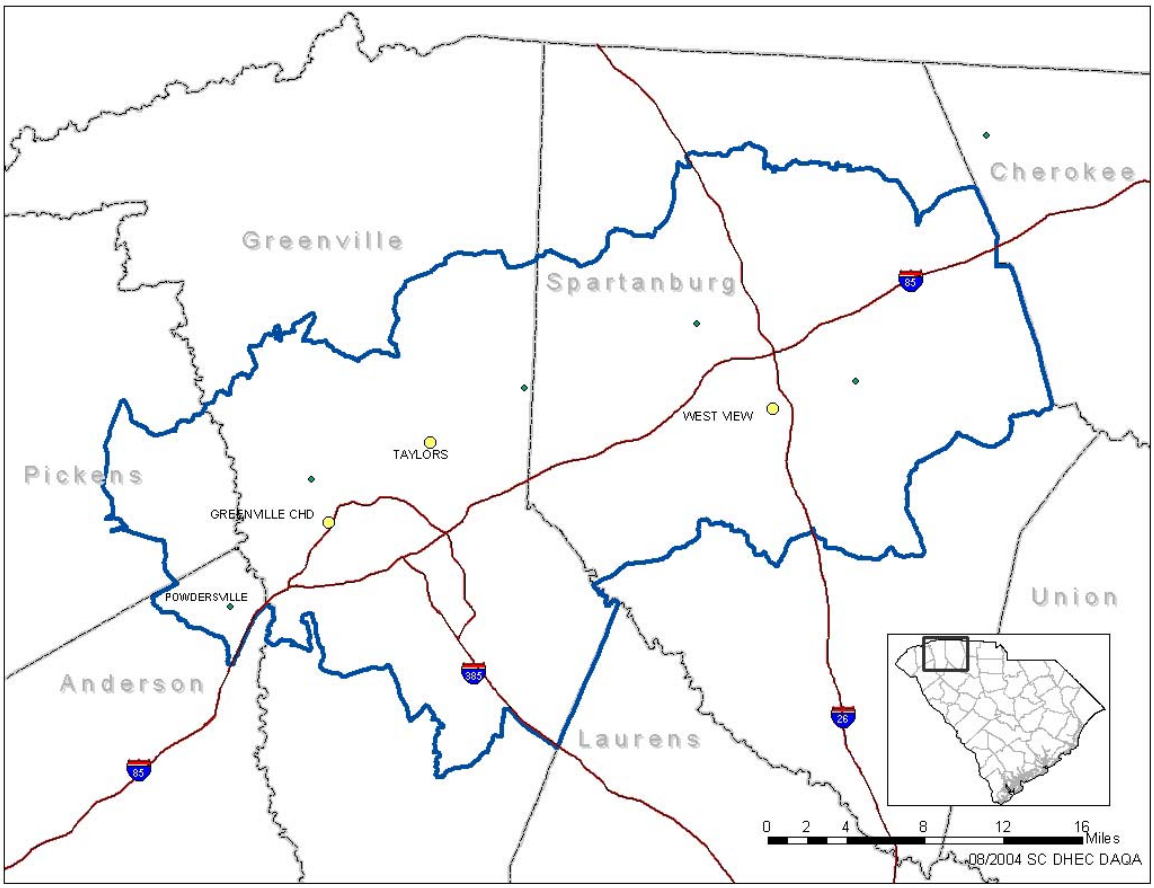
The Greenville-Spartanburg MPA



The Greenville-Spartanburg Monitoring Planning Area (MPA) is located in the upstate of South Carolina at the base of the state's mountains. This proximity to the state's higher elevations lends itself to mild winters with some occasional light snowfall and warm summers with occasional hotter periods. Greenville and Spartanburg are connected by Interstate 85, which cuts through the upstate from Georgia to North Carolina. Other major routes of access from the lower parts of the state include Interstate 26 through Spartanburg into North Carolina and Interstate 385 into Greenville. Including Anderson, which lies southwest of Greenville, the population of this entire metro area is more than 830,000. Most of the area is characterized by smaller towns and suburbs scattered between the two metropolitan centers. Industry abounds throughout the region, due in part to the heavily populated areas and the some 30 to 35 miles that separate Greenville and Spartanburg's urban areas. Much of the industry is distributed along the interstates, primarily the Interstate 85 corridor.

Greenville-Spartanburg Community Monitoring Zone (CMZ)

The Agency has determined that the best representation of the exposure of the public to fine particulate pollution for the Greenville-Spartanburg urban area is through the use of spatial averaging. The averaging will be based on the three (3) Federal Reference Method (FRM) samplers operated in the Greenville-Spartanburg Monitoring Planning Area (MPA) located within, or near, the city limits of Greenville, Taylors and Spartanburg. The monitoring data from the sites will each be compared to the Fine Particulate (PM2.5) 24–hour National Ambient Air Quality Standard (NAAQS) and averaged, using the methods prescribed in the Code of Federal Regulations (CFR), for comparison to the Annual PM2.5 NAAQS.

All sites meet internal and external siting criteria as defined in the CFR[1] and guidance[2]. The zone of representation of all samplers was expected to be at least neighborhood or larger at the time of installation. The samplers were sited to reasonably represent the predominant land uses, population densities, activities, and exposure to fine particulate within the MPA. Unusual impacts observed at the monitoring site or effecting the MPA or region are documented, and if appropriate, the effected data is flagged consistent with the exceptional event policy. There are several periods in 2001-2003 where data has been flagged, primarily related to wildfire smoke impact. The flagged data has not been excluded for this analysis to provide the most conservative conclusions and comparison to the standard.

