

Technical Memorandum

September 11, 2018

STI-918019-6975-TM

To: Jason Wong, County of Marin, Department of Public Works

From: Josette E. Marrero, Paul T. Roberts

Re: **Summary of Air Quality Measurements at the San Rafael Rock Quarry during the Background Monitoring Period**

Overview

This memorandum summarizes air quality monitoring data collected in the area surrounding the San Rafael Rock Quarry (SRRQ) between May and early July 2018. Sonoma Technology, Inc. (STI) has been assisting in the review of the air quality aspects of the SRRQ's Phase 1 Reclamation of their northeast quadrant ([Figure 1](#)). The monitoring includes continuous hourly measurements of particulate matter (PM_{2.5} and PM₁₀) and black carbon (BC), as well as 24-hr discrete filter samples to quantify crystalline silica and metals; these measurements are made at a site in Marin Bay Park Court. In addition, meteorological data (winds, temperature, and relative humidity) are being collected at the Marin Municipal Water District Tank. These two months of data are considered the "background" monitoring period and represent typical quarry activities. These data will be used for comparison against similar data collected during reclamation activities, which began during the week of July 23, 2018, and are scheduled to continue for 10 weeks.

Data Collected

Air quality monitoring instrumentation and meteorological equipment were installed during the last week of April 2018. Instrument operation and data flow (including data storage to STI servers and uploading to the project website) were verified in the following weeks. The first full day of meteorological measurements was May 3, 2018, while BC and PM measurements started on May 4, 2018. For the 82 days spanning May 3 through July 23, hourly BC and PM data were collected at least 90% of the time (out of 1,968 hours). To determine and assess 24-hour averages, only days with 75% of possible hourly measurements are considered valid and included in analysis. BC measurements were incomplete, and excluded from 24-hour averages, on five days during the background monitoring period. PM_{2.5} data were incomplete and excluded on six days, and PM₁₀ on seven days. Meteorological data were collected every day.

PM_{2.5} and PM₁₀ data are missing between May 18 and May 21 because the zero readings on instruments were being recalibrated to correct unusually high negative values that were observed. PM measurements collected between May 4 and May 18 were adjusted by using a baseline correction factor. Intermittent power issues led to missing BC and PM data on June 4 and 5. Lastly, PM₁₀ data are missing on June 20, and BC data are missing from June 29 to July 2, because of instrument maintenance on those dates.



Figure 1. The San Rafael Rock Quarry and surrounding area. Monitoring sites for air quality (yellow cross) and meteorology (white triangle) data are north of the quarry. The northeast quadrant, where Reclamation Phase 1 will take place, is outlined in red.

Quality Control Checks

Data quality criteria are evaluated through (1) automatic data checks conducted through the data management system, and (2) data review by analysts (daily data review and periodic, more thorough validation). Raw data are ingested into STI's data management system (Insight) where data are stored and automatic quality control (QC) checks are performed. The automated QC checks are used to flag data based on the conditions listed in [Table 1](#): range, zero, sticking, and rate of change. If any of

these conditions are present, data are flagged as invalid or suspect and then further reviewed for validity.

Examples specific to data collected at the SRRQ revolve around range and sticking. PM measurements below $-2 \mu\text{g}/\text{m}^3$ and BC lower than $-0.5 \mu\text{g}/\text{m}^3$ are marked as invalid (mass concentrations cannot generally be negative, but this allows for some error in the limit of detection of the instruments). Also, PM data are marked invalid if values greater than $950 \mu\text{g}/\text{m}^3$ are reported, since this is an error code reported by the instrument. For either BC or PM measurements, data are flagged as suspect if the same value is reported for four or more consecutive hours.

Table 1. The four automatic quality control (QC) checks used to determine the validity of data collected. If the conditions listed are present, data are flagged and later reviewed.

