UPDATE #5 TO:

A METHODOLOGY TO DETERMINE ANNUAL EFFECTIVENESS OF EMISSION MITIGATION TECHNIQUES IN THE ODSVRA

By Mel Zeldin
Consultant to San Luis Obispo County APCD

Introduction

The original methodology and data covered the years 2011 through 2014, designated as the "baseline period" prior to the implementation of seasonal mitigation measures by the California State Parks beginning in 2015. As a summary, a strict set of meteorological conditions were defined and called "filter days." The "filter day" classification strategy looks only at the 1000-1500 time period (hourly values) under stringent meteorological parameters that essentially hold meteorology constant such that PM10 concentrations measured at CDF are directly related to the emissions from the ODSVRA. The methodology was previously provided to the Technical Committee members.

As a summary, the specific criteria for defining a filter day are as follows:

During the six-hour period, 1000-1500:
1) All PM10, S1, and CDF wind speed and direction measurements must be valid;
2) The S1 vector average wind direction must be between 285 and 300 degrees for the six-hour period;
3) The S1 site must have all hourly wind speeds greater than or equal to 5 m/s;
4) The S1 site must have at least 3 of the six hourly wind speed greater than 10 m/s;
5) The S1 site must not have any hourly wind direction > 310 degrees;
6) The CDF site must not have any hourly wind direction < 285 degrees.

Updates were prepared after the 2015 and 2016 seasons to compare the first two years of the mitigation rollout to the baseline period. The intent was to determine if the CDF concentrations in 2015-16 were different from the baseline period. Compared to the baseline, 2015 was an anomalous year with respect to the number of filter day events. While the filter days during the baseline period ranged from 10 to 21 events in a year, with 85% of such days occurring during the April-June period, only 5 such days occurred in 2015, presumably due to the El Nino influences upon the spring weather conditions. In 2016, there were 12 filter days, representing a more robust number of such days, approximately similar in number to the baseline years of 2011 and 2014.

Results through June 2017 are now available. The number of filter days during that period was 15 which is more typical of the number of events which occurred annually during the baseline period.

This update examines the results of the 2015 through (June) 2017 filter day data as compared to the 2011-2014 baseline period.

It should also be clearly noted that the filter days represent a specific subset of days when meteorological conditions are conducive to elevated PM10 at CDF. Of the 366 hourly data values on filter days during the baseline 4-year period, 358, or 97.8% of all such values were 100 ug/m^3 or greater, validating the filter day criteria as successfully identifying days with high PM10 hourly levels at CDF when winds are from the west-northwest (source to receptor).

Review of the Baseline Period

There were at total of 61 filter days aggregated over the four-year baseline period. Because average wind speeds varied slightly year to year, annual data were normalized to wind speed to get an average concentration per m/s for each year. From these annual values, averages and standard deviations were determined, as shown below in Table 1:

Table 1 - Filter Day Summary for the Baseline Period

YEAR	# FILTER DAYS	CDF PM10	S1 WIND (m/S)	PM10/M PER S
2011	10	270	10.3	26.2
2012	16	357	11.8	30.3
2013	21	325	11.5	28.3
2014	14	317	10.7	29.6
	Avg	317.0	Avg	28.6
			Std Dev	1.8
			3 std dev	5.4
			Target 95% conf.	23.2
	Target level	257.1	% reduction needed	18.9%

Note that the normalized values for all four years are remarkably similar. 2011 had the fewest number of data "filter days" with an annual total of 10. Based on these results baseline, it is suggested that at least 10-12 "filter days" per year would be best to achieve a robust enough normalized annual value.

As a double check of the average normalized value as shown in the above table, all 366 data points for the 61 days over the four years were averaged and then normalized. The resulting value was 28.7 -- within 0.1 PM10/m/s to the average of the annual four yearly values.

With the understanding that the standard deviation represents the inter-annual meteorological variability of filter day events, to have confidence that an observed normalized annual value (ug/m^3 PM10 per m/s wind) is statistically significant beyond the inter-annual variability, a value of 3 standard deviations was used as the confidence level necessary to determine that any observed reductions were due to mitigations, not meteorology. (The three sigma level was used because for a t-test with 3 degrees of freedom, the 95% confidence interval is 3 sigmas.) This results in a target normalized value of 23.2 ug/m^3 per m/s, or 18.9% reduction from the mean value over the 4-year period.

