Mount Cotton Quarry Dust Investigation

December 2008 to December 2009

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Queensland Government

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Summary

In March 2008 the Queensland Government conducted a one-month dust monitoring program in the Mount Cotton community to assess the impact of quarrying operations on surrounding air quality. While this monitoring study demonstrated that quarrying operations did not result in ambient dust or silica levels above relevant nuisance and health criteria in the surrounding Mount Cotton community, it was noted that 'worst-case' dust levels were unlikely to have been experienced in the wider community during the monitoring period. To address the limitations of the initial investigation, the Queensland Government instigated a second dust monitoring investigation in the Mount Cotton community from December 2008 to December 2009.

No evidence was found that quarry operations led to PM_{10} (particles less than 10 micrometres in diameter) levels above the Environmental Protection (Air) Policy 2008 (EPP Air) 24-hour air quality objective of 50 µg/m^3 in the surrounding community. All exceedences of the EPP Air PM_{10} objective measured during the investigation were caused by dust events affecting the whole South-East Queensland region (such as dust storms or bushfire smoke) or local non-quarry PM_{10} sources. Overall, PM_{10} concentrations measured at Mount Cotton were lower than those measured at other South-East Queensland monitoring sites over the same period.

$PM_{2.5}$ (particles less than 2.5 micrometres in diameter) levels were found to comply with the EPP Air annual average objective of 8 µg/m^3 over the investigation period. The annual average $PM_{2.5}$ concentrations at Mount Cotton were found to be similar to those measured at other South-East Queensland ambient air quality monitoring sites located in residential areas, and lower than $PM_{2.5}$ levels measured at roadside and commercial area locations, over the same period. Compliance with the EPP Air 24-hour objective of 25 µg/m^3 was not possible as discrete 24-hour $PM_{2.5}$ sampling was not conducted. However, from the seven-day average $PM_{2.5}$ measurements it could be concluded that the EPP Air 24-hour $PM_{2.5}$ objective would have been exceeded at the monitoring site closest to the quarry on at least two occasions – in May 2009 and during a dust storm in September 2009. While wind direction data suggested that quarry dust emissions were likely to have contributed to the elevated $PM_{2.5}$ measurement in May, it was not possible to quantify the contribution from quarrying activities.

Annual average $PM_{2.5}$ crystalline silica concentrations in the Mount Cotton community were very low, less than ten per cent of the guideline value of 3 µg/m^3 set in the Victorian Government's Protocol for Environmental Management for Mining and Extractive Industries (PEMMEI). Crystalline silica was detected in 90 per cent of $PM_{2.5}$ samples collected at the monitoring site located within 300 metres of the quarry boundary, but in less than 50 per cent of samples at a distance of 1.5 kilometres from the quarry.

Nuisance dust levels measured at the monitoring sites were less than 50 per cent of the quarry development approval limit of 120 mg/m^2/day most of the time. The development approval limit was exceeded only once – at the site closest to the quarry boundary during August 2009. While ash content and wind direction data identify quarry dust emissions as a likely contributing source to this exceedence, it was not possible to determine the relative proportions of quarry and non-quarry dust in the collected sample. Low nuisance dust levels at this site during other sampling periods with similar meteorological conditions suggested that any contribution to this exceedence from the quarry site was unlikely to be the result of routine operations.

Monitoring results confirmed that quarrying activities were a source of particles and crystalline silica in the surrounding community, however it was evident that particles generated by other

sources were a significant factor in overall community exposure, particularly at monitoring sites located more than one kilometre from quarry operations.

The outcomes from this investigation supported the conclusions of the initial March 2008 study that the Mount Cotton community is unlikely to suffer any adverse health effects from particle and crystalline silica generated by quarrying activities in the area.

Background

People living in the Mount Cotton area have raised concerns about the impacts of air emissions from quarrying activities on the health and well-being of the surrounding community. These concerns have primarily focused on respirable crystalline silica in dust emissions, and its potential to cause lung diseases, including silicosis.

The two main quarries in the area are Karreman's Quarry (processing approximately 2.7 million tonne/year) and Barro Group Pty Ltd (processing approximately 0.5 million tonnes/year). Both quarries are located adjacent to West Mount Cotton Road, Mount Cotton.

The emissions to air, land and water from the quarrying activities in the Mount Cotton area are regulated by the Department of Environment and Heritage Protection (DEHP) as Environmentally Relevant Activities under conditions of development approvals issued in accordance with the *Environmental Protection Act 1994*. The DEHP sets standard development approval conditions for quarries regarding dust emissions, including nuisance dust emissions and dust emissions potentially affecting human health. Specifically, the approvals require dust or other particulate matter generated from the quarrying activities to not cause a nuisance at a nuisance sensitive place such as a school, child care facility or domestic residence. The quarries must monitor air quality at the direction of the DEHP and/or when complaints are received. The quarries also monitor air quality at the workplace in order to meet Workplace Health and Safety requirements.

In response to residents' concerns, the Queensland Government conducted an initial one-month dust monitoring program in the Mount Cotton community between 3 March and 7 April 2008. Monthly dustfall, 24-hour PM_{10} and 24-hour PM_{10} crystalline silica levels were measured at four community sites within five kilometres of quarrying operations. This monitoring program showed that quarrying operations did not result in ambient dust and crystalline silica levels above relevant nuisance and health criteria in the surrounding Mount Cotton community. From the monitoring results, Queensland Health formed the view that the Mount Cotton community was unlikely to have suffered any adverse health effects from PM_{10} dust and respirable crystalline silica generated from quarrying activities in the Mount Cotton area.

However, frequent rainfall events and the relatively low frequency of winds blowing from quarrying operations towards the monitoring sites meant that it was unlikely that 'worst-case' dust levels in the wider community were present during the monitoring period. In addition, compliance with the annual criteria for ambient crystalline silica could not be definitively concluded on the basis of one month's monitoring. For these reasons, the Queensland Government conducted further monitoring over a twelve month period from December 2008 to December 2009 at three locations around Karreman's Quarry (the larger of the two quarries) to address these shortcomings in the initial monitoring program. This report details the findings of this second monitoring program.

Monitoring study design

The potential health effects of dust are closely related to particle size. The size range of airborne particles varies from less than 0.1µm up to about 500µm (or half a millimetre). Human health effects of airborne dust are mainly associated with particles less than 10µm in diameter (termed PM_{10}), which are small enough to be inhaled into the lower respiratory tract. PM_{10} particles can arise from combustion processes (e.g. motor vehicle engines) and mechanical processes (e.g. rock crushing, windblown dust).

There is an increasing body of evidence to suggest that of the PM_{10} fraction, those particles less than 2.5µm in diameter (termed $PM_{2.5}$) may be the major area of concern with regard to adverse effects on human health. $PM_{2.5}$ particles arise predominantly from combustion processes, although some particles generated by mechanical processes will be in the $PM_{2.5}$ size range.

The compositon of, or contaminants present in, the particles may also be of concern. Dusts from quarrying can contain silica in both crystalline and non-crystalline forms. Only exposure to respirable crystalline silica is associated with adverse health effects.

Particulate matter can also cause considerable nuisance problems through soiling of property. Nuisance effects can be caused by particles of any size, but are most commonly associated with those larger than 20µm. A common method used to assess dust nuisance is to measure dust deposition, or the amount of dust that settles out of the air over a known area in a fixed period of time.

The monitoring program undertaken by the Queensland Government in the Mount Cotton community surrounding Karreman's Quarry between December 2008 and December 2009 was modelled on the initial study, with the addition of $PM_{2.5}$ particle sampling. The monitoring program obtained data on:

- PM_{10} levels – for assessment against national standards based on health;
- $PM_{2.5}$ levels – for assessment against national standards based on health;
- $PM_{2.5}$ crystalline silica levels – for assessment against health-based criteria; and
- Deposited dust levels – for assessment of dust nuisance.

PM_{10} results were compared against the Queensland Environmental Protection (Air) Policy 2008 (EPP Air) 24-hour air quality objective of 50 µg/m^3. $PM_{2.5}$ results were compared against the EPP Air annual objective of 8 µg/m^3. The period over which $PM_{2.5}$ samples were collected (seven days – necessary to collect sufficient material for crystalline silica analysis) did not permit comparison against the EPP Air 24-hour $PM_{2.5}$ objective of 25 µg/m^3.

In the absence of an EPP Air objective or national ambient air quality guideline for crystalline silica, measured $PM_{2.5}$ crystalline silica levels were compared against the annual guideline of 3 µg/m^3 set in the Victorian Government's Protocol for Environmental Management for Mining and Extractive Industries (PEMMEI)[1]. The Victorian criterion is based on the Californian Office of Environmental Health Assessment (OEHHA) chronic inhalation Reference Exposure Level (REL) of 3 µg/m^3 for respirable crystalline silica for community exposures[2], but measures the crystalline silica concentration in the $PM_{2.5}$ fraction rather than the respirable fraction (particles less than approximately four micrometres in diameter). The chronic inhalation REL has been defined by the OEHHA as "an airborne level that would pose no significant health risk to individuals indefinitely exposed to that level"[3]. Queensland Government monitoring of ambient crystalline silica levels adjacent to road construction works has determined that $PM_{2.5}$ crystalline silica measurements provide a very close approximation of respirable crystalline silica levels[4].

The quarry has a development approval condition for dust deposition issued by the DEHP which is designed to limit dust nuisance impacts in the surrounding community. Quarry operations must not result in a dust deposition rate for the insoluble solids fraction above 120 mg/m^2/day over a 30 day period. Deposited dust levels measured at the community monitoring sites were compared against this development approval condition.

Three monitoring sites in the community were chosen for the investigation (Figure 1), based on locations of community concern. Monitoring was conducted at:

- Avalon Road, Sheldon (Site 1) – approximately 1.5km north-northwest of the quarry;
- West Mount Cotton Road, Mount Cotton (Site 2) – approximately 0.3km north-east of the quarry; and
- West Mount Cotton Road, Mount Cotton (Site 3) – approximately 1km south-east of the quarry.

Two of these sites (Site 1 and Site 3) were included in the previous monitoring investigation. The other site (Site 2) was chosen for its close proximity to quarry operations.

Figure 1: Location of the monitoring sites in relation to the quarry site.

PM_{10} concentration data was collected on a continuous basis (as 30-minute averaged concentrations) at Site 3, beginning in late January 2009. Monitoring was conducted using a TEOM® (tapered element oscillating microbalance) Model 1400AB analyser operated in accordance with Australian Standard AS 3580.9.8:2001[5]. The analyser drew air through a PM_{10} size-selective inlet (to remove particles larger than 10µm). The PM_{10} particle stream then passed through a filter mounted on a hollow vibrating glass tube. PM_{10} mass was measured by the change in the oscillating frequency of the glass tube following particle deposition on the filter. The information provided by the TEOM® analyser permitted assessment to be made against the EPP Air 24-hour average air quality objective for PM_{10}. The short time resolution also enabled an assessment of the levels of PM_{10} particles associated with different wind direction ranges.