There are three FRM sites within the MPA, the two required 1:1 (daily) schedule core sites and a supplementary site placed to provide better representation of this relatively large (for South Carolina) urbanized area. The supplementary site samples on the 1:3 (every third day) schedule.

The **Taylors Fire Station** (045-045-0009) core sampler (Taylors) is centrally located in the MPA. A collocated FRM as also operated at this site on a 1:6 schedule to provide precision data. Other gaseous species including Ozone and NOx have been monitored at this site since the installation of the particulate samplers.

The **West View Elementary School** (045-083-0010) core sampler (West View) is located near Spartanburg, in a mixed residential/commercial area representing the suburban fringe characteristic of the MPA.

The **Greenville EQC** (045-045-0008) sampler (Greenville) was placed at an existing monitoring site when preferred sites were unavailable. It is located south west of the Greenville central business district at the boundary of an area predominated by office buildings and an area of single-family residences. This area has more varied topography than the core sites.

There is currently one additional fine particulate monitoring site located within the MPA.

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[1] 40 CFR Part 58, Appendix D, 2.8

[2] Guidance for Network Design an Optimum Site exposure for $PM_{2.5}$ and PM_{10}, EPA-454/R-99-022 December 1997, 5.1-5.2

The **Powdersville** site (045-007-0003) is located in northeast Anderson County and has had a continuous monitor operating since 1991. The site was initially established as an ozone site for the Greenville-Spartanburg-Anderson MSA. The monitor is a Rupprecht and Patashnick 1400A, operated at 50°C. This monitor type has been shown to provide very good agreement with the FRM samplers in the South Carolina network. The data from this site is reported to AIRNow[3] and is included in the calculation of the area Air Quality Index (AQI).

Comparison to the 24-Hour Standard

None of the sites in the Greenville-Spartanburg MPA have measured 24-hour average concentrations near the level of the 24-hour PM2.5 NAAQS. Data completeness for the periods listed in Table 1 was sufficient for comparison to the standard.

Table 1

Greenville-Spartanburg MPA Comparison to the 24-Hour NAAQS										
AQS Site Code	98th Percentile						Design Value			
	1999	2000	2001	2002	2003	2004	1999-01	2000-02	2001-03	2002-04
45-045-0008-1			33.5	32.3	35.1	38.3			33.6	35.2
45-045-0009-1	35.7	37.1	33.5	28.5	31.3	27.3	35.4	33.0	31.1	29.0
45-045-0009-2	37	38.3	28.5	29.2	36.3	23.6		32.0	31.3	29.7
45-083-0010-1	33.5	35.1	32.2	28.3	32.3	26.9	33.6	31.9	30.9	29.2

Adequacy for Spatial Averaging[4]

For the purpose of spatial averaging, the Community Monitoring Zone (CMZ) is defined as the complete Greenville-Spartanburg MPA. The MPA boundary encompasses the higher population and activity areas associated with the Greenville-Spartanburg urbanized area.

Review of the sampling data collected at the three representative sites from calendar years 2001-2003 show that the three specific requirements stated in Appendix D of 40 CFR Part 58 are met.

1) The sites represent neighborhood or larger spatial measurement scale,
2) The CMZ represents homogeneous air quality, defined as:
    a) Sites' annual averages must be within 20% of the CMZ- wide average on an annual basis; and,
    b) Reasonably correlated on a daily basis (r >.6),
3) Entire CMZ should principally be affected by the same major emissions sources of $PM_{2.5}$.

[3] http://www.epa.gov/airnow/

[4] Guidance for Network Design an Optimum Site exposure for $PM_{2.5}$ and PM_{10}, EPA-454/R-99-022 December 1997 5.5

The guidance indicates three years of PM2.5 air quality data is needed before final evaluation of site eligibility can be made, but we believe that sufficient data is available for a determination of adequacy for the application of spatial averaging for this CMZ and comparison to the NAAQS to be performed, consistent with the method described in Appendix N of 40 CFR, Part 50.

Spatial Scale of the Samplers

At the time of initial network design, all of the samplers were intended to represent areas defined as neighborhood scale (.5 to 4 km) or larger. The homogeneity of the data collected at and comparison of data between the sites support the conclusion that none of the sites are unduly impacted by local sources. Although most directly representative of the area immediately adjacent to each site, it is believed that each sampler is also representative of noncontiguous areas within the CMZ having similar population density, transportation, land, and heating fuel use, and impacts from the emissions from the regional point and mobile sources.

