Appendix A

Ambient PM2.5 Data Analysis

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Appendix A: Ambient PM2.5 Data Analysis

A.1 Introduction

The District evaluates the San Joaquin Valley's (Valley) ambient PM2.5 concentrations through a variety of metrics. The District conducted a variety of analyses of ambient air quality data to better understand the nature of observed improvements as well as areas within the data set that have been more resistant to improvement. This Appendix presents the District's analysis of ambient air quality data, the results of which are summarized in Chapter 3.

Filter based PM2.5 monitoring began in 1999, followed by the start of real-time measurements in 2002. The Valley's PM2.5 monitoring network is reviewed and described in the District's Annual Monitoring Network Plans.[1] The District uses ambient air quality data as maintained in U.S. Environmental Protection Agency's (EPA) Air Quality System (AQS)[2], the official repository for ambient air quality data. Copies of official PM2.5 data and design value reports are available upon request. PM2.5 data from 2011 are preliminary as of the time of these analyses. Data certification for 2011 will be complete in mid-2012. Where possible and applicable, the District includes 2011 data throughout this Appendix.

A.2 Design Values

Design values are one metric for assessing air quality improvements. Design value calculations are three-year averages that follow EPA protocols for rounding, averaging conventions, data completeness, sampling frequency, data substitutions, and data validity. For the complete details on how design values are calculated, refer to 40 Code of Federal Regulations (CFR) Part 50 Appendix N and the April 1999 EPA document *Guideline on Data Handling Conventions for the PM NAAQS*.[3] The results provide consistency and transparency to determine basin-wide attainment for both components of the federal PM2.5 National Ambient Air Quality Standard (NAAQS) as set in 2006: the 24-hour PM2.5 standard of 35 µg/m³, and the annual PM2.5 standard of 15.0 µg/m³. If any monitoring site within the air basin has either a 24-hour or annual PM2.5 design value higher than the respective standard, then the entire air basin is designated nonattainment.

Figure A-1 below provides a general description of how the 24-hour average and annual average design values are calculated for PM2.5. For complete details on how these design values are calculated, please refer to the footnote for figure A-1.

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[1] For more details on the San Joaquin Valley air monitoring sites, refer to San Joaquin Valley Air Pollution Control District Ambient Air Monitoring Network Plan, June 30, 2011.

[2] U.S. Environmental Protection Agency. Technology Transfer Network; Air Quality System: *AQS Web Application.* Retrieved from website: http://www.epa.gov/ttn/airs/airsaqs/aqsweb/

[3] This EPA guidance document can be found at http://epa.gov/ttncaaa1/t1/memoranda/pmfinal.pdf

Figure A-1: General PM2.5 Design Value Calculation Methods[4]

Averaging Period	Level	Calculation Method
24-hour	35 µg/m³	**Step 1:** *Determine the 98th percentile value for each year over a consecutive three year period.* **Step 2:** *Average the three 98th percentile values.* **Step 3:** *Round the resulting value to the nearest 1.0 µg/m³.* **Step 4:** *Compare the result to the standard.*
Annual	15.0 µg/m³	**Step 1:** *Calculate the average of each quarter of each year over a three year period.* **Step 2:** *Average the four quarters in a calendar year to determine the average for each year.* **Step 3:** *Average the three annual values.* **Step 4:** *Round the resulting value to the nearest 0.1 µg/m³.* **Step 5:** *Compare the result to the standard.*

The following figures show the trend of the 24-hour average and annual average values for each PM2.5 site by year, as well as the three-year average design values for these metrics through the year 2011. Note that some sites do not yet show a 2011 value since the 2011 data for these have not yet been fully reviewed for quality assurance and control (Madera-City and Clovis). The 2011 values for these sites will be included in a later draft of this plan once they become available. Also, 2011 data is still considered preliminary until it is certified to the EPA.

Figure A-2 shows single-year, 98th percentile averages, and these values are used to generate the three-year average 24-hour design values in figure A-3. Figure A-4 shows single-year average PM2.5 concentrations, and these values are used to generate the three-year average annual design values in figure A-5. Average ambient PM2.5 concentrations vary by monitoring site within the Valley. In general, monitoring sites in the northern part of the Valley record the lowest ambient PM2.5 concentrations. Currently more Valley air monitoring sites meet the 1997 24-hour average standard of 65 µg/m^3 than the annual average standard of 15.0 µg/m^3. Although the single year 98th percentile and annual average values were higher in 2011 compared to the last few years, the 2009-11 design values for some of the sites are showing a downward trend, including the peak Valley design value, while other have shown an increase. A downward trend will need to occur for all of the sites in the region as the Valley progresses towards attainment of the federal standard.

[4] For formal methodology of PM2.5 design value calculations, see 40 CFR Part 50 Appendix N.

Figure A-2: Single Year 24-hour Average PM2.5 98th Percentile Values (µg/m^3)

SJV Monitoring Site	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Stockton	79.0	55.0	58.0	50.0	41.0	36.0	44.0	42.0	48.0	61.6	40.4	29.7	44.8
Manteca													38.9
Modesto	100.0	71.0	69.0	69.0	47.0	45.0	55.0	52.0	57.4	53.9	54.5	37.3	54.7
Turlock											53.1	43.5	57.4
Merced	91.9	60.0	49.3	55.1	44.2	43.0	48.3	43.8	52.7	54.0	45.2	35.5	35.4
Madera-City													
Fresno-1st	120.0	90.0	75.0	75.0	56.0	52.0	71.0	51.0	67.0	57.4	55.8	48.8	69.5
Fresno-Winery		64.8	61.5	71.9	49.7	49.4	71.2	55.0	57.4	44.5	48.2	37.0	59.6
Clovis	59.2	72.5	71.5	53.2	48.1	52.4	63.0	51.3	60.9	49.0	49.0	44.3	
Corcoran	53.0	55.1	89.5	65.1	42.2	49.4	74.5	50.1	57.9	47.9	53.4	46.8	
Hanford													64.6
Visalia	114.0	103.0	96.0	70.0	47.0	54.0	65.0	50.0	59.7	62.1	53.9	36.3	50.7
Bakersfield-Golden	95.3	93.9	95.9	80.4	51.9	53.9	74.9	64.4	67.7	60.8	68.6		
Bakersfield-California	97.4	92.7	94.9	73.0	48.3	61.5	63.2	60.5	73.0	64.5	66.7	53.3	65.5
Bakersfield-Planz		76.5	90.6	66.8	47.5	47.6	66.4	64.7	72.2	72.3	65.5	56.2	43.2

Figure A-3: 24-hour Average PM2.5 Design Values (three-year averages, µg/m^3)

SJV Monitoring Site	1999-2001	2000-2002	2001-2003	2002-2004	2003-2005	2004-2006	2005-2007	2006-2008	2007-2009	2008-2010	2009-2011
Stockton	64	54	50	42	40	41	45	51	50	44	38
Manteca											
Modesto	80	70	62	54	49	51	55	54	55	49	49
Turlock									53	48	51
Merced	67	55	50	47	45	45	48	50	51	45	39
Madera-City											
Fresno-1st	95	80	69	61	60	58	63	58	60	54	58
Fresno-Winery	63	66	61	57	57	59	61	52	50	43	48
Clovis	68	66	58	51	55	56	58	54	53	47	
Corcoran	66	70	66	52	55	58	61	52	53	49	
Hanford											
Visalia	104	90	71	57	55	56	58	57	59	51	47
Bakersfield-Golden	95	90	76	62	60	64	69	64	66		
Bakersfield-California	95	87	72	61	58	62	66	66	68	62	62
Bakersfield-Planz	84	78	68	54	54	60	68	70	70	65	55

Notes for figures A-2 and A-3

- Empty cell: No data or insufficient data, Asterisk (*): Values do not meet completeness criteria
- Turlock 2008: This site only operated for about six weeks in 2008. Data for this site and time period is available in AQS. Since this site operated for less than one full quarter in the calendar year, its data is not representative of an annual average and is therefore not included in annual analysis. However, this data is used for 24-hour average analysis.
- Bakersfield-Golden 2010: This site only operated for one week in 2010. Data for this site and time period is available in AQS. Since this site operated for less than one full quarter in the calendar year, its data is not representative of an annual average and is therefore not included in annual analysis. However, this data is used for 24-hour average analysis.

Figure A-4: Single Year Annual Mean PM2.5 Concentrations (µg/m^3)

SJV Monitoring Site	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Stockton	19.7	15.5	13.9	16.7	13.6	13.2	12.5	13.1	12.9	14.4	11.3	10.6	11.3
Manteca													10.7
Modesto	24.9	18.7	15.6	18.7	14.5	13.6	13.9	14.8	15.0	16.0	13.0	12.1	14.7
Turlock											16.1	12.5	17.1
Merced	22.6	16.7	14.5*	18.7	15.7	15.2	14.1	14.8	15.2	14.9*	13.6	11.2	10.4
Madera-City													
Fresno-1st	27.6	24.5	19.8	21.5	17.8	16.3	16.7	16.8	18.8	17.4	15.1	13.0	15.3
Fresno-Winery		18.4	18.6	21.3	17.8	17.0	16.9	17.6	16.8	16.5	14.6	13.4	15.4
Clovis	19.8	16.3	18.0	16.2	18.5*	16.4	16.3	16.4	16.4	16.2	18.3	14.7	
Corcoran	14.3*	16.4	19.2	21.5	16.2	17.4	17.5	16.9	18.4	15.8	17.7	17.9	
Hanford													18.0
Visalia	27.6	23.9	22.5	23.2	18.2	17.0	18.8	18.8	20.4	19.8	16.0	13.6	16.1
Bakersfield-Golden	26.2	22.6	21.8	24.1	19.6	18.2	19.1	18.6	19.9	17.9	20.0		
Bakersfield-California	23.8	22.5	21.2	22.7	17.1	18.9	18.0	18.7	22.0	21.9	19.0	14.2	16.2
Bakersfield-Planz		20.3	20.8	23.5	17.8	17.4	19.8	19.3	21.8	23.5	22.5	17.6	14.5

Figure A-5: Annual PM2.5 Design Values (three-year averages, µg/m^3)

SJV Monitoring Site	1999-2001	2000-2002	2001-2003	2002-2004	2003-2005	2004-2006	2005-2007	2006-2008	2007-2009	2008-2010	2009-2011
Stockton	16.4	15.3	14.7	14.5	13.1	12.9	12.8	13.5	12.9	12.1	11.1
Manteca											
Modesto	19.7	17.7	16.2	15.6	14.0	14.1	14.6	15.3	14.7	13.7	13.3
Turlock											
Merced	17.9	16.6	16.3	16.5	15.0	14.7	14.7	15.0	14.6	13.2	11.7
Madera-City											
Fresno-1st	24.0	21.9	19.7	18.6	16.9	16.6	17.4	17.7	17.1	15.2	14.5
Fresno-Winery	18.5	19.4	19.2	18.7	17.2	17.2	17.1	17.0	16.0	14.8	14.5
Clovis	18.0	16.8	17.6	17.0	17.1	16.4	16.4	16.3	17.0	16.4	
Corcoran		19.0	19.0	18.4	17.0	17.2	17.6	17.0	17.3	17.1	
Hanford											
Visalia	24.7	23.2	21.3	19.5	18.0	18.2	19.3	19.7	18.8	16.5	15.2
Bakersfield-Golden	23.6	22.8	21.8	20.6	19.0	18.6	19.2	18.8	19.3		
Bakersfield-California	22.5	22.1	20.3	19.6	18.0	18.5	19.6	20.9	21.0	18.4	16.5
Bakersfield-Planz		21.5	20.7	19.6	18.4	18.9	20.3	21.5	22.6	21.2	18.2

Notes for figures A-4 and A-5

- Empty cell: No data or insufficient data, Asterisk (*): Values do not meet completeness criteria
- Turlock 2008: This site only operated for about six weeks in 2008. Data for this site and time period is available in AQS. Since this site operated for less than one full quarter in the calendar year, its data is not representative of an annual average and is therefore not included in annual analysis. However, this data is used for 24-hour average analysis.
- Bakersfield-Golden 2010: This site only operated for one week in 2010. Data for this site and time period is available in AQS. Since this site operated for less than one full quarter in the calendar year, its data is not representative of an annual average and is therefore not included in annual analysis. However, this data is used for 24-hour average analysis.

A.3 Additional Factors Influencing Design Vales and Concentrations

Official design values alone do not necessarily provide for the best or most complete understanding of air quality trends. A number of additional factors beyond actual measured concentrations significantly impact the District's design values. These factors must be considered to fully understand design value trends in the District.

A.3.1 Monitor Types

The District and ARB presently use three types of PM2.5 monitors in the Valley:

- Filter-based Federal Reference Method (FRM), defined as the standard for data collection;
- Real-time Beta-attenuation method (BAM) monitors designated as federal equivalent method (FEM) (hereafter BAM/FEM); and
- Ordinary BAMs, not designated FEM (hereafter referred to as BAM).

Only FRM and BAM/FEM monitors produce data that is suitable for comparison with the NAAQS. Real-time monitors (BAM/FEM and BAM) produce hourly measurements that the District uses every day to produce daily air quality forecasts, wood burning prohibitions, public health notifications, and Real-time Air Advisory Network (RAAN) notifications for schools.

The District's Annual Monitoring Network Plans summarize the types of monitors used at Valley air monitoring sites. The District is considering replacing some PM2.5 FRMs with BAM/FEMs, due to FRM maintenance and part replacement difficulties. Historical data shows that there may be differences in measured concentrations between FRM and FEM monitors in the Valley, and therefore monitor type may impact design values. This issue will be analyzed further in future Monitoring Network Plans.

A.3.2 Exceptional Events

The Valley has experienced three main types of exceptional events: wildfires, high winds, and fireworks. With proper documentation and EPA concurrence, data influenced by exceptional events can be excluded from official design value calculations; however, the amount of required documentation is extensive, requiring significant District resources.[5] Exceptional events (EE) are not reasonably preventable or controllable, so it is inappropriate to use data influenced by these events without recognition of these circumstances.

EPA generally reviews only those requests that will directly affect an area's attainment status. Even without formal submittal, the District tracks these events and their impact on design values as part of its ongoing air quality analysis. In its effort to more accurately characterize ambient PM2.5 concentrations, the District evaluated the

[5] EPA's Treatment of Air Quality Monitoring Data Influence by Exceptional Events, Codified in 40 CFR Chapter 1 (7-1-2010 Edition), Section 50.14.

Valley's PM2.5 data with careful consideration of exceptional events, including those not formally submitted to EPA.

A.3.2.1 PM2.5 Exceptional Event Documentation Submitted to EPA

The District submitted documentation for the July 4 and 5, 2007 fireworks exceptional event and the Air Resources Board submitted documentation for the summer 2008 wildfires exceptional event. If EPA approves this documentation, data from those events will be excluded from official design value calculations.

On July 4th and 5th, 2007, elevated hourly PM2.5 concentrations at Fresno-First and Bakersfield-California coincided with fireworks activity. Figure A-6 summarizes the effects of removing this data from the official design values. The main effect of removing the data was lowering the PM2.5 annual mean values at Fresno-First and Bakersfield-California by 0.4 and 0.2 $\mu g/m^3$, respectively.

