials that are not fine - such as stockpiles of soil, overburden and aggregate products - wind speeds of greater than 7 m/s have been well established (see Figure 14, Golder (2018)) as the point where dust erosion has the potential to cause off site effects that are more than minor.

Relevance of the Yaldhurst Study

32. In paragraph 49 of her evidence, Ms Wickham concludes that PM_{10} discharges are very likely to result in an increase in PM_{10} within the airshed that exceeds the threshold level of 2.5 µg/m^3 (24 average). However, the proposed Roydon Quarry design is vastly different to existing nearby gravel quarries in that key dust sources have been eliminated. I discuss these differences in my primary evidence dated 23 September 2019 at paragraphs 47 to 63. As such, past experience (in particular the monitoring available from the Yaldhurst study) is not directly applicable to the Proposal.

33. To make the Yaldhurst Study experience relevant to the Proposal, it is necessary to consider the reduction in potential effects the Proposal design is likely to achieve. Ms Wickham disagrees with the reduction factor I use (her paragraphs 92-96 for example). I disagree with her view on this and explain this further in paragraphs 52 to 56 of this evidence. I note that Ms Wickham does not appear to have undertaken her own independent analysis of this key factor. Her analysis of the Yaldhurst Study and her use of this to assess the potential PM_{10} and RCS air quality effects of the Proposal indicates that Ms Wickham considers there is no reduction and therefore the reduction factor is effectively 1.

34. In paragraph 70 of Ms Wickham's evidence, it is stated that the Yaldhurst Study period was a particularly wet summer and ambient PM_{10} levels may have been lower than during other years. I disagree with this assessment and also the subsequent statement that any conclusions drawn from the Yaldhurst Study are not likely to be conservative. Ms Wickham's view is based on the analysis provided in Attachment B2 of her evidence, where she also concludes that RCS measured during the study monitoring period may be lower than during other years. Ms Wickham's view of this appears to be a result of the soil moisture being 22.3 % compared to the 10 year average of 17.9%, which is not a valid reason.

35. In my view the dust emissions associated with the Yaldhurst RCS study were very unlikely to be low compared to other years. While there was a

concentrated rainfall event (during the study period) this is likely to have elevated soil moisture levels for a short time. I do not consider this will have had a corresponding impact on the average level of surface moisture within the Yaldhurst Quarries itself. This is because the quarry surface moisture levels decrease rapidly with the absence of rain (typically drying out within ½ a day), whereas soil systems have a much slower decay in moisture with changing ambient conditions.

36. As such the concentrated distribution of the total rainfall during the study period was not likely to reduce the fraction of days when the quarry floor would be dry and prone to dust erosion compared to years. Ms Wickham's assessment of the frequency of days where rainfall is > 1 mm for the study period in her Attachment B2 is consistent with this in my view.

37. Therefore, I am satisfied as to the usefulness of the Yaldhurst Study for the purposes I have used it and that its data is representative/typical of what will occur in other years.

38. Paragraph 81 of Ms Wickham's evidence discusses Golder's analysis of hourly PM_{10} increments across the Yaldhurst quarry area that were measured during south westerly winds and during operational hours. I agree with Ms Wickham's view that other wind conditions needed to be considered (which I accounted for in my own analysis) and also that the most significant increment in PM_{10} results from north west wind conditions (paragraph 82 of her evidence).

39. In preparing my primary evidence I analysed both hourly and 24 hourly increments in PM_{10} that were directly measured changes across the quarries. The results of which are built into the second column of data provided in Table 4 of my primary evidence. Therefore, my primary evidence did consider a range of wind directions and analysed both hourly and 24 hourly changes in PM_{10} based on the Yaldhurst Study data.

40. The hourly data analysis was useful as I could compare these results to 24 hour PM_{10} increments which are mostly consistent with results established by Ms Wickham and reported in Attachment B of her evidence. In other words, the assessment of incremental PM_{10} effects from the Yaldhurst Study that I presented in my primary evidence, superseded information provided earlier by Golder. This appears to have been over-looked by Ms Wickham when drafting paragraph 82 of her evidence.

41. In paragraph 83, Ms Wickham describes her approach to look at the difference between daily PM_{10} at various locations near to the Yaldhurst Quarries and the background site (i.e. the Proposal site). It is stated that this was the purpose of the background site. However, this only allows for a comparison of monitoring result statistics at the Yaldhurst site versus the background site. The background site does not strictly allow for the direct measurement of incremental changes in ambient PM_{10} due to the Yaldhurst Quarries alone, for any one day.

42. This is a subtle but important difference, as it means that the approach employed by Ms Wickham to estimate incremental ambient PM_{10} changes due to the Yaldhurst Quarries (discussed in Attachment B.5 to her evidence), has a flaw which can produce a number of false maxima values. Therefore, the maximum and the 99th percentile values for increased PM_{10} in Tables B-4 and B-6 of Attachment B.5 of Ms Wickham's evidence, are not reliable in my view. By comparison, the 99.5th percentile values are likely to be reliable and provide more realistic estimates of the true extent of incremental ambient PM_{10} that is caused by the Yaldhurst Quarries.

43. The issue with Ms Wickham's approach is that the incremental PM_{10} calculations are based on differences between various locations near the Yaldhurst Quarries compared to the site at Roydon, that is some 5 kms away. However, the proposed Roydon quarry background will not always reflect the ambient PM_{10} levels at locations that were generally upwind of the quarries on a particular day.

44. This problem is avoided by the approach I employed, which is to consider hourly and daily average changes in PM_{10} measured upwind and downwind of the quarries. The daily PM_{10} changes relates to days which were dominated (i.e. more than 10 hours per day) by a specific type of wind condition (southerly, south westerly, north-westerly etc). This compares the difference in 24 hour PM_{10} recorded at the associated upwind and downwind sites for those days. This approach is also not without limitations (especially the low number of data points), but I consider it is of similar robustness to the approach employed by Ms Wickham's, given her maximum and 95th percentile values are used. On this basis – and ignoring her highest values – I consider both assessment outcomes to be similar and could be given similar weight.

45. As such, I consider the criticisms expressed in paragraph 82 of Ms Wickham's evidence are not relevant to the assessment I have undertaken.

46. My own analysis of upwind and downwind PM_{10} monitoring data (hourly and 24 hour averages) concludes that increases in ambient PM_{10} are typically in the range of 10 to 20 µg/m^3 as 24 hour average. These are very similar to the range of 95th and 99th 24 hour percentile values presented Table B-4 of Attachment B.5 to Ms Wickham's evidence. This relates to all winds except for northwest winds which indicate increments in the range of 30 to 45 µg/m^3. For these winds, my maximal results and Ms Wickham's 99th percentile estimates are consistent.

47. The statement within the first sentence of Attachment B6 to Ms Wickham's evidence is inaccurate. Neither the original air quality assessments by Golder (2018) and Golder (2019) or the assessment presented in my primary evidence have assessed PM_{10} concentrations against a 24 hour average wind direction. Instead, what I have assessed is daily PM_{10} values for days where different types of wind conditions (synonymous with Canterbury) were dominant.

48. Attachment B6 to Ms Wickham's evidence goes on to suggest that hourly BAM data for PM_{10} (NES certified method) is not reliable whereas hourly data from a Nephelometer is reliable. I disagree with this and consider the reverse is more likely to be true. Ms Wickham's evidence is effectively suggesting that a referenced method, which produces a 24-hour PM_{10} concentration based on hourly measurements, nevertheless produces hourly values of PM_{10} that are not reliable. Furthermore, her evidence is suggesting that a non-referenced method which is known to produce unreliable 24-hour PM_{10} concentrations, nevertheless produces reliable hourly values of PM_{10} – at least more reliable than produced by a referenced method.