Type of Automatic QC Check	Condition
Range	Values are outside of reasonable minimum and maximum concentrations
Zero	Values are reported as "0"
Sticking	Values are repeated for a number of consecutive sampling intervals, typically four or more intervals
Rate of Change	Values change rapidly without reasonable cause

Data Interpretation

Analysis of the monitoring data is intended to discover typical patterns in BC and PM, including patterns related to meteorological conditions, time of day, or day of the week when concentrations were highest. The SRRQ generally operates Monday through Friday, meaning that weekend data are more characteristic of local conditions not impacted by the SRRQ. Effects of quarry activities on local air quality would be seen as an enhancement in pollutant concentrations on weekdays over weekend days. In addition, wind speeds are expected to be higher during the daytime; higher wind speeds would likely allow for transport of PM and contribute to increased daytime PM concentrations.

The following sections present some of the meteorological and particle concentration trends observed during the background monitoring period.

General Data Trends

A time series plot of BC and PM measurements during the background monitoring period is shown in [Figure 2](#). While PM_{10} concentrations are consistently higher than $\text{PM}_{2.5}$ concentrations, both show similar trends, with peak and minimum concentrations occurring at the same time. BC measurements also follow this pattern. It should be noted that, although PM concentrations are measurements of

mass and cannot physically be negative, sometimes negative values are reported, particularly for $PM_{2.5}$. This is common on clean air days, where little $PM_{2.5}$ is generated, and the ambient measurements are at or below the limits of detection of the BAM instruments.

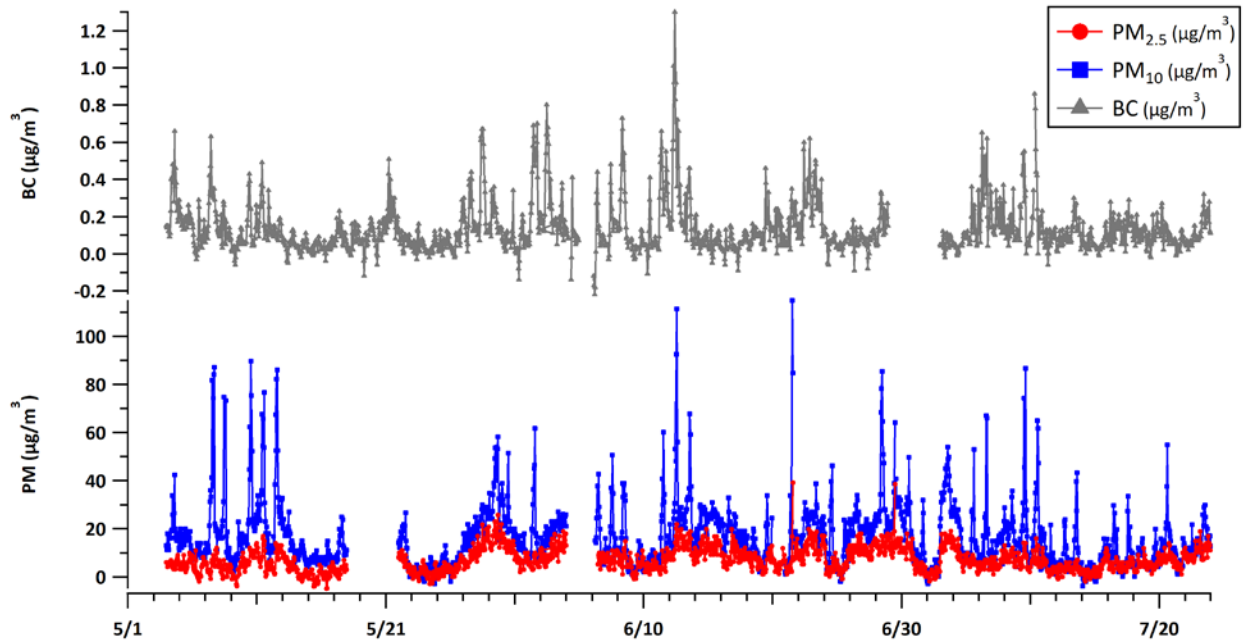


Figure 2. Hourly black carbon (top, grey), $PM_{2.5}$ (bottom, red), and PM_{10} (blue) measurements collected from May 4, 2018, through July 23, 2018, at the Marin Bay Park monitoring site.