In the summer of 2008, just months after adoption of the 2008 PM2.5 Plan, California experienced a record number of wildfires, burning more than a million acres. The resulting emissions, mostly from outside of the Valley, caused serious public health impacts and unprecedented levels of PM2.5 and ozone in the Valley and throughout the state. Valley PM2.5 concentrations were elevated for a number of days during this period.

These exceptional events caused the Valley's PM2.5 design values to be higher than normal. Figure A-6 summarizes the effects of removing this data from official design values. The prolonged 2008 wildfire event had a noticeable impact on design value calculations, especially for monitoring sites closest to the wildfire in the northern portion of the Valley. The largest difference occurred at the Stockton air monitoring site, where the 24-hour value was 61.6 $\mu g/m^3$ with the exceptional event data included, and 48.2 $\mu g/m^3$ with that data removed. Excluding days that were impacted by smoke reduces the PM2.5 annual mean value by 1.5 $\mu g/m^3$.

If EPA approves this documentation, data from those events will be excluded from official design value calculations. The EPA has a policy of acting only upon those exceptional event documents that have a direct impact on an area's attainment status. As such, the EPA reviews and makes decisions on the concurrence or non-concurrence of the District's PM10 exceptional event documents, but has not yet made a decision on the submitted PM2.5 documents mentioned above since that decision would not change the District's attainment status of the PM2.5 NAAQS.

Since the timeframe discussed in the above analysis is outside of the 2009-2011 period, these exceptional events would not affect the 2011 design values. However, this analysis is illustrative of how these events can influence a design value calculation, and possibly whether an area is able to achieve attainment of the PM2.5 NAAQS. Subsequent firework and wildland fire use exceptional events have occurred since the 2007 and 2008 documentation that has been submitted to EPA. On July 4th, 2010, elevated PM2.5 concentrations at Bakersfield-Planz, Fresno-First and Bakersfield-California coincided with fireworks activity. On September 25 – 30, 2010, Corcoran and Madera-City experienced smoke impacts and elevated PM2.5 levels from a wildland fire use fire in the Sierra Nevada. Since the District has not submitted official documentation of these events to EPA, the impact on the 24-hour and annual mean PM2.5 values will not be shown.

Figure A-6: 2007 and 2008 Exceptional Events Impact on 24-hour and Annual PM2.5 Values

Year	Site	Annual Mean Before EE Concurrence	Annual Mean with EPA EE Concurrence	Difference $\mu g/m^3$	24-hour Mean Before EE Concurrence	24-hour Mean with EPA EE Concurrence	Difference $\mu g/m^3$
2008	Stockton	14.4	12.9	-1.5	61.6	48.2	-13.4
	Modesto	16.0	14.7	-1.3	53.3	49.5	-3.8
	Merced	14.9	13.9	-1.0	51.1	45.2	-5.9
	Clovis	16.0	14.8	-1.2	49.0	49.0	0.0
	Fresno-First	17.4	16.1	-1.3	57.4	54.4	-3.0
	Fresno-Winery	16.5	15.6	-0.9	44.5	44.5	0.0
	Visalia	21.0	19.5	-1.5	62.1	55.5	-6.6
	BAK-CA	21.9	20.0	-1.9	64.5	63.4	-1.1
	BAK-Planz	23.5	22.8	-0.7	72.3	72.3	0.0
2007	Fresno - First	18.8	18.4	-0.4	67.0	66.0	-1.0
	BAK-CA	22.0	21.8	-0.2	73.0	73.0	0.0

A.3.2.2 High-Wind Events Effects on PM2.5 Data

The District has also been evaluating the possible PM2.5 impact of high wind events, though the District has not submitted formal PM2.5 exceptional event document to EPA for these events at this time. In most of these cases, the District submitted formal PM10 exceptional event documentation for these dates and monitors. Geologic particulates are the primary component of elevated PM10 during high wind events, but the geologic component of PM2.5 is still under investigation.

The District has observed similarities in hourly increases in PM10 and PM2.5 during certain high wind events, though. High-wind events affected Bakerfield-Planz on January 4, 2008 and October 13, 2009, and corresponding PM2.5 measurements were unusually high at 100.3 $\mu g/m^3$ and 167.7 $\mu g/m^3$, respectively. Figure A-7 summarizes an example of the impact of the 2008 and 2009 high wind events on Bakersfield-Planz design values.

Another high wind event occurred on April 11, 2010. Bakersfield Planz recorded a PM2.5 concentration of 107.8 μg/m^3. This concentration was not included in the example calculations in table Y. Similarly, the District submitted documentation to EPA in regards to a PM10 exceptional event affecting Bakersfield-California on April 11, 2010. PM2.5 levels were also much higher than normal in conjunction with this event.

Figure A-7: Example of High-Wind Event Influence on Bakersfield–Planz Design Value

	High-Wind Events			
	24-hour Design Values (μg/m^3)		Annual Design Values (μg/m^3)	
Year	*Included*	*Excluded*	*Included*	*Excluded*
2007*	72.2	72.2	21.8	21.8
2008	72.3	61.0	23.5	22.6
2009	65.5	65.4	22.5	21.4
2007-09 DV	**70**	**66**	**22.6**	**21.9**
Difference		**4**		**0.7**

* - No high wind events were captured in the 2007 data set.

A.4 Meteorological Influence on PM2.5 Concentrations

In order to disperse particulates in the atmosphere, horizontal and/or vertical mixing needs to be present. Wind flow (horizontal mixing) and temperature instability (decreasing temperature with height leading to vertical mixing) provides the strongest mechanisms for dispersing pollutants. Wind speed can greatly influence the pollutant concentrations. The higher the wind speed the lower the PM2.5 concentrations. Winds mix pollutants and disperse them over a larger area and tend to lead to better horizontal mixing.

Atmospheric stability refers to the vertical mixing of the atmosphere. An inversion is the temperature increasing with vertical height. Surface based temperature inversions tend to trap pollutants near the surface and during long duration pollution episodes can lead to building particulate concentrations. Prolonged periods of high pressure and stable conditions with low wind speeds can cause stagnant conditions that trap pollutants near the surface. PM2.5 concentrations increase during these poor dispersion periods. During low pressure events, unstable conditions and stronger wind speeds occur. PM2.5 concentrations can decrease or increase depending on the strength and characteristics of the low pressure system.

2011-12 Wood-Burning Season

During the 2011-12 wood-burning season (November 2011 to February 2012), the San Joaquin Valley experienced a strong stagnation episode from December 2011 to January 2012, causing a prolific number of days above the PM2.5 24-hour NAAQS of 35 μg/m^3 and demanding an unprecedented number of wood-burning prohibitions to be issued throughout the region. Unusual climate conditions caused by the La Niña weather pattern have resulted in historically dry and poor air quality conditions in the San Joaquin Valley and throughout the state of California.

A La Niña is caused by a buildup of cooler-than-normal subsurface waters in the tropical Pacific. Eastward-moving atmospheric and oceanic waves help bring the cold water to the surface through a complex series of events still being studied. La Niña often results in drier than normal precipitation and stagnant weather conditions in the Central Valley and most of California. In fact, December 2011 tied December 1989 (a strong La Niña year) as the driest December on record for the Valley.

The unusually cold overnight temperatures and warm air aloft during this past wood-burning season has created strong surface-based temperature inversions (ranging from 500 feet to 2,500 feet) that have trapped particulate pollution within a very small volume of air. Due to the La Niña weather pattern, the Valley has experienced four times as many days at or below freezing during this year's winter season compared to last year. Combined with clear skies and afternoon sunlight, secondary particulate aerosol formation occurred, contributing to higher PM2.5 levels.

These extreme, prolonged poor dispersion conditions have not been seen since the 1999 -2000 and 2000-2001 La Niña years. Figures A-8 and A-9 show the PM2.5 concentration comparison between the three La Niña years for the Fresno-First and Bakersfield-California air monitoring sites, respectively. Please note in 2012, the Fresno-First site was moved from the cross streets of First and Shields to First and Garland. The data from both Fresno site locations are shown together in figure A-9. The 1999-2000 and 2000-2001 PM2.5 concentrations are filter based, whereas, 2011-2012 PM2.5 (preliminary) concentrations are from real-time instruments. The duration of the PM2.5 events were similar amongst the years, however the order of magnitude of the concentration was less during the 2011-2012 season. This provides evidence that a reduction in winter-time emissions has occurred, in large part due to District Rule 4901 (Wood Burning Fireplaces and Wood Burning Heaters), since the potential for high PM2.5 concentrations under dry and stagnant conditions has seemingly diminished since a decade ago.

Figure A-8: Stagnation Episodes Comparison at Fresno-First

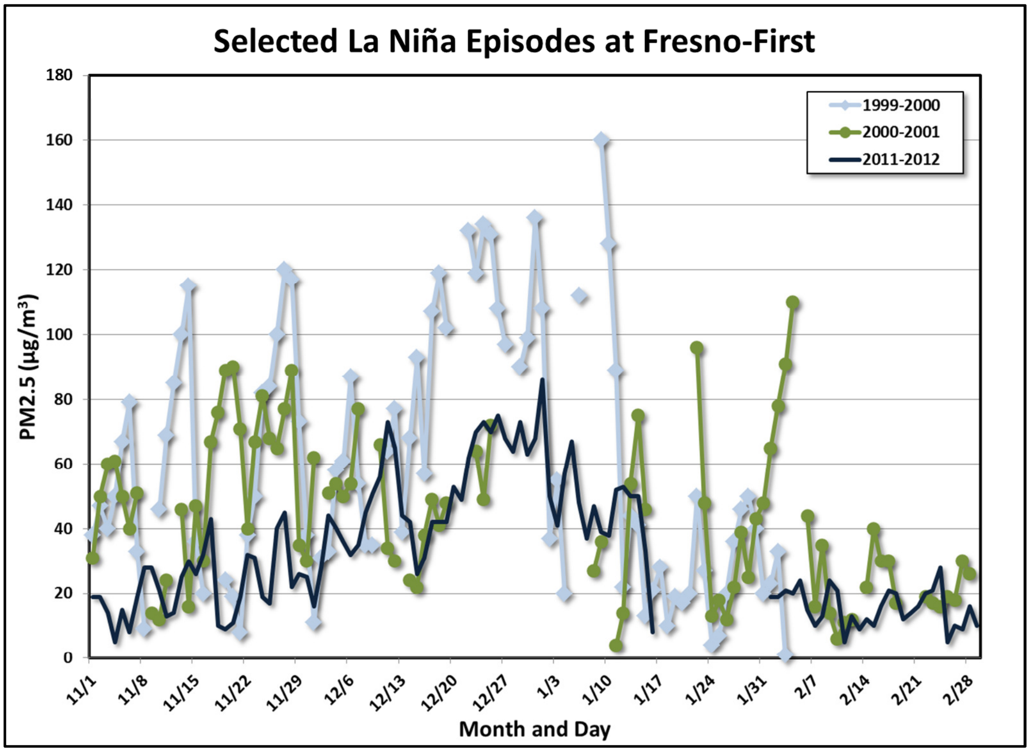
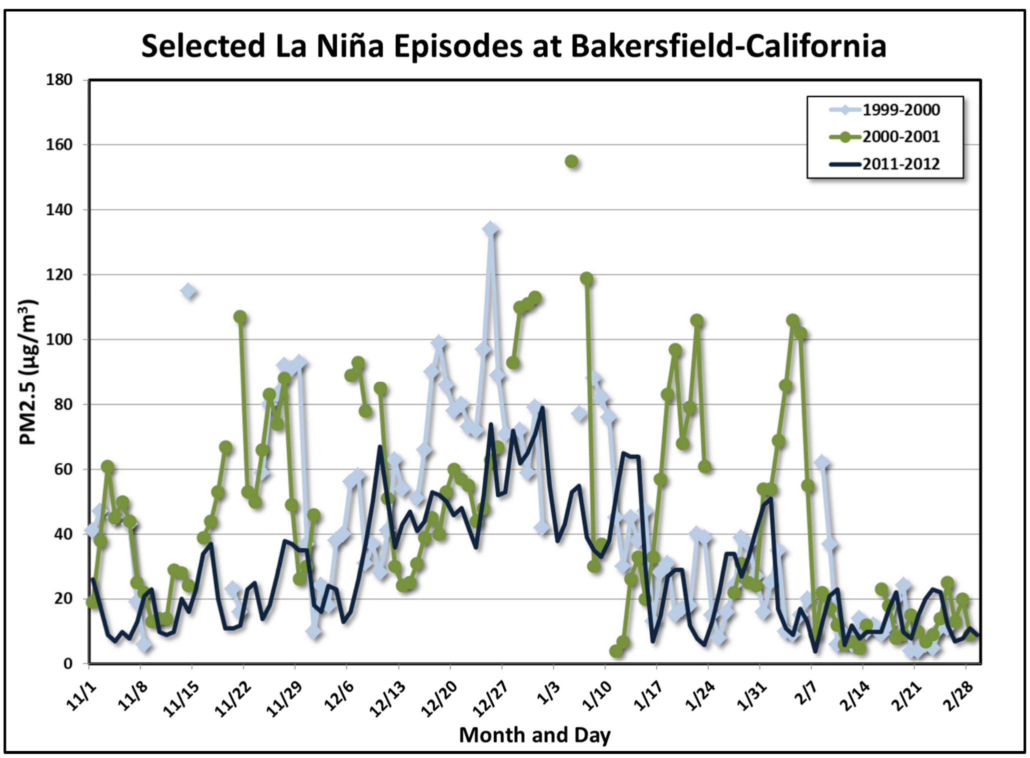


Figure A-9: Stagnation Episodes Comparison at Bakersfield-California



A.5 Ambient PM2.5 Data Trends

Design values summarize a site's large amount of data with just two concentrations: an annual average, and a value representing 24-hour peaks. These parameters are important for attainment determinations, but design values alone will not reveal how public health might be impacted by PM2.5 from day-do-day or throughout the day. Aside from design values, there are other ways to analyze air quality trends that provide a deeper understanding of the movements and shape of the data. This section explores a number of alternative methods in an effort to better understand the change in the San Joaquin Valley's air quality in recent years.

A.5.1 Days over the 24-hour PM2.5 Thresholds

The number of days over the level of the PM2.5 NAAQS is another indicator of PM2.5 progress, though it would not be used for attainment determinations. Focusing on historical air monitoring sites from the northern, central, and southern portions of the San Joaquin Valley, figures A-10 and A-11 show the trend of the number of days above the level of both the 1997 and 2006 24-hour average PM2.5 NAAQS (65 $\mu g/m^3$ and 35 $\mu g/m^3$, respectively) at the sites of Modesto, Fresno-First, and Bakersfield-California. These counts have been estimated and normalized to account for the varying sampling schedules of the Valley's 1-in-6-day, 1-in-3-day, and daily PM2.5 monitors. Since the calculation form of the 24-hour NAAQS is a 98th percentile standard, per monitoring site, an area could attain the NAAQS even when the region experiences a limited number of days over the standard, i.e. the values within the 100th and 99th percentiles of the dataset are not used in the design value calculations.