49. This is not a valid assumption in my view and the provision of one graph of hourly PM_{10} (for the 16 of January 2018) does not provide any substantive evidence to support Ms Wickham's above claim. In this particular example, it is more likely that the BAM hourly concentrations are responding to increased wind speeds as would be expected during the windier and warmer day time. Whereas the Nephelometer is likely to be demonstrating its tendency to measure mist/fog during late evening/small hour periods when fog tends to occur. In my view the very low wind speeds measured during

these early hours supports this scenario as the likely cause of Nephelometer trends shown in Ms Wickham's figures B.17, B.18 and B.19.

50. I remain satisfied that it was appropriate to use data obtained from the BAM and the Nephelometer (I used all available data sets), despite the fifth paragraph of Attachment B6 to Ms Wickham's evidence.

51. In summary, it is my opinion the analysis provided in Attachment B6 to Ms Wickham's evidence is unreliable. Furthermore, its description of my own assessment mispresents the actual approach that I have employed. As I discuss in paragraph 44 of this evidence, the results of my analysis of PM_{10} data from the Yaldhurst Study are consistent with Ms Wickham's own assessment of these data if her maximum and 99.9 percentile values are ignored.

Reduction factor for incremental dust impacts

52. Ms Wickham criticises the 10-fold reduction factor I have used. In my view the reduction factor is appropriate based on accepted science regarding the physical drivers for potential dust emission that support this reduction factor. These include the physical/operational features of the large block of quarries at Yaldhurst versus the Proposal. From this analysis and the use of established facts and science, a conservative reduction factor can be reliably estimated. I explain this in more detail in paragraphs 54 to 56 of this evidence.

53. In paragraphs 11 and 12 of my first rebuttal brief (dated 21 October 2019), I explained the basis for my estimate of the reduction in off-site ambient particulate impacts measured by the Yaldhurst Study compared to the Proposal.

54. **Attachment B** to this evidence provides an analysis of relative PM_{10} emissions per year for different sources at the proposed Roydon quarry, existing Yaldhurst Quarries and other Fulton Hogan owned and operated quarries at Pound and Roberts Road.

55. The results in Attachment B for the proposed Roydon quarry and the Yaldhurst Quarries highlight a ratio in annual PM_{10} emissions of how the much larger unpaved exposed area of the Yaldhurst Quarries (20x), higher total production (3x), processing of top-coarse at Roydon only compared to more finely crushed product at Yaldhurst (4x reduction in specific PM_{10} emissions), and greater use of haul trucks for aggregate transfer/unloading,

indicates Yaldhurst Quarries would produce in the order of 30x PM_{10} emissions than the proposed Roydon quarry.

56. My original conservative estimate of the reduction factor of 10x (as discussed in paragraph 110 of my primary evidence) was based on a consideration of area and design changes between the two sites. Use of emission factor equations and applying these to the respective quarries to estimate relative annual emissions confirms that a 10-fold reduction factor is likely to be conservative – it is probably much higher. This is especially given that the PM_{10} emissions associated with the asphalt plant and concrete batching plant at the Yaldhurst Quarries site have been ignored in my analysis.

57. In paragraph 53 of Ms Wickham's evidence, it is stated that in the absence of requiring offsets, Regulation 17(1) requires the application to be declined. I consider this is not justified given the quantified level of incremental PM_{10} that has been comprehensively established by the Yaldhurst Study and the relative levels of incremental ambient PM_{10} that are likely to result from the Proposal (i.e. > 10-fold reduction from Yaldhurst levels). I maintain that the activities at the proposed Roydon Quarry are not likely to result in an exceedance.

Existing PM_{10} emissions

58. Attachment B to this evidence also provides a summary of annual PM_{10} emissions from other Fulton Hogan sites that are located within or adjacent to the gazetted airshed for Christchurch City.

59. The Roberts and Pound Road sites effectively work together as a combined extraction, aggregate haulage, clean fill and processing site. I understand Roberts Road would cease operation prior to the proposed Roydon quarry commencing, while additional areas of Pound Road will be rehabilitated as the Roydon quarry becomes operational. Both these sites sit within the Christchurch airshed.

60. The existing Pound Road site's air consent also allows for a significant discharge of PM_{10} from the operation of an Asphalt Plant (20,000 kg/year). I note the Barters Road clean fill site, directly adjacent to the Christchurch airshed, will also be progressively rehabilitated.

61. The emission rates from these sites is set out in Table 1 below. As can be seen from the table, Fulton Hogan has a range of options to offset any PM_{10} generated by the proposed Roydon quarry through reductions that can be

achieved on any of these existing sites. For the Proposal, I understand the central processing plant and any mobile plant will now both be located 500 m or more away from the gazetted airshed boundary; and so, I consider these are sufficiently far away to have a negligible impact on ambient PM_{10} levels within the gazetted airshed.

62. The PM_{10} emissions from the proposed active quarry areas (i.e. excluding the central processing and mobile plant areas which are 500 m or more away from the gazetted airshed boundary) are calculated to be the order of 3 times lower than those generated from fugitive emissions occurring at the Pound/Roberts Rd operations. The total estimated PM_{10} emissions from the Proposal (including process emissions) are also in the order of 20x lower than those that the existing air consent allows for from an Asphalt Plant at the Pound Road site.

63. I therefore consider that Fulton Hogan would, if required, be able to offset an equivalent or greater amount of PM_{10} emissions from the Proposal, through either one or a combination of the sources identified in Table 1. These could take effect within 12 months of the Roydon Quarry being granted consent and remain effective for the remaining duration of the consent, as required by Regulation 17(3)(b).

Table 1: Summary of Annual PM_{10} emission estimates (kg/yr)

Site	Site prep.	Erosion	Bulk handling (loading/unloading)	Trucks/unpaved	Processing	Total
Yaldhurst Quarries[(a)]	-	8,400	1,500	21,700	3,900	35,400
Pound & Roberts Road – current[(b)]	-	1,500	400	200	900	2,900
Barters Road block - current	-	200	NC*	NC	0	200
Pound Road Asphalt Plant	-	-	-	-	20,000	20,000
Proposed Roydon Quarry[(c)]	100	100	460	300	200	1,200

*NC = Not calculated,
[a] 2,000,000 T/yr, [b] 440,000 T/yr, [c] 600,000 T/yr

Background Ambient PM_{10}

64. In paragraph 55 of Ms Wickham's evidence, it is concluded 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 occasions when

compared to the NESAQ for PM_{10}. I agree with this and consider it is largely a result of natural background levels in summer as a result of wind erosion of deposited dust within the large riverbed systems, as well as agricultural practices that have more localised (less widespread) impacts on ambient PM_{10}.

65. In paragraph 56 of Ms Wickham's evidence, it is stated that Canterbury's rural air quality is "somewhat degraded", with limited room for new discharges of PM_{10}, particularly if impacting on daily PM_{10} levels. I consider the "somewhat" in this instance does not equate to substantial degradation and that the air quality in rural Canterbury is not substantially degraded (it is good air quality); and there is plenty of assimilative capacity for discharges of crustal based particulate from quarries, agricultural activities and similar, that are dominated by coarse PM_{10} (i.e. low $PM_{2.5}$ fraction) and where these discharges only cause localised and low impacts on existing ambient levels. This includes activities such as the proposed quarry, and agricultural practices.

66. I note the examples of background PM_{10} in rural regions of Auckland that are described in paragraph 54 of Ms Wickham's evidence. These examples are not significantly different to the data obtained from the proposed Roydon quarry site.

67. In paragraph 85 of Ms Wickham's evidence, a table is presented showing comparative statistics for daily average PM_{10} levels measured at the proposed Roydon quarry site, versus near to the Yaldhurst quarry sites. This covers the worst-case period of the year in my view for high background and quarry induced ambient PM_{10} levels. As such it is also useful to compare some of these statistics (at Roydon and Yaldhurst) with those for part of Christchurch and Kaiapoi for 2019 – shown in Table 2 below.