The statistical distribution of BC and PM measurements is summarized in [Table 2](#). Average hourly concentrations were $0.14 \mu\text{g}/\text{m}^3$ for BC, $7.0 \mu\text{g}/\text{m}^3$ for $PM_{2.5}$, and $16.2 \mu\text{g}/\text{m}^3$ for PM_{10} . During the two-month background monitoring period, winds were most commonly from the south and southwest ([Figure 3](#)). The SRRQ lies south of the meteorology and AQ measurement sites, so particulate concentration observed during this time are representative of quarry activities. Wind speeds ranged from calm (less than 1.5 m/s) to speeds of 8.7 m/s , with an average of 3.0 m/s . Calm winds were observed roughly 26% of the time and corresponded to the lowest particulate concentrations observed (average BC = 0.11 , $PM_{2.5} = 5.4$, $PM_{10} = 11.0 \mu\text{g}/\text{m}^3$). During instances of calm winds, the SRRQ is not impacting BC and PM concentrations at the monitoring site, and the measurements represent local background conditions.

Table 2 also includes average weekday and weekend values and shows that average concentrations are lower on weekends. The percent difference between weekdays and weekends is 24.0% for BC, 4.3% for $PM_{2.5}$, and 19.8% for PM_{10} . The weekday-weekend comparison will be revisited after the reclamation period is complete.

Table 2. Statistical summary of all BC and PM concentrations during the SRRQ background monitoring period (May 4–July 23, 2018). Average values are reported along with the standard deviation (1σ), and average values for weekdays and weekends are also included.

	BC ($\mu\text{g}/\text{m}^3$)	PM _{2.5} ($\mu\text{g}/\text{m}^3$)	PM ₁₀ ($\mu\text{g}/\text{m}^3$)
<i>All Days</i>			
Average (1σ)	0.14 (0.14)	7.0 (4.9)	16.2 (13.2)
1 st quartile	0.05	3.1	7.1
Median	0.1	6.1	13.1
3 rd quartile	0.17	10.0	21.3
Maximum	1.3	39.1	115
<i>Weekdays Only</i>			
Average (1σ)	0.14 (0.14)	7.1 (5.4)	17.2 (14.3)
<i>Weekends Only</i>			
Average (1σ)	0.11 (0.11)	6.8 (4.2)	14.1 (9.9)

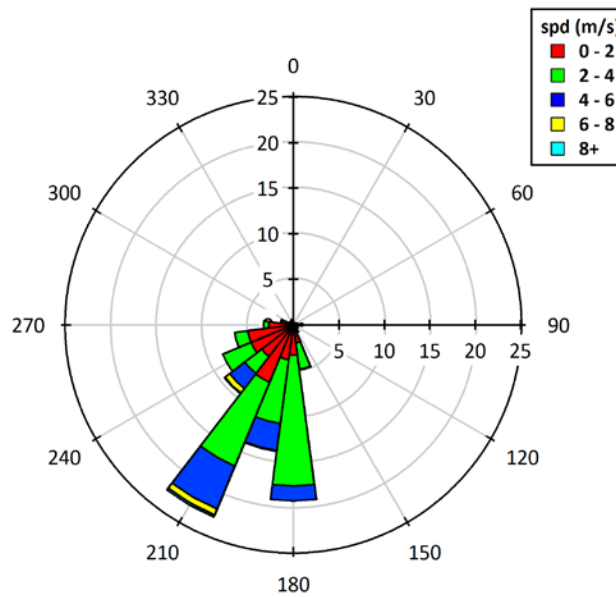


Figure 3. Wind rose showing typical wind directions (from the south and southwest) and speeds measured at the Marin Municipal Water District Tank on May 3–July 23, 2018.