Figure A-10: Trend in Days over the 1997 24-hour PM2.5 NAAQS

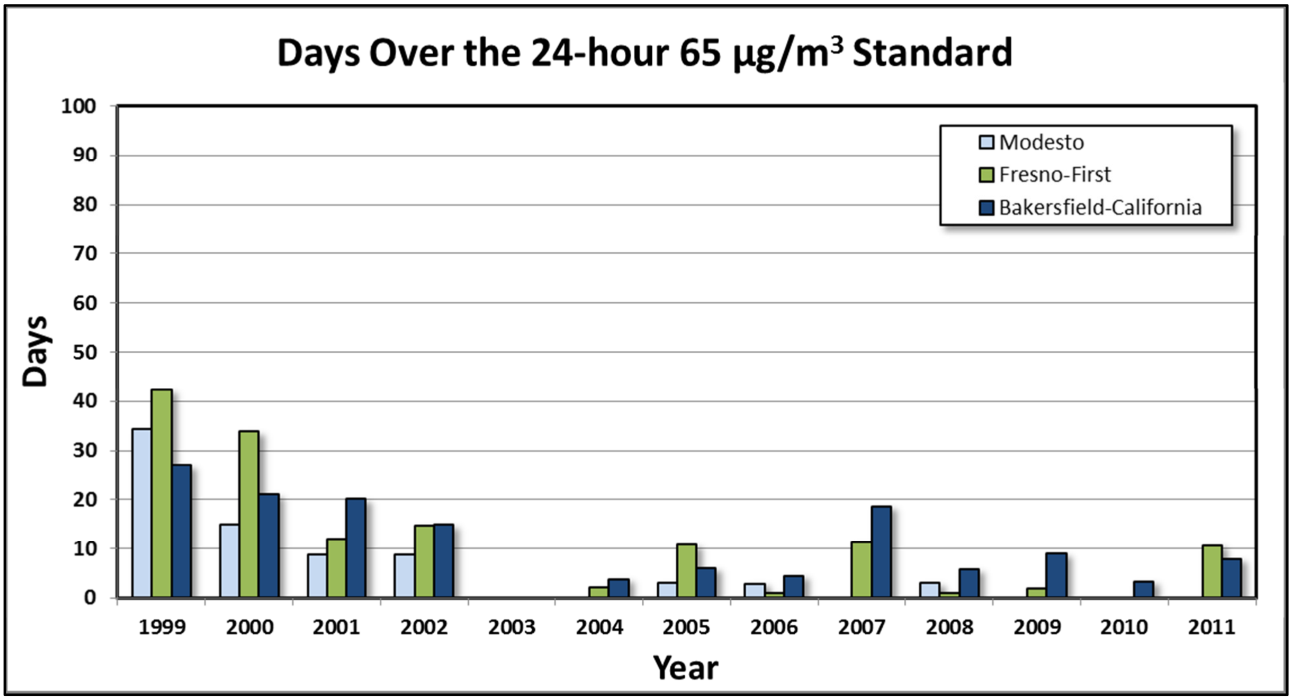
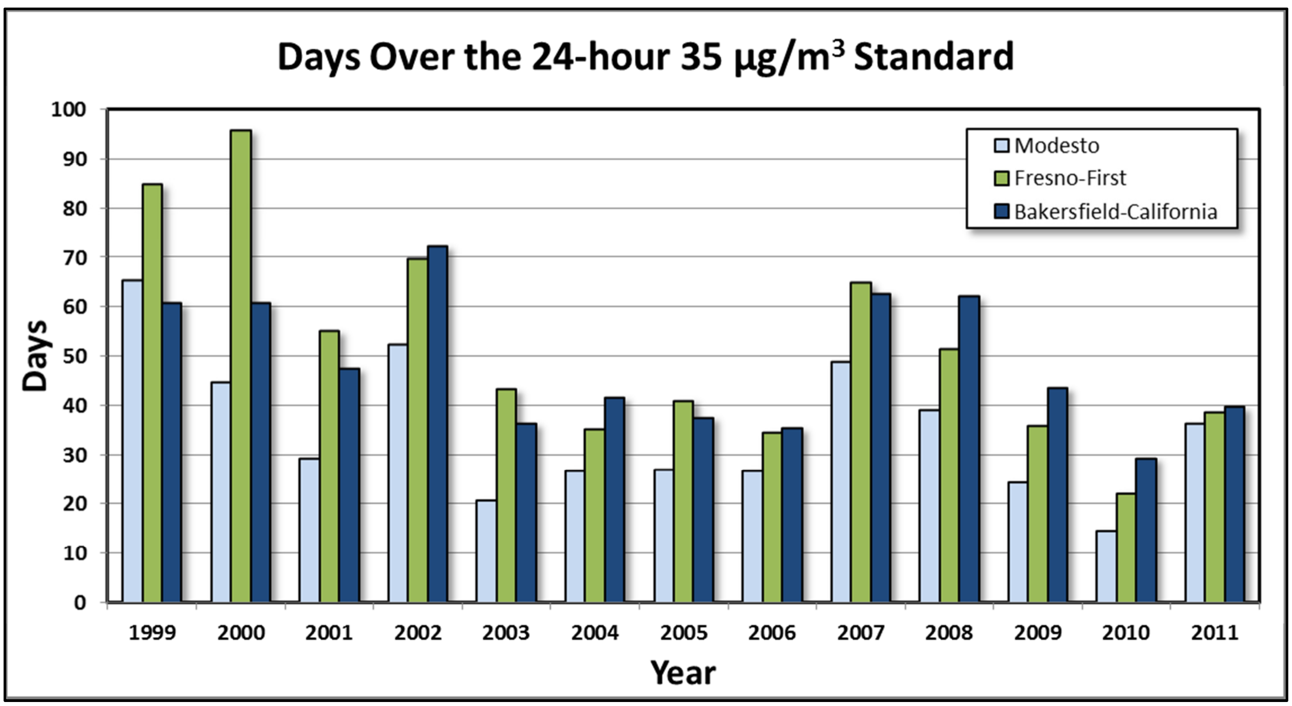


Figure A-11: Trend in Days over the 2006 24-hour PM2.5 NAAQS



As can be observed in figure A-10, the District has experienced a significant drop in the number of exceedances of the 65 µg/m³ standard. In 1999, approximately 103 exceedances of this standard occurred between the sites of Modesto, Fresno-First, and

Bakersfield-California. Comparing this to the 17 exceedances that occurred in 2011, this represents an 83% decrease in the number of violations among these sites.

Figure A-11 shows that similar progress has been made towards the 35 µg/m³ standard, although not as dramatic. Relative to 1999-2000, when PM2.5 first began to be recorded in the San Joaquin Valley, the recent years of 2009-2011 have seen great improvement. The District's emissions reduction strategy, the investment from the regulated industry in control technology, and the public's willingness to make a change for cleaner air have all played key roles in the reduction of concentrations over this time period. In fact, there has been a 46% decrease in violations among these sites when comparing 1999 to 2011. Despite this notable progress, the San Joaquin Valley still experiences many exceedance days over the lower standard during the winter months. Under unfavorable meteorological conditions, as experienced during the 2011-12 winter season, violations of the 35 µg/m³ standard can be rampant throughout the Valley. The values for 2011 in figure A-11 show this resulting spike as compared to the years 2009 and 2010, when meteorology was more favorable. Poor dispersion conditions were experienced during the 1999-2000 winter timeframe, similar to 2011, yet when comparing the number of exceedances between these two time periods, a striking difference is observed. Even with unfavorable meteorology, 2011 still had fewer exceedances of the 24-hour standards, showing a reduction in emissions.

A.5.2 1st and 4th Quarter Averages

Since the Valley's highest PM2.5 concentrations occur during the Fall and Winter months, the 1st (January through March) and 4th (October through December) quarters tend to have the highest average concentrations. Observing the trend in these quarterly averages can shed light on how the peak of the PM2.5 season is changing over time.

As such, a review of historical 24-hour PM2.5 filter data shows a general trend of reductions in both the average over the quarter, as well as the height of the peaks. The data used in this analysis utilizes PM2.5 filter values from 1999 through 2011 focusing on the 1st and 4th quarters at six sites in the District that tend to have the highest concentrations. The six sites that were focused upon were Clovis, Fresno-First, Corcoran, Visalia, Bakersfield-California, and Bakersfield-Planz.

The Bakersfield-California site is typical of the trend in improvement for these six sites. The rate of reduction of PM2.5 in the first quarter is not as great as the rate of reduction in the fourth quarter. At the Bakersfield-California site the average PM2.5 showed a downward trend of 0.37 µg/m³ per year for the 1st quarter and 1.15 µg/m³ per year for the 4th quarter, as shown below in figures A-12 and A-13, respectively. It will be important for this trend of reductions in the quarterly averages to continue as the District comes closer to attaining the annual average PM2.5 standard of 15.0 µg/m³.

Figure A-12: 1st Quarter Average Trend at Bakersfield-California

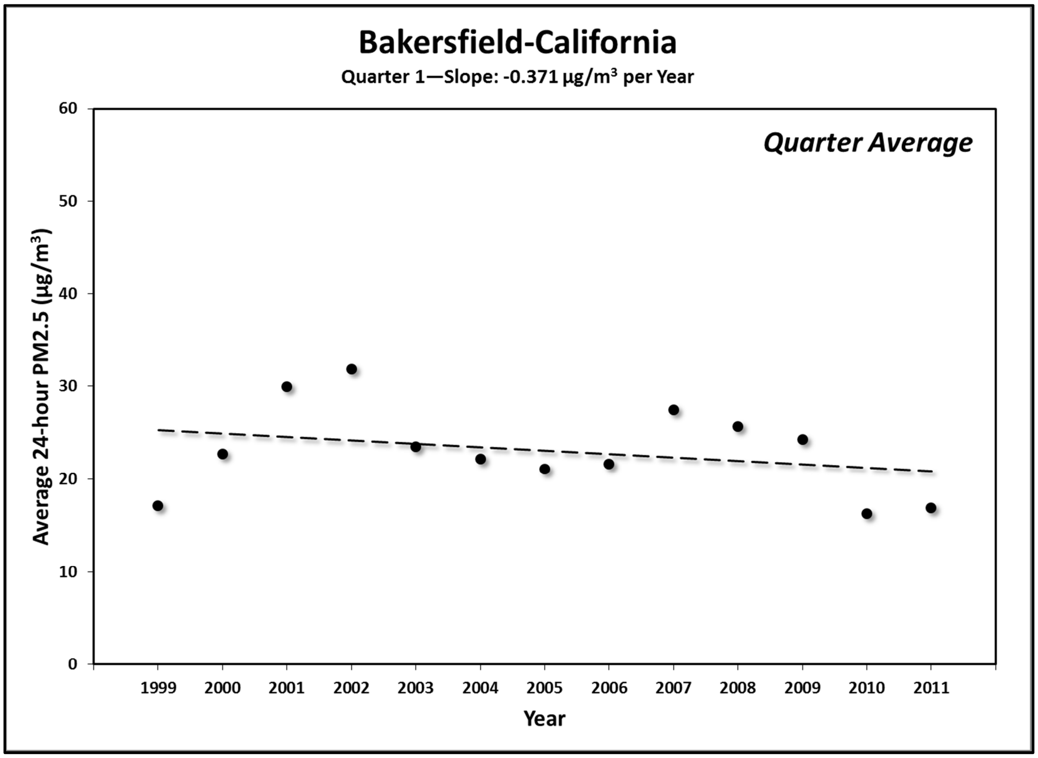
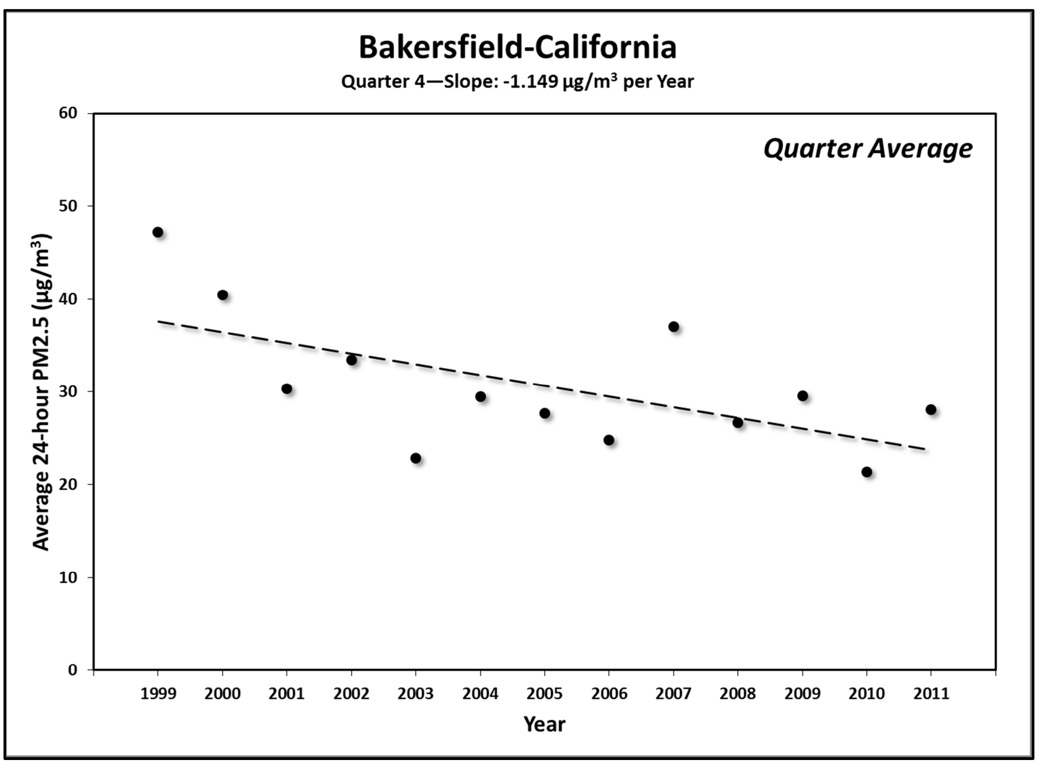