Table 2: Summary of daily PM_{10} statistics ($\mu g/m^3$)

Statistic	Roydon (Site 4)	Yaldhurst (Site 2)	Christchurch Winter 2019+	Kaiapoi Winter 2019+
Maximum	45	47	68	76
99.5th %ile	43	46	59	69
99th %ile	40	45	57	63
95th %ile	29	36	37	39
90th %ile	25	30	29	31
4 month mean	16*	21*	24#	25#
NES PM_{10} compliance (50 $\mu g/m^3$, 24 hr)	Yes	Yes	No (6 days exceedance)	No (8 days exceedance)

** four month summer mean likely to be > annual mean*

 # four month winter mean (May to August), likely to be > annual mean

+ Data from Environment Canterbury, https://www.ecan.govt.nz/your-region/your-environment/air-quality/the-science-behind-our-air-quality/data-from-past-years/ and http://data.ecan.govt.nz/Catalogue/Method?MethodId=98#tab-data (daily PM_{10} data from Christchurch Woolston and St Alban sites, and Kaiapoi site during 1 January to 4 November 2019)

68. Table 2 shows that there is elevated PM_{10} around the existing Yaldhurst Quarries area and at the proposed Roydon quarry site. However, at Roydon these are isolated events, and upper percentile values at Roydon in the summer of 2018 are much lower than those occurring in urban airsheds during the winter months of 2019, or downwind of the Yaldhurst Quarries during the summer months of 2018. As discussed in paragraph 22 of my first rebuttal evidence dated 21 October 2019, I consider it is an anomaly that the gazetted airshed boundary of Christchurch adjoins the proposed Roydon quarry site. I consider the data in Table 2 supports this view.

69. In paragraph 71 of Ms Wickham's evidence, it is concluded that exceedances of the NESAQ for PM_{10} are likely within 100 m, and may also occur within 200 m, of the Yaldhurst quarry boundaries. This may well be the case, but this conclusion is not relevant to the potential effects at the proposed Roydon

quarry. These are likely to be an order of magnitude, or more, lower than those associated with the existing Yaldhurst Quarries.

70. Likewise, the analysis of the decay in PM_{10} levels measured at increasing distances from the Yaldhurst Quarries (paragraph 89 of Ms Wickham's evidence) will not mirror the faster decay of concentrations that can be expected from the proposed Roydon quarry.

71. Therefore, given the assessment of increased daily PM_{10} within 200 m of the Yaldhurst Quarries is a 99th percentile of 15 µg/m^3 (Paragraph 86 of Ms Wickham's evidence), then impacts less than 1.5 µg/m^3 can be expected from the proposed Roydon quarry.

72. I refer the commissioners to my evidence regarding the inference in paragraph 70 of Ms Wickham's evidence that the Yaldhurst Study produced atypically low ambient PM_{10} results for that location.

73. Attachment D to Ms Wickham's evidence provides a summary of estimated PM_{10} emissions from the proposed Roydon Quarry. I consider many of the inputs assumed for these calculations are highly inaccurate and likewise the emission factor equations themselves have a high level of inaccuracy. I have had a fellow colleague review the emission factor equations employed by Ms Wickham and he reaches the same view as myself that the approach of Ms Wickham has produced a gross overestimate of likely PM_{10} emissions from the Proposal.

74. Attachment B to this evidence provides a summary of Ms Wickham's calculations for the Proposal and these are compared to my own calculations. My assessment of PM_{10} emissions from the Proposal (1 tonne/yr) are an order of magnitude lower than Ms Wickham's estimates (8 tonnes/yr). This is despite my assumption of a 600,000 T/yr processing rate versus Ms Wickham's assumption of 400,000 T/yr. Some of the reasons why Ms Wickham appears to grossly overstated emissions can be summarised as follows:

- Emission factors have been calculated with the combination of erroneous inputs being applied to conservative equations.

- The absence of Barmac type crusher plant producing dry 5 mm dust and chip at Roydon (fines crushing).

- Only using cone crushers at Roydon to make Basecourse material which are typically around 4-5% moisture and 20 mm minimum size (tertiary crushing).

- Gross overstatement of truck movements over exposed surfaces.

- Underlying assumptions of low moisture levels that are unrealistic for the Proposal.

75. As I have stated earlier in this evidence, the emission factor equations can be useful to demonstrate relative contributions of PM_{10} from different sources given they have realistic inputs (i.e. truck movements, distances on unpaved surfaces, mitigation control efficiencies, etc). However, it would be imprudent to place absolute accuracy on these values, which is why modelling these emissions to predict downwind concentrations of PM_{10} is likely to be misleading. This situation is somewhat reflective of assessing odour emissions from some processes such as mushroom composting and by-products rendering, where a mitigation/control-based assessment is the only practical option for considering the potential air quality effects.

76. Ms Wickham's statement in paragraphs 97 infers that the calculated PM_{10} emissions should have been modelled to reliably predict ambient PM_{10} levels beyond the proposal boundary. My view is that this was not a practical option that would produce reliable information. The consideration of measured PM_{10} impacts near the existing Yaldhurst Quarries and considering how these would reduce given the scale, design and increased level of emission controls, was the only practical approach for assessing this Proposal.

77. In summary, it is my view that the statements in Ms Wickham's evidence (at paragraphs 98 and 99) are based on unreliable analysis of PM_{10} emissions from the Proposal and unrealistic extrapolation of PM_{10} impacts measured via the Yaldhurst Quarries study. Furthermore, I consider Ms Wickham (paragraph 56 of her evidence) would overstate the ability for the local environment at Roydon to assimilate its residual particulate emissions from the Proposal. I refer the commissioners to my comments in paragraph 65 of my evidence on this matter. Ms Wickham has correctly pointed out that there is an existing level of degradation of air quality at the proposed site, but has overstated its significance and implications for the Proposal in my view.

Respirable Crystalline Silica (RCS)

78. In paragraph 105 of Ms Wickham's evidence, it is stated that my estimates of hourly RCS cannot be valid or robust, because PM_4 measurements were only made at monthly intervals, with three datapoints at each site. I do not agree with this general statement. There is always limited data available for such an analysis (three sites with three monthly average values) but the variability dictates what can be reliably inferred from the results.

79. To be clear, I established the one-month average concentration ratios of $PM_{2.5}$ to PM_4, as well as the fraction of RCS within the PM_4. This produced three monthly average $PM_{2.5}$ to PM4 ratios and RCS to PM_4 ratio estimates for Sites 2, 3 and 4 (as specified for the Yaldhurst Study).

80. The Yaldhurst monitoring data also had ambient 1 hour $PM_{2.5}$ concentrations at the same sites. Using the above ratios and the 1 hour $PM_{2.5}$ concentrations, I can generate estimates of the 1 hour RCS concentrations for each site. The variability in the ratios at each site indicates a likely error in the range of 2 to 3 times the estimated RSC concentrations. However, that is still useful and enables robust conclusions given the estimated values are more than 3 times lower than the appropriate hourly health guideline criteria.

81. My estimates indicate the maximum calculated hourly RCS concentration to be 8.4 $\mu g/m^3$ (at site 3), which is in the order of 5 times lower than the TCEQ 1-hour concentration of 47 $\mu g/m^3$. For sites 2 and 4, the calculated hourly RCS concentrations are at least 8 times lower than the TCEQ 1-hour criterion.

82. Therefore, despite the limited data and high variability of the estimates, a reliable conclusion can be drawn from the Yaldhurst Study regarding the potential for health effects associated with hourly RCS exposure levels. This conclusion is that these were very likely to be well below the TCEQ 1-hour criterion. Therefore, for the Proposal I can conclude that hourly RCS exposure levels will be very low against both hourly and long-term health guidelines for RCS.