The Greenville sampler has shown evidence of occasional atypical impact, invariably in the winter months. The impact is characterized by a high ratio of Greenville concentration to Taylors concentration. Fourteen (14) samples between the beginning of sampling (August 14, 2001) and March 2004 (encompassing 299 valid samples) have been identified as possible outliers. Atypical days included both elevated and low mass days and were based on the unusual ratio of the mass collected at the two sites. Examinations of collocated and concurrent Total Suspended Particulate (TSP) samples indicate the atypical concentrations are associated with the presence of combustion products (carbonaceous material, soot and ash associated with fuel oil wood burning and coal use) notably in the finer fraction. Particulate samples collected immediately prior to the atypical samples do not show the higher carbon content and the visible fine fraction appears to be primarily crustal material. Potential sources of the atypical impacts have been identified in an adjacent residential area where wood coal and fuel oil is used as primary heating fuel. The possibility of impact from a boiler located at an office building adjacent to the site is also being investigated. This pattern and mix of fuel use may have occasional unusual impact on the sampler but the Agency believes the impact on, and representation of, the monitor is consistent with that expected in similar communities within the CMZ. This sampler is representative of many similar situations and is appropriate for the evaluation of long term or chronic effects.[5]

Homogeneous Air Quality

The annual PM2.5 averages at all sampling sites within the CMZ are similar and well within 20 percent of the spatial average[6] for each year. The metrics for comparison to the CMZ spatial average are listed in Table 2 and the annual average at each site and the CMZ spatial

[5] 40CFR Part.58 Appendix D, 2.8.0.4
[6] 40CFR Part.58 Appendix D, 2.8.1.6.1

average are in Table 3.

Table 2

Spatial Average Statistics ($\mu g/m^3$) Greenville-Spartanburg MPA									
Year	Spatial Average	Spatial Std	Spatial COV	Max Average	Min Average	Average + 20%	Average - 20%	Average +10%	Average -10%
1999	17.7*	8.030	0.476	17.565	16.187	21.24	14.16	19.47	15.93
2000	16.2*	7.942	0.495	16.660	15.456	19.44	12.96	17.82	14.58
2001	14.8**	7.470	0.503	15.394	14.321	17.76	11.84	16.28	13.32
2002	14.5	6.560	0.466	14.542	13.628	17.40	11.60	15.95	13.05
2003	14.3	6.779	0.480	14.582	13.649	17.16	11.44	15.73	12.87

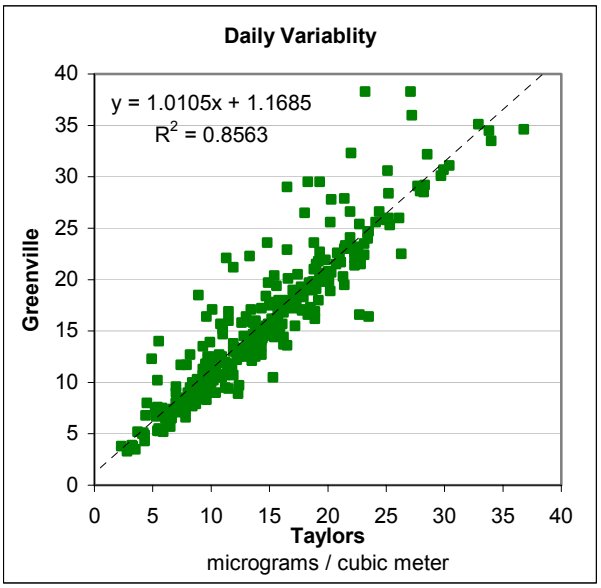
* Only West View and Taylors sites operating
** Greenville did not have min.75% data completeness

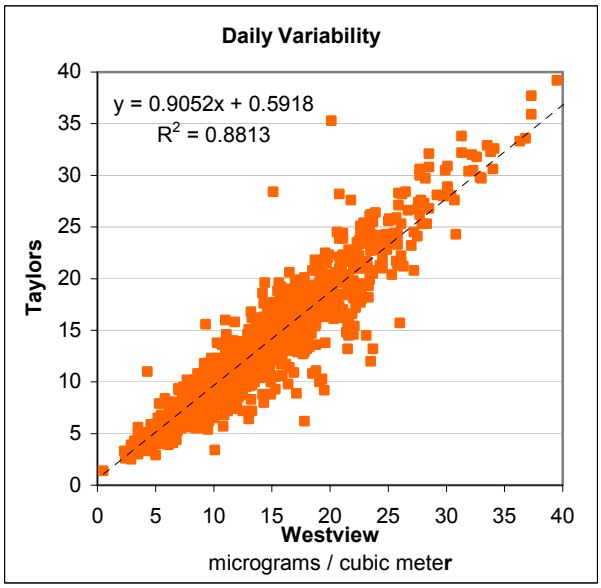
Table 3

PM2.5 Annual Mean and Spatial Average (2001-2003) Greenville-Spartanburg MPA					
		Greenville	Taylors	West View	Spatial Mean
2001	Annual mean ($\mu g/m^3$)	……	15.2	14.3	14.75
	% data completeness		96	88	……
2002	Annual mean ($\mu g/m^3$)	16.1	14.2	13.3	14.53
	% data completeness	90	96	78	……
2003	Annual mean ($\mu g/m^3$)	15.1	14.1	13.6	14.27
	% data completeness	90	94	92	……
	3-year mean	……	……	……	**14.5**

The day-to-day variability of the sampling and monitoring sites within the CMZ is very similar. Using methods suggested in EPA guidance documents[7], daily concentrations measured at the sites within the CMZ were compared over the period covering all available sample days. Seasonal time series plots including all samplers and monitors within 50 miles of the CMZ were generated for all seasons. A remarkable similarity in concentration throughout the period and area was evident (Figure 1). The several atypical Greenville FRM samples were first noted in these presentations. The scatter plot was the most appropriate tool available for visible comparison of the sampler pairs and liner fit and correlation calculations used as an appropriate measure of the nature and magnitude of the variability. Several examples of the daily variability are provided below.