Peak Hourly BC and PM Measurements

For each of the species measured, maximum concentrations were observed when wind was blowing directly from the south, i.e., from the direction of the SRRQ. This is illustrated in the pollution roses in [Figure 4](#). When only the data collected under southerly winds are considered, average concentrations are noticeably higher ([Table 3](#)) than when all data are considered ([Table 2](#)). When the wind is blowing from the direction of the quarry (excluding calm winds less than 1.5 m/s), average BC = $0.22 \mu\text{g}/\text{m}^3$, $\text{PM}_{2.5} = 8.7 \mu\text{g}/\text{m}^3$, and $\text{PM}_{10} = 20.7 \mu\text{g}/\text{m}^3$.

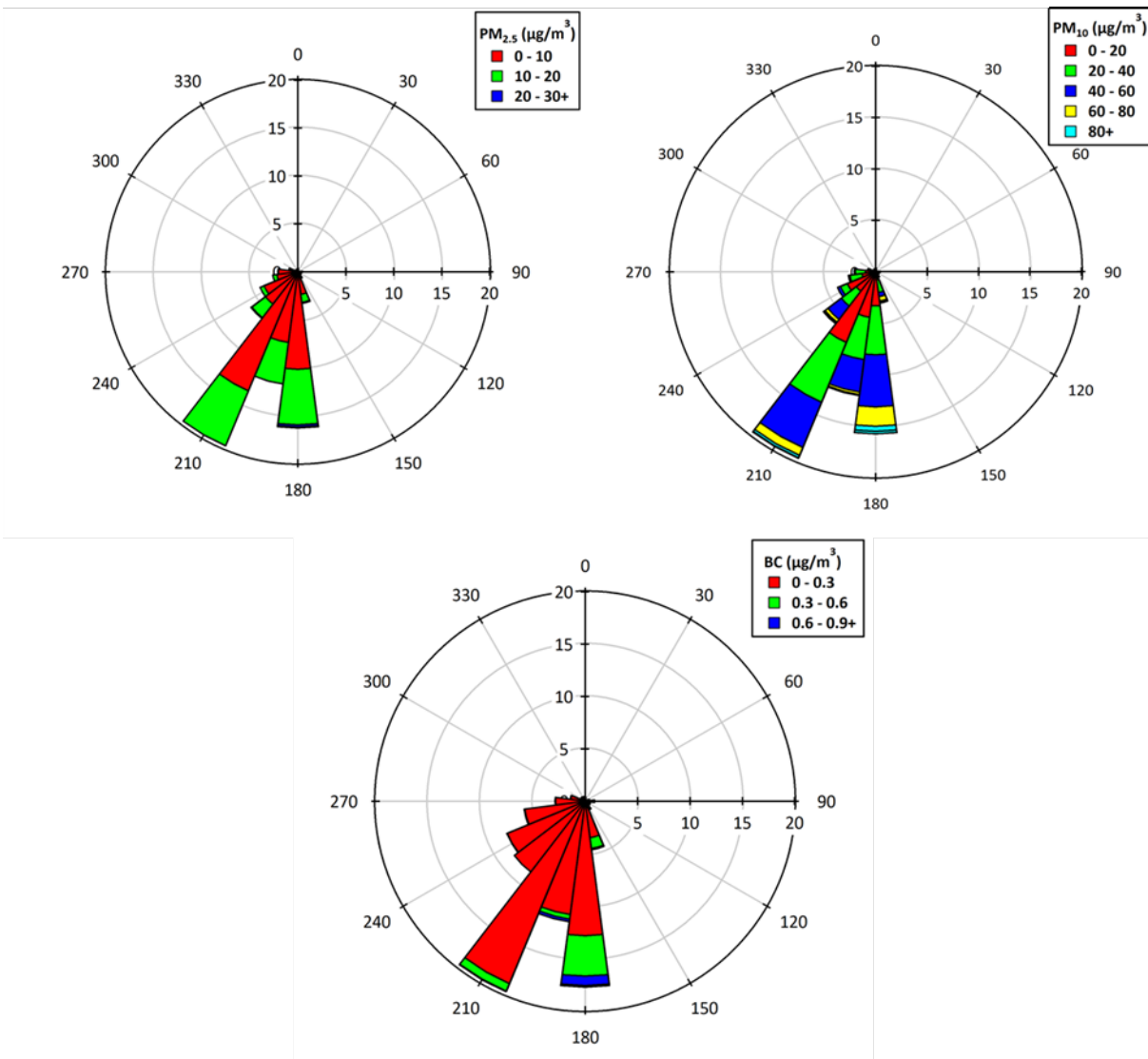


Figure 4. Pollution roses for $\text{PM}_{2.5}$ (top left), PM_{10} (top right), and BC (bottom), illustrating that the highest particulate concentrations (blue) were observed when winds were from the south (the direction of the SRRQ).

Table 3. Statistical summary of black carbon (BC) and particulate (PM) concentrations during the SRRQ background monitoring period when winds were from the south. Average values are reported along with the standard deviation (1σ).

	BC ($\mu\text{g}/\text{m}^3$)	PM _{2.5} ($\mu\text{g}/\text{m}^3$)	PM ₁₀ ($\mu\text{g}/\text{m}^3$)
Average (1σ)	0.22 (0.18)	8.7 (5.2)	20.7 (14.9)
1 st quartile	0.11	4.97	11.0
Median	0.17	8.0	18.1
3 rd quartile	0.28	11.9	26.8
Maximum	1.3	39.1	115

The time series in Figure 2 illustrates how frequently spikes in BC and PM₁₀ were observed during the background monitoring period. For analysis purposes, spikes were defined as the top 10% of BC and PM hourly measurements. Using this filter, the highest concentrations were observed in the early afternoon (12:50 PST), during southerly winds with speeds of approximately 3.3 m/s. Hourly concentrations were on average 0.46, 16.7, and 45.3 $\mu\text{g}/\text{m}^3$ for BC, PM_{2.5}, and PM₁₀, respectively, when these spikes occurred. A summary is provided in Table 4.

