Southwest $PM_{2.5}$ Data Analysis

This is a short analysis of $PM_{2.5}$ FRM data for monitors in southwest Pennsylvania.

Monitor Information

Site Name	County	FRM Start Date	FRM Sample Frequency	Speciated Start Date	Speciated Frequency
Florence	Washington	1/1999	1/1	4/2002	1/6
Beaver Falls	Beaver	1/2000	1/3	NA	NA
Lawrenceville	Allegheny	2/1999	1/1		1/6
North Braddock	Allegheny	1/1999	1/3	NA	NA
Greensburg	Westmoreland	2/1999	1/3	4/2002	1/6
Johnstown	Cambria	2/1999	1/3	NA.	NA

Data Analysis:

Design Value Contribution Analysis:

There are six monitors that exceed the annual $PM_{2.5}$ NAAQS (15.0 $\mu g/m^3$) in southwest Pennsylvania. This analysis examines concentrations at five of these monitors. For comparison, the Florence monitor was added to the analysis.

Annual $PM_{2.5}$ design values for 2006 are listed for the six FRM monitoring sites in southwest Pennsylvania are listed in Table 1. Design values across southwest Pennsylvania have remained relatively stable for these six monitors over the last five years.

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

Site	2002-2004	2003-2005	2004-06
Florence	13.3	13.6	13.1
Beaver Falls	15.4	16.5	16.2
Lawrenceville	15.3	15.5	15.2
North Braddock	16.5	16.6	16.0
Greensburg	15.1	15.7	15.4
Johnstown	15.3	15.6	15.3

The nature of the annual standard makes it difficult to determine what causes a monitor to exceed it. For a well-run monitor, between 365 and 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 six monitors in southwest Pennsylvania. The list includes all of the monitors with annual PM2.5 design values above the standard and the Florence monitor, which is below the standard.

Table 2.
Design Value Contribution Analysis

Site	0-15.0	15.0-40.5	40.5-65.5	>65.5	Sum
Florence	-3.8581	2.1420	0.3290	0.0000	**-1.3871**
Beaver Falls	-2.9426	3.3328	0.7991	0.0000	**1.1893**
Lawrenceville	-3.1914	2.8158	0.6044	0.0000	**0.2288**
North Braddock	-2.8912	3.4658	0.4210	0.0000	**0.9956**
Greensburg	-3.0418	2.9773	0.4142	0.0000	**0.3497**
Johnstown	-3.1316	3.0328	0.4396	0.0000	**0.3409**

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 Florence monitor, which currently meets the annual $PM_{2.5}$. The five monitors that exceed the annual standard appear to have a much higher incidence of days with fine-particulate concentrations above 15.0 $\mu g/m^3$.

Design Value Contribution Analysis Summary:

- **Five FRM monitors in southwest Pennsylvania exceed the annual $PM_{2.5}$ standard (as of 2006).**
- **The monitors currently exceeding the annual $PM_{2.5}$ standard appear to have substantially fewer number of 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 in southwest Pennsylvania.**

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 six monitors in southwest Pennsylvania from 2000-06 were correlated with one another to determine how well the monitors tracked over time.

The largest distance between the monitors in southwest Pennsylvania is approximately 90 miles (between Johnstown and Florence). The bulk of the monitors are within 40 miles of one another. Air flow can be quite restricted due to the mountainous terrain in the region. With the exception of Johnstown (Ridge and Valley) all of the monitors reside within the Allegheny Plateau; an area of elevated terrain cut with many steep river valleys. Most of the monitors reside within a river valley and therefore are subject to local inversions and other terrain induced weather phenomena.

Table 3 lists the correlation coefficients for all six FRM monitoring sites in southwest 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.
Southwest Pennsylvania $PM_{2.5}$ Correlation Coefficients

	Florence	Beaver Falls	Lawrenceville	North Braddock	Greensburg	Johnstown
Florence		0.8563	0.9156	0.8760	0.8619	0.8118
Beaver Falls	0.8563		0.8717	0.8639	0.8009	0.8034
Lawrenceville	0.9156	0.8717		0.9460	0.8955	0.8673
North Braddock	0.8760	0.8639	0.9460		0.8720	0.8453
Greensburg	0.8619	0.8009	0.8955	0.8720		0.8624
Johnstown	0.8118	0.8034	0.8673	0.8453	0.8624	

Correlation coefficients indicate that the six monitors in southwest Pennsylvania generally respond similarly. Of course monitors that are relatively close to one another (Lawrenceville and North Braddock) correlate better than monitors that are far apart (Johnstown and Florence). Correlation seems to vary with the time of year (not shown). In general the six southwest monitors have higher correlations during the 2nd and 3rd quarters than during the 1st and 4th quarters.

Correlation Coefficient Analysis Summary:

- **Correlation coefficients constructed from 2000-06 FRM data for all six monitors in southwest Pennsylvania indicate all of the monitors respond similarly. This is somewhat surprising since monitors in southwest Pennsylvania are more likely to be influenced by local terrain features.**
- **Correlations are better between the monitors that are closest to one another.**
- **Correlations are better during the 2nd and 3rd quarters than during the 1st and 4th quarters.**

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 six monitors in southwest Pennsylvania; the five monitors currently exceeding the annual $PM_{2.5}$ standard and one monitor near the western boundary of the state (Florence) that meets the standard. 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.
Southwest Pennsylvania $PM_{2.5}$ Coefficient of Divergence

	Florence	Beaver Falls	Lawrenceville	North Braddock	Greensburg	Johnstown
Florence		0.7102	0.6619	0.6694	0.5158	0.6878
Beaver Falls	0.7102		0.3930	0.4631	0.6341	0.6223
Lawrenceville	0.6619	0.3930		0.2402	0.2811	0.4717
North Braddock	0.6694	0.4631	0.2402		0.3995	0.5464
Greensburg	0.5158	0.6341	0.2811	0.3995		0.4810
Johnstown	0.6878	0.6223	0.4717	0.5464	0.4810	

The results of this analysis indicate there are some significant differences in daily fine-particulate concentrations across southwest Pennsylvania. The largest difference in concentrations appears to be between the Florence monitor that is attaining the annual $PM_{2.5}$ standard, and the other five monitors that are not attaining the annual $PM_{2.5}$ standard. There also seems to be greater differences in daily $PM_{2.5}$ concentrations between monitors that are further appart. Differences also seem to be seasonal with greater differences during the 1st and 4th quarters than during the 2nd and 3rd quarters. This may be due to differences in local and regional wind patterns over the year. Local influences may be stronger during winter months causing more regional variability.

Coefficients of Divergence Analysis Summary:

- **Coefficients of Divergence constructed from 2000-06 FRM data indicate there are some significant monitor variability in southwest Pennsylvania.**
- **The five monitors exceeding the $PM_{2.5}$ standard show less variability in daily $PM_{2.5}$ concentrations between each other than with the one monitor included in the analysis that meets the annual $PM_{2.5}$ standard.**
- **Generally, differences in daily $PM_{2.5}$ concentrations are lower during the 2nd and 3rd quarters than during the 1st and 4th quarters. This may be due to local meteorological influences being more controlling over the winter months while more regional flow dominates during the summer months.**