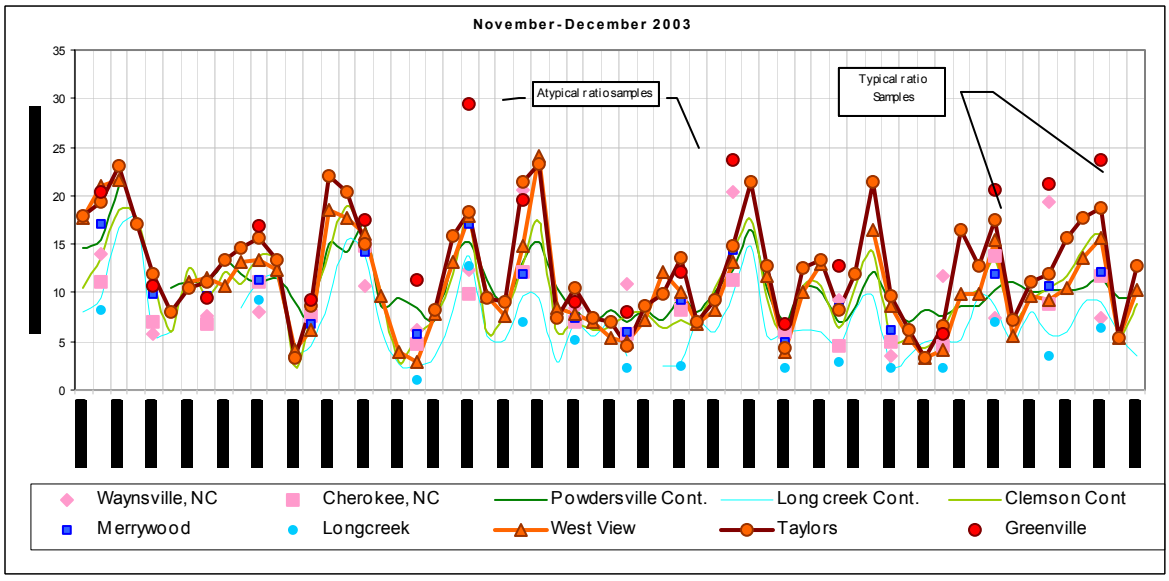
[7] Guidance for Data Quality Assessment, Practical Methods for Data Analysis, EPA QA G-9, QA00 Update EPA/600/R-96/084





The day-to-day variability is remarkable between sites in the CMZ with time series graphs of data within the CMZ and across the region tracking large spatial scale concentration changes. Within the CMZ the calculated daily correlation between sites averages 0.91. To present the most conservation representation, the variability evaluations included both data flagged as exceptional events and the atypical days identified at the Greenville site.

Figure 1
Typical Day-to-Day Variation



All apparent outliers at the Greenville site identified through the use of the plots and statistical screening occurred in the winter months. Possible outliers noted in the datasets from other sites were distributed throughout the year. The data at each site is not normally distributed and strict outlier tests have not been applied.

Emissions Sources

The CMZ is not impacted by any large or unusual sources of fine particulate. There are approximately 570 regulated sources contained within the CMZ, fairly evenly distributed across the urbanized area. Not unexpectedly, the distribution of facilities is consistent with the population distribution and is along the I-85 corridor.

The principle components of the fine particulate are measured in the Taylors speciation samples. The largest contributor to fine mass is sulfate, followed by carbon. This is characteristic of all fine particulate in the southeastern United States. There are no large sulfur dioxide or sulfate sources in or near the CMZ. Evidence supports the determination that the entire CMZ is uniformly impacted by the same major emissions sources contributing to $PM_{2.5}$ concentrations.

Figures 2 and 3 are illustrations of the even and relatively low rate of emissions from the regulated facilities in and around the CMZ. All facilities are indicated, with sources of the specific pollutant designated by the triangle symbols.