Table 4. Typical time of day, wind conditions, and hourly average particulate concentrations when the highest concentrations during the background monitoring period were observed. This includes the top 10% of data, as well as instances when hourly data were greater than the strictest 24-hour state and national air quality standards.

Spikes	Time of Day (PST)	Wind Dir. (°)	Wind Speed (m/s)	BC ($\mu\text{g}/\text{m}^3$)	PM _{2.5} ($\mu\text{g}/\text{m}^3$)	PM ₁₀ ($\mu\text{g}/\text{m}^3$)
Top 10%	12:50	187	3.3	0.46	16.7	45.3
PM _{2.5} > 35 $\mu\text{g}/\text{m}^3$ and PM ₁₀ > 50 $\mu\text{g}/\text{m}^3$	14:06	180	3.0	0.26	13.8	68.4

Another way to assess spikes in the time series is to consider only hourly PM concentrations above the strictest 24-hour California and EPA air quality standards (PM_{2.5} > 35 $\mu\text{g}/\text{m}^3$ and PM₁₀ > 50 $\mu\text{g}/\text{m}^3$). There were a total of 51 hourly measurements on 21 different days that exceeded the California 24-hr standards. Of these instances, only two were for PM_{2.5}, and the remaining 49 were for PM₁₀. The high concentrations typically occurred around 2:00 p.m. (PST), again during southerly winds (average speed of 3.0 m/s). Average hourly concentrations when either standards were exceeded (Table 4) were 0.26, 13.8, and 68.4 $\mu\text{g}/\text{m}^3$ for BC, PM_{2.5}, and PM₁₀, respectively.

Comparison to 24-Hour Air Quality Standards

To put PM concentrations measured near the SRRQ in perspective with both California and national (U.S. EPA) ambient air quality standards, 24-hour averages of the hourly data were calculated.¹ Black carbon is not considered a criteria pollutant, and air quality standards for black carbon have not been established.