83. At paragraph 79 of Ms Wickham's evidence, she contends that hourly or daily levels of RCS may be elevated in some Yaldhurst locations compared with background. The monitoring supports this statement, but in my view, it is important to clarify that the level of elevation is not environmentally significant

and is unlikely to cause any short-term health guideline to be exceeded. This conclusion is even more certain for much lower short-term RCS concentrations that are likely to be caused by the Proposal compared to the Yaldhurst Quarries

Fine Fraction of PM_{10}

84. In paragraph 74 of Ms Wickham's evidence, it is concluded the Yaldhurst Quarries do not have substantial discharges of $PM_{2.5}$. I agree with this conclusion and it also applies to the Proposal with much greater certainty.

Air Quality Monitoring

85. Paragraphs 12 to 15 of this evidence provide my responses to Ms Wickham's recommendations for monitoring in paragraph 7 of her evidence. I provide additional comments as follows.

86. The analysis provided in attachment B4 to Ms Wickham's evidence does not provide evidence for the lower dust management trigger levels that are recommended in paragraph 108 of her evidence. In addition to my paragraph 12 of this evidence, the relationships between the hourly PM_{10} levels and NES compliance that are shown in attachment B4 (Ms Wickham's evidence) are only relevant to the Yaldhurst Quarries area. The monitoring of PM_{10} to provide a dust management trigger would occur just within the quarry site boundary – this makes sense given the purpose of dust nuisance management, but it is not a location where the NES applies or even close to it.

87. Paragraphs 109 (vii) of Ms Wickham's evidence indicates non-reference ambient PM_{10} monitoring methods are calibrated against a referenced method using a co-location exercise. I agree with this and note that because there is likely to be two non-referenced Nephelometer type instruments and one referenced instrument, this enables such a process to be undertaken. My recommendation is that the co-location study does not need to follow a detailed procedure that is used to enable non-referenced methods to be used for regulatory monitoring of PM_{10}.

88. Instead a co-location study for each Nephelometer versus the referenced method over several weeks and at the start of each summer period would suffice. This can be staggered with only one device at time so one remains in the field at a strategic location. This would allow for K-factor for each

device to be confirmed and help reduce the risk of these devices generating alarms of trigger concentration values that are not reliable.

89. Paragraphs 109 (viii) and (ix) of Ms Wickham's evidence recommend long-term and intermittent short-term monitoring of RCS at the boundary of the site and near houses. I do not consider that the potential RCS exposure from the Proposal justifies this level of onerous monitoring, especially based on the Yaldhurst Study results and subsequent conclusions. That aside, a one-off programme of monitoring over three months, during a summer period would not be unreasonable as it is likely to provide further confidence to the local community that they should have no concerns of air quality related health effects due to the proposed quarry operations.

90. Paragraph 109 (x) of Ms Wickham's evidence recommends a default separation distance of 500 m for the mobile crushing plant and the nearest boundary. This is not practical as it would require the plant to operate in the middle of the site only where the main process plant is located. The recommended minimum separation distance of 250 m is sufficient for this small crusher operation given that I understand it will only operate at a 120 tonnes/hr average for 120 days per year and will generally work within 100 m, and to the west of, the central processing plant. As for the main processing plant, the mobile plant would only operate as a tertiary crusher to produce top coarse product which has a low dust generation potential. This would be readily controlled to minor levels via water misting controls operating on this system.

Conclusions

91. I conclude that Ms Wickham's evidence has relied too heavily upon the ambient effects of the Yaldhurst Study as a direct indication of the potential PM_{10} and RCS related effects of the Proposal. In practice the latter Proposal is for a vastly different type of quarry design that is very likely to have a fraction of the potential for air quality effects compared to the cumulative impact of the Yaldhurst Quarries.

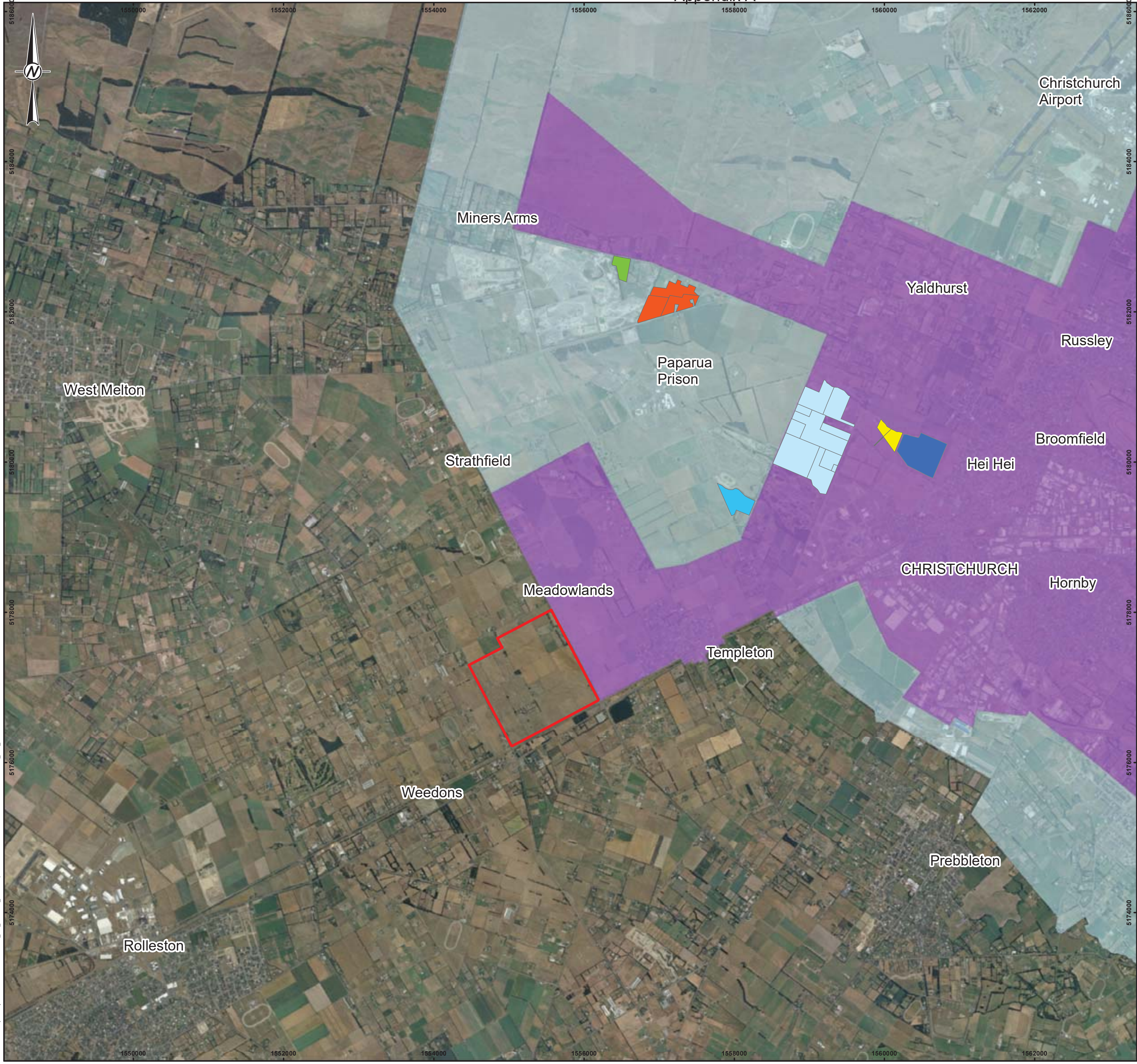
92. As such, I disagree with Ms Wickham's conclusion regarding potential PM_{10} effects and compliance with the NESAQ as stated in paragraph 111 of her evidence.