Figure 2
Fine Particulate Emissions Density

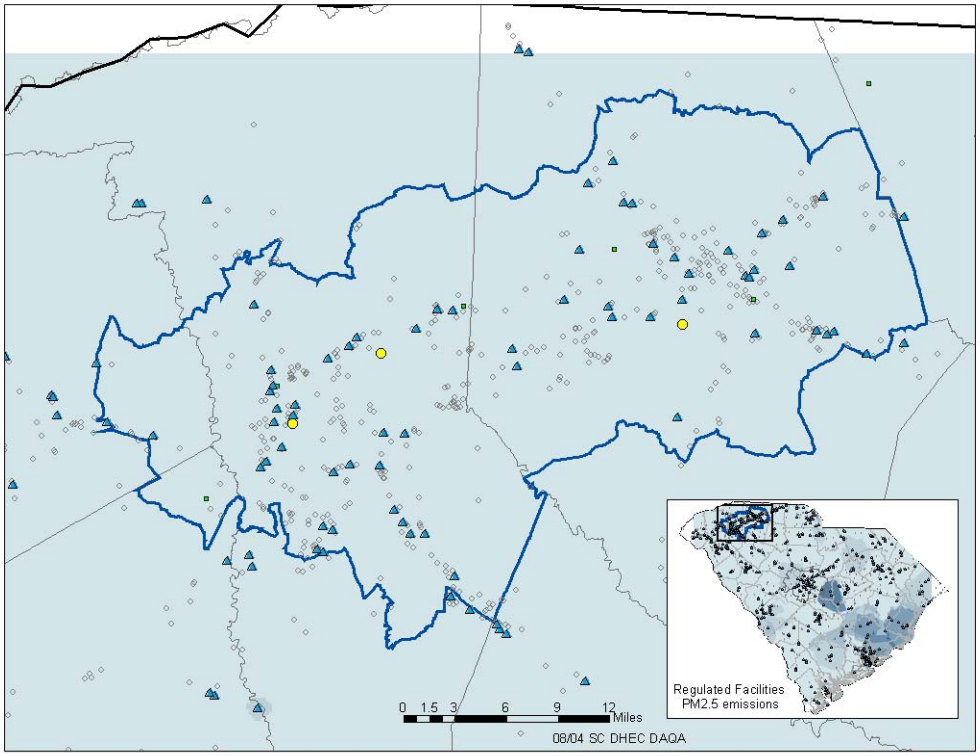
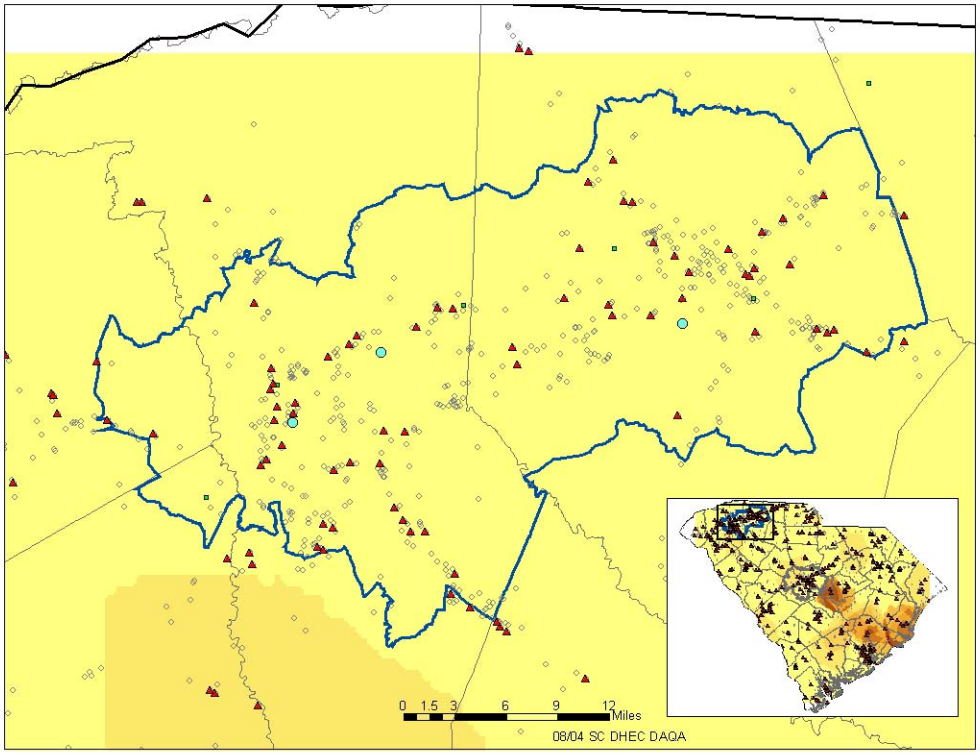
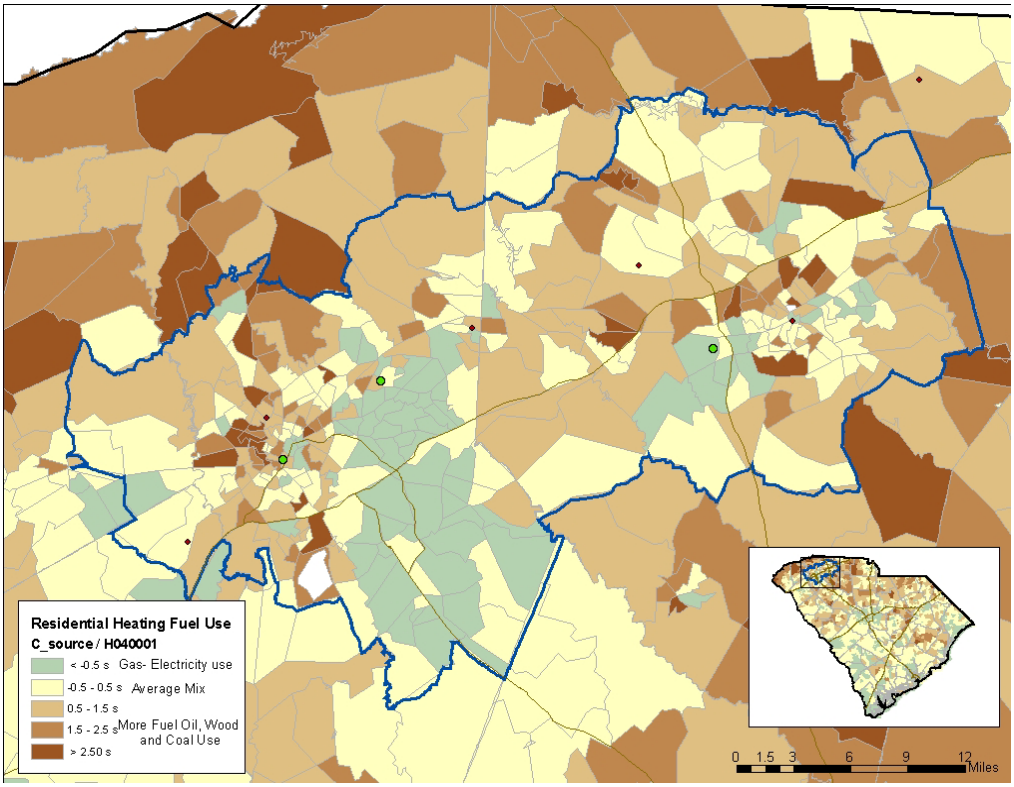


