Southcentral $PM_{2.5}$ Data Analysis

This is an analysis of $PM_{2.5}$ FRM data for monitors in southcentral Pennsylvania.

Monitor Information

Site Name	County	FRM Start Date	FRM Sample Frequency	Speciated Start Date	Speciated Frequency
Arendtsville	Adams	1/1/1999	1/1	4/1/2002	1/6
Carlisle	Cumberland	2/15/2000	1/1	NA	NA
Harrisburg	Dauphin	1/1/1999	1/1	4/1/2002	1/6
Lancaster	Lancaster	1/9/1999	1/3	4/1/2002	1/6
Little Buffalo (Perry County)	Perry	1/1/2000	1/3	4/1/2002	1/6
Reading	Berks	2/26/1999	1/3	NA	NA
York	York	1/1/2000	1/3	4/1/2002	1/6

Data Analysis:

Design Value Contribution Analysis:

Five of the seven monitors in southcentral Pennsylvania exceed the annual $PM_{2.5}$ NAAQS (15.0 $\mu g/m^3$). Annual $PM_{2.5}$ design values for 2004-06 are listed for the seven FRM monitoring sites in southcentral Pennsylvania are listed in Table 1. Design values across southcentral Pennsylvania have remained relatively stable over the last five years.

Table 1.
Annual $PM_{2.5}$ design Values

Site	2001-03	2002-04	2003-05
Arendtsville	13.3	13.6	13.0
Carlisle	14.9	**15.1**	14.4
Harrisburg	**15.4**	**15.8**	15.0
Lancaster	**16.8**	**17.5**	**16.3**
Little Buffalo (Perry County)	12.8	12.8	
Reading	**17.0**	**17.3**	**16.2**
York	**17.0**	**17.0**	**17.3**

The nature of the annual standard makes it difficult to determine what causes a monitor to exceed the annual $PM_{2.5}$ standard. For a well-run monitor, between 365 to 1096 FRM measurements make up its annual design value. The shear number of samples makes it

very difficult to determine what days (samples) are contributing to monitor's annual design value.

A monitor's annual $PM_{2.5}$ design value is determined by first calculating its quarterly average. Quarterly averages are then averaged to calculate the monitor's average annual $PM_{2.5}$ concentration. Three consecutive years of average annual $PM_{2.5}$ concentrations are then averaged to determine a monitor's annual $PM_{2.5}$ design value. Thus any one particular sample will make only a minor contribution to a monitor's annual $PM_{2.5}$ design value.

The Pennsylvania DEP has come up with a methodology to quickly analyze a monitor's design value and determine which measurements (or types of measurements) are contributing to a site's design value. Each twenty-four hour $PM_{2.5}$ FRM measurement's contribution to the monitor's annual design value is calculated. FRM 24-hour concentrations are then grouped into different sample ranges to gauge each sample range's contribution to the monitor's annual design value. Monitors then can be compared to determine which monitor sample ranges are important.

For the purposes of this analysis, contributions are determined such that contributions from samples less than 15.0 $\mu g/m^3$ are negative and those samples that are greater than 15.0 $\mu g/m^3$ are positive. The break point of 15.0 $\mu g/m^3$ represents the break-off point for the annual $PM_{2.5}$ standard. Mathematically the contributions for each sample range can be represented by this equation:

For values less than or equal to 15.0 $\mu g/m^3$:

$$0 < x \leq 15$$

$$\sum_{x=0}^{15} \frac{x - 15}{n * 12}$$

For values greater 15.0 $\mu g/m^3$:

$$15 < x < Max$$

$$\sum_{15}^{Max} \frac{x - 15}{n * 12}$$

Contributions from several ranges of sample concentrations then can be summed to determine a monitor's annual design-value concentration. Table 2 shows the results of the design-value contribution analysis for the seven monitors in southcentral Pennsylvania (2005).

Table 2.
Design Value Contribution Analysis

Site	0-15.0	15.0-40.5	40.5-65.5	>65.5	Sum
Arendtsville	-4.0612	2.4386	0.2743	0.0000	**-1.3482**
Carlisle	-3.6048	3.2636	0.4220	0.0539	**0.1347**
Harrisburg	-3.1818	3.4400	0.4707	0.0529	**0.7819**
Lancaster	-2.6645	3.8887	1.0820	0.1572	**2.4634**
Little Buffalo (Perry County)	-4.3304	2.0228	0.1301	0.0000	**-2.1775**
Reading	-3.1425	3.5379	0.5934	0.1697	**1.1586**
York	-2.5897	4.1302	0.6090	0.1962	**2.3000**

The break lines in Table 2 are roughly based on the twenty-four hour AQI scale for $PM_{2.5}$ with the lower scale being cut of at 15.0 $\mu g/m^3$. The table indicates a substantially higher number of days within in the good range (0-15 $\mu g/m^3$) for the two monitors currently meeting the annual $PM_{2.5}$ in the southcentral region (Little Buffalo and Arendtsville). The monitors also appear to have a much lower incidence of days with fine-particulate concentrations above 40.5 $\mu g/m^3$. PA DEP forecasters have observed several occasions where concentrations in the Lancaster and York monitors have been much higher than the surrounding areas. This information is based on measurements from the PA DEP's continuous monitoring network. These gradients are also present in the FRM measurements when they are available. Southcentral Pennsylvania also appears to have a higher number of days above 40.5 $\mu g/m^3$ than other regions of the Commonwealth.