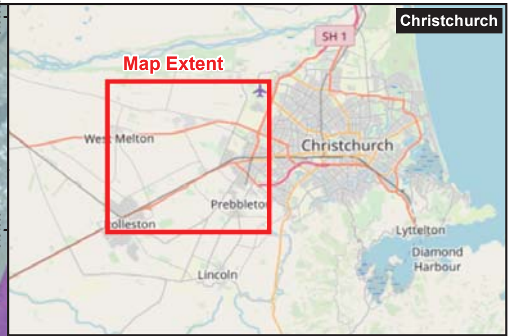
93. My overall assessment of Ms Wickham's evidence is that it has overstated how much PM_{10} is likely to be discharged from the Proposal and the potential

for health effects from particulate discharges associated with the Proposal. Further, Ms Wickham has heavily criticised the original assessment of air quality effects prepared by Golder (2018) and my later assessments and evidence. I have considered her arguments that the air quality effects of Proposal have not been assessed thoroughly. After re-consideration, I am satisfied the air quality effects – as evaluated by myself – have been robustly considered.

94. I conclude that the air quality effects of the Proposal are able to be mitigated to an acceptable level, and compliance is expected with Regulation 17 of the NESAQ and the NESAQ target for ambient PM_{10}. Once operational, these outcomes will be able to be confirmed by robust monitoring which is proposed for the quarry. Notwithstanding this, Fulton Hogan has a range of options for PM_{10} offsets available to it, from both within and adjacent to the Christchurch airshed, should the commissioners be of a mind that an offset is required.

Roger Cudmore
6 November 2019





LEGEND

- Roydon Quarry site boundary
- Gazetted Airshed
- Clean Air Zone
- Fulton Hogan - Roberts Road Quarry
- Fulton Hogan - Barters Road Quarry
- Fulton Hogan - Pound Road Quarry
- Road Metals - Expansion
- Winstone Aggregates - Dunn Property
- Waterloo Park Quarry

NOTES

1. Aerial: LINZ and Eagle Technology, CC-BY-3.0-NZ.
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3. Schematic only, not to be interpreted as an engineering design or construction drawing.

0 2,000 4,000
METRES

REFERENCE SCALE: 1:50,000 (at A3)

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
FULTON HOGAN LIMITED

PROJECT
ROYDON QUARRY

TITLE
CANTERBURY AIR SHEDS AND QUARRY ACTIVITY

CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-25
PREPARED	AE
REVIEW	KB
APPROVED	KB

PROJECT NO.	REPORT	REV.	FIGURE
1781870	001	0	02

Appendix B

Attachment B – Rebuttal evidence of R Cudmore - PM10 Emission Calculations

Summary of Ms. Wickham's and Golder's estimates for Roydon is presented in Table G1. Detailed calculations are provided in Table G2 to G7.

Table G1: Summary of Ms. Wickham's and Golder's estimates for Roydon

	L. Wickham	Golder		Comments
1.0 Site Preparation				
1.1 Topsoil removal	377	116	kg	Difference is due to assumption on area opened per year. An area of 5 ha/year is considered more reasonable for the first year, as well as 2.2 ha for the other years. All other assumptions remain the same. Although it is considered unlikely that all material will need to be loaded and loaded from trucks as some will be pushed up to form bunds.
1.2 Loading of topsoil into trucks\loader	69	22	kg	
1.3 Dumping of topsoil	69	22	kg	
PM10 for site preparation first year	515	161	kg	
PM10 for site preparation subsequent year	Not calculated	71	kg	Golder assumed 2.2 ha of topsoil is removed for the subsequent years
2.0 Wind erosion				
2.1 Dust pickup	2,210	98	kg/yr	L.W assumptions exclude any control and incorrectly assume 26 ha of open area vulnerable due dust erosion. Golder calcs apply 5 ha of active area that is controlled via covering exposed ground with reject material and water suppression (control efficiency of 84% for covering and 70% for additional water control). In effect reject cover ground has close to zero emissions.
3.0 Gravel loading/unloading				
3..1 LW Loading of gravel into trucks \ loader to conveyor	71.3	59	kg/yr	Difference is due to the use of a higher excavation rate of 600,000 tonne/year. Golder calcs are for loader tipping material into conveyor hopper and then conveyor unloading into process plant hopper both with water emission control
3.2 L.W Unloading of gravel from trucks/Golder: conveyor to processing plant hopper	71.3	59	kg/yr	
3.3 Excavation	Not calculated	59	kg/yr	Golder has accounted for emissions from loader excavating at the face.
4.0 Gravel processing (includes fixed and mobile plant)				Note, these rates/equipment estimates are expected to be sufficient to allow for mobile plant operation
4.1 Crushing (controlled)	108	65	kg/yr	Golder calcs allow for 2 crushers and an excavation rate of 600,000 tonne/year, plus an additional 80% reduction as the site only has wet top coarse production. No secondary crushing to fine grade products onsite.

	L. Wickham	Golder		Comments
4.2 Screening (controlled)	148	133	kg/yr	Golder allowed for 3 screens and an excavation rate of 600,000 tonne/year, plus an additional 80% reduction.
4.3 Conveyor transfers (uncontrolled\controlled)	2,200	28	kg/yr	Golder used emission factor for controlled emission (0.000023 kg/tonne) and assumed 10 transfer points at process plant L.W assumed uncontrolled conveyor transfers and 10 transfer points. Golder allowed for 80% reduction due to top course plant operation and controls.
4.4 Truck loading - conveyor crushed	20	30	kg/yr	Golder allowed for higher excavation rate of 600,000 tonne/year and a controlled efficiency of 70% for the use of water
5.0 Trucks				
5.1 Trucks -topsoil transferring first year	1,400	251	kg/yr	Golder calcs allow for 5 ha rather than 26 ha and capacity of trucks is 20T
Total PM10 (first year)	**6.7**	**0.9**	**T/yr**	
5.2 Trucks -topsoil transferring subsequent year	Not calculated	28	kg/yr	Golder assumed 2.2 ha topsoil is removed for other years
5.3 Trucks - mobile plant subsequent years	3,499	124	kg/yr	Truck capacity is expected to be typically 20 tonnes on average and minority of annual extraction is processed in mobile site (peak of 158,400 tonnes compared to L.W 250,000 m³ - 500,500 tonnes). Note when mobile plant is being used for first central extraction area, the mobile plant will be maintained within 100m of the extraction face and therefore the emissions are covered by the loader to face and loader to conveyor hopper emissions in 3.0 above).
6.0 Clean fill operation				
6.1 Loader pushing up cleanfill	Not calculated	149	kg/yr	Golder calculated the emissions from the cleanfilling operation. The same equations used for Sections 4.0 and 5.0 have been used. The moisture content of 1% was assumed for cleanfill material and a maximum of 160,000 tonne/yr cleanfill was estimated based on 1/3 of the pit filled. This gives to 8000 cleanfill trucks/day travelling on unformed roads. (approximately 100 m in return)., the remainder of access will be either sealed or regularly washed reject material with an almost zero emission.
6.2 Trucks Dumping cleanfill	Not calculated	149	kg/yr	
6.3 Road	Not calculated	125	kg/yr	
Total PM10 (subsequent years)	**8.3**	**1.2**	**T/yr**	