$PM_{2.5}$ samples were collected at Site 1 and Site 2 over seven days periods throughout the entire twelve month investigation period using Partisol® Model 2025 sequential low-volume air samplers operated in accordance with Australian/New Zealand Standard AS/NZS 3580.9.10:2006[6]. The sequential air samplers operated by drawing air through a PM_{10} size-selective inlet (to remove particles larger than 10µm), then through a $PM_{2.5}$ very-sharp cut cyclone (to remove particles larger than 2.5µm). The $PM_{2.5}$ particles were then deposited on a pre-weighed 47mm diameter Teflon® filter over a seven day period. At the end of the seven day sampling period the filter was automatically transferred to a holding canister and a new filter was loaded into the sampling filter position. After sampling the filter was again weighed, with the difference in weight being the mass of $PM_{2.5}$ particles collected. The $PM_{2.5}$ mass concentration was calculated by dividing the mass of particles collected by the volume of air drawn through the sampler. Field sampling was conducted by departmental staff and the gravimetric analysis was carried out by the Queensland Government Safety in Mines, Testing and Research Station (Simtars).

The particle matter collected by the Partisol® samplers was analysed for crystalline silica content. Sample collection was conducted over seven days to collect sufficient particle matter for the crystalline silica analysis. Analysis of the crystalline silica content of the $PM_{2.5}$ particles was determined by infrared spectroscopy using a method based on the National Health and Medical Research Council and National Institute for Occupational Safety and Health methods[7,8]. The analysis was carried out by Simtars.

Dust deposition measurement was by means of a collection bottle, which retained the dust settling on a fixed surface area over a period of time. The dust was removed from the bottle, filtered and weighed, and the results reported in terms of the weight of dust collected per unit of surface area over a fixed period of time, e.g. $mg/m^2/day$. Collection and analysis were carried out in accordance with Australian/New Zealand Standard AS/NZS 3580.10.1:2003[9]. The analysis method included the determination of both dissolved and insoluble deposited matter, and further breakdown of the insoluble matter into combustible matter and ash, in the total dust sample collected. Insoluble matter is the solid material collected by filtering the sample, while the dissolved matter is determined by evaporating some or all of the liquid filtrate. As a general rule, the dissolved material is of no interest in assessing nuisance effects, especially in a coastal environment where a large proportion of the dissolved matter would be marine salt. Combustible matter is that portion of the insoluble matter lost during combustion and is an indication of the amount of organic matter in the dust. The ash content is an indication of the mineral content of the dust.

To assist with the determination of the contribution of quarrying activities to overall particle levels, wind speed and direction measurements at a height of 10 metres above ground level, averaged over 30-minute periods, were recorded at Site 3 from the commencement of monitoring at this site in late January 2009. For the period of the investigation when local wind data was not available (23 December 2008 to 29 January 2009), wind measurements at Mount Cotton were derived from measurements taken at other locations within the Queensland Government's South-East Queensland ambient air quality monitoring network.

Results and Discussion

Meteorology

Wind direction was a key factor in determining the impacts of dust from quarrying operations at the three monitoring sites. Thirty-minute averaged wind speed and direction at Site 3 over the investigation period are summarised in the wind rose shown in Figure 2. For each of the 16 wind direction ranges (this is the direction the wind is blowing from), the frequency of wind speeds in each of the various ranges is indicated by the length of the rose arm for that wind direction.

Figure 2: Site 3 wind rose – 29 January 2009 to 23 December 2009.

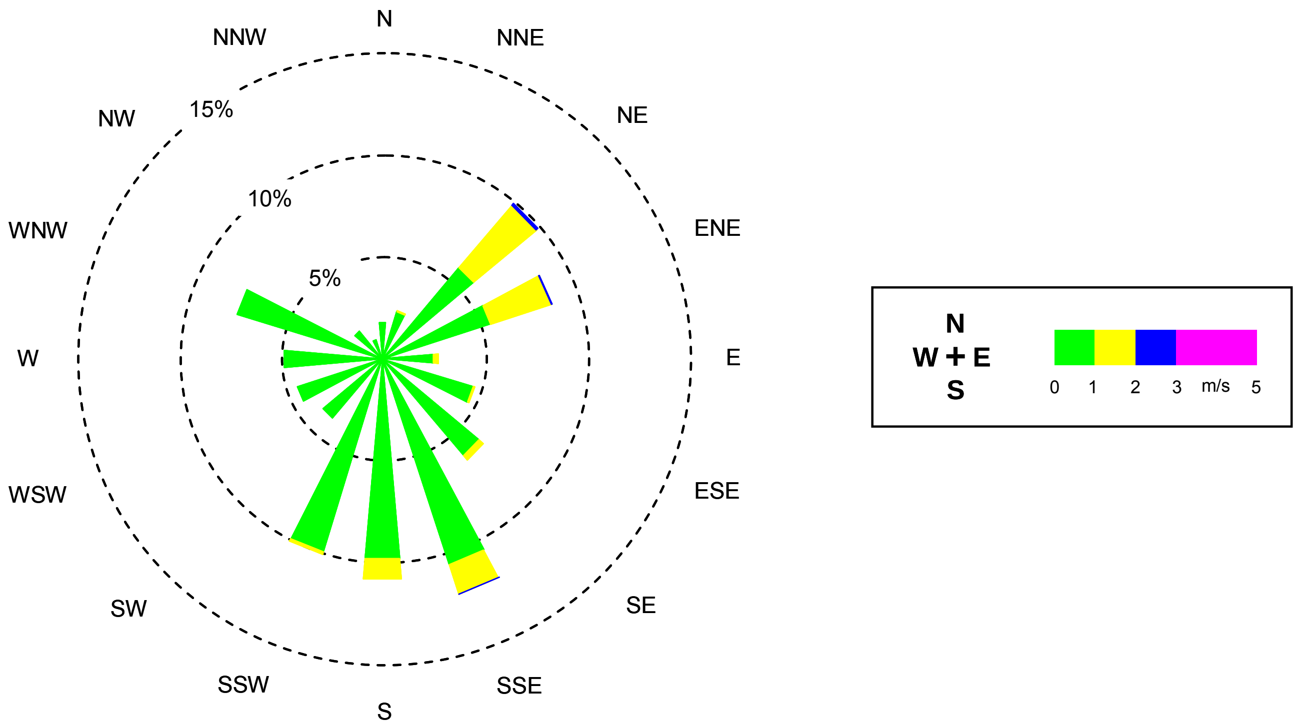


Table 1 lists the wind direction ranges necessary for dust generated by operations at Karreman's Quarry to impact at the three monitoring sites and the proportion of winds within these ranges during the period when local wind measurements were available.

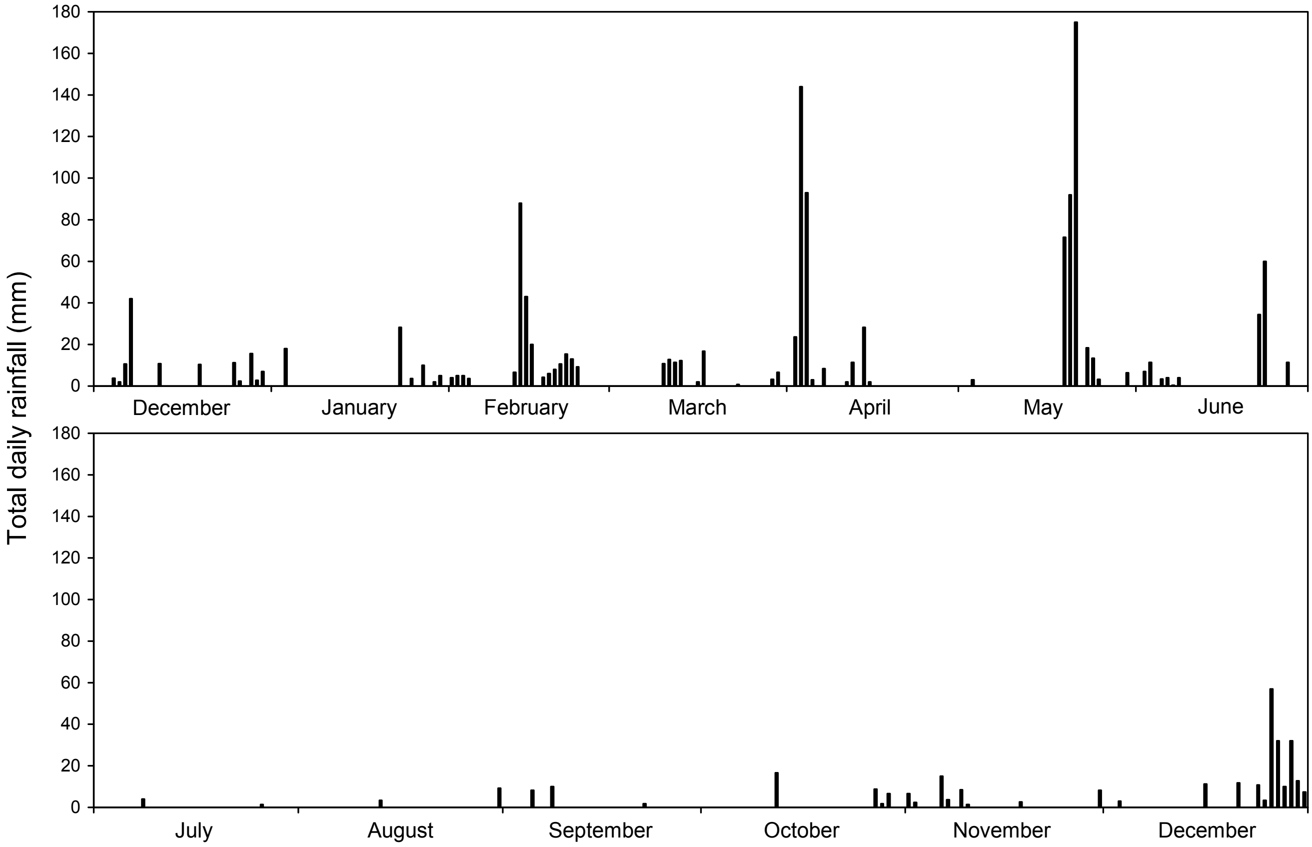
Table 1: Wind direction ranges for dust from quarrying operations to impact monitoring sites.

Monitoring site	Wind direction range for impacts from quarrying operations	Proportion of winds within the range for impacts from quarrying operations (%)
Site 1	SSE to S	23
Site 2	SSW to WNW	30
Site 3	WNW to N	12

During the investigation period the most prevalent winds were from the northeast or south. None of the three monitoring site locations were located directly downwind from the quarry during northeast wind conditions. Under northeast wind conditions any dust from quarrying activities would be carried over some of the least populated areas within the surrounding community. During southerly winds dust from quarrying activities could impact on Site 1 (particularly on SSE winds) and Site 2 (particularly on SSW winds). Over the investigation period, Site 2 experienced the highest proportion of winds within the range for impacts from quarrying operations, while Site 3 experiences the lowest proportion.