Daily averages (Table 5) were 0.14 $\mu\text{g}/\text{m}^3$ for BC, 7.0 $\mu\text{g}/\text{m}^3$ for $\text{PM}_{2.5}$, and 16.2 $\mu\text{g}/\text{m}^3$ for PM_{10} . The 24-hour average $\text{PM}_{2.5}$ and PM_{10} are significantly lower than the state and national 24-hour air quality standards. Concentrations during the reclamation period will also be examined and compared to air quality standards. Comparing annual California standards to this two-month background monitoring period reveals that PM concentrations measured downwind of the quarry are nearing the allowable annual California standards of 12 $\mu\text{g}/\text{m}^3$ for $\text{PM}_{2.5}$ and 20 $\mu\text{g}/\text{m}^3$ for PM_{10} . While standards are not currently being exceeded, this will be an important comparison point following the end of the 10-week reclamation period.

Table 5. Summary of state (California EPA) and federal (U.S. EPA) 24-hr and annual ambient air quality standards for particulate matter (PM_{10}) and ultrafine particulate matter ($\text{PM}_{2.5}$), and 24-hr averages observed in this study. Standard deviation is shown in parentheses.

Pollutant	SRRQ Average ($\mu\text{g}/\text{m}^3$)	CA Standard ^a ($\mu\text{g}/\text{m}^3$)		EPA Standard ^a ($\mu\text{g}/\text{m}^3$)	
		24-hr	Annual	24-hr	Annual
$\text{PM}_{2.5}$	7.0 (3.9)	-	12	35	12
PM_{10}	16.2 (8.5)	50	20	150	-
BC	0.14 (0.1)	-	-	-	-

^a Ambient air quality standards obtained from the Bay Area Air Quality Management District (<http://www.baaqmd.gov/research-and-data/air-quality-standards-and-attainment-status>).

Future Plans

The SRRQ began Phase 1 of the reclamation of the northeast quadrant of the quarry in July 2018. The project is expected to continue for 10 weeks, throughout most of September. Starting on July 10, STI switched to daily collection of 24-hour filter samples for silica and metal concentrations instead of following the EPA 6-day monitoring schedule.

¹ This calculation is merely for comparison, as compliance with the standards is determined from 3-year averages. For instance, 24-hour averaged $\text{PM}_{2.5}$ is considered out of attainment if the 3-year average of 98th percentiles is greater than 35 $\mu\text{g}/\text{m}^3$; similarly 24-hour PM_{10} is out of attainment if the 3-year average of 99th percentiles is greater than 150 $\mu\text{g}/\text{m}^3$.

Filter samples collected during the background monitoring period (12 each for silica and metals) are currently being stored at STI offices in Petaluma. A subset of these background filters will be selected for laboratory analysis, at a date still to be determined. The subset of filters will be chosen to include days that saw high BC and PM concentrations as well as blanks for comparison.

Another subset of the daily filters collected during the reclamation period will also be selected for analysis. Following the end of the reclamation period, hourly PM and BC samples will continue throughout April 2020. Collection of 24-hour filter samples will return to the EPA 6-day monitoring schedule, until summer 2019, when another 10-week reclamation period is scheduled to occur.

Summary

The 2018 background air quality monitoring period at the SRRQ ran from May 3 until July 9, 2018. During this time, 1-minute meteorological data and hourly measurements of BC and PM were collected at two locations north of the rock quarry. Quality control checks were also established. Accounting for data filtering and instrument maintenance, 90% of possible hourly data were successfully collected during this 68-day period.

The prevailing wind direction was from the south, or from the direction of the SRRQ, allowing for the impact of typical quarry activities to be monitored. The highest particulate concentrations were observed when moderate winds were coming from the direction of the quarry. These spikes in BC and PM concentrations were typically observed at midday, between 12:00 p.m. and 2:00 p.m. PST. Currently, 24-hour PM concentrations are within ambient air quality standards established by both the California EPA and U.S. EPA.

Air quality monitoring and filter collection will continue throughout the 10-week quarry reclamation period, which began the week of July 23, 2018. Ultimately, the analysis described in this memorandum will be revisited and compared to measurements collected during the reclamation period.