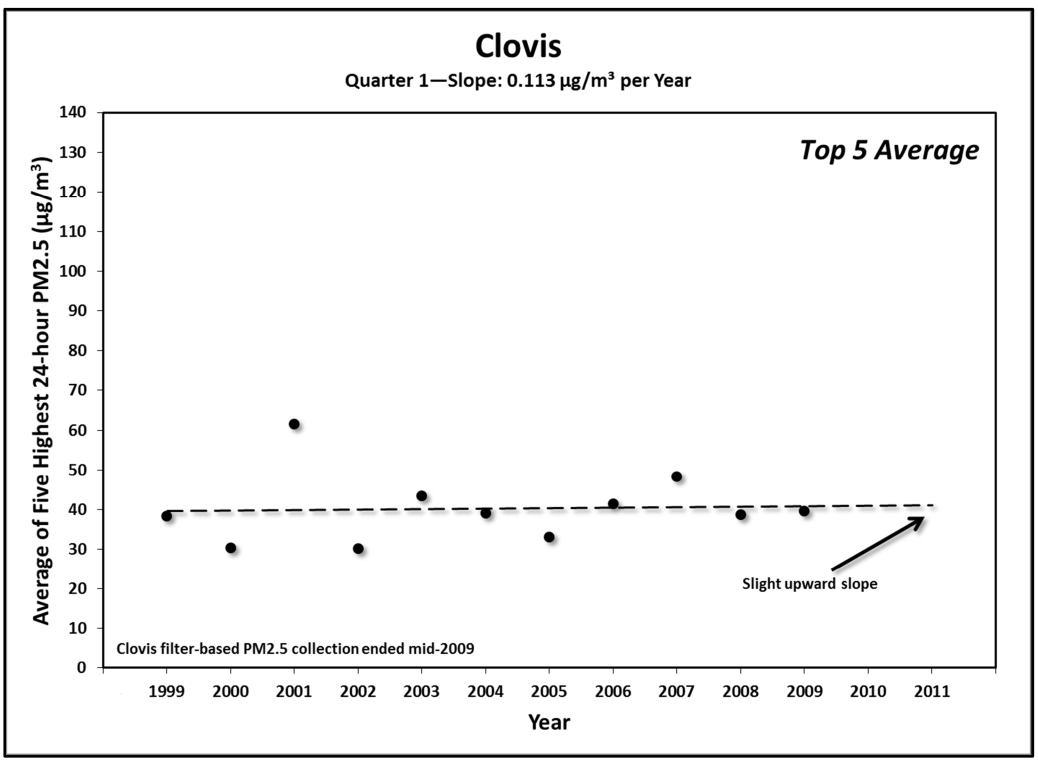
Figure A-13: 4th Quarter Average Trend at Bakersfield-California



To compare the peaks of each quarter, a similar comparison was completed averaging over the five worst days of each quarter to represent the need to reduce the episodic nature of PM2.5 pollution. This analysis showed a greater trend of reduction at most sites. For example, the Visalia air monitoring site showed a trend in reduction in the average of the five worst days of 3.30 µg/m³ per year for the 1st quarter, compared to a trend in reductions of the simple average over the same period of 1.22 µg/m³ per year. The general downward trend of the top five average among the sites included in this analysis shows that the severity of the peak PM2.5 episodes during each winter is being reduced over time. In light of the District's Risk-based Strategy, it will important that this pattern continues to ensure that the public is not being exposed to extremely high concentrations of PM2.5, as this has happened in the past.

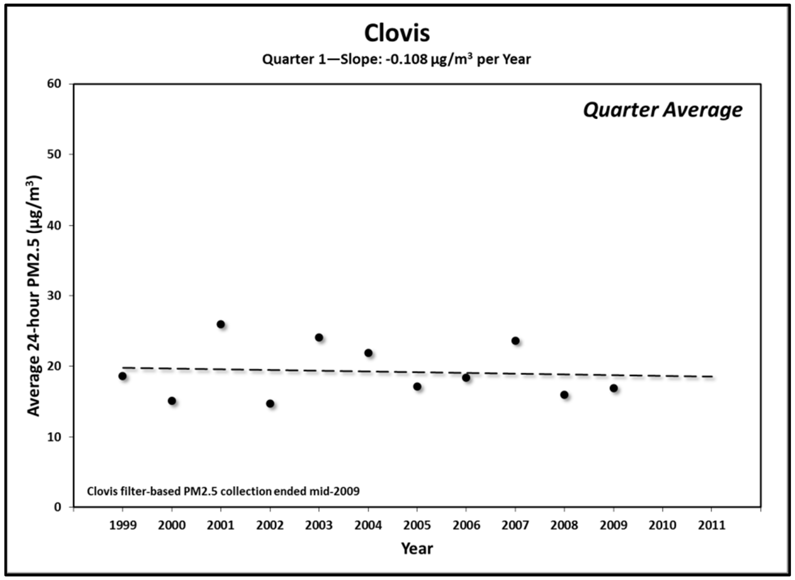
While this method of analyzing the worst days showed a trend of reduction for most sites, the Clovis site did not show improvement, but is rather indicating a minor increase at that monitor during the 1st quarter, as shown in figure A-14 below. However, this upward trend could just be a coincidence of the random variation of the data, and not conclusively show that concentrations are increasing. It's fair to say that the 1st-quarter average trend at the Clovis site is at least flat, and not significantly increasing or decreasing.

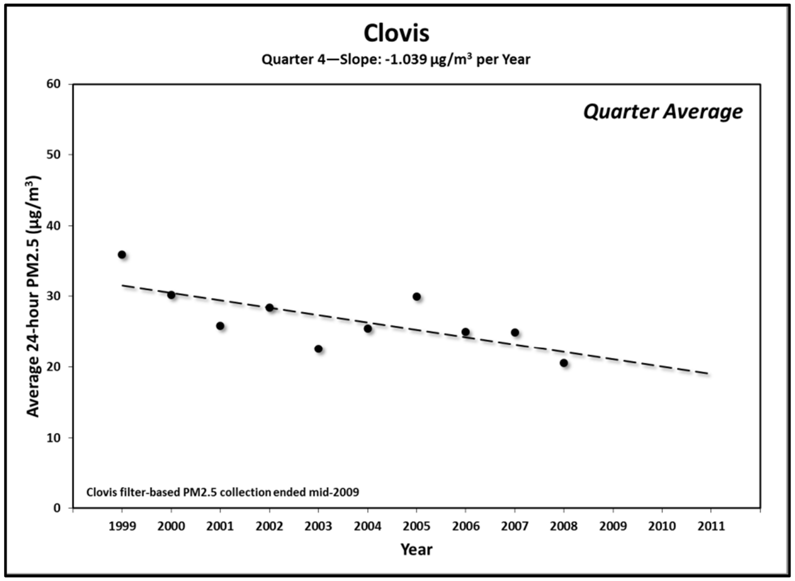
Figure A-14: 1st Quarter Average Trend at Clovis

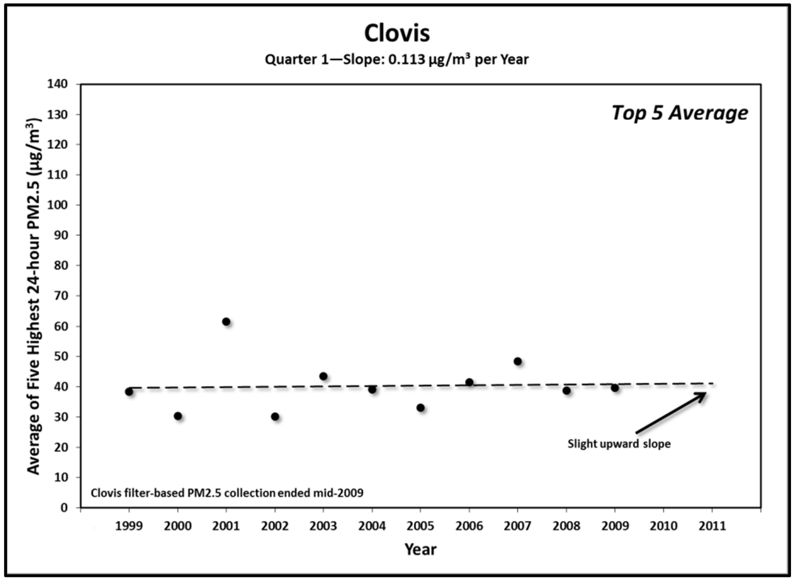


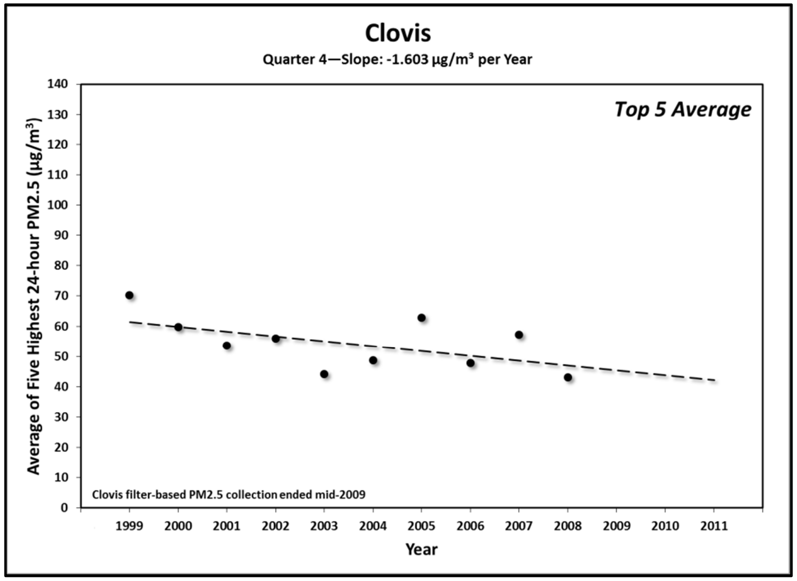
The following charts, figures A-15.1 through A-15.24 show the 1st- and 4th-quarter 24-hour PM2.5 averages, along with the average of the top five values within each of these quarters for the six monitoring sites included in this analysis.

Figures A-15.1 through A-15.4: 1st and 4th Quarter PM2.5 Average Trends at Clovis