Table G2: Ms. Wickham's and Golder's estimates for Roydon – Site preparation

1.0 Site preparation					
	L. Wickham		**Golder revised**		**Comments**
1.1 Topsoil removal by scraper					
TSP	0.029	kg/Mg	0.029	kg/Mg	AP-42 Table 11.9-4
PM30	0.029	kg/Mg	0.029	kg/Mg	
Assume	0.5	m deep	0.5	m deep	0.5 to 1.0 m depth (Golders, 2018). At section 3.5. Page 9.
First stage only	26	ha	5	ha	Assume 5 ha for the first year and 2.2 ha for the subsequent years
	260,000	m2	50,000	m2	
Topsoil to remove	130,000	m3	25,000	m3	
Assume	1	Mg/m3	1.6	Mg/m3	Assume topsoil density
	130,000	Mg	40,000	Mg	
PM30	3,770	kg	1,160	kg	
Assume PM10	10%		10%		Assume 10% of PM30
PM10	**377**	**kg**	**116**	**kg**	
1.2 Loading of excavated material into trucks\loader movements					
Topsoil to load	130,000	Mg	40,000	Mg	
PM10	k x 0.0016 x (U/2.2)1.2 / (M/2)1.4		k x 0.0016 x (U/2.2)^1.3 / (M/2)^1.4		AP42 Section 13.2 Aggregate Handling The correct equation k x (0.0016) x (U / 2.2)1.3/[(M / 2)1.4] used by Golder – this makes very little difference to factor.
k	0.35		0.35		AP42
U	3.9	m/s	3.9	m/s	mean wind speed, Annual average Golders met set
M	3.4	%	3.4	%	AP-42 Table 13.2.4-1 (exposed ground)
PM10	0.000529578	kg/Mg	0.000561	kg/Mg	
PM10	**69**	**kg**	**22**	**kg**	
1.3 Truck dumping of topsoil					
PM10	k x 0.0016 x (U/2.2)1.2 / (M/2)1.4		k x 0.0016 x (U/2.2)^1.3 / (M/2)^1.4		AP42 Section 13.2 Aggregate Handling
PM10	**69**	**kg**	**22**	**kg**	
Total PM10 for site preparation year 1	**515**	**kg/year**	**161**	**kg/year**	
Total PM10 for site preparation other years	Not calculated		**71**	**kg/year**	Scaled based on 2.2 ha comparing to 5 ha for year 1

Table G3: Ms. Wickham's and Golder's estimates for Roydon – Wind erosion

2.0 Wind erosion of exposed areas								
	L. Wickham			**Golder revised**				**Comments**
2.1 Dust pickup								
TSP	0.85	Mg/ha/yr			PM10 emission	0.085	Mg/ha/yr	AP-42 Table 11.9-4, assumed 10% of TSP emission
	26	ha		Area	Cleanfill area (starting rehab)	1	ha	
	22.1	Mg/yr			Cleanfill dumping area	0.75	ha	
Assume PM10	10%	PM30			Cleanfill area where truck is dumping	0.25	ha	
PM10	**2,210**	**kg/yr**			Daily Active Excavation area	0.3	ha	
					Residual active excavation area	0.7	ha	
					Central processing area	1	ha	Assumed residual open
					Mobile plant	1	ha	Assumed conservative
				Uncontrolled emission	Cleanfill area (starting rehab)	0.09	Mg/year	
					Cleanfill dumping area	0.06	Mg/year	
					Cleanfill area where truck is dumping	0.02	Mg/year	
					Daily Active Excavation area	0.03	Mg/year	
					Residual active excavation area	0.06	Mg/year	
					Central processing area	0.09	Mg/year	
					Mobile plant	0.09	Mg/year	
				Controlled emission	Cleanfill area (starting rehab)	0.014	Mg/year	84% Reduction, controlled due to reject material *
					Cleanfill dumping area	0.010	Mg/year	84% Reduction, controlled due to reject material *
					Cleanfill area where truck is dumping	0.006	Mg/year	70% Reduction, controlled (due to being wetted)
					Daily Active Excavation area	0.008	Mg/year	70% Reduction, controlled (due to being wet)
					Residual active excavation area	0.010	Mg/year	84% Reduction, controlled due to reject material*
					Central processing area	0.026	Mg/year	70% Reduction, controlled (due to being wetted)
					Mobile plant	0.026	Mg/year	70% Reduction, controlled (due to being wetted)
					Total PM10 emission	**98**	**kg/year**	**Controlled emission**

*NPI Emission estimation technique manual for fugitive emissions version 2.0 January 2012

Table G4: Ms. Wickham's and Golder's estimates for Roydon – Gravel loading/unloading

3.0 Gravel loading \ unloading						
	L. Wickham			Golder revised		Comments
3.1 Loading of gravel into trucks / loader to conveyor						
k	0.35			0.35		AP42 13.2.4.1
U	3.9	m/s		3.9	m/s	mean wind speed
M	7.4	%		5	%	lower estimate, provided by Fulton Hogan
	0.000178269	kg/Mg		0.00033	kg/Mg	k x 0.0016 x (U/2.2)^1.3 / (M/2)^1.4
	400,000	Mg/year		600,000	Mg/year	Extraction rate (Fulton Hogan)
PM10	**71.3**	kg/year		196	kg/year	Uncontrolled emission
				70	%	Wet extracted material, therefore assume water control (efficiency of 70%)
				59	kg/year	Controlled emission
3.2 Unloading of gravel into trucks / unloading of gravel from conveyor						
PM10	**71.3**	kg/year		**59**	kg/year	Controlled emission
3.3 Excavation						
	Not calculated			**59**	kg/year	Controlled emission

Table G5: Ms. Wickham's and Golder's estimates for Roydon – Gravel processing

4.0 Gravel processing (includes fixed and mobile plant)						
	L. Wickham			Golder revised		Comments
4.1 Crushing (controlled)						
PM10	0.00027	kg/Mg		0.00027	kg/Mg	AP-42 11.19.2
	400,000	Mg/year		600,000	Mg/year	
	108	kg/year		324	kg/year	Assuming 2 crushers, controlled emission
Reduction factor				0.8		Assuming 80% reduction as Roydon only has wet top coarse production, i.e. 20 mm for smallest product. No Barmac/APS crusher onsite.
PM10	**108**	kg/year		**65**	kg/year	
4.2 Screening (controlled)						
PM10	0.00037	kg/Mg		0.00037	kg/Mg	AP-42 11.19.2
	400,000	Mg/year		600,000	Mg/year	
PM10	148	kg/year		666	kg/year	assuming 3 screens, controlled emission
Reduction factor				0.8		Assuming 80% reduction as Roydon only has wet top coarse production, i.e. 20 mm for smallest product. No Barmac/APS crusher onsite.
PM10	**148**	kg/year		**133**	kg/year	
4.3 Conveyor transfer points (uncontrolled)\(controlled) *						
PM10	0.00055	kg/Mg		0.000023	kg/Mg	AP-42 11.19.2 controlled emission factor
Assume	10			10		transfer points
	400,000	Mg/year		600,000	Mg/year	
PM10	2,200	kg/year		138	kg/year	controlled emission

4.0 Gravel processing (includes fixed and mobile plant)						
	L. Wickham			Golder revised		Comments
Reduction factor				0.8		Assuming 80% reduction as Roydon only has wet top coarse production, i.e. 20 mm for smallest product. No Barmac/APS crusher onsite.
PM10	**2200**	kg/year		**28**	kg/year	
4.4 Truck loading - conveyor crushed						
PM10	0.00005	kg/Mg		0.00005	kg/Mg	AP-42 11.19.2
	400,000	Mg/year		600,000	Mg/year	
PM10	20	kg/year		30	kg/year	
Reduction factor				0		
PM10	**20**	kg/year		**30**	kg/year	

* Note that Ms Wichkam assumed no control for the conveyor transfer points, however these are controlled therefore Golder assumed controlled emission factor

Table G6: Ms. Wickham's and Golder's estimates for Roydon – Trucks on unsealed areas

5.0 Trucks on unsealed areas of site							
	L. Wickham				Golder revised		
5.1 Trucks \or Loader - Topsoil first year							
Assume	26	ha	Open ground		5	ha	Open ground
Assume	0.5	m	excavated to 0.5m		0.5	m	excavated to 0.5m
Topsoil to remove	130,000	m3			25,000	m3	
					40,000	Tonne	Based on topsoil density of 1.6 Mg/m3
Truck capacity	5	m3			20	Tonne	Average truck capacity
No. trucks	26,000	trucks/yr			4,000	trucks/yr	
1 lb/VMT	281.9	g/VKT			281.9	g/VKT	
k	1.5		AP-42 Table 13.2.2-2		1.5		AP-42 Table 13.2.2-2
a	0.9		AP-42 Table 13.2.2-2		0.9		AP-42 Table 13.2.2-2
b	0.45		AP-42 Table 13.2.2-2		0.45		AP-42 Table 13.2.2-2
s	4.8	%	Silt content, AP-42 Table 13.2.2-1 Plant road, gravel processing		4.8	%	Silt content, AP-42 Table 13.2.2-1 Plant road, gravel processing
W	5	Mg	mean vehicle weight (tons)		20	Mg	Mean vehicle weight
Assume	5.5	Mg	assumed average between empty (3) and full (8)		30	Mg	Average weight assuming 20 T capacity and 20T tare
PM10	0.83	lb/VMT			1.85	lb/VMT	
	233.28	g/VKT			522.44	g/VKT	
	0.23	kg/VKT			0.52	kg/VKT	
Assume each truck	1000	m	distance travelled on unsealed ground on site (i.e. 500 m one way and 500 m back)		400	m	Assume travel distance of 400 m
	20,000	trucks/yr			4000	trucks/yr	