A second factor potentially impacting on measured dust levels through possible dust suppression was rainfall. Daily rainfall totals from the Bureau of Meteorology recording site at Mount Cotton West[10] across the investigation period are shown in Figure 3.

Figure 3: Mount Cotton rainfall – December 2008 to December 2009.



Rainfall at Mount Cotton was below long-term median levels for much of the investigation period, particularly between July 2009 and mid-December 2009. This indicated that particle measurements were likely to have captured the upper range of community exposure. Some suppression of dust generation from exposed surfaces will have resulted during heavy rainfall episodes in February, April and May 2009. Monitoring data collected during periods of heavy rainfall have been excluded from some analyses into the contribution from quarrying operations on particle levels at the monitoring locations that appear in this report.

Regional particle events

As mentioned above, 2009 was a significantly drier than average year across much of Australia. The dry conditions gave rise to a number of dust storm and bushfire events which, at times, led to elevated particle levels across the entire South-East Queensland region, including Mount Cotton. Table 2 summarises the regional particle events which occurred during the Mount Cotton quarry dust investigation period.

Table 2: South-East Queensland regional particle events between December 2008 and December 2009.

Date	Major factor	Details
2 July 2009	Wind blown dust	Dust transported from northern South Australia across southern Queensland by strong westerly winds
26 to 28 August 2009	Wind blown dust, smoke	A combination of windblown dust generated by hot dry gusty north-westerly winds and smoke from widespread grass fires
23 to 27 September 2009	Dust storms	Strong winds associated with the passage of two weather fronts whipped up dry sediment from inland evaporation pans and floodplains in central Australia into extensive dust storms that affected much of eastern Australia.
3 October 2009	Wind blown dust	Strong winds accompanying the passage of a weather front carried dust from inland Australia over the South-East Queensland region.
14 to 15 October 2009	Wind blown dust	Strong winds accompanying the passage of a weather front carried dust from inland Australia over the South-East Queensland region.
30 November to 1 December 2009	Smoke	In the second half of November there were a number of large fires in bushland in the Lockyer Valley between Esk and Gatton. During westerly winds particles from the Lockyer Valley fires were transported over coastal areas of south-east Queensland.

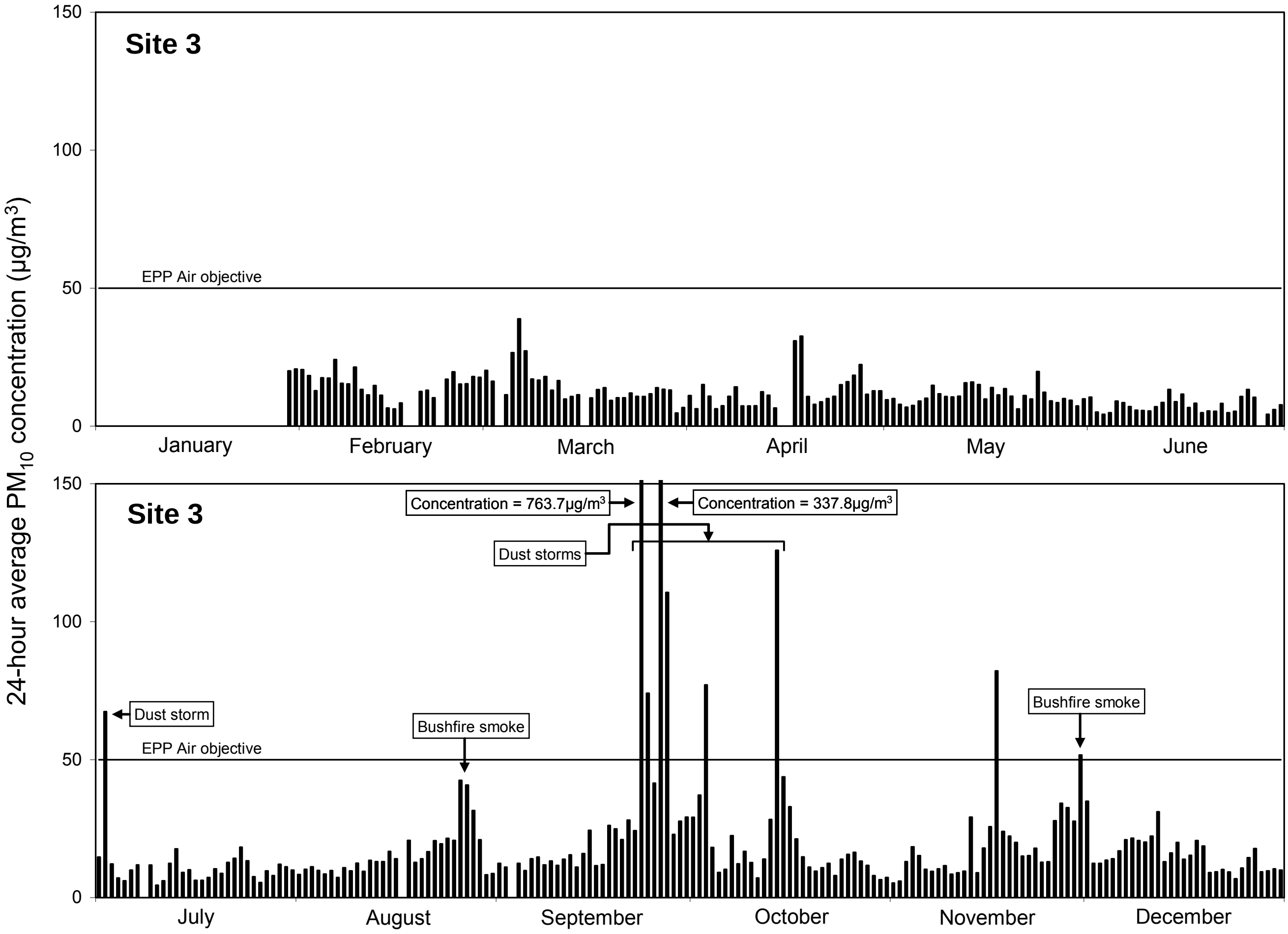
Monitoring data collected during the above periods are not indicative of quarrying operation impacts and have been excluded from some analyses into the contribution from quarrying operations on particle levels at the monitoring locations that appear in this report.

PM_{10}

The 24-hour average PM_{10} concentrations obtained from the TEOM® instrument at Site 3 are displayed graphically in Figure 4. The highest 24-hour PM_{10} concentration measured was 763.7 µg/m^3 on 23 September 2009 during a dust storm. Excluding regional particle events, the highest PM_{10} concentration measured was 82.2 µg/m^3 on 17 November 2009. The average PM_{10} concentration between January and December 2009 was 18.8 µg/m^3.

During the investigation period there were nine days when the 24-hour PM_{10} concentration was greater than the EPP Air objective value of 50 µg/m^3. Eight of these exceedences occurred during the regional particle events described above and were not the result of activities taking place at the quarry site. On the day of the remaining exceedence, 17 November 2009, 30-minute average PM_{10} concentrations greater than 50 µg/m^3 were measured during wind directions ranging from north to north-east and also south-southeast. Winds only blew from the direction of the quarry for a total of 90 minutes during the day. It is therefore unlikely that quarry activities were the major cause of the high particle levels on 17 November. While the source of the high PM_{10} levels was not able to be confirmed, the hot dry conditions existing at the time suggest that smoke from an unidentified fire was most likely responsible.

Figure 4: Daily 24-hour average PM_{10} concentrations at the Site 3 monitoring site, January to December 2009.



Comparison of the range of PM_{10} concentrations measured at Mount Cotton with those measured at other monitoring sites in South-East Queensland during 2009 is provided in Table 3. Two sets of comparison data are provided – one covering all days of the year and a second set where days corresponding to regional particle events have been removed.

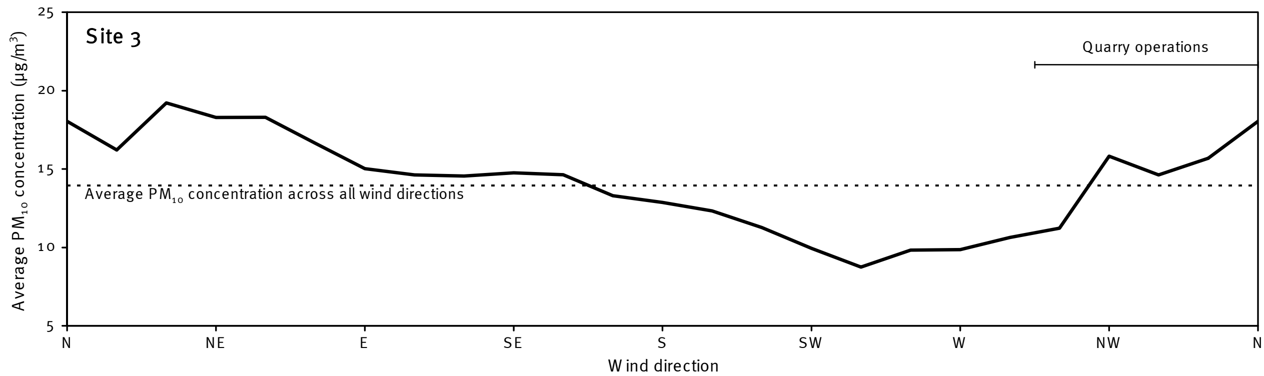
Overall, PM_{10} concentrations measured at Mount Cotton were lower than those measured at other South-East Queensland monitoring sites, including those located in residential areas (Wynnum and Springwood).

Table 3: 2009 daily average PM_{10} concentration statistics for South-East Queensland monitoring sites

Location	Maximum ($\mu g/m^3$)	Average ($\mu g/m^3$)	Median ($\mu g/m^3$)	Number of days standard exceeded
All days				
Mount Cotton	763.7	18.8	12.4	9
Wynnum	933.8	23.0	15.9	9
Pinkenba	564.6	21.2	17.3	8
Brisbane CBD	1013.4	22.9	16.7	7
South Brisbane	1060.3	28.4	21.2	15
Woolloongabba	850.8	25.6	19.7	12
Rocklea	1033.4	25.0	17.6	9
Springwood	960.0	21.1	14.7	10
Regional particle event days removed				
Mount Cotton	82.2	14.0	12.1	1
Wynnum	49.7	17.1	15.3	0
Pinkenba	47.2	17.9	16.9	0
Brisbane CBD	43.4	17.0	16.4	0
South Brisbane	49.0	21.8	20.8	0
Woolloongabba	52.3	20.2	19.1	1
Rocklea	49.2	19.0	17.4	0
Springwood	38.1	15.6	14.5	0
The Environmental Protection (Air) Policy 2008 air quality objective for PM_{10} is a 24-hour average of 50 $\mu g/m^3$.				