Figure 3
Sulfur Dioxide Emissions Density



Other area-wide sources of emissions include transportation and, in the cooler months, residential heating. All monitoring sites in the CMZ meet the requirements for distance from roads and represent typical area impacts related to gas or diesel vehicle emissions. The possible contribution of the variety of residential fuel use in across the CMZ is captured by the placement of the monitors in neighborhoods characteristic of the mix seen throughout the CMZ (See Figure 4).

Figure 4
Residential Fuel Use 2000 Census Data



Network Adequacy for Spatial Averaging

In addition to the CFR requirements, the guidance[8] also recommends a review of Temporal Behavior, Consistent Trends, Spatial Placement of the Monitors, Chemical Composition and the Population Density and Air Quality Patterns.

Temporal Behavior

The guidance states: 'One site should not be consistently and substantially higher (e.g.30%) than all other sites'[9]. Table 4 shows the range of differences in annual means between the individual sites and the spatial average.

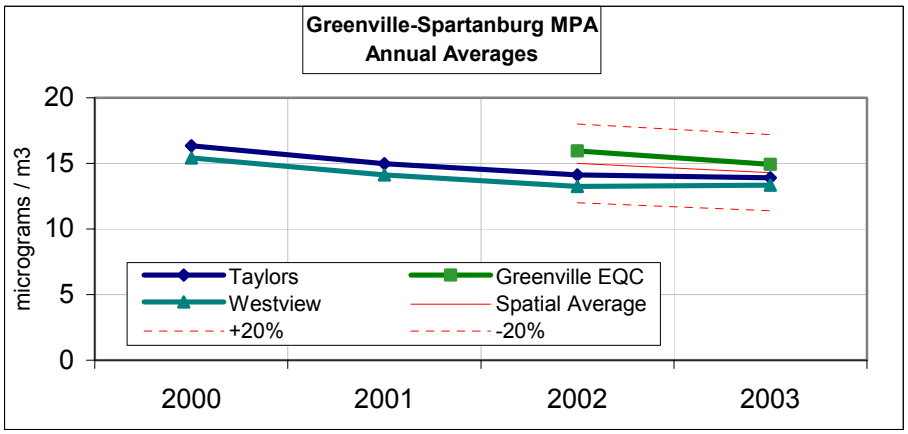
Table 4

%D 2002 / 2003	Greenville	Taylors	West View	Spatial Average
Greenville	-	-13.0 / -6.8	-20.5 / -11.9	-10.5 / -6.0
Taylors	11.5 / 6.4	-	-6.6 / -5.6	2.2 / -1.8
West View	17.0 / 10.7	6.2 / 4.6	-	8.3 / 5.3
Spatial Average	9.5 / 5.7	-2.3 / 0.7	-9.0 / -5.6	-

[8] Guidance for Network Design an Optimum Site exposure for $PM_{2.5}$ and PM_{10}, EPA-454/R-99-022 December 1997
[9] ib., 5.5.1

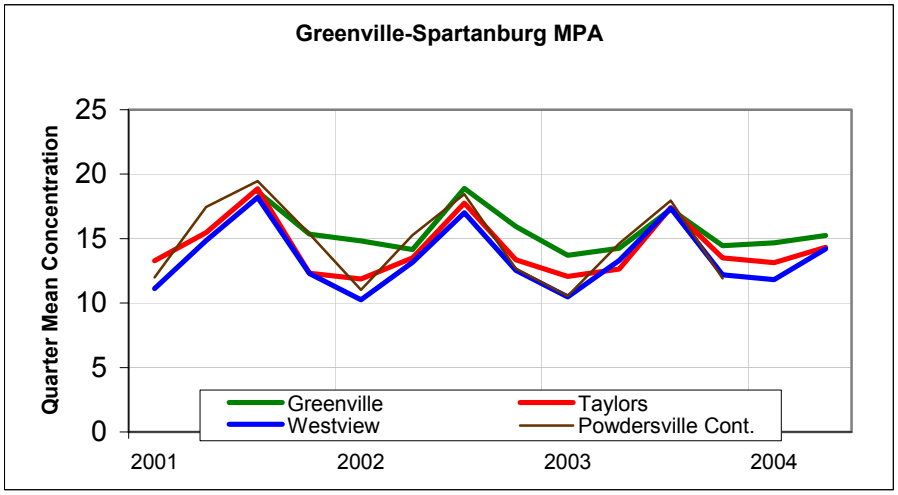
Review of the annual averages available for the sites being included in the spatial average show small year-to-year differences between concentrations at the sites (Figure 5), with the two complete years of data available from the Greenville site having the largest difference. It cannot be determined how much of this difference is due to the difference in sampling frequency. Differences in average have been seen in collocated samplers because of the difference in sample population due to the different sets of sampling days. Absolute and relative differences have varied from year to year. Relative rankings have been consistent, with Greenville the highest, and West View the lowest, annual averages.