5.0 Trucks on unsealed areas of site							
	L. Wickham				**Golder revised**		
PM10	4666	kg/yr			836	kg/yr	
Assume	0.7		with watering @ 70% efficient emissions reduction		0.7		
PM10	**1,400**	**kg/yr**			**251**	**kg/yr**	Controlled emission
5.2 Trucks \or Loader - Topsoil subsequent year							
Assume travel distance					**100**	**m**	Assume travel distance of 100 m
PM10	Not calculated				**28**	**kg/yr**	Scaled based on 2.2 ha and 100 m for subsequent years comparing to 5 ha and 400m for first year
5.3 Trucks \ or loader to mobile plant							
Trucks to mobile crushing site					Trucks \ or loader to mobile crushing site		
Gravel to move	250,000	m3			158,400	Tonne/yr	Assume average production rate of 120 t/hr for the mobile plant and working 11hrs/day and 120 days/yr
Truck capacity	5	m3			20	Tonne	Average truck capacity
No. trucks	50,000	trucks/yr			7,920	trucks/yr	
1 lb/VMT	281.9	g/VKT			281.9	g/VKT	
k	1.5		AP-42 Table 13.2.2-2		1.5		
a	0.9		AP-42 Table 13.2.2-2		0.9		
b	0.45		AP-42 Table 13.2.2-2		0.45		
s	4.8	%	Silt content, AP-42 Table 13.2.2-1 Plant road, gravel processing		4.8	%	
W	5	Mg	mean vehicle weight (tons)		20	Mg	
Assume	5.5	tonnes	assumed average between empty (3) and full (8)		30	Mg	Average weight assuming 20 T capacity and 20T tare.
PM10	0.8	lb/VMT	k x (s/12)a(W/3)b		1.9	lb/VMT	k x (s/12)a(W/3)b
	233	g/VKT			522	g/VKT	
	0.233	kg/VKT			0.522	kg/VKT	
Assume each truck	1,000	m	travelled on unsealed ground on site (i.e. 500 m one way and 500 m back)		100	m	Assume travel distance of 100 m base on 50m between mobile plant and washed reject material road/area
	50,000	trucks/yr			7,920	trucks/yr	
PM10	11,664	kg/yr			414	kg/yr	
Assume water reduction	70%		Watering control reduction		70%		Watering control reduction
PM10	**3,499**	**kg/yr**			**124**	**kg/yr**	Controlled emission water control

Table G7: Golder's estimates for Roydon – Cleanfill operation

6.0 Clean fill operation*			
	Golder estimates		
6.1 Loader pushing up cleanfill			
PM10			
k	0.35		AP42 13.2.4.1
U	3.9	m/s	Mean wind speed
M	1	%	Based on advice from Fulton Hogan
	0.00311075	kg/Mg	k x 0.0016 x (U/2.2)1.2 / (M/2)1.4
Amount of cleanfill	100,000	m3/year	Assuming 1/3 of the extracted volume will be filled
	160,000	Mg/year	Assuming cleanfill density of 1.6 kg/m3
PM10	498	kg/year	uncontrolled emission
Assume water reduction	70%		
PM10	**149**	kg/year	Controlled emission
6.2 Trucks Dumping cleanfill			
PM10			
k	0.35		
U	3.9		
M	1	%	Based on advice from Fulton Hogan
	0.00311075	kg/Mg	
Amount of cleanfill	160,000	Mg/year	Assuming 1/3 of the extracted volume will be filled
PM10	498	kg/year	uncontrolled emission
Assume water reduction	70%		
PM10	**149**	kg/year	Controlled emission
6.3 Road			
Trucks between reject material road and dumping area			
No. cleanfill trucks	8,000	trucks/yr	
Truck capacity	20	Tonne	Average truck capacity
1 lb/VMT	281.9	g/VKT	
k	1.5		
a	0.9		
b	0.45		
s	4.8		
W	30	Tonne	Average weight assuming 20 T capacity and 20T tare.
PM10	1.9	lb/VMT	
	522	g/VKT	
	0.522	kg/VKT	
Assume each truck	100	m	Assume travel distance based on 50 m between reject material road and dumping area
	8,000	trucks/yr	
PM10	418	kg/yr	uncontrolled emission
Assume water reduction	70%		
PM10	**125**	**kg/yr**	controlled emission

*Note: Ms. Wickham hasn't calculated emission associated with cleanfill activities

Golder's estimates for Roydon, Yaldhurst, Pound Rd, Roberts Rd and Barters quarries are presented in Table G8. Breakdowns are provided in Table G9 to G13.

Table G8: Summary of Annual PM10 emission estimates (kg/yr)

Site	Site prep.	Erosion	Bulk handling (loading/unloading)	Trucks/ unpaved	Processing	Total
Yaldhurst Quarries[a]	-	8,400	1,500	21,700	3,900	35,400
Pound & Roberts Rd - current[b]	NC	1,500	400	200	900	2,900
Barters block - current	-	200	NC*	NC	0	200
Pound Asphalt	-	-	-	-	20,000	20,000
Roydon[c]	100	100	460	300	200	1,200

- *NC = Not calculated,
- [a] 2,000,000 T/yr, [b] 440,000 T/yr, [c] 600,000 T/yr

Table G9: Golder's estimates for Roydon, Yaldhurst, Pound Rd, Roberts Rd and Barters quarries- Wind erosion

Sites	**Roydon**		**Yaldhurst**		**Pound Rd**		**Barters**		**Roberts Rd**	
PM10 emission factor (Mg/ha/yr)	0.085		0.085		0.085		0.085		0.085	
Open area (ha)	5	Assumed total open area	115	assume 50% of 230 ha is open area	42.6	Current open area	6.44	Current open area	14.6	Current open area
Uncontrolled emission (Mg/year)	0.43		9.78		3.62	Current emission rate -uncontrolled	0.55	Current emission rate -uncontrolled	1.24	Current emission rate -uncontrolled
Controlled emission (kg/year)	**98**	control efficiency of 84% for the use of gravel and 70% for wet material	**8,407**	based on 20% of the open area has water suppression	**1,086**	Control efficiency of 70% for wet material	**164**	Control efficiency of 70% for wet material	**372**	Control efficiency of 70% for wet material

Table G10: Golder's estimates for Roydon, Yaldhurst, Pound Rd, Roberts Rd and Barters quarries- Gravel loading/unloading

	Roydon[a]			Yaldhurst[b]				Pound road [c]/Roberts Rd		
Excavation (Roydon and Yaldhurst Quarries)								Excavation at Roberts Rd (Roberts Rd only)		
k	0.35									
U	3.9	m/s								
M	5	%								
	0.00033	kg/Mg								
	600,000	Mg/year								
Uncontrolled	196	kg/year								
Reduction	70	%								
PM10	**59**	kg/year		**196**	kg/year	Scaled by the Yaldhurst extraction rate of 2 million tonnes/yr to the Roydon rate of 0.6 million tonnes/yr		**44**	kg/year	Scaled by Pound rd processing rate of 0.44 million T/hr to the Roydon rate of 0.6 million tonnes/yr
loader to conveyor \truck										
PM10	**59**	kg/year		**196**	kg/year	Same as the above		**44**	kg/year	Same as the above
Truck/conveyor unloading (Roydon and Yaldhurst Quarries)								Pit run truck unloading at Pound Rd (Pound Road only)		
	59	Kg/year		**98**	kg/year	Same as the above, but assumed 50% gravels transferred by trucks		**44**	kg/year	Same as the above