An analysis of the relationship between PM_{10} concentration and wind direction at Site 3 made was undertaken to determine if higher PM_{10} concentrations were associated with certain wind directions. Using all 30-minute average PM_{10} and wind measurements between January and December 2009 (excluding those measurements collected during regional particle events), average PM_{10} concentrations for discrete 15 degree wind direction ranges were calculated and compared to the average PM_{10} concentration across the whole year. This relationship is graphed in Figure 5.

Figure 5: Average PM_{10} concentrations for 15 degree wind direction ranges at Site 3, January to December 2009



It can be seen that PM_{10} concentrations above the yearly average were associated with some winds coming from the direction of the quarry site. However, similar or higher average PM_{10} levels were found for wind directions between north and east, where there is no contribution from quarrying activities. From these findings, it can be seen that dust emissions from the quarry site do contribute to PM_{10} levels at Site 3, but that other urban and natural PM_{10} sources are equally important in overall community exposure.

$PM_{2.5}$

The seven-day average $PM_{2.5}$ monitoring results obtained from the Partisol® instruments at Site 1 and Site 2 are summarised in Table 4 and presented graphically in Figure 6. The highest seven-day average $PM_{2.5}$ concentrations were 19.5 µg/m^3 at Site 1 and 33.0 µg/m^3 at Site 2 for the period from 23 September to 29 September 2009 when two major dust storms occurred. Excluding regional particle events, the highest seven-day $PM_{2.5}$ concentrations were 19.0 µg/m^3 at Site 1 for the period from 3 June to 9 June 2009 and 25.6 µg/m^3 at Site 2 for the period from 13 May to 19 May 2009.

Table 4: Seven-day average $PM_{2.5}$ monitoring results at Site 1 and Site 2 monitoring sites, December 2008 to December 2009

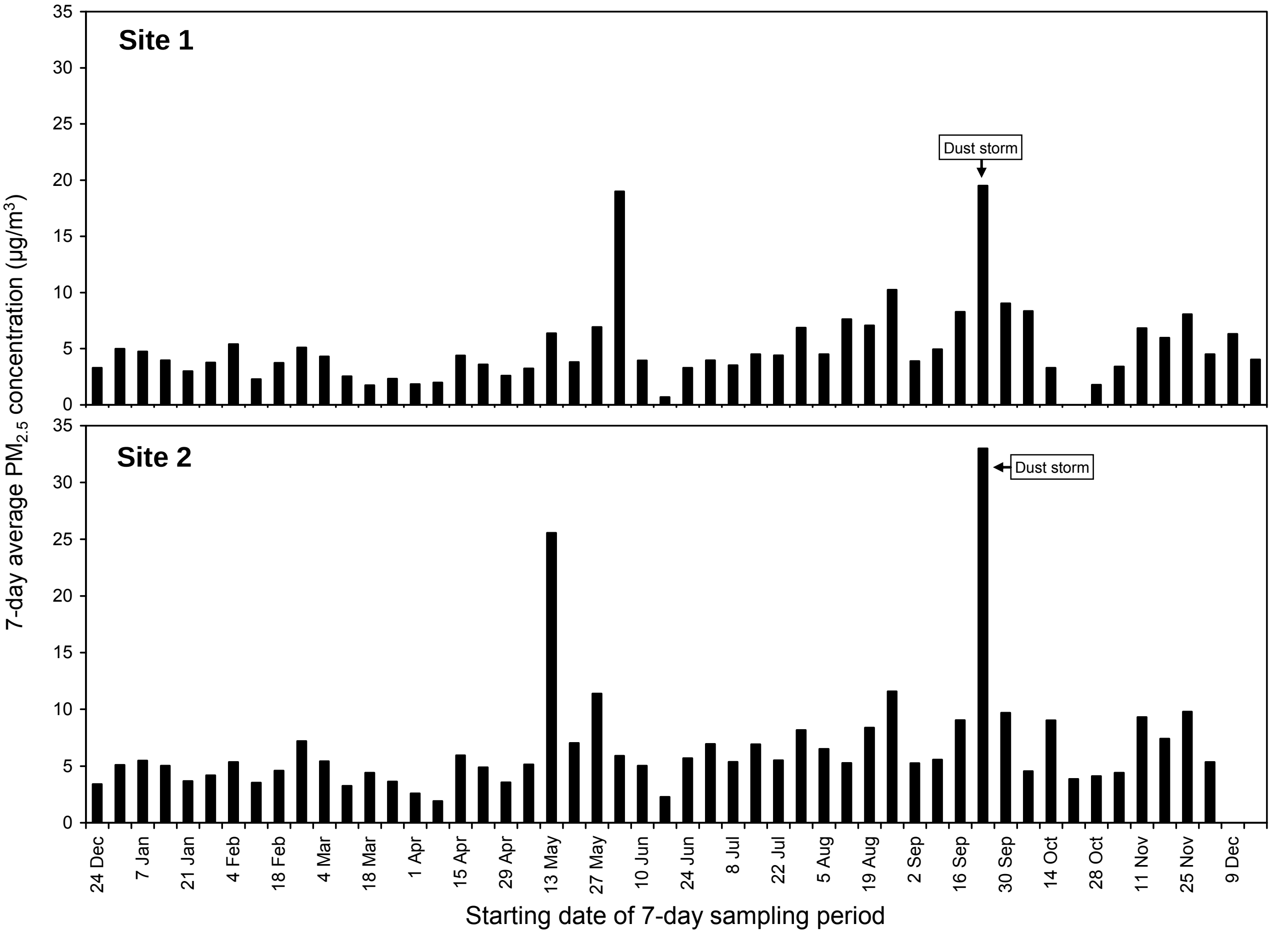
Sampling period	Site 1		Site 2		Rainfall (mm)
	7-day $PM_{2.5}$ concentration (µg/m^3)	Winds from direction of quarry (%)	7-day $PM_{2.5}$ concentration (µg/m^3)	Winds from direction of quarry (%)	
24/12/08 to 30/12/08	3.3	2.7	3.4	19.6	39.0
31/12/08 to 06/01/09	5.0	32.2	5.1	23.3	18.0
07/01/09 to 13/01/09	4.8	35.4	5.5	16.1	0.0
14/01/09 to 20/01/09	4.0	24.1	5.0	13.1	0.0
21/01/09 to 27/01/09	3.0	11.0	3.7	14.9	41.8
28/01/09 to 03/02/09	3.8	15.8	4.2	0.3	21.0
04/02/09 to 10/02/09	5.4	31.4	5.4	13.9	3.6
11/02/09 to 17/02/09	2.3	38.9	3.5	38.6	161.8
18/02/09 to 24/02/09	3.7	42.2	4.6	31.1	62.2
25/02/09 to 03/03/09	5.1	24.8	7.2	31.5	0.0
04/03/09 to 10/03/09	4.3	51.7	5.4	8.2	10.8
11/03/09 to 17/03/09	2.6	49.8	3.3	18.0	55.2
18/03/09 to 24/03/09	1.8	62.3	4.4	35.3	0.8
25/03/09 to 31/03/09	2.3	30.7	3.6	56.1	9.8
01/04/09 to 07/04/09	1.9	53.8	2.6	25.4	272.0
08/04/09 to 14/04/09	2.0	55.3	1.9	16.2	41.6
15/04/09 to 21/04/09	4.4	17.8	6.0	66.6	2.0
22/04/09 to 28/04/09	3.6	7.5	4.9	50.3	0.0
29/04/09 to 05/05/09	2.6	25.5	3.6	63.2	3.0
06/05/09 to 12/05/09	3.2	29.2	5.2	61.2	0.0
13/05/09 to 19/05/09	6.4	24.3	25.6	52.1	71.6
20/05/09 to 26/05/09	3.8	42.7	7.0	52.8	302.0

Table 4 (continued)**:** Seven-day average $PM_{2.5}$ monitoring results at Site 1 and Site 2 monitoring sites, December 2008 to December 2009

Sampling period	Site 1		Site 2		Rainfall (mm)
	7-day $PM_{2.5}$ concentration ($\mu g/m^3$)	Winds from direction of quarry (%)	7-day $PM_{2.5}$ concentration ($\mu g/m^3$)	Winds from direction of quarry (%)	
27/05/09 to 02/06/09	6.9	37.7	11.4	48.4	13.4
03/06/09 to 09/06/09	19.0	25.4	5.9	55.8	23.2
10/06/09 to 16/06/09	4.0	4.8	5.0	62.3	0.0
17/06/09 to 23/06/09	0.7	27.2	2.3	57.1	94.4
24/06/09 to 30/06/09	3.3	0.0	5.7	59.0	11.4
01/07/09 to 07/07/09	4.0	10.0	7.0	65.6	0.0
08/07/09 to 14/07/09	3.5	6.8	5.4	67.2	4.0
15/07/09 to 21/07/09	4.5	2.4	6.9	56.8	0.0
22/07/09 to 28/07/09	4.4	12.7	5.5	39.6	1.4
29/07/09 to 04/08/09	6.9	10.3	8.2	45.0	0.0
05/08/09 to 11/08/09	4.5	23.6	6.5	35.1	0.0
12/08/09 to 18/08/09	7.6	17.3	5.3	31.3	3.4
19/08/09 to 25/08/09	7.1	7.2	8.4	17.9	0.0
26/08/09 to 01/09/09	10.2	13.1	11.6	35.9	9.2
02/09/09 to 08/09/09	3.9	14.5	5.3	17.6	18.2
09/09/09 to 15/09/09	5.0	9.0	5.6	33.1	0.0
16/09/09 to 22/09/09	8.3	17.4	9.1	10.9	1.8
23/09/09 to 29/09/09	19.5	0.7	33.0	56.3	0.0
30/09/09 to 06/10/09	9.0	24.3	9.7	16.9	0.0
07/10/09 to 13/10/09	8.4	27.9	4.6	24.9	16.6
14/10/09 to 20/10/09	3.3	22.8	9.0	33.1	0.0
21/10/09 to 27/10/09	Sampler did not run		3.9	1.1	8.8
28/10/09 to 03/11/09	1.8	35.6	4.1	7.7	17.4
04/11/09 to 10/11/09	3.4	51.1	4.4	4.6	28.6
11/11/09 to 17/11/09	6.8	13.4	9.3	6.5	0.0
18/11/09 to 24/11/09	6.0	16.9	7.4	0.3	2.6
25/11/09 to 01/12/09	8.1	24.7	9.8	3.4	8.2
02/12/09 to 08/12/09	4.5	19.3	5.4	8.9	3.0
09/12/09 to 15/12/09	6.3	24.1	Sampler filter problem		0.0
16/12/09 to 22/12/09	4.0	19.7	Sampler filter problem		23.0

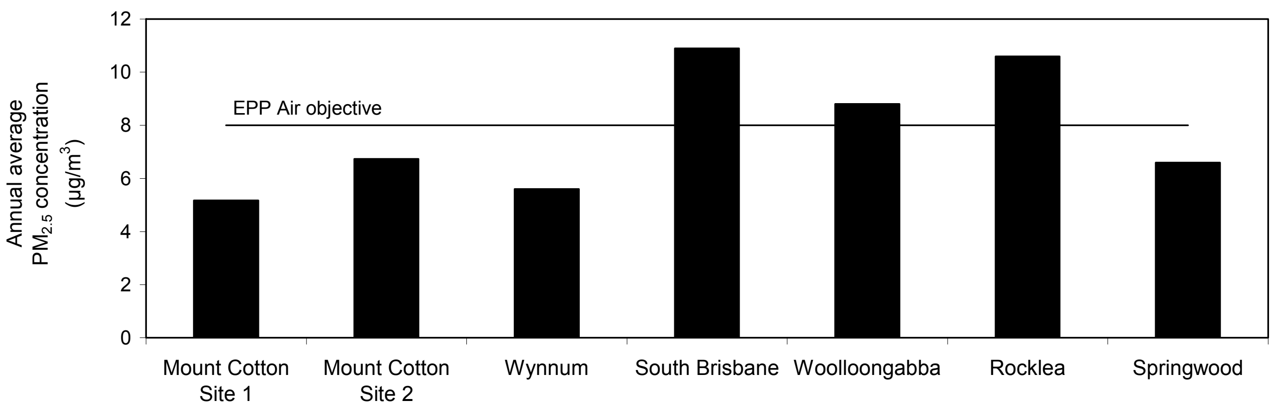
The *Environmental Protection (Air) Policy 2008* air quality objectives for $PM_{2.5}$ are a 24-hour average of $25 \mu g/m^3$ and an annual average of $8 \mu g/m^3$.