Evaluation of the 2015 through June 2017 Mitigation Period

The results for wind fence mitigation years, 2015 through June 2017 are shown in Table 2:

Table 2 - Filter Day Summary for the Mitigation Period

YEAR	# FILTER DAYS	CDF PM10 (ug/m3)	S1 WIND (m/s)	PM10/M PER S
2015	5	336	10.2	32.9
2016	12	261	10.4	25.1
2017*	15	290	11.0	26.4
Avg		295.7	10.5	28.1

** Through June only.*

From these results, it can be seen that in the three years of mitigation, on an annual average basis, there is a small, reduction on the order of 1.7% from the baseline period. Using a t-test comparing the annual "PM10/m/s" values for the baseline period versus the mitigation period, this difference is not statistically significant.

Although the filter days represent much of a meteorological constant of conditions, nevertheless there is clearly year-to-year variability in conditions, as depicted by the varying number of events per year. Another such variable is the intensity of events. One way to examine the intensity is to look at the more extreme conditions -- events that produce hourly values of PM at CDF >= 400 ug/m^3.

In Table 3, the number of filter days and the number of hours >= 400 ug/m^3 are shown along with the calculated frequency of occurrence of such hours.

Table 3 - Comparison of Frequency of High CDF PM Levels Between Baseline and Mitigation Periods

PERIOD	YEAR	# FILTER DAYS	# HOURS >= 400 UG/M^3 AT CDF	FREQUENCY OF OCCURRENCE (%)
Baseline	2011	10	3	5.00%
	2012	16	34	35.42%
	2013	21	32	25.40%
	2014	14	25	29.76%
	Average frequency for the baseline period			23.89%
Mitigation	2015	5	10	33.33%
	2016	12	13	18.06%
	2017*	15	19	21.11%
	Average frequency for the mitigation period			24.17%

*Through Jun

As can be seen in Table 3, the frequency of the most intense PM10 hourly conditions as measured at CDF are virtually identical for both the baseline and mitigation years. The difference is not statistically significant for the baseline years and the 3 annual values for the mitigation years. Also, much as the low number of events in 2015 represents a likely anomalous year, similarly, 2011 represents an anomalous year with respect to a lack of high intensity PM10 levels at CDF. Thus inter-annual meteorological variability can occur for both the frequency of such events as well as the intensity of such events.

CDF PM10 vs Wind Speeds

Another analytical approach to gain insight into the relationship between wind speeds and CDF PM10 concentrations is a simple scatter plot of the hourly data on the filter days. In Figure 1, the S1 tower hourly wind speeds are plotted against the hourly CDF PM10 for the baseline period.