Note: [a] 600,000 T/yr, [b] 2,000,000 T/yr, [c] 440,000 T/yr

Table G11: Golder's estimates for Roydon, Yaldhurst, and Pound Rd quarries- Gravel processing

	Roydon[a]		Yaldhurst Quarries[b]		Comments	Pound Rd[c]		Comments
Crushing (controlled)								
PM10	0.00027	kg/Mg						
	600,000	Mg/year						
PM10 Before applying reduction	324	kg/year	**1080**	kg/year	Scaled based on the estimated Yaldhurst extraction rate of 2 million tonnes/yr comparing to the Roydon rate of 0.6 million tonnes/yr	240	kg/year	Scaled based on Pound rd processing rate of 0.44 million T/hr to the Roydon rate of 0.6 million tonnes/yr
Reduction factor	0.8					0.8		Assuming 80% reduction as Pound only has wet top coarse production, i.e. 20 mm for smallest product. No Barmac/APS crusher onsite.
PM10	**65**	kg/year				**48**	kg/year	
Screening (controlled)								
PM10	0.00037	kg/Mg						
	600,000	Mg/year						
PM10 Before applying reduction	666	kg/year	**2,220**	kg/year	Same as the above	493	kg/year	Scaled based on Pound rd processing rate of 0.44 million T/hr to the Roydon rate of 0.6 million tonnes/yr
Reduction factor	0.8					0.8		
PM10	**133**	kg/year				**99**	kg/year	
Conveyor transfer points (controlled)								
PM10	0.000023	kg/Mg						
Assume	10							
	600,000	Mg/year						
PM10	138	kg/year	**460**	kg/year	Same as the above	102	kg/year	Same as the above
Reduction factor	0.8					0.8		
PM10	**28**	kg/year				**20**	kg/year	
Truck loading - conveyor crushed								
PM10	0.00005	kg/Mg						
	600,000	Mg/year						
PM10	**30**	kg/year	**100**	kg/year	Same as the above	**22**	kg/year	Same as the above

Note: [a] 600,000 T/yr, [b] 2,000,000 T/yr, [c] 440,000 T/yr

Table G12: Golder's estimates for Roydon and Yaldhurst quarries- Trucks on unsealed area

	Roydon				Yaldhurst Quarries		
Trucks \or Loader Movements - Topsoil first year (Roydon Only)							
Assume	5	ha	Open ground				
Assume	0.5	m	excavated to 0.5m				
Topsoil to remove	25,000	m3					
	40,000	Tonne	Based on topsoil density of 1.6 Mg/m3				
Truck capacity	20	Tonne	Average truck capacity				
No. trucks	4,000	trucks/yr					
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	4.8	%	Silt content, AP-42 Table 13.2.2-1 Plant road, gravel processing				
W	20	Mg	Mean vehicle weight				
Assume	30	Mg	Average weight assuming 20 T capacity and 20T tare				
PM10	1.85	lb/VMT					
	522.44	g/VKT					
	0.52	kg/VKT					
Assume each truck	400	m	Assume travel distance of 400 m				
	4000	trucks/yr					
PM10	836	kg/yr					
Assume	0.7						
PM10	**251**	**kg/yr**	Controlled emission		Not calculated		
Trucks \or Loader Movements - Topsoil subsequent year (Roydon Only)							
Assume travel distance	**100**	**m**	Assume travel distance of 100 m				
PM10	**28**	**kg/yr**	Scaled based on 2.2 ha and 100 m for subsequent years comparing to 5 ha and 400m for first year		Not calculated		
Trucks \ or loader movements - mobile plant (Roydon Only)					**Truck entering/leaving the site - unsealed road (Yaldhurst Only)**		
Gravel to move	158,400	Tonne/yr	Assume average production rate of 120 t/hr for the mobile plant and working 11hrs/day and 120 days/yr		2,000,000	Tonne/yr	Extraction rate for Yaldhurst quarries

	Roydon				Yaldhurst Quarries		
Truck capacity	20	Tonne	Average truck capacity		20	Tonne	Average truck capacity
No. trucks	7,920	trucks/yr			100,000	trucks/yr	
1 lb/VMT	281.9	g/VKT			281.9	g/VKT	
k	1.5				1.5		
a	0.9				0.9		
b	0.45				0.45		
s	4.8	%			4.8	%	
W	20	Mg			20	Mg	
Assume	30	Mg	Average weight assuming 20 T capacity and 20T tare.		30	Mg	Average weight assuming 20 T capacity and 20T tare.
PM10	1.9	lb/VMT	k x (s/12)a(W/3)b		1.9	lb/VMT	k x (s/12)a(W/3)b
	522	g/VKT			522	g/VKT	
	0.522	kg/VKT			0.522	kg/VKT	
Assume each truck	100	m	Assume travel distance of 100 m base on 50m between mobile plant and washed reject material road/area		1,000	m	on unsealed road
	7,920	trucks/yr			100,000	trucks/yr	
PM10	414	kg/yr			52,244	kg/yr	
Assume water reduction	70%		Watering control reduction		70%		Watering control reduction
PM10	**124**	**kg/yr**	Controlled emission water control		**15,673**	**kg/yr**	Controlled emission water control
					Extraction to processing plant on unsealed road (Yaldhurst Only)		
					500	m	on unsealed road
					3,918	**kg/yr**	Half assumed via trucks due to conveyor at Miner's block

Table G13: Golder's estimates for Roydon, Yaldhurst and Pound Road quarries- Cleanfill operation

	Roydon[a]		Yaldhurst quarries[b]			Pound Rd[c]		
Loader pushing up cleanfill								
PM10								
k	0.35							
U	3.9	m/s						
M	1	%						
	0.00311075	kg/Mg						
Amount of cleanfill	100,000	m3/year						
	160,000	Mg/year						
PM10	498	kg/year						
Assume water reduction	70%							
PM10	**149**	kg/year	**498**	kg/year	Scaled based on the estimated Yaldhurst extraction rate of 2 million tonnes/yr comparing to the Roydon rate of 0.6 million tonnes/yr	**110**	kg/year	Scaled based on Pound rd processing rate of 0.44 million T/hr to the Roydon rate of 0.6 million tonnes/yr
Trucks Dumping cleanfill								
PM10								
k	0.35							
U	3.9							
M	1	%						
	0.00311075	kg/Mg						
Amount of cleanfill	160,000	Mg/year						
PM10	498	kg/year						
Assume water reduction	70%							
PM10	**149**	kg/year	**498**	kg/year	Same as the above	**110**	kg/year	Same as the above
Movement on unsealed road								
No. cleanfill trucks	8,000	trucks/yr						
Truck capacity	20	Tonne						
1 lb/VMT	281.9	g/VKT						
k	1.5							
a	0.9							
b	0.45							
s	4.8							
W	30	Tonne						
PM10	1.9	lb/VMT						
	522	g/VKT						
	0.522	kg/VKT						
Assume each truck	100	m	500	m	on unpaved road	200	m	on unpaved road
	8,000	trucks/yr						
PM10	418	kg/yr						
Water reduction	70%							
PM10	**125**	kg/year	**2090**	kg/year	Scaled based on Yaldhurst extraction rate of 2 million tonnes/yr and travel distance of 500m comparing to the Roydon rate of 0.6 million tonnes/yr and travelling 100 m	**186**	kg/year	Scaled based on Pound rd processing rate of 0.44 million T/hr and travel distance of 200 m to the Roydon rate of 0.6 million tonnes/yr and travelling 100 m

Note: [a] 600,000 T/yr, [b] 2,000,000 T/yr, [c] 440,000 T/yr