Figure 6: Seven-day average $PM_{2.5}$ concentrations at the Site 1 and Site 2 monitoring sites, December 2008 to December 2009.



Average $PM_{2.5}$ concentrations complied with the EPP Air annual average objective of 8 µg/m^3 at both monitoring sites. The average $PM_{2.5}$ concentration over the 12-month monitoring period was 5.2 µg/m^3 at Site 1 and 6.7 µg/m^3 at Site 2. Excluding results from the seven-day periods when regional particle events occurred, the average $PM_{2.5}$ concentrations were 4.7 µg/m^3 and 5.8 µg/m^3 at Sites 1 and 2 respectively. As Figure 7 shows, the annual average $PM_{2.5}$ concentrations measured at Mount Cotton were similar to those measured at monitoring sites in residential areas (Wynnum and Springwood) during the same period, and lower than levels at roadside and commercial area monitoring sites (South Brisbane, Woolloongabba and Rocklea).

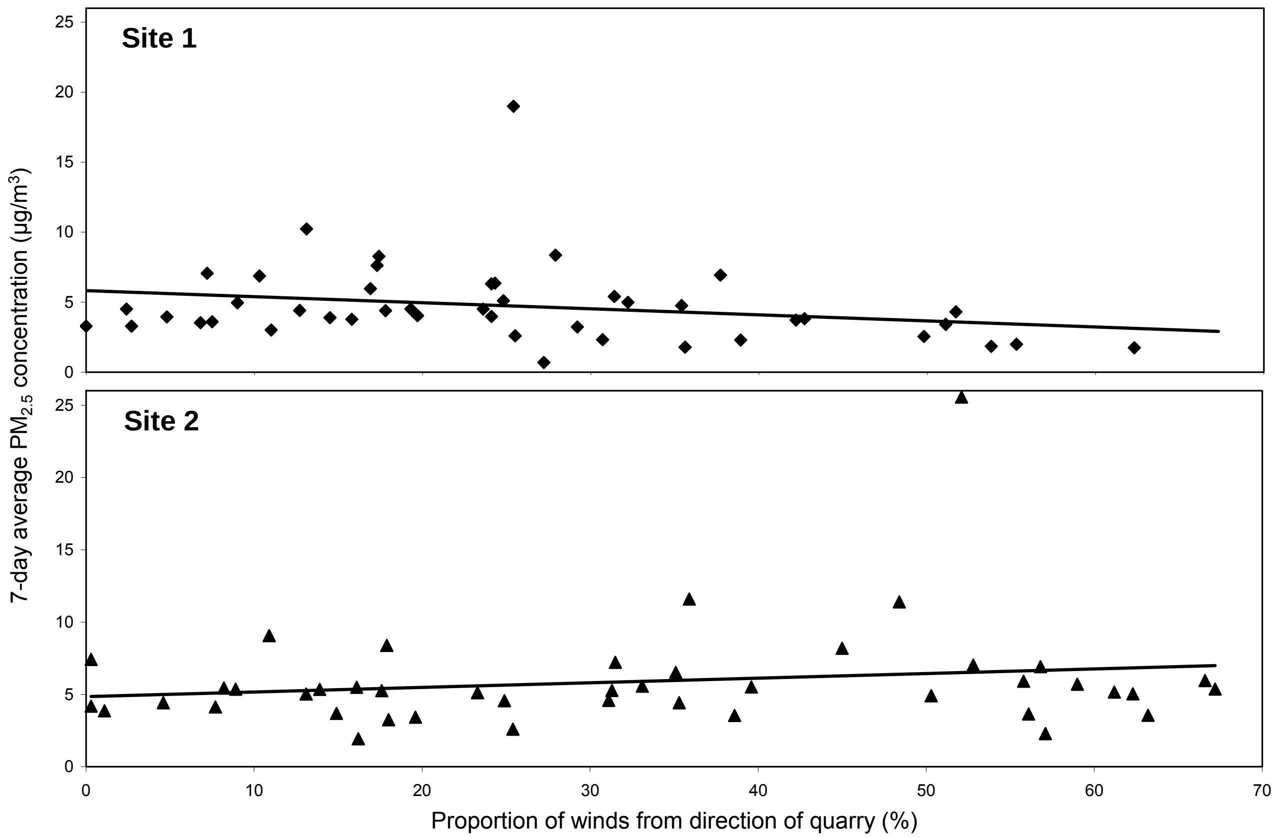
Figure 7: Annual average $PM_{2.5}$ concentrations at South-East Queensland monitoring sites, 2009.



As discrete 24-hour $PM_{2.5}$ samples were not collected at the Mount Cotton monitoring sites, it was not possible to directly compare measured $PM_{2.5}$ concentrations against the EPP Air 24-hour objective of 25 µg/m^3. However, the fact that the seven-day average $PM_{2.5}$ concentrations at Site 2 for the periods 13 to 19 May 2009 and 23 to 29 September 2009 were greater than 25 µg/m^3 indicates that the EPP Air 24-hour objective was exceeded on at least one day during each of these periods. Winds blew from the direction of the quarry for 52 per cent of the time between 13 and 19 May, so it is likely that quarry dust emissions contributed to the elevated $PM_{2.5}$ levels during this period. The exceedence in September was the result of dust storms.

The relationship between seven-day $PM_{2.5}$ concentrations and the proportion of winds blowing from the direction of the quarry towards the two $PM_{2.5}$ monitoring sites during the sampling period is displayed graphically in Figure 8. Sampling periods when regional particle or heavy rainfall events occurred have been excluded from this analysis. At site 2 there was a small upward trend in $PM_{2.5}$ concentration with increasing proportion of winds from the direction of the quarry (shown by the heavy line), while at Site 1 the trend was downward. The conclusion drawn from these findings is that while dust emissions from quarry operations contribute to $PM_{2.5}$ levels at sites situated close to the quarry boundary, other urban and natural sources of $PM_{2.5}$ particles are more significant contributors to ambient $PM_{2.5}$ concentrations than quarry dust emissions at locations further from the quarry (Site 1 was located 1.5 kilometres from the quarry boundary).

Figure 8: Relationship between seven-day average $PM_{2.5}$ concentrations and the proportion of winds from the direction of quarry operations at Mount Cotton monitoring sites, December 2008 to December 2009.



$PM_{2.5}$ crystalline silica

The seven-day average $PM_{2.5}$ crystalline silica monitoring results obtained from analysis of the $PM_{2.5}$ filter samples collected by the Partisol® instruments at Site 1 and Site 2 are summarised in Table 5 and presented graphically in Figure 9. The highest seven-day average $PM_{2.5}$ crystalline silica concentrations were 1.65 µg/m^3 at Site 1 and 4.92 µg/m^3 at Site 2 for the period from 23 September to 29 September 2009 when two major dust storms occurred. Excluding regional particle events, the highest seven-day $PM_{2.5}$ crystalline silica concentrations were 0.64 µg/m^3 at Site 1 for the period from 7 October to 13 October 2009 and 0.53 µg/m^3 at Site 2 for the period from 25 November to 1 December 2009. Crystalline silica was detected in 49 per cent of $PM_{2.5}$ samples at Site 1 and 90 per cent of $PM_{2.5}$ samples at Site 2.

Table 5: Seven-day average $PM_{2.5}$ crystalline silica monitoring results at Site 1 and Site 2 monitoring sites, December 2008 to December 2009

Sampling period	Site 1		Site 2		Rainfall (mm)
	7-day $PM_{2.5}$ crystalline silica concentration (µg/m^3)	Winds from direction of quarry (%)	7-day $PM_{2.5}$ crystalline silica concentration (µg/m^3)	Winds from direction of quarry (%)	
24/12/08 to 30/12/08	ND	2.7	ND	19.6	39.0
31/12/08 to 06/01/09	ND	32.2	ND	23.3	18.0
07/01/09 to 13/01/09	ND	35.4	0.13	16.1	0.0
14/01/09 to 20/01/09	ND	24.1	0.13	13.1	0.0
21/01/09 to 27/01/09	ND	11.0	0.13	14.9	41.8
28/01/09 to 03/02/09	ND	15.8	0.07	0.3	21.0
04/02/09 to 10/02/09	0.07	31.4	0.07	13.9	3.6
11/02/09 to 17/02/09	ND	38.9	ND	38.6	161.8
18/02/09 to 24/02/09	0.07	42.2	0.13	31.1	62.2
25/02/09 to 03/03/09	0.07	24.8	0.20	31.5	0.0
04/03/09 to 10/03/09	0.13	51.7	0.20	8.2	10.8
11/03/09 to 17/03/09	ND	49.8	0.07	18.0	55.2
18/03/09 to 24/03/09	ND	62.3	0.13	35.3	0.8
25/03/09 to 31/03/09	ND	30.7	0.07	56.1	9.8
01/04/09 to 07/04/09	ND	53.8	0.06	25.4	272.0
08/04/09 to 14/04/09	ND	55.3	ND	16.2	41.6
15/04/09 to 21/04/09	0.26	17.8	0.32	66.6	2.0
22/04/09 to 28/04/09	0.06	7.5	0.13	50.3	0.0
29/04/09 to 05/05/09	0.06	25.5	0.13	63.2	3.0
06/05/09 to 12/05/09	ND	29.2	0.13	61.2	0.0
13/05/09 to 19/05/09	0.06	24.3	0.13	52.1	71.6
20/05/09 to 26/05/09	ND	42.7	0.06	52.8	302.0
27/05/09 to 02/06/09	ND	37.7	0.19	48.4	13.4
03/06/09 to 09/06/09	ND	25.4	0.06	55.8	23.2
10/06/09 to 16/06/09	0.06	4.8	0.19	62.3	0.0