Figure 5
Annual PM2.5 Averages



Differences between the sites are not substantially more than the difference seen in some collocated FRM samplers. For example, the Columbia downtown duplicate sampler annual averages have been higher than the Reference for every complete calendar year, the difference ranging from 1.5-5.8%.

Figure 6
Quarter Mean Concentration Averages



Examination of quarterly averages shows a similar pattern in the short- and long-term

trend. The Greenville site data does indicate, on average, higher particulate concentrations in the winter months relative to the other area sites. The higher concentrations appear to reflect both typical activities and the impact of the previously mentioned atypical samples in the represented neighborhoods. The higher concentration, warm season months have virtually the same average concentrations at all sites in the CMZ.

Consistent Trends

All sites in the CMZ with more than two complete annual averages show similar trends throughout their sampling period. The two points available for Greenville should not be considered as defining a trend, but they confirm similar variation in concentration across all sites. The difference of individual sites from the spatial average and the range of the site averages has been reasonably consistent, with 2003 MPA site annual averages range converging slightly when compared to 2002.

Spatial Placement of the Monitors

Consistent with the intent to monitor the highest expected concentrations in the MPA, the samplers were placed along the I-85 corridor, which marks the approximate centerline of the urbanized area and is the anchor for most of the population, vehicle use and industrial activity (see Figure 6).

Review of data collected at all monitors and samplers within 50 miles the MPA indicates relatively consistent day-to-day, quarter-to-quarter and year-to-year concentrations. Interpolation of the fine particulate data collected within and near the MPA, including all samplers and monitors within ~50 miles to establish some context does not indicate any strong concentration gradients within or across the MPA. The small gradient indicated along the axis of the monitor locations, averaging less than $0.1\mu g/M^3$/mile, reflects the variation in population density across the MPA. Local PM2.5 modeling is not available for comparison with monitored PM2.5 concentrations in the MPA or southeast United States.

Chemical Composition

Collection and analysis of fine particulate for chemical composition analysis has only been performed at the Taylors site. These samples are collected and analyzed on a 1:6 sampling schedule using the PM2.5 Chemical Speciation Trends Network (STN) protocols and contract lab. This site was selected for the speciation sampling because of its central location in the MPA urbanized area. Based on the similarity demonstrated in the mass concentration with the other MPA sites, the Taylors samples should be representative of MPA fine particulate composition.

Review of the compositional data collected through calendar year (CY) 2003 indicates no unusual characteristics. Sulfate and carbon are the two most significant contributors to fine mass. A very small increase in the proportion of nitrate and carbon mass is detected in the winter months, with a higher proportion of the carbon being identified as elemental. This is the same

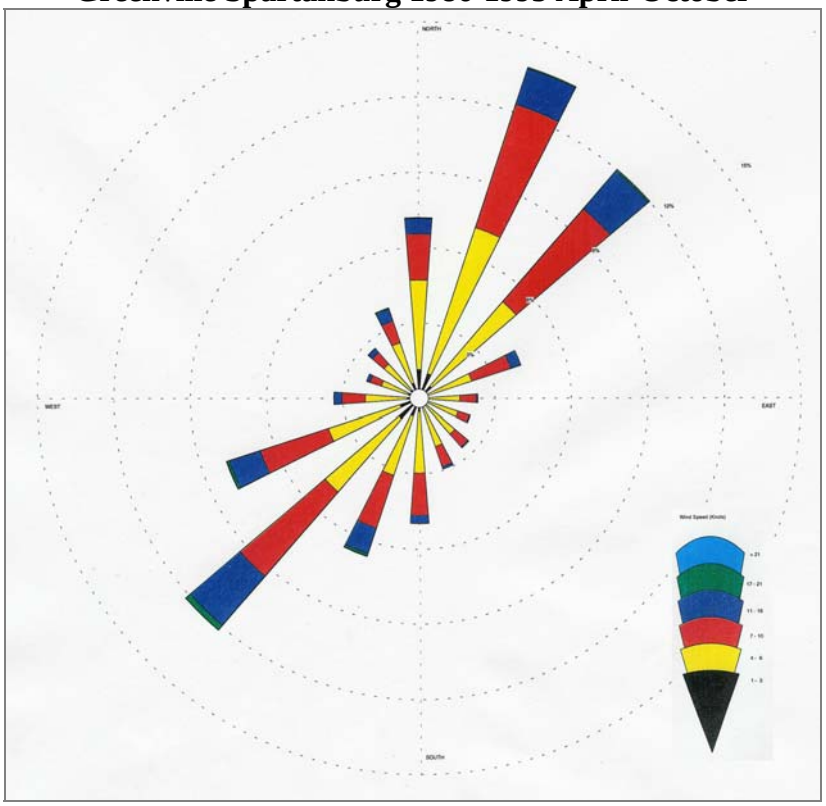
pattern seen in data collected at other urban and rural STN protocol sites and in the rural IMPROVE data collected in South Carolina and the southeast United States[10].

Population Density and Air Quality Patterns

During network design, placement of the samplers was biased toward areas with the higher and relatively similar population densities to represent maximum population exposure to fine particulate. The FRM samplers represent residential populations near the urban center, residential areas in the sprawling areas between the urban centers and older established areas near the urban edge. These monitors represent not only the areas immediately surrounding the sampler, but also similar areas throughout the MPA (See Figure 8).

The air movement through the region reflects the predominant southwest to northeast wind pattern seen throughout the state. The pattern is accentuated by the influence of the Appalachian foothills immediately to the north west of the CMZ. The wind rose in Figure 7 illustrates the predominant wind conditions during the summer months when highest pollutant concentrations are measured. In the winter months there is a slightly higher probability of winds from the northeast[11].