Design Value Contribution Analysis Summary:

- **Five of the seven FRM monitors in southcentral Pennsylvania exceed the annual $PM_{2.5}$ standard (as of 2005).**
- **Monitors currently exceeding the annual $PM_{2.5}$ standard appear to have substantially fewer days with AQI ratings in the good range and substantially more days where daily concentrations exceed 40.5 $\mu g/m^3$ than the monitors meeting the annual standard.**
- **PA DEP forecasters have observed sharp gradients in fine-particulate concentrations across southcentral Pennsylvania (from the continuous monitors).**
- **In general, monitors in southcentral Pennsylvania have more days above 40.5 $\mu g/m^3$ than other regions of the Commonwealth.**

Correlation Coefficient Analysis:

Correlation coefficients are a statistical measure to determine how well two different samples track one another. There are three possibilities; the two samples react similarly, they appear to be random or they react oppositely. Daily FRM $PM_{2.5}$ measurements from the seven monitors in southcentral Pennsylvania from 2000-05 were correlated with one another to determine how well the monitors tracked over time.

The monitors are all within approximately 70 miles of one another. Air flow is generally unrestricted for most of the sites except Little Buffalo (Perry County) which resides north of the Blue Ridge Mountain. The monitors should correlate well with one another since they are relatively close to one another and there are generally few significant restrictions in regional low-level air flow.

Table 3 lists the correlation coefficients for all seven FRM monitoring sites in southcentral Pennsylvania. Coefficients range from 1.0 to –1.0. Correlation ranges and their meaning are broken down as follows:

1.0 to 0.667	Positive correlation (samples move in a similar direction)
0.667 to -0.667	Samples not well correlated (0.334 to – 0.334, random)
-0.667 to –1.0	Negative correlation (samples move in opposite direction)

Table 3.
Southcentral Pennsylvania $PM_{2.5}$ Correlation Coefficients

	Lancaster	York	Arendtsville	Harrisburg	Carlisle	Little Buffalo	Reading
Lancaster		0.9212	0.8084	0.9194	0.8807	0.8301	0.9382
York	0.9249		0.8474	0.8962	0.8720	0.8471	0.8801
Arendtsville	0.8084	0.8474		0.8844	0.8809	0.9114	0.7723
Harrisburg	0.9194	0.8962	0.8844		0.9440	0.9125	0.8981
Carlisle	0.8807	0.8720	0.8809	0.9440		0.9289	0.8627
Little Buffalo	0.8301	0.8471	0.9114	0.9125	0.9289		0.8360
Reading	0.9382	0.8801	0.7723	0.8981	0.8627	0.8360	

Correlation coefficients indicate that the seven monitors in southcentral Pennsylvania generally respond similarly. It is interesting to note that the five nonattainment monitors correlate better with each other than the two sites that are measuring attainment for the annual $PM_{2.5}$ standard. The greater the magnitude of nonattainment the greater the discrepancy in the correlation coefficient differences.

Correlation Coefficient Analysis Summary:

- **Correlation coefficients constructed from 2000-05 FRM data for all seven monitors in southcentral Pennsylvania indicate all of the monitors respond**

similarly. This is not unusual since all of the monitors are located within 70 miles of one another.

- **In general the five monitors not meeting the annual $PM_{2.5}$ standard correlate better with one another than the other two monitors that are attaining the standard. The magnitude in the difference in correlation coefficients generally increases with the magnitude of nonattainment.**

Coefficients of Divergence Analysis:

Correlation of divergence is a statistical measure to quantify the magnitude of difference between two groups of samples. FRM samples between 2000 and 2006 were analyzed to determine the coefficients of divergence between all seven monitors in southcentral Pennsylvania. Table 4 summarizes the results of this analysis. In general numbers close to zero indicate small differences in concentrations between the various monitors. Numbers close to one or above indicate significant differences in the daily $PM_{2.5}$ concentrations between the two monitors.

Table 4.
Southcentral Pennsylvania $PM_{2.5}$ Coefficient of Divergence

	Lancaster	York	Arendtsville	Harrisburg	Carlisle	Little Buffalo	Reading
Lancaster		0.2282	1.1731	0.4894	0.7300	1.1525	0.3181
York	0.2282		0.9356	0.4136	0.6675	1.0153	0.3839
Arendtsville	1.1731	0.9356		1.0370	0.8104	0.8104	0.3774
Harrisburg	0.4894	0.4136	1.0370		0.4609	0.5380	0.5007
Carlisle	0.7300	0.6675	0.8104	0.4609		0.3857	0.7135
Little Buffalo	1.1525	1.0153	0.8104	0.5380	0.3857		1.0174
Reading	0.3181	0.3839	0.3774	0.5007	0.7135	1.0174	

The results of this analysis indicate there are significant differences in daily fine-particulate concentrations across the region. In general the magnitude is greatest between monitors that are complying with the annual $PM_{2.5}$ standard and those that are not. The greatest differences in magnitude are between the two monitors that are measuring attainment (Little Buffalo and Arendtsville) the two monitors with the highest annual $PM_{2.5}$ design values (Lancaster and York). This finding is consistent with the large $PM_{2.5}$ concentrations periodically observed by PA DEP's air-quality forecasters.