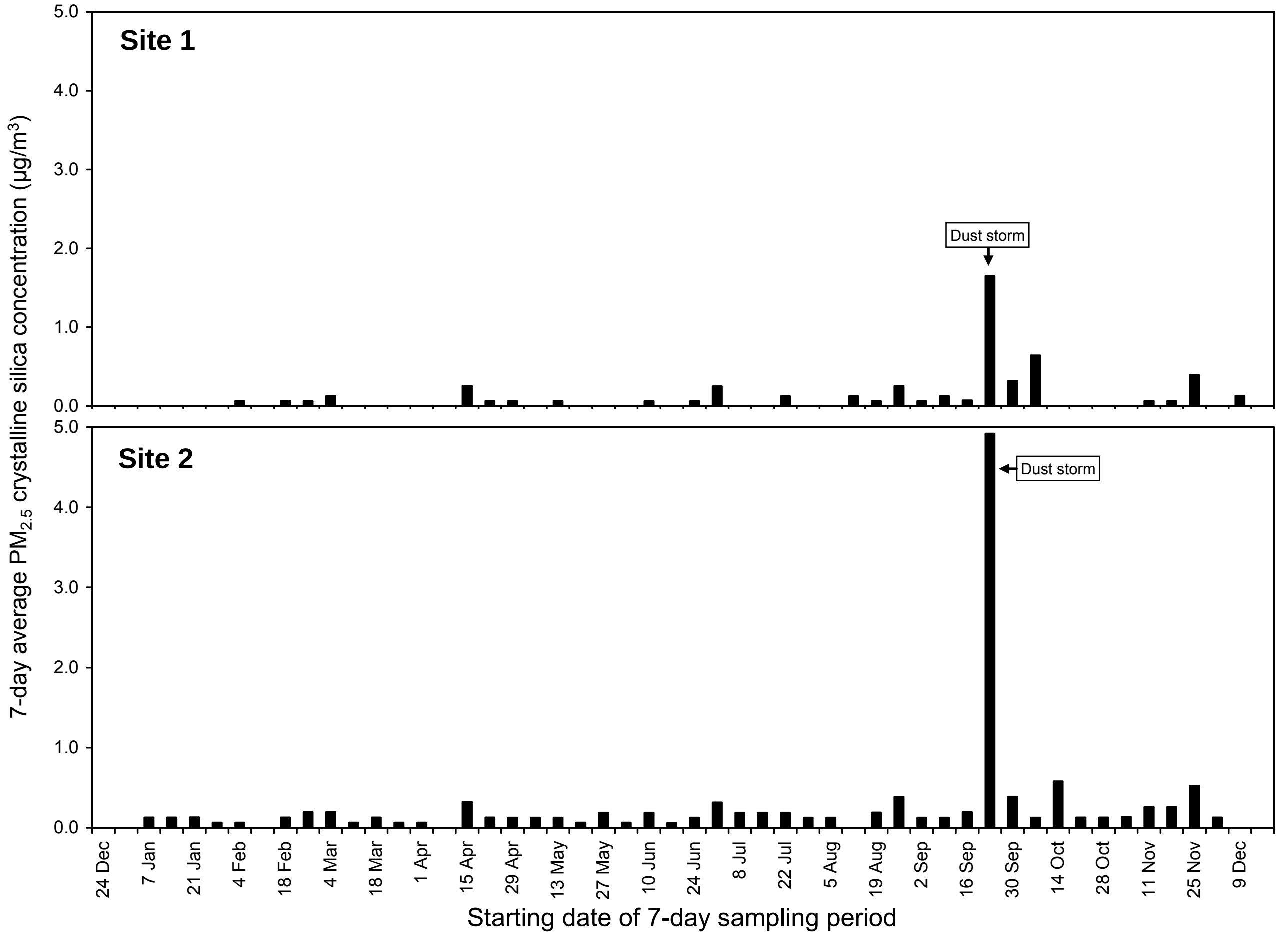
Table 5 (continued)**:** Seven-day average $PM_{2.5}$ crystalline silica monitoring results at Site 1 and Site 2 monitoring sites, December 2008 to December 2009

Sampling period	Site 1		Site 2		Rainfall (mm)
	7-day $PM_{2.5}$ crystalline silica concentration ($\mu g/m^3$)	Winds from direction of quarry (%)	7-day $PM_{2.5}$ crystalline silica concentration ($\mu g/m^3$)	Winds from direction of quarry (%)	
17/06/09 to 23/06/09	ND	27.2	0.06	57.1	94.4
24/06/09 to 30/06/09	0.06	0.0	0.13	59.0	11.4
01/07/09 to 07/07/09	0.25	10.0	0.32	65.6	0.0
08/07/09 to 14/07/09	ND	6.8	0.19	67.2	4.0
15/07/09 to 21/07/09	ND	2.4	0.19	56.8	0.0
22/07/09 to 28/07/09	0.13	12.7	0.19	39.6	1.4
29/07/09 to 04/08/09	ND	10.3	0.13	45.0	0.0
05/08/09 to 11/08/09	ND	23.6	0.13	35.1	0.0
12/08/09 to 18/08/09	0.13	17.3	ND	31.3	3.4
19/08/09 to 25/08/09	0.06	7.2	0.19	17.9	0.0
26/08/09 to 01/09/09	0.26	13.1	0.39	35.9	9.2
02/09/09 to 08/09/09	0.06	14.5	0.13	17.6	18.2
09/09/09 to 15/09/09	0.13	9.0	0.13	33.1	0.0
16/09/09 to 22/09/09	0.08	17.4	0.19	10.9	1.8
23/09/09 to 29/09/09	1.65	0.7	4.92	56.3	0.0
30/09/09 to 06/10/09	0.32	24.3	0.39	16.9	0.0
07/10/09 to 13/10/09	0.64	27.9	0.13	24.9	16.6
14/10/09 to 20/10/09	ND	22.8	0.58	33.1	0.0
21/10/09 to 27/10/09	Sampler did not run		0.13	1.1	8.8
28/10/09 to 03/11/09	ND	35.6	0.13	7.7	17.4
04/11/09 to 10/11/09	ND	51.1	0.13	4.6	28.6
11/11/09 to 17/11/09	0.07	13.4	0.26	6.5	0.0
18/11/09 to 24/11/09	0.07	16.9	0.26	0.3	2.6
25/11/09 to 01/12/09	0.39	24.7	0.53	3.4	8.2
02/12/09 to 08/12/09	ND	19.3	0.13	8.9	3.0
09/12/09 to 15/12/09	0.13	24.1	Sampler filter problem		0.0
16/12/09 to 22/12/09	ND	19.7	Sampler filter problem		23.0

ND = not detected. The minimum measurable $PM_{2.5}$ crystalline silica concentration that could be determined with the sampling equipment and laboratory method used was in the range 0.12 to 0.16$\mu g/m^3$. Where $PM_{2.5}$ crystalline silica concentrations were below the minimum measurable concentration the value is reported as ND in the table.

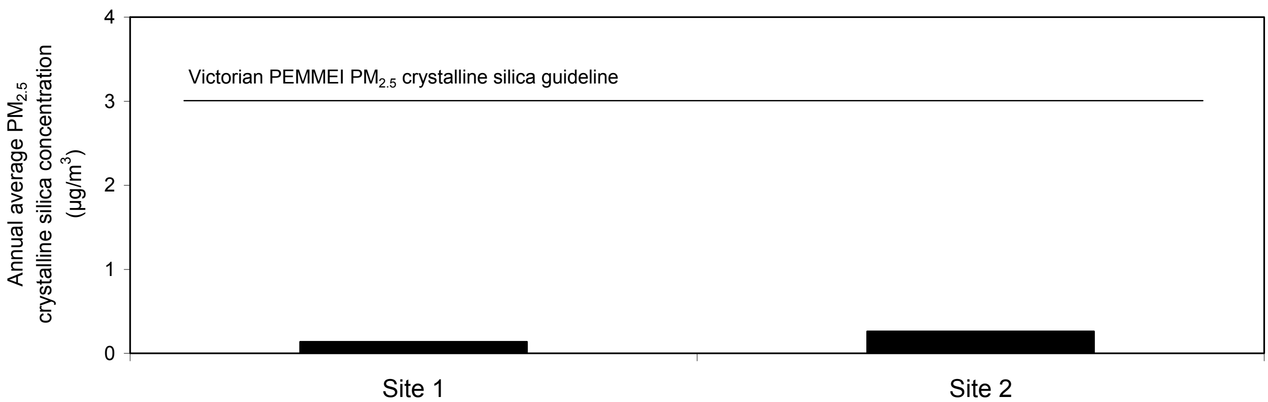
The Victorian Government's Protocol for Environmental Management for Mining and Extractive Industries guideline for $PM_{2.5}$ crystalline silica is an annual average of 3$\mu g/m^3$.

Figure 9: Seven-day average $PM_{2.5}$ crystalline silica concentrations at the Site 1 and Site 2 monitoring sites, December 2008 to December 2009.



Annual average $PM_{2.5}$ crystalline silica concentrations at Site 1 were 0.14 µg/m^3, or 5 per cent of the Victorian guideline, and 0.26 µg/m^3, or 9 per cent of the Victorian guideline, at Site 2 (see Figure 10). Annual average values were calculated using half the minimum measurable concentration value for samples where no crystalline silica was detected.