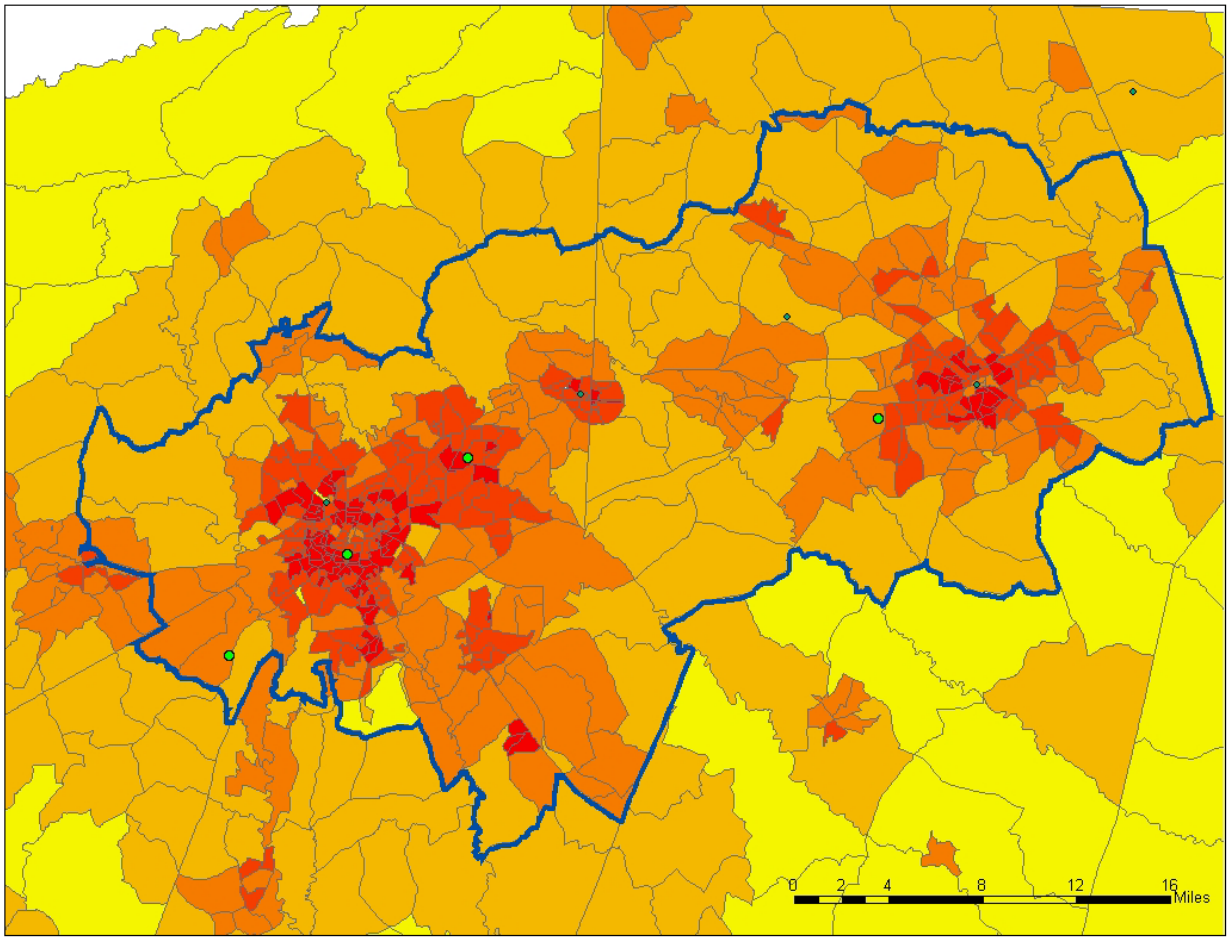
Figure 7
Greenville Spartanburg 1986-1995 April-October



[10] Analysis of Visibility and Particulate Data in the Southeast, VISTAS, May 2003
[11] South Carolina State Climatology Office, http://water.dnr.state.sc.us/climate/sco/

The lower population density edges may be underrepresented by the population-biased design, but the higher activity areas are believed to provide a conservative estimate of exposure throughout the MPA. The orientation (perpendicular to the long axis of the MPA) and range of the concentration gradients (~1.5µg/M^3 in 2003) documented by monitoring within and near the MPA demonstrate that one CMZ encompassing the complete MPA is appropriate.[12]

Figure 8
Population Density - 2000 Census



[12] 40 CFR Pt 58 Appendix D 2.8.1.7.3 ".. If there is not a large difference between the downtown concentration and other residential areas, a separate CBD zone would not be appropriate)."

Special monitoring

The atypical samples noted in the presentation of the data as a time series and in the scatter plots indicate the need for better understanding of the conditions affecting the concentrations near communities in part characterized by older single family residences and above average dependence on the use of coal and fuel oil for winter heating.

The Agency is planning additional monitoring to during the winter of 2004-2005 to better characterize the occurrence and characteristics of the atypical samples noted at the Greenville sampling location. Meteorology (wind speed and direction) has been added at the site and the building is being upgraded to accommodate continuous monitoring for both mass and black carbon. The continuous mass will be reported in near real time to the EPA AIRNow program for inclusion in the AQI.