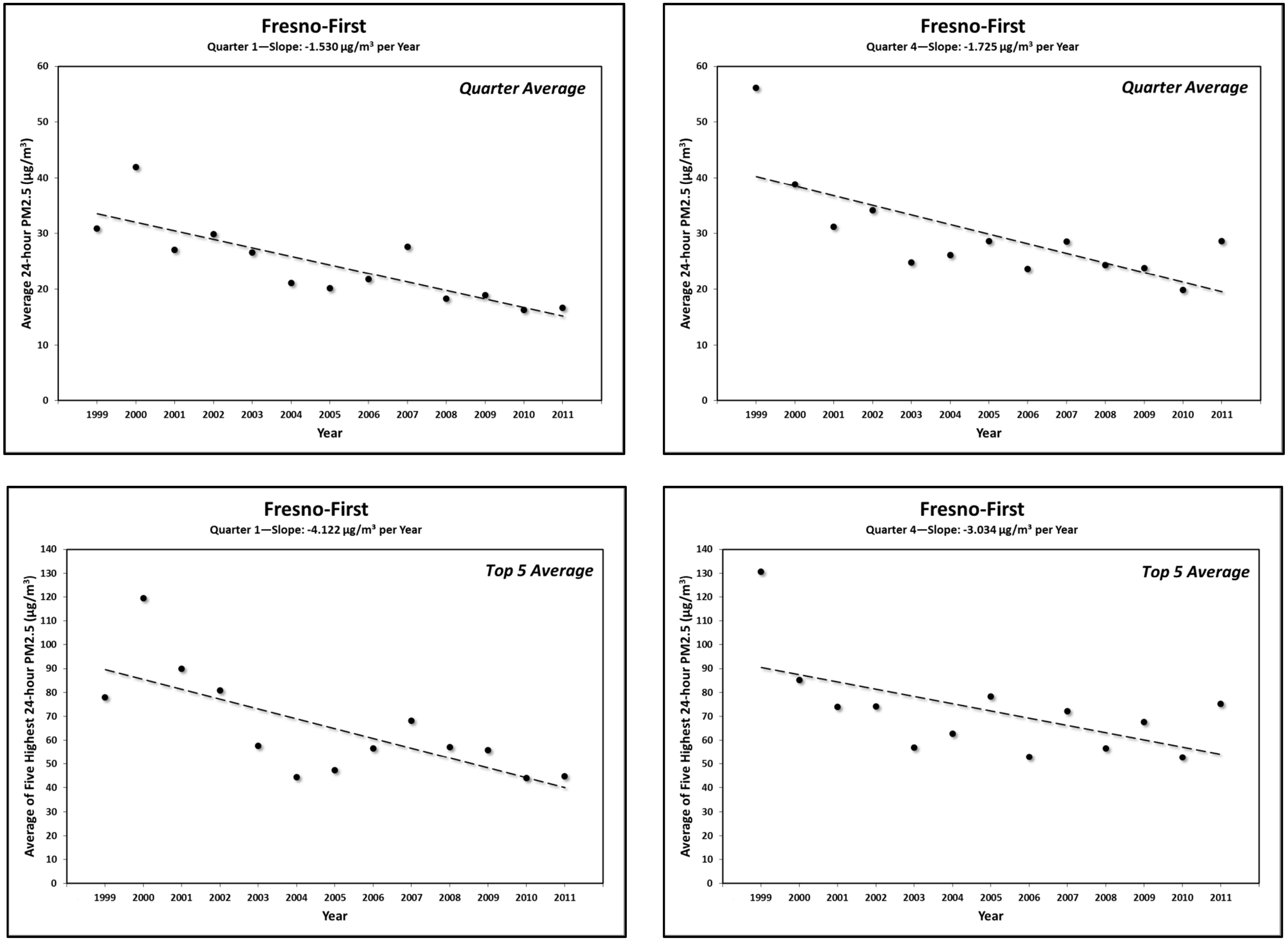




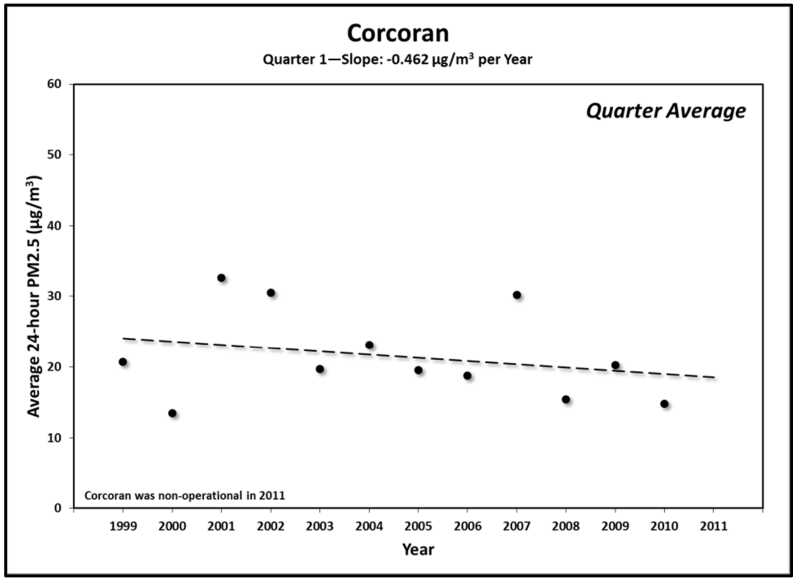


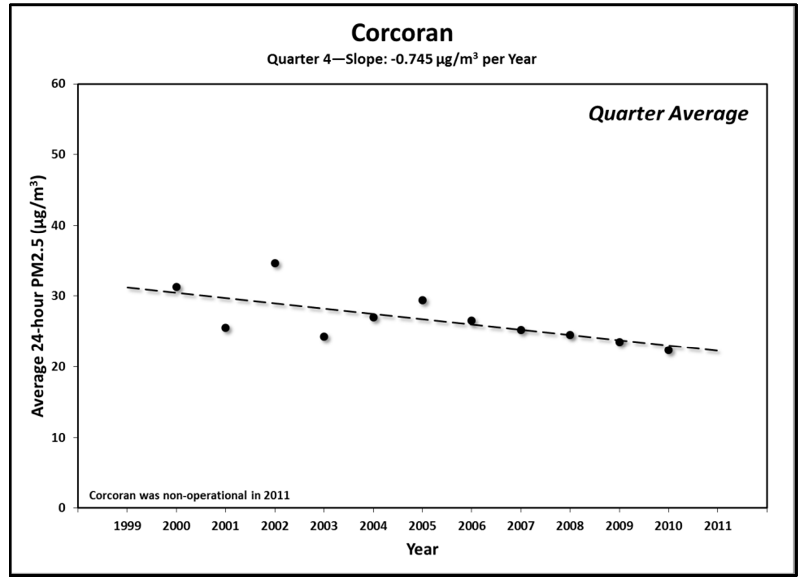


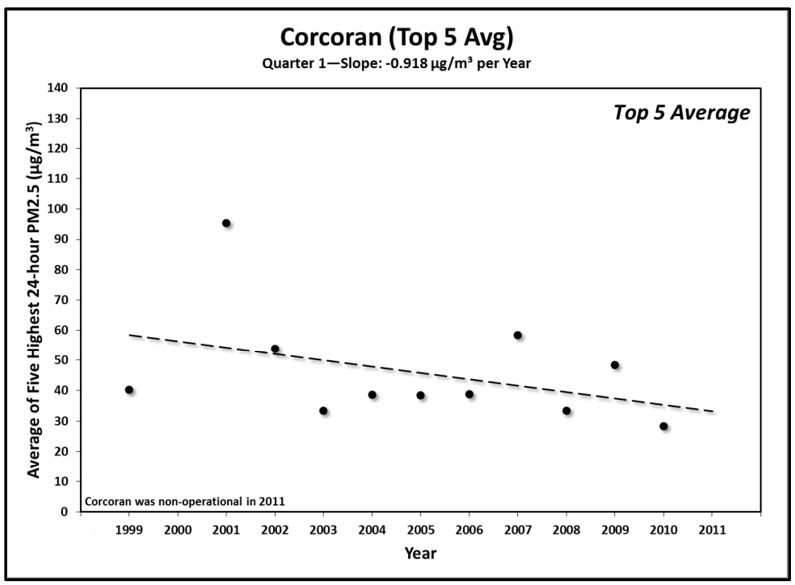
Figures A-15.5 through A-15.8: 1st and 4th Quarter PM2.5 Average Trends at Fresno-First

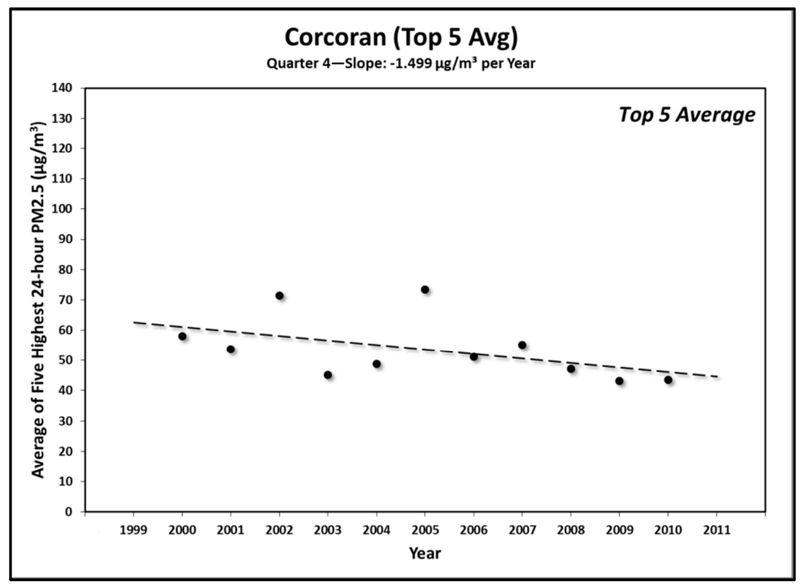


Figures A-15.9 through A-15.12: 1st and 4th Quarter PM2.5 Average Trends at Corcoran

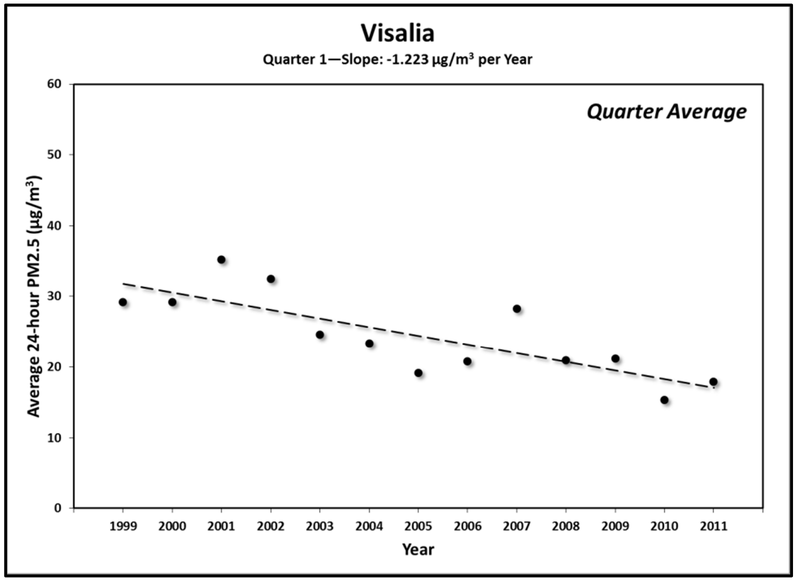


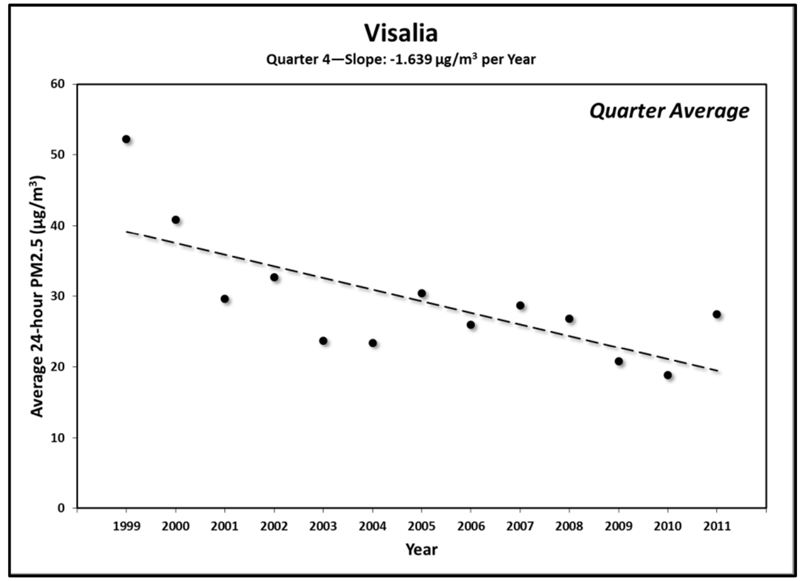


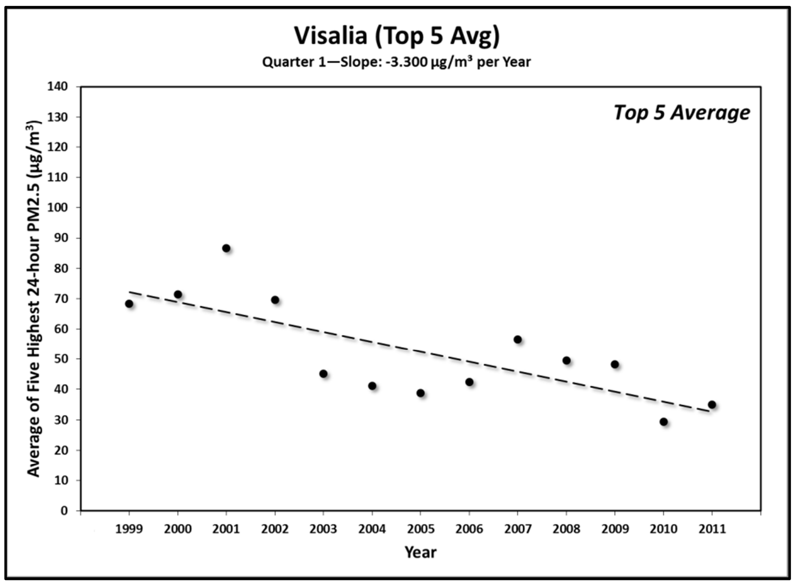


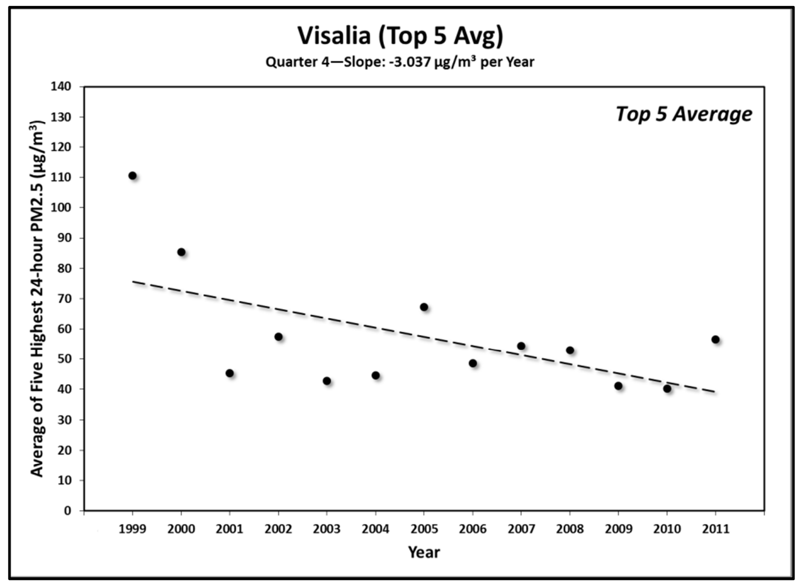


Figures A-15.13 through A-15.16: 1st and 4th Quarter PM2.5 Average Trends at Visalia

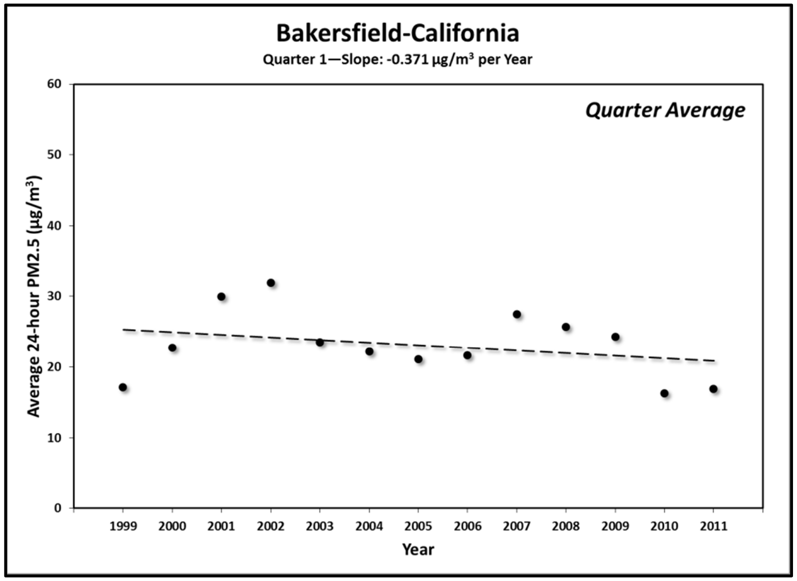


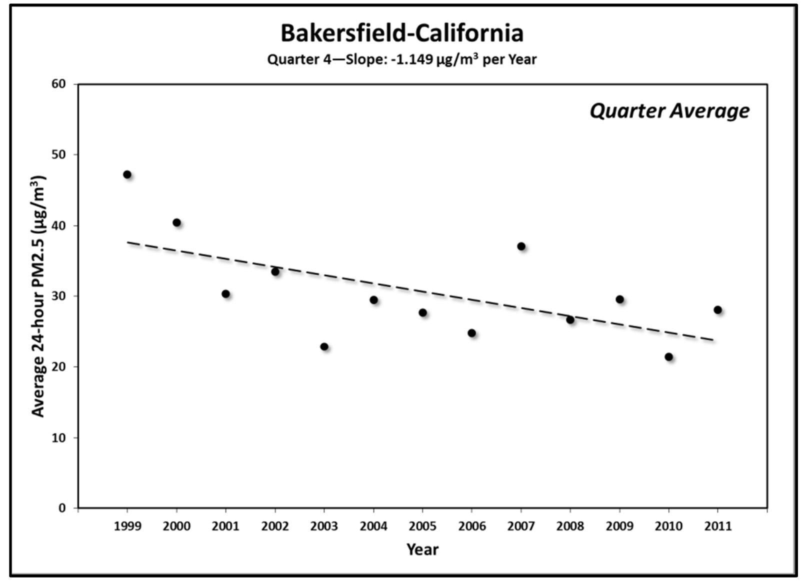


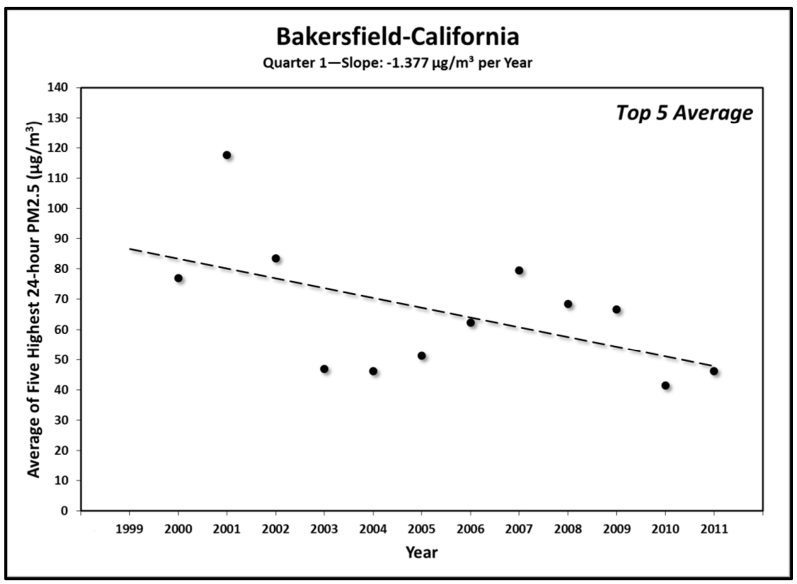


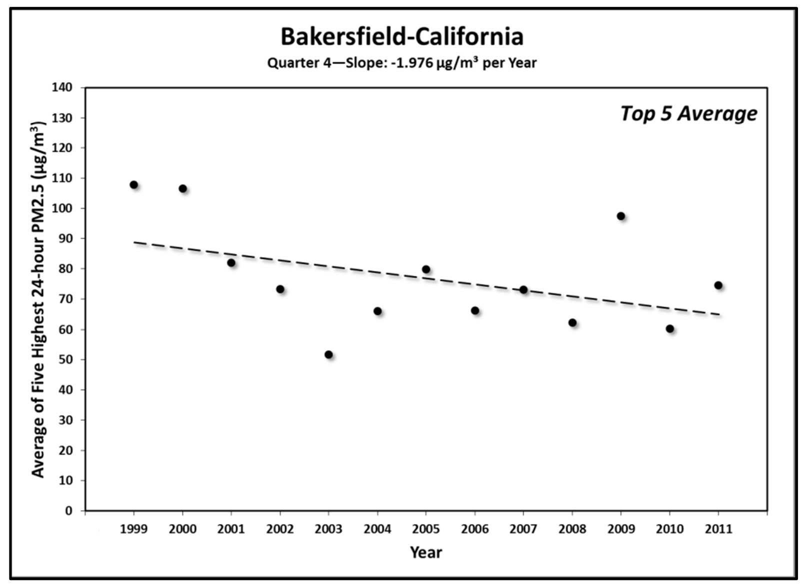


Figures A-15.17 through A-15.20: 1st and 4th Quarter PM2.5 Average Trends at Bakersfield-California

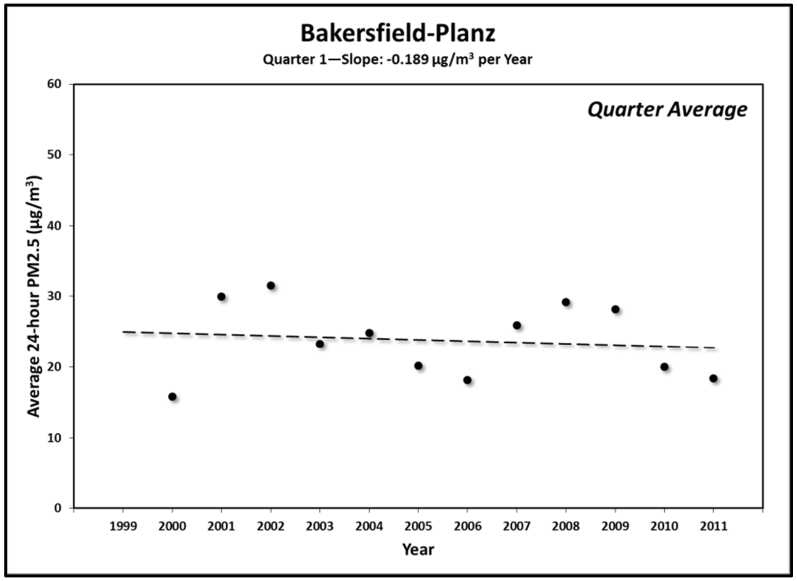


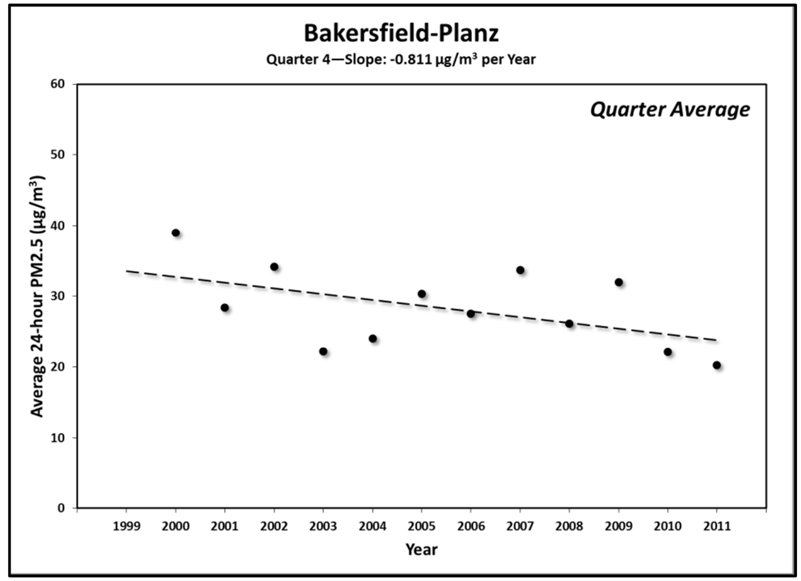


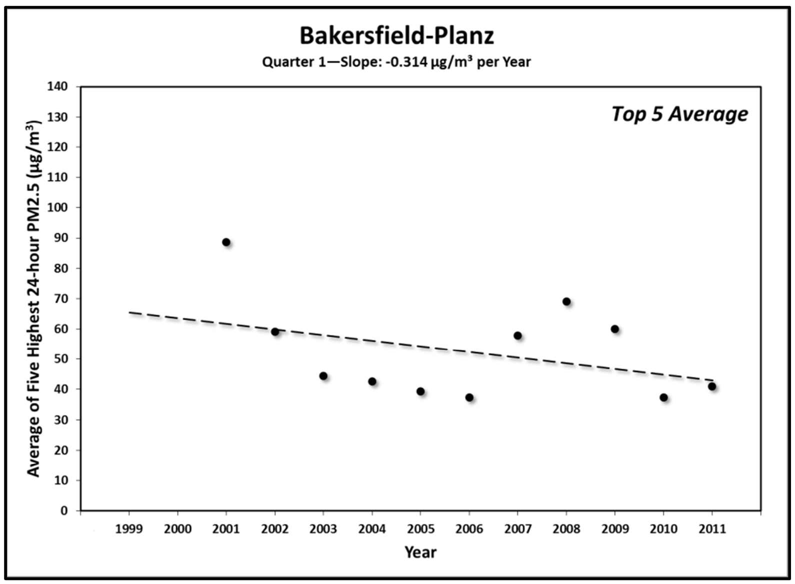


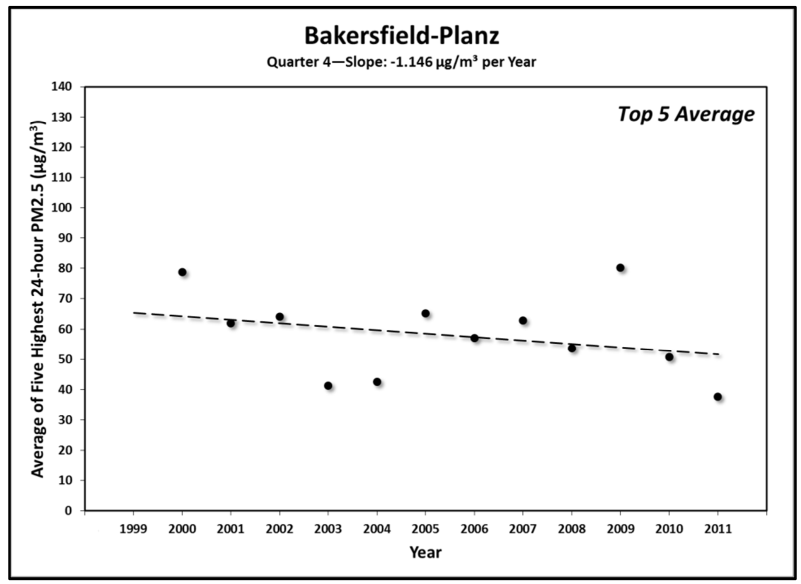


Figures A-15.21 through A-15.24: 1st and 4th Quarter PM2.5 Average Trends at Bakersfield-Planz









A.5.3 Diurnal Profiles

Calculating and comparing annual and 24-hour averages for PM2.5 can be helpful in their own right; however, these metrics can often mask the trend in hourly concentrations throughout the day. An hourly analysis of PM2.5 measurements can show what portions of the day tend to have the highest concentrations, and which portions of the day have the lowest. Comparing the diurnal (or daily) profiles over time can show how this curve has changed from year to year.

As mentioned in Section A.3.1 of this Appendix, many of the Valley's air monitoring sites use real-time PM2.5 monitors, which produce hourly PM2.5 measurements. The District uses this data every day to produce daily air quality forecasting, wood burning prohibitions, public health notifications, and Real-time Air Advisory Network (RAAN) notifications for schools. Based on historical hourly data the District compiled long-term diurnal (or daily) profiles to analyze how PM2.5 concentrations vary throughout the day at each Valley monitoring site.

This analysis was conducted by averaging the PM2.5 concentrations for each hour of the day over the specified averaging time (calendar year), i.e. all of the hour 0 values were averaged, the hour 1 values were averaged, etc. These average values for each hour and for each year/season were then plotted so that a comparison could be made between the years/seasons for each site. The height and shape of the profile curves can then be analyzed to understand how the average daily concentrations have changed over time.

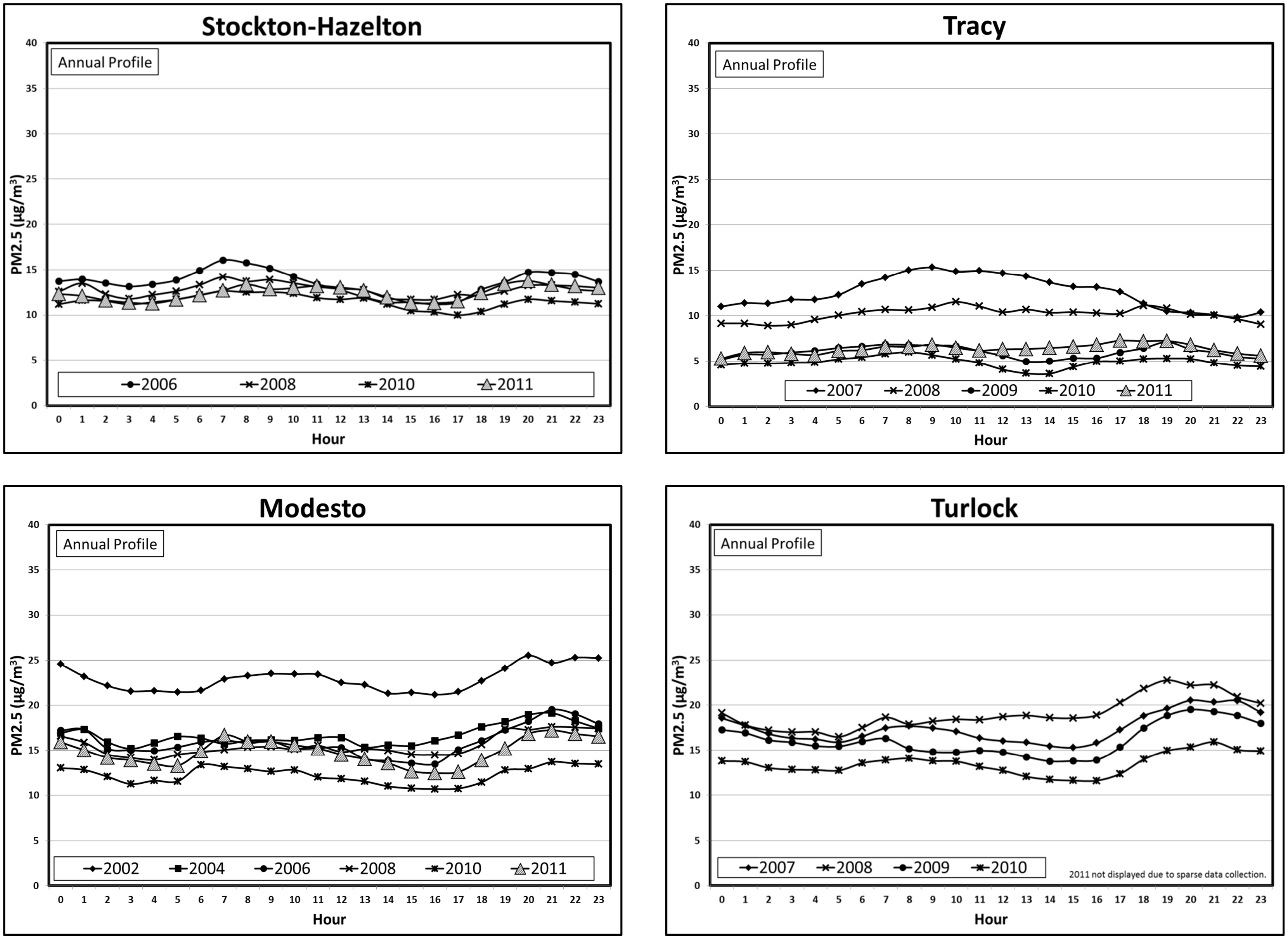
A.5.4 Annual Profiles

The following charts, figures A-16.1 through A-16.14, show the yearly average diurnal profiles of most of the real-time monitoring sites in the San Joaquin Valley. Sites profiled here are those in which a comparison could be made with previous years.

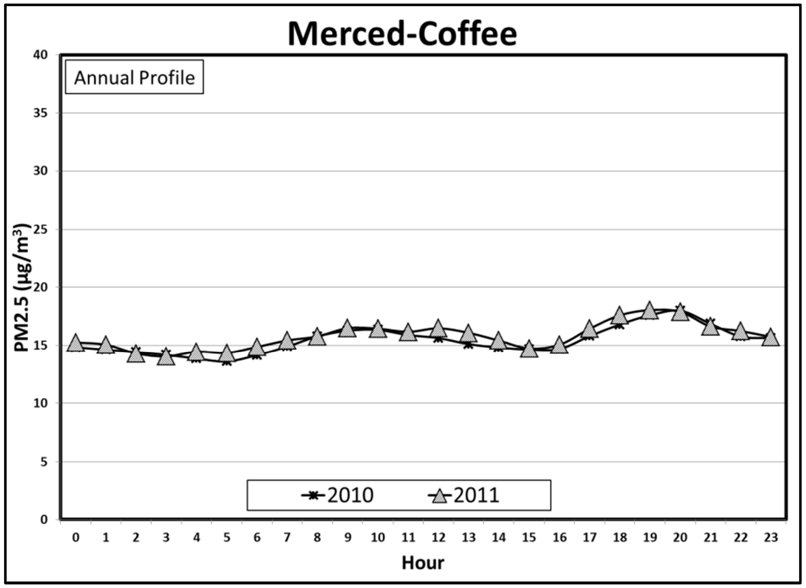
As can be observed in these profiles, the year 2011 (represented by triangles in all of the charts) tended to experience higher PM2.5 concentrations when compared to 2010. In the larger metropolitan areas like Bakersfield and Fresno, this difference between 2011 and 2010 was more pronounced. Although concentrations were higher in 2011, partly due to unfavorable meteorology, the evening peaks were still much "flatter" than in years past. Focusing on the Bakersfield-California and Fresno-First sites, the higher evening peaks in the year 2002 can be observed. Comparing this to the evening peaks in recent years, including 2011, one can see that the curve is not as pronounced. This could be attributable to the wood-burning prohibitions, which became mandatory during the winter of 2003-04.

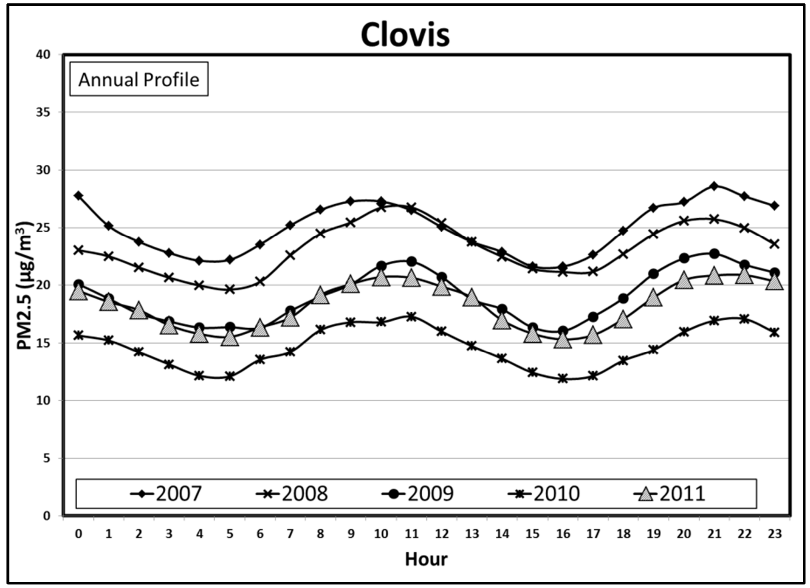
Note that in the charts below, the sites with a longer history only show a profile every other year/season in an effort to improve the view of the change over time.

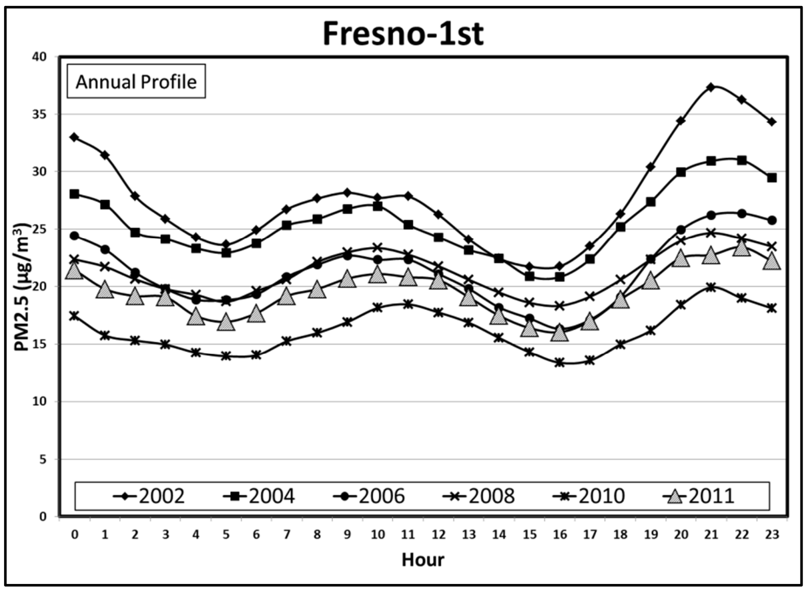
Figures A-16.1 through A-16.4: PM2.5 Diurnal Profiles: Stockton-Hazelton, Tracy, Modesto, Turlock

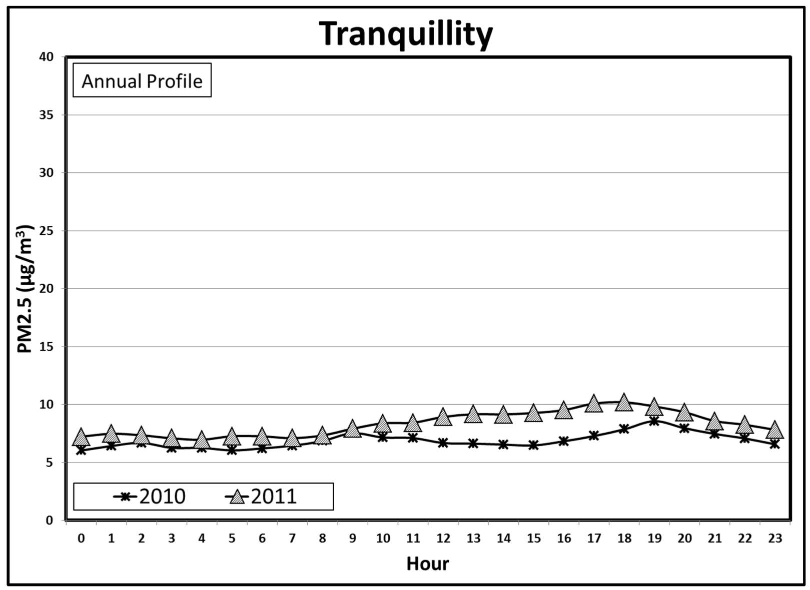


Figures A-16.5 through A-16.8: PM2.5 Diurnal Profiles: Merced-Coffee, Clovis, Fresno-First, Tranquillity

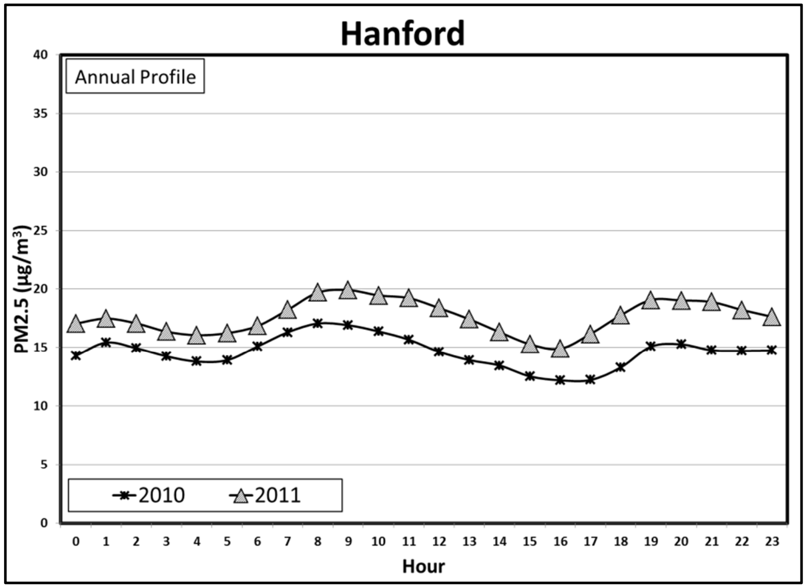


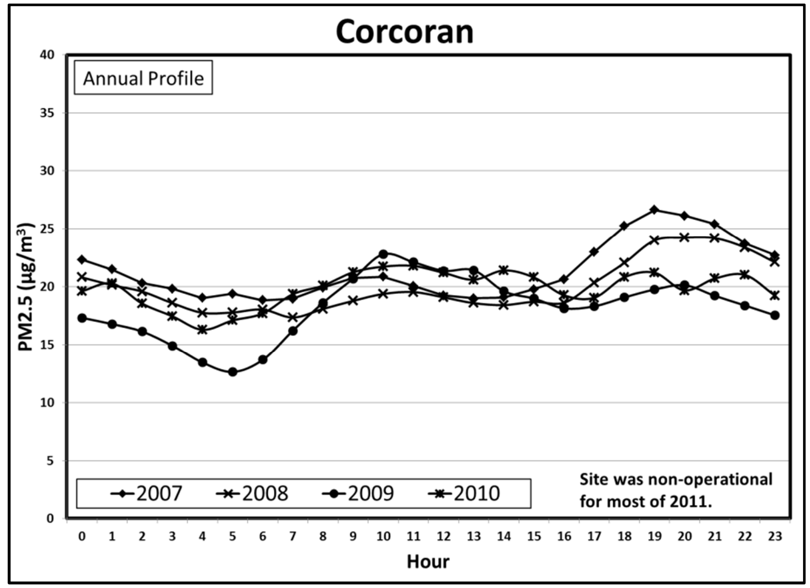


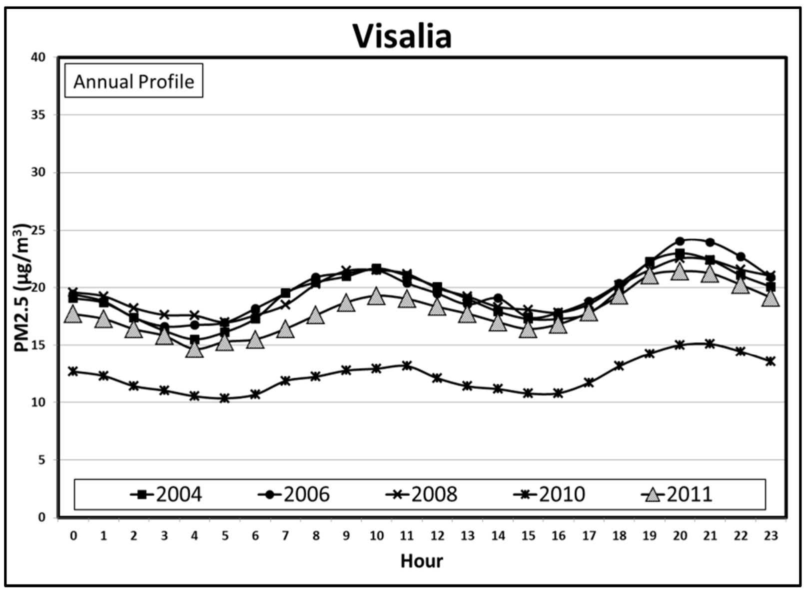


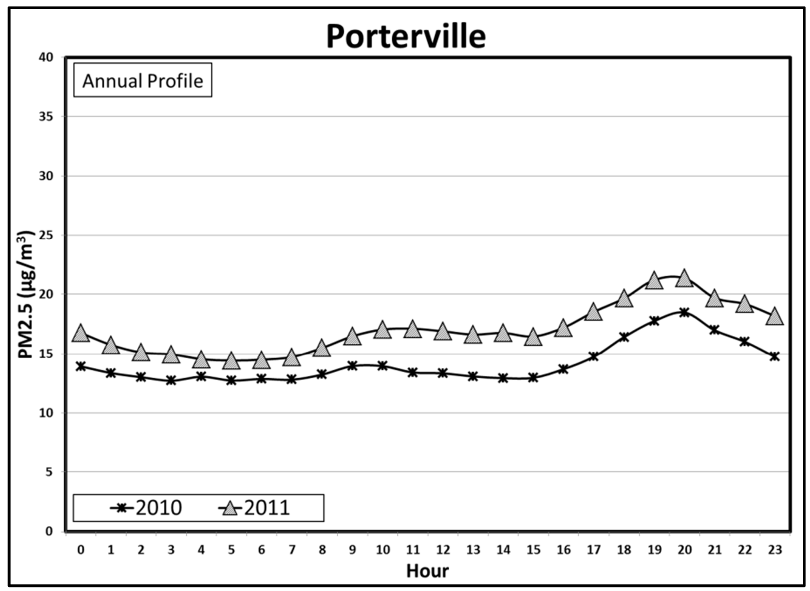


Figures A-16.9 through A-16.12: PM2.5 Diurnal Profiles: Hanford, Corcoran, Visalia, Porterville

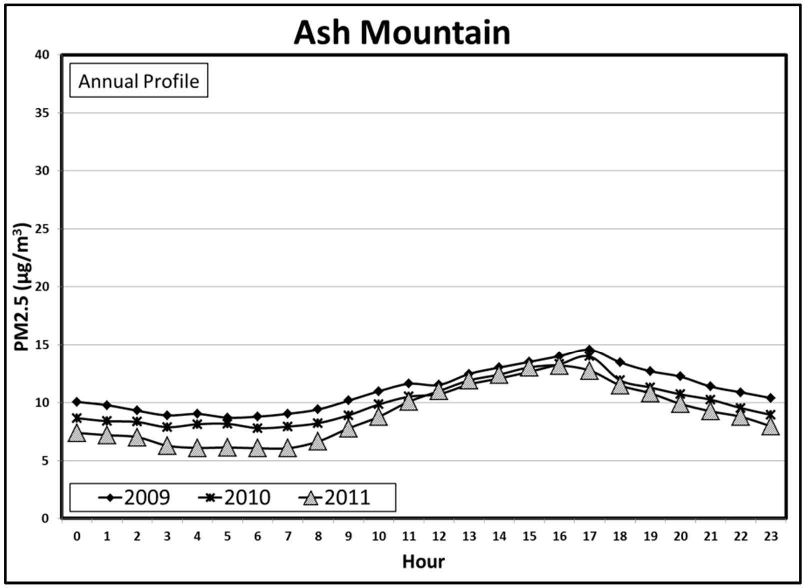


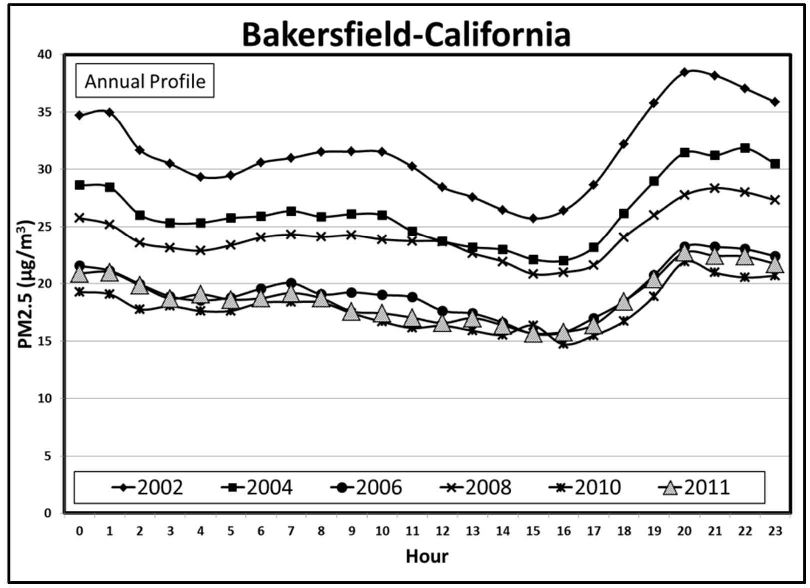






Figures A-16.13 through A-16.14: PM2.5 Diurnal Profiles: Ash Mountain, Bakersfield-California





A.5.5 PM2.5 Driven Air Quality Index Analysis

The EPA and the District use the Air Quality Index (AQI) to provide daily information about the Valley's air quality, how unhealthy air may affect the public, and how the public can protect their health. AQI scales exist for all of the criteria pollutants regulated by the Clean Air Act, which includes PM2.5. The current 24-hour average PM2.5 AQI scale is defined in figure A-17 below.

Figure A-17: 24-hour PM2.5 AQI Scale

Concentration (µg/m^3)	AQI Category	AQI Color	AQI Range
0 - 15.4	Good	Green	0-50
15.5 - 40.4	Moderate	Yellow	51-100
40.5 - 65.4	USG	Orange	101-150
65.5 - 150.4	Unhealthy	Red	151-200
150.5 - 250.4	Very Unhealthy	Purple	201-300
250.5+	Hazardous	Maroon	301+

The District analyzed the trends in the PM2.5 data from the sites with at least two years of daily AQI observations based on real-time data. Note that this analysis represents the AQI based on PM2.5 data only, and does not include ozone or PM10. Through this exclusion of the other pollutants, an observation of the isolated change in air quality related only to PM2.5 is possible. For the majority of the sites across the San Joaquin Valley, the 2008-2010 timeframe experienced a resolute improvement in PM2.5 air quality. Over these three years, the frequency of Good AQI days increased sharply, coupled with a decrease in the frequency of the Moderate and Unhealthy for Sensitive Groups (USG) categories. For example, at the Fresno-First site, the number of Good days increased from 155 in 2008, to 205 in 2009, and to 227 in 2010. On the other side of the spectrum, the USG days at the Bakersfield-California site decreased from 61 in 2008, to 34 in 2009, and to 16 in 2010. This shows a downward shift among the categories, where Unhealthy days shifted down to USG days, USG days shifted down to Moderate days, and Moderate days shifted down to Good days. Since Good days cannot shift any lower, this category will continue to grow as air quality improves.

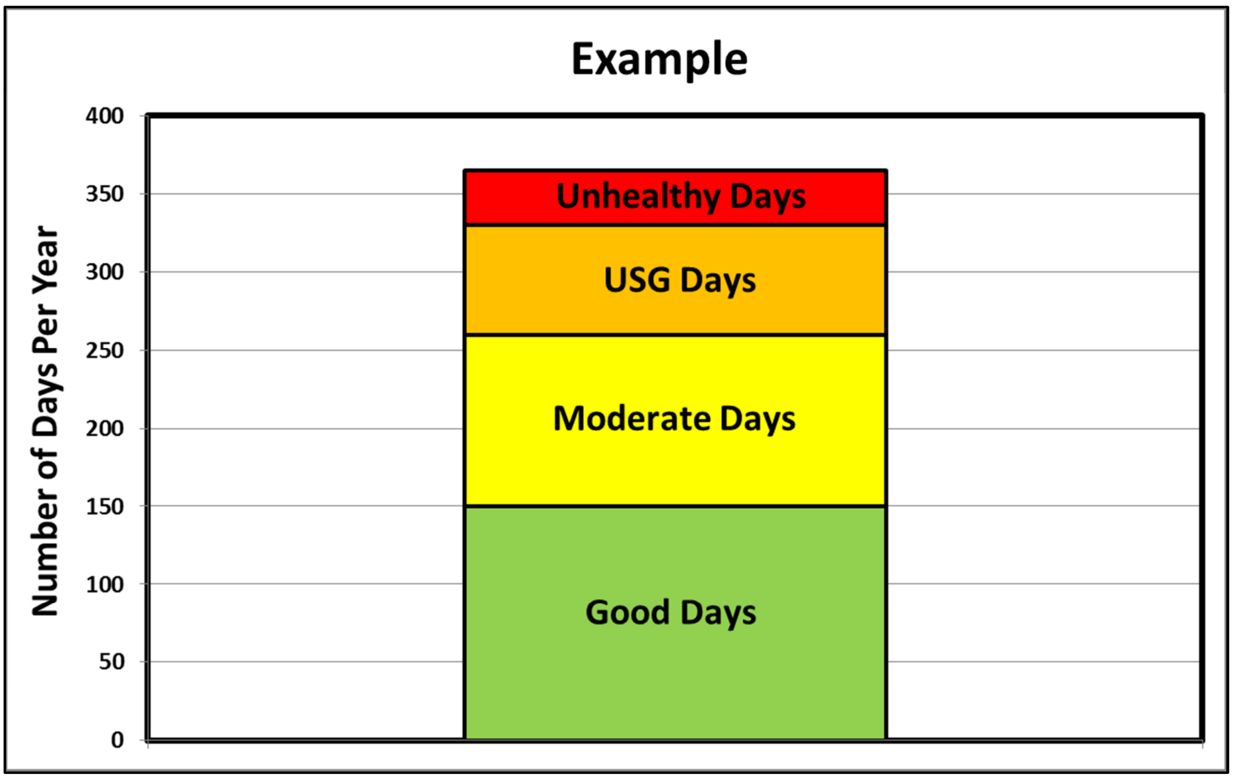
Although the improvement over the 2008-2010 timeframe is partly attributable to favorable meteorology, emissions reductions were also occurring over these three years. The District's Rule 4901 (Wood Burning Fireplaces and Wood Burning Heaters) was strengthened just before the 2008-2009 winter season, lowering the curtailment threshold from 65 µg/m^3 to 30 µg/m^3. It is interesting that the sharp improvement in PM2.5 air quality began as the amended wood-burning rule took effect, which shows that there may be a connection between the two.

In 2011, the PM2.5 air quality declined throughout the majority of the District when compared to the past few years. An abnormally stagnant and dry 2011-12 winter contributed greatly to this deterioration, which is apparent when comparing the number of Good AQI days in 2011 to the years prior. It should be noted that although the

District experienced a decline in air quality during 2011, there were still more Good AQI days and fewer USG AQI days than years in the past. For example, the Modesto site in 2011 observed 252 Good AQI days and 16 USG AQI days, but when compared to the year 2006, when the site had 233 Good AQI days and 22 USG AQI days, one can see that 2011 was not an outlier in terms of PM2.5 concentrations. Although the air quality for the year 2011 did not continue the favorable trend from 2008-2010, it was still not as severe as in years past when PM2.5 first began to be collected in the San Joaquin Valley.

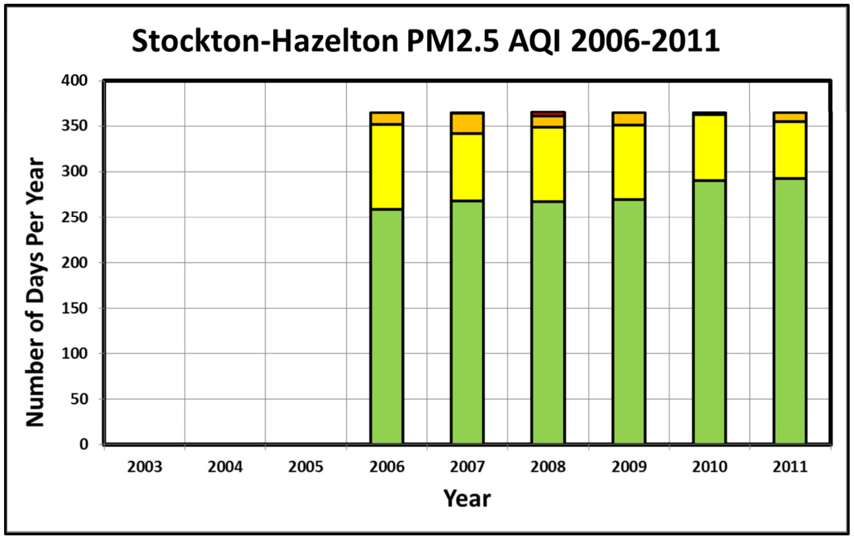
In the charts below, figure A-18 and figures A-19.1 through A-19.12, the stacked bars represent the number of days within each year that fell within each of the AQI categories. Summing the observations among all of the categories within a year gives the full 365 days in the year (and 366 days for leap years). Within each bar, the categories are ordered as Good, Moderate, etc. from the bottom up. See figure A-18 below as an example.

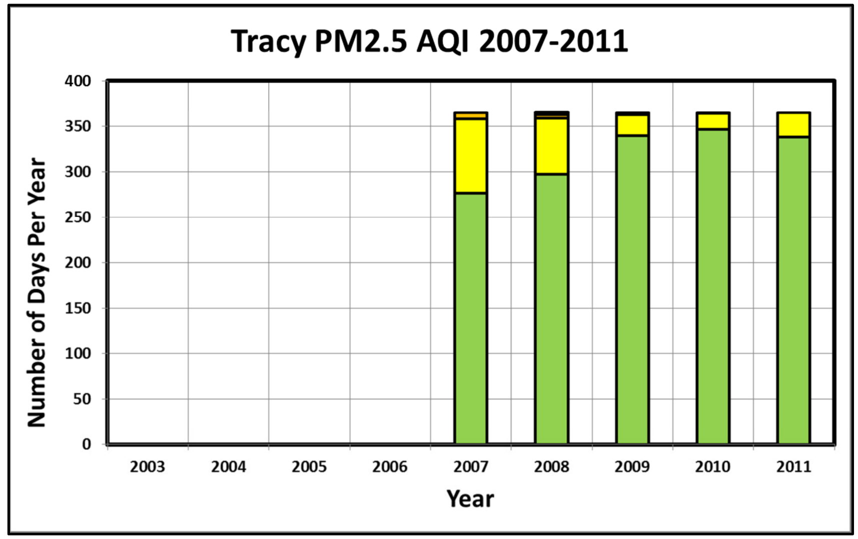
Figure A-18: Air Quality Index (AQI) Categories

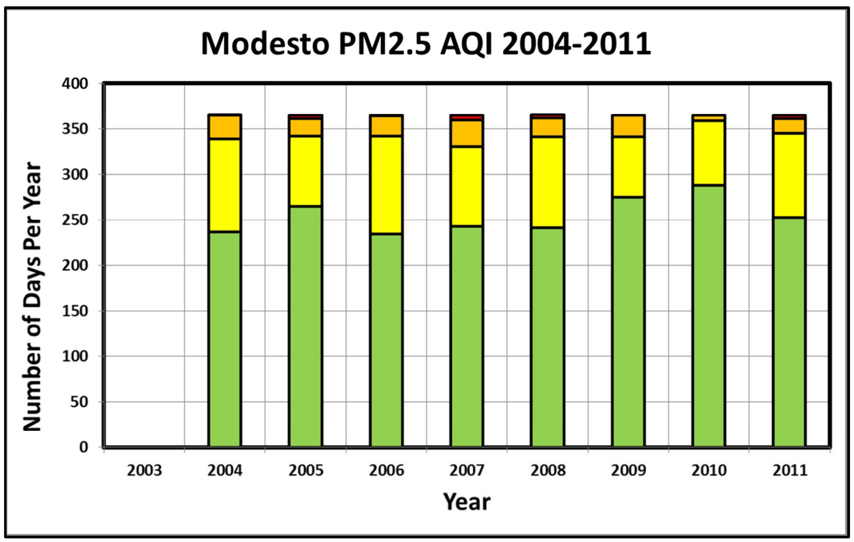


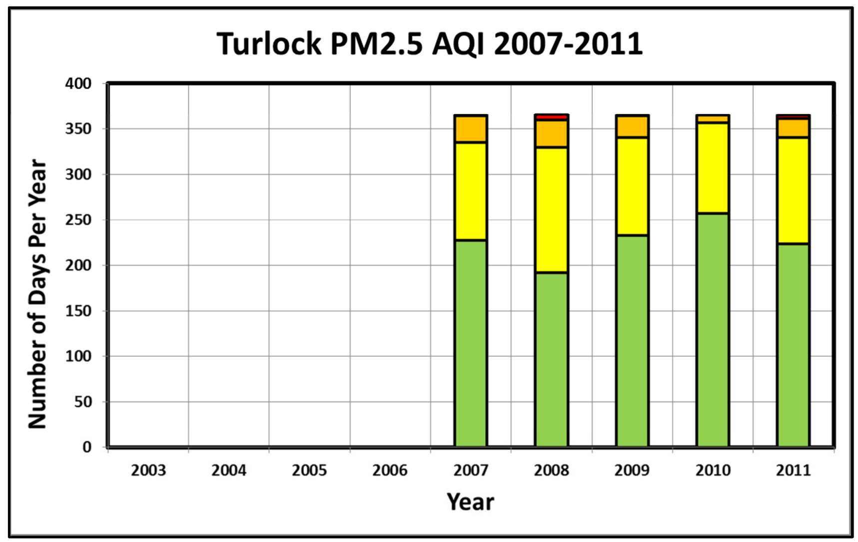
It should be noted that often during the course of a year, a monitor may be non-operational due to regular maintenance or repairs. When this happens, the monitor may not record PM2.5 concentrations for a number of days. This provides a year with only a partial dataset, which is non-representative of the entire year. For years in this situation, adjustments have been made to estimate the missing days, thus giving the year a full set of days to display.

Figures A-19.1 through A-19.4: Number of Days per AQI Category per Year; Stockton-Hazelton, Tracy, Modesto, and Turlock

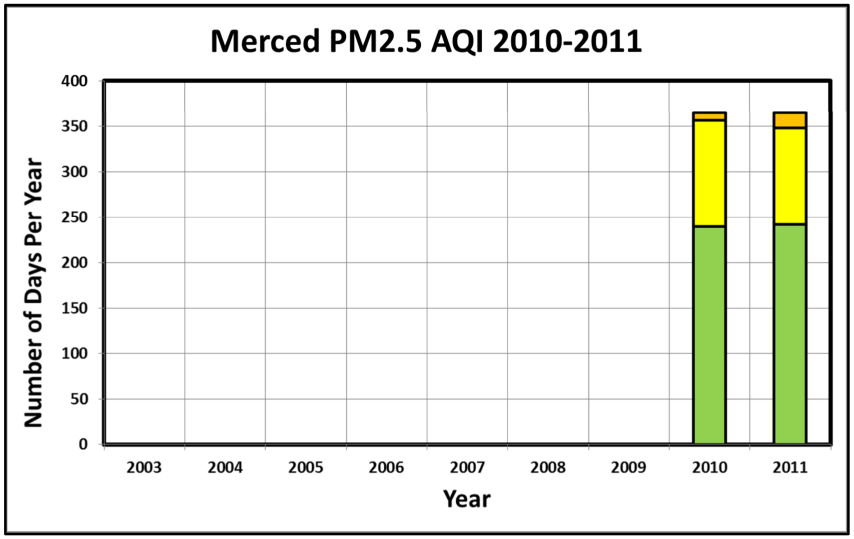


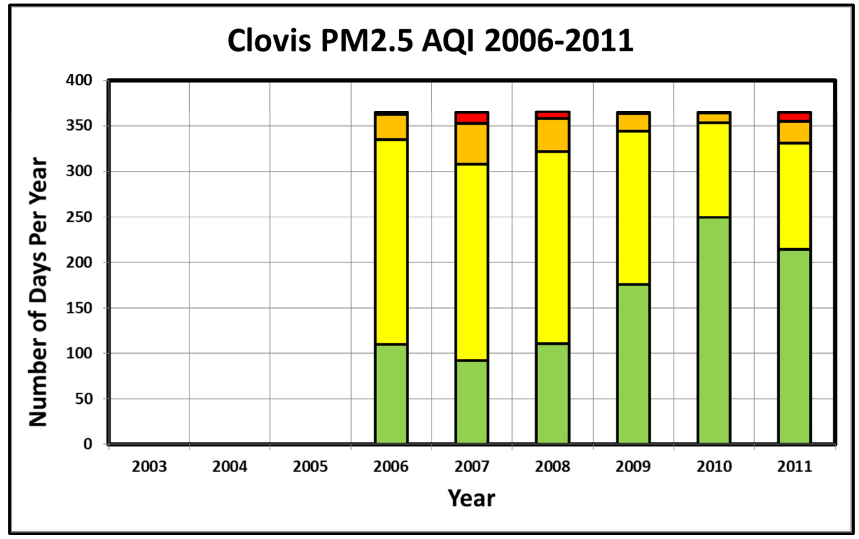