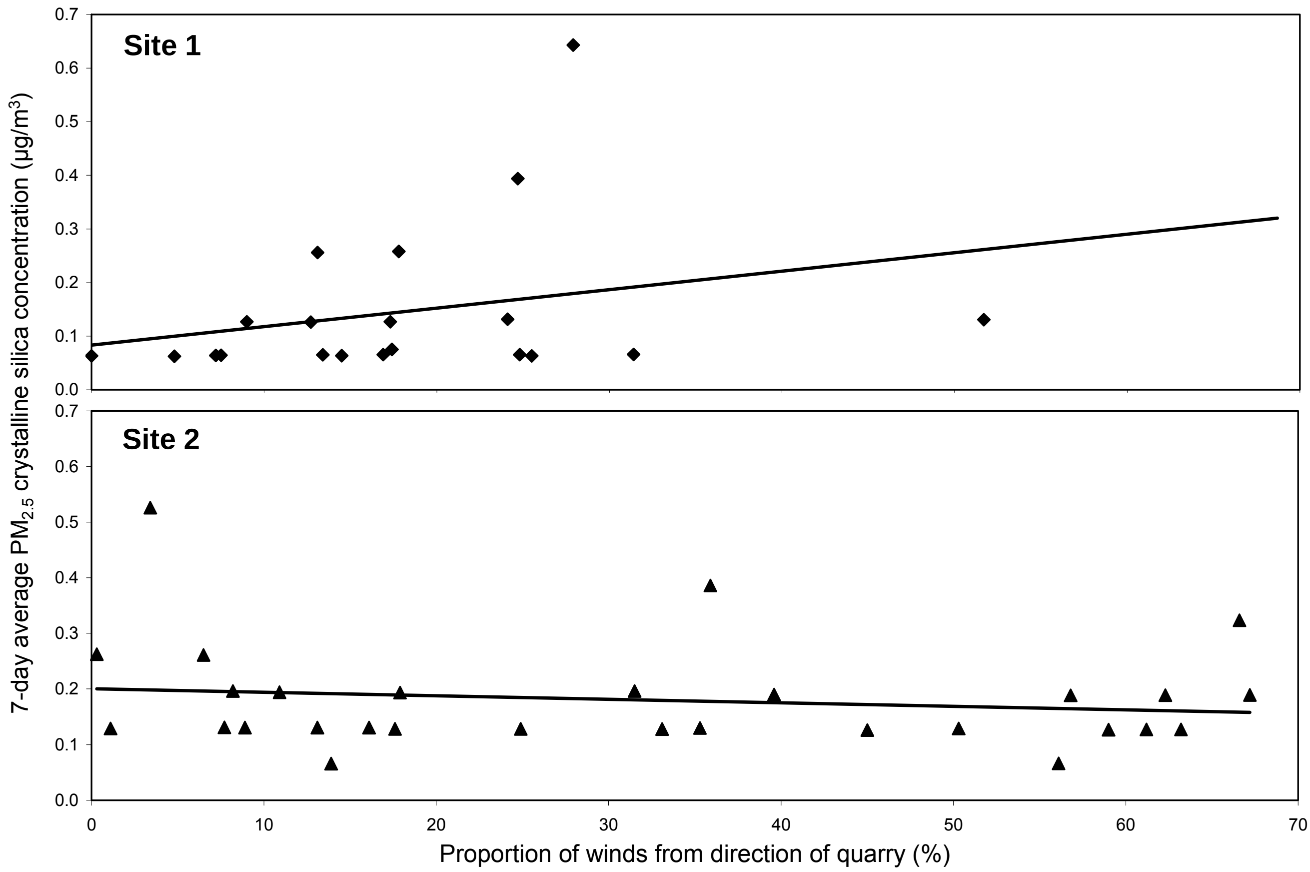
Figure 10: Annual average $PM_{2.5}$ crystalline silica concentrations at Mount Cotton monitoring sites



In a health risk assessment of community exposure to crystalline silica in the vicinity of road construction works[4], Queensland Health formed the view that the community was unlikely to suffer any adverse health effects from exposure to respirable crystalline silica at an annual average concentration of 1.43 µg/m^3. Crystalline silica concentrations present in the Mount Cotton community were lower than this level and, based on the above assessment, community exposure at Mount Cotton is similarly unlikely to lead to any adverse health effects.

The relationship between seven-day $PM_{2.5}$ crystalline silica concentrations and the proportion of winds blowing from the direction of the quarry towards the two monitoring sites during the investigation period is plotted in Figure 11. Sampling periods when regional particle or heavy rainfall events occurred, or where no crystalline silica was detected, have been excluded from this analysis. While a trend towards increasing crystalline silica concentrations with a higher proportion of winds coming from the direction of the quarry during the investigation period is evident at Site 1, a slight downward trend was observed at Site 2 (shown by the heavy lines in Figure 11). The trend seen at Site 2 was somewhat unexpected given the site's closer proximity to the quarry and higher overall measured crystalline silica levels. One possible explanation for this result is the presence of additional airborne crystalline silica sources impacting at Site 2. The $PM_{2.5}$ sampler at Site 2 was located less than 50 metres from West Mount Cotton Road close to the road entrance to the quarry, and it is possible that during dry conditions passing traffic stirred up dust containing silica from the road verge which was then collected by the $PM_{2.5}$ sampler.

Figure 11: Relationship between seven-day average $PM_{2.5}$ crystalline silica concentrations and proportion of winds from the direction of quarry operations at the Mount Cotton monitoring sites, December 2008 to December 2009.



Dust deposition

Dust deposition measurements for the three monitoring sites during the period December 2008 to December 2009 are summarised in Tables 6 to 8, and displayed graphically in Figure 12. Dust generated by quarry activities would be expected to have a high mineral content, which would appear as ash in the dust deposition analysis.

With one exception, deposition rates for the insoluble dust fraction collected over four-week periods at the three monitoring sites were within the 120 mg/m^2/day criterion used to assess dust nuisance. Average deposition rates over the four-week sampling periods were typically less than 50 per cent of the quarry development approval limit value for nuisance dust. Average insoluble dust deposition rates over the entire twelve month investigation period were 24 mg/m^2/day at Site 1, 45 mg/m^2/day at Site 2 and 29 mg/m^2/day at Site 3.

A deposition rate of 208 mg/m^2/day was measured at Site 2 for the period 5 August to 3 September 2009. During this period winds blew from the direction of the quarry for 28 percent of the sampling period. The high ash content of the collected dust indicates that dust emissions from the quarry site could have contributed to this result, however it is not possible to distinguish between dust from quarry operations and that from other sources such as wind blown dust from exposed ground. The fact that lower dust deposition rates were measured at Site 2 during dry conditions with a greater proportion of winds blowing from the direction of the quarry (up to 62 per cent, see Table 7) suggests that any quarry contribution to dust deposition at Site 2 during August was not the result of routine activities occurring on the quarry site.

Table 6: Four-weekly dust deposition rates at the Site 1 monitoring site, December 2008 to December 2009

Sampling period	Insoluble solids (mg/m^2/day)	Ash (mg/m^2/day)	Combustible matter (mg/m^2/day)	Winds from direction of quarry (%)	Rainfall (mm)
23/12/08 to 23/01/09	85	50	35	21.7	85.2
23/01/09 to 18/02/09	29	11	18	26.9	206.0
18/02/09 to 19/03/09	25	13	12	43.2	88.2
19/03/09 to 17/04/09	17	7	10	47.2	326.2
17/04/09 to 14/05/09	12	12	<1	18.4	3.0
14/05/09 to 11/06/09	12	3	9	32.9	410.2
11/06/09 to 08/07/09	14	13	1	11.7	109.8
08/07/09 to 05/08/09	15	10	5	8.1	1.4
05/08/09 to 03/09/09	23	15	8	16.5	12.6
03/09/09 to 01/10/09	11	5	6	9.2	20.0
01/10/09 to 29/10/09	29	16	13	24.3	33.8
29/10/09 to 25/11/09	15	6	9	27.9	40.2
25/11/09 to 23/12/09	19	9	10	21.5	34.2

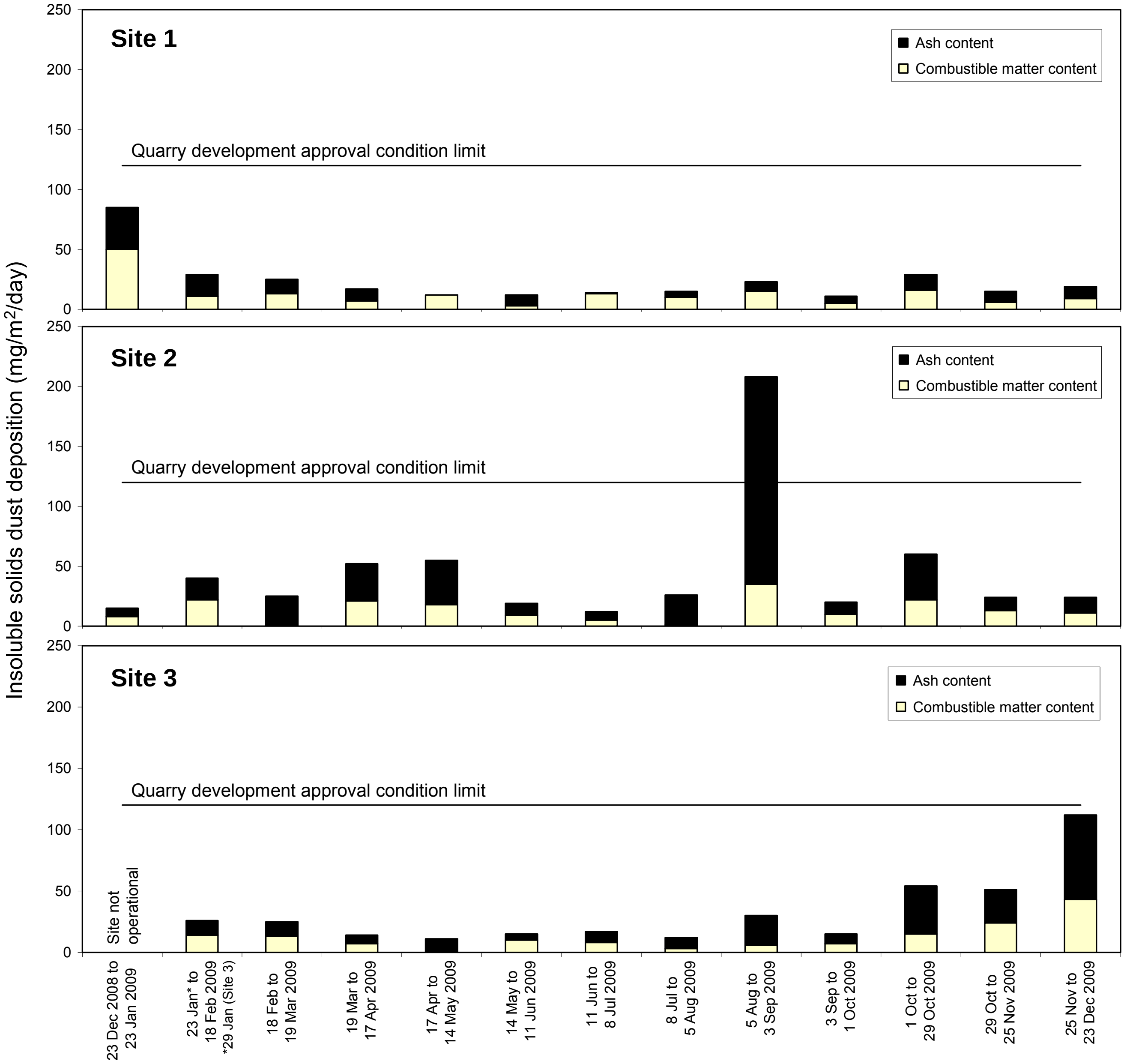
Table 7: Four-weekly dust deposition rates at the Site 2 monitoring site, December 2008 to December 2009

Sampling period	Insoluble solids (mg/m^2/day)	Ash (mg/m^2/day)	Combustible matter (mg/m^2/day)	Winds from direction of quarry (%)	Rainfall (mm)
23/12/08 to 23/01/09	15	7	8	17.8	85.2
23/01/09 to 18/02/09	40	18	22	16.6	206.0
18/02/09 to 19/03/09	25	24	1	22.5	88.2
19/03/09 to 17/04/09	52	31	21	34.6	326.2
17/04/09 to 14/05/09	55	37	18	61.9	3.0
14/05/09 to 11/06/09	19	10	9	53.7	410.2
11/06/09 to 08/07/09	12	7	5	59.6	109.8
08/07/09 to 05/08/09	26	25	1	52.3	1.4
05/08/09 to 03/09/09	208	173	35	27.7	12.6
03/09/09 to 01/10/09	20	10	10	30.1	20.0
01/10/09 to 29/10/09	60	38	22	18.6	33.8
29/10/09 to 25/11/09	24	11	13	4.8	40.2
25/11/09 to 23/12/09	24	13	11	7.9	34.2

Table 8: Four-weekly dust deposition rates at the Site 3 monitoring site, January 2009 to December 2009

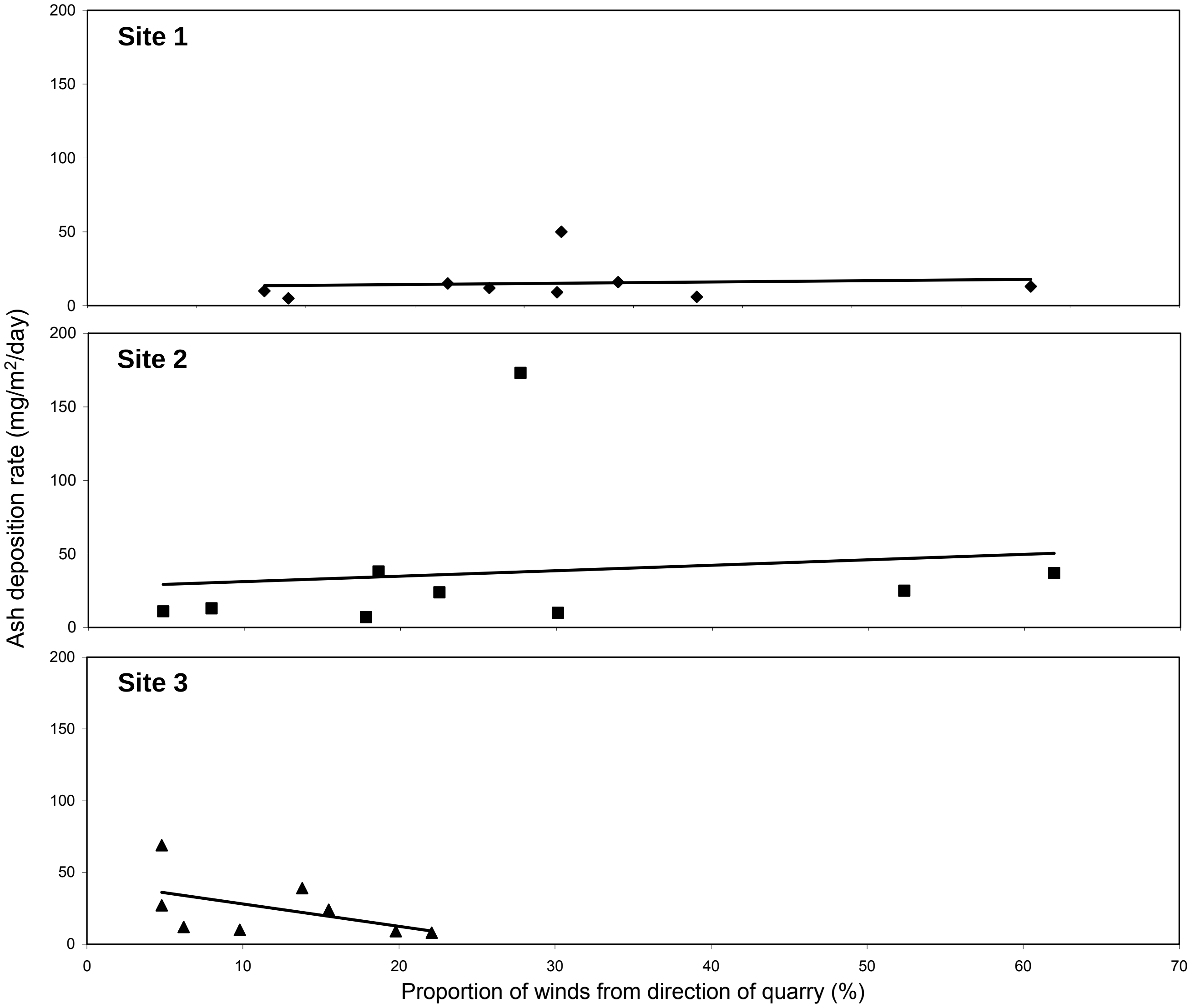
Sampling period	Insoluble solids (mg/m^2/day)	Ash (mg/m^2/day)	Combustible matter (mg/m^2/day)	Winds from direction of quarry (%)	Rainfall (mm)
29/01/09 to 18/02/09	26	12	14	4.4	190.4
18/02/09 to 19/03/09	25	12	13	6.2	88.2
19/03/09 to 17/04/09	14	7	7	4.0	326.2
17/04/09 to 14/05/09	11	10	1	9.8	3.0
14/05/09 to 11/06/09	15	5	10	21.7	410.2
11/06/09 to 08/07/09	17	9	8	29.1	109.8
08/07/09 to 05/08/09	12	9	3	19.8	1.4
05/08/09 to 03/09/09	30	24	6	15.5	12.6
03/09/09 to 01/10/09	15	8	7	22.1	20.0
01/10/09 to 29/10/09	54	39	15	13.8	33.8
29/10/09 to 25/11/09	51	27	24	4.8	40.2
25/11/09 to 23/12/09	112	69	43	4.8	34.2

Figure 12: Four-weekly average insoluble solids dust deposition rates at the Mount Cotton monitoring sites, December 2008 to December 2009.



Dust generated by quarry activities would be expected to have a high mineral content, which is approximated by the ash content value in the dust deposition analysis. The relationship between ash deposition rate for each four-week sampling period and the proportion of winds blowing from the direction of the quarry during the sampling period is shown in Figure 13 for each monitoring site. To exclude dust suppression impacts caused by heavy rainfall events from this analysis, deposition data for sampling periods where more than 100mm of rain fell have been removed.

Figure 13: Relationship between four-week average ash deposition rate and the proportion of winds from the direction of quarry operations at the Mount Cotton monitoring sites, December 2008 to December 2009.



Little or no relationship between ash deposition rate and the frequency of winds from the direction of the quarry is evident for Sites 1 and 3. There is a slight overall increase in ash deposition rate with increasing frequency of winds from the direction of the quarry at Site 2. These results are consistent with the respective distances between the quarry and the monitoring site. Particulate matter sampled by the deposited matter method is predominantly larger dust particles which, because of their size, rapidly settle from the air in the vicinity of the point of emission. The monitoring results suggest that dust deposition is only likely to approach levels considered to constitute a nuisance within a few hundred metres of the quarry boundary. Locations situated more than one kilometre from the quarry boundary appear unlikely to experience dust nuisance from quarry operations.

Conclusions

Monitoring in the Mount Cotton community adjacent to Karreman's Quarry between December 2008 and December 2009 has found that ambient particle concentrations generally complied with ambient air quality objectives. Average crystalline silica concentrations over the period of monitoring were well below the annual average guideline value.

Below-average rainfall during much of the investigation period meant that the monitoring results obtained in 2009 will have provided an indication of the upper range of community exposure to ambient particles.

There was no evidence that quarry operations were leading to PM_{10} levels above the EPP Air objective in the surrounding community. Overall, PM_{10} concentrations measured at Mount Cotton were lower than those measured at other South-East Queensland monitoring sites over the same period. While PM_{10} levels exceeded the EPP Air 24-hour air quality objective of 50 µg/m^3 on nine days during the 12-month investigation period, eight of these exceedences occurred during dust events affecting the whole South-East Queensland region (such as dust storms or bushfire smoke) and were not related to quarry operations. Non-quarry PM_{10} sources were shown to be the main cause of the remaining PM_{10} objective exceedence.

$PM_{2.5}$ levels were found to comply with the EPP Air annual average objective of 8 µg/m^3 over the investigation period. The annual average $PM_{2.5}$ concentrations at Mount Cotton were found to be similar to those measured at other South-East Queensland ambient air quality monitoring sites located in residential areas, and lower than the $PM_{2.5}$ levels measured at roadside and commercial areas over the same period. It was not possible to determine compliance with the EPP Air 24-hour objective of 25 µg/m^3 as discrete 24-hour $PM_{2.5}$ sampling was not conducted at the Mount Cotton monitoring sites. However, it can be concluded from the seven-day average $PM_{2.5}$ measurements that the EPP Air 24-hour objective would have been exceeded at Site 2 on at least two occasions – in May 2009 and during the September 2009 dust storm event. Wind direction data suggested that quarry dust emissions were likely to have contributed to the elevated $PM_{2.5}$ measurement in May.

Annual average $PM_{2.5}$ crystalline silica concentrations in the Mount Cotton community were very low, less than ten per cent of the Victorian PEMMEI annual average guideline value. Crystalline silica was detected in 90 per cent of $PM_{2.5}$ samples at Site 2 close to the quarry boundary, but this fell to less than 50 per cent of samples at a distance of 1.5 kilometres from the quarry at Site 1.

Nuisance dust levels measured at the monitoring sites were typically less than 50 per cent of the quarry development approval limit of 120 mg/m^2/day. The development approval limit was exceeded only once – at Site 2 during August 2009. Ash content and wind direction data identify quarry dust emissions as likely to have contributed to this exceedence, however it was not possible to determine the relative proportions of quarry and non-quarry dust in the collected sample. Low nuisance dust levels at Site 2 during other periods with similar meteorological conditions suggest that any contribution to this exceedence from the quarry site was unlikely to be the result of routine operations.

While monitoring results confirmed that quarry activities were a source of particles in the surrounding community, other particle sources were a significant factor in overall community exposure. The relationship between short-term PM_{10} concentrations and wind direction at Site 3 showed that urban and natural PM_{10} particle sources had a greater influence on ambient PM_{10} concentrations than dust emissions from the quarry over the investigation period as a whole. The relationship between $PM_{2.5}$ concentrations and wind direction found that dust emissions from quarry operations influenced ambient $PM_{2.5}$ levels at Site 2 close to the quarry boundary, but that non-quarry $PM_{2.5}$ sources were the main influence on ambient $PM_{2.5}$ levels further away at Site 1. Ash deposition rates showed a positive correlation with winds from the direction of the quarry only close to the quarry bourdary at Site 2.

The rise in $PM_{2.5}$ crystalline silica levels at Site 1 with increasing frequency of winds from the direction of the quarry demonstrated that the quarry was a source of crystalline silica. A similar relationship was not observed at Site 2, despite this site recording more frequent and higher crystalline silica concentrations. The possible presence of other sources of crystalline silica, such as re-entrainment of silica-containing dust by traffic using West Mount Cotton Road, could possibly account for this.

The results from this investigation reinforce the conclusions of the initial March 2008 study that the Mount Cotton community is unlikely to suffer any adverse health effects from particle and crystalline silica generated from quarrying activities in the Mount Cotton area.

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