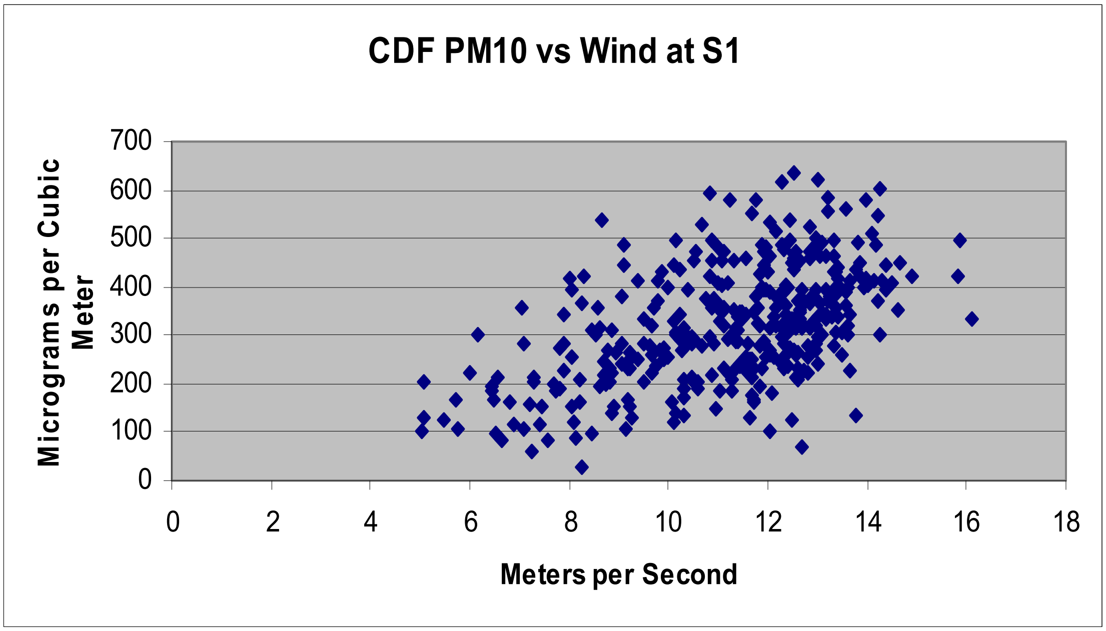

Figure 1

Because this scatter plot is from data generally at the upper tail of the overall distribution of such data points for all days and all hours, one would generally expect a fair degree of scatter, which is what is observed. Statistically, the correlation coefficient (r) of 0.52 is significant given the large sample size of hourly values in the data set, but is likely not as large as would be if the data from all days and hours (which include a lot of non-windy days) were included.

The next analysis looked at the CDF wind speed versus CDF PM10. A stronger statistical relationship could indicate more localized sources nearer the site having influence on the resulting PM10. A similar scatter plot for the baseline period for CDF hourly wind versus PM10 is shown below in Figure 2:

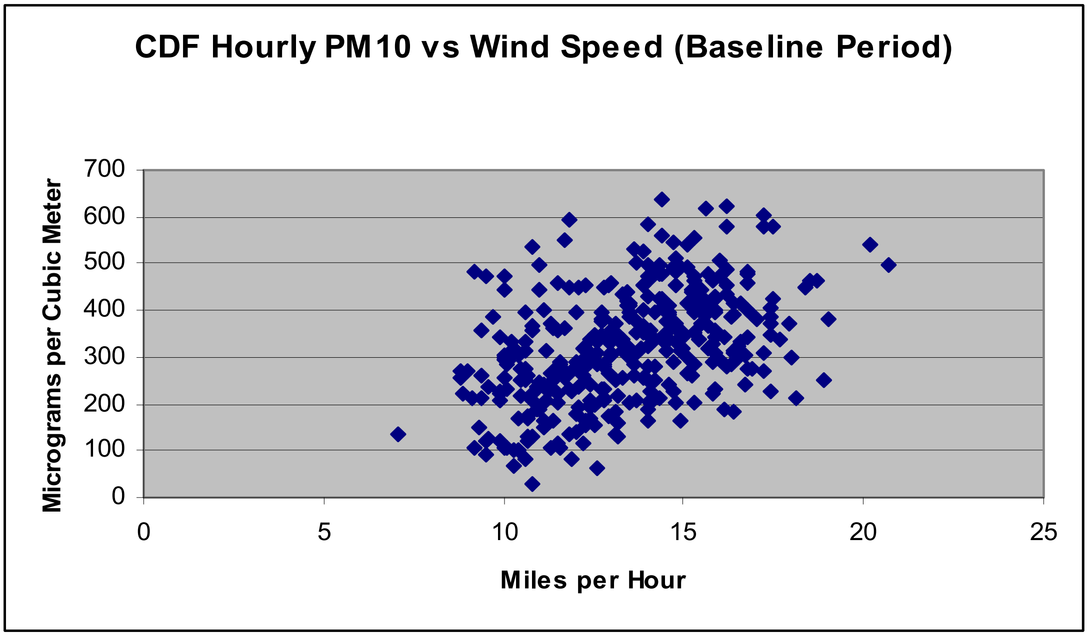

Figure 2

For these data, r=0.46 -- slightly less than that for the wind speeds at the S1 tower. So there is no indication from this analysis that a more significant localized source near CDF accounts for the observed levels, and it also points to the S1 tower wind data being a better wind parameter for assessing ODSVRA impacts on the CDF PM10 than the CDF wind data.

What the composite of all these data suggests is that there is a complex emissions system taking place within the ODSVRA, and that mitigation solutions may be complex as well.

Since we have four years of baseline data, and three years of wind fence mitigation in the same location, future changes to mitigation strategies would, under the filter day analysis, be compared annually to the data for the baseline period and the 2015-17 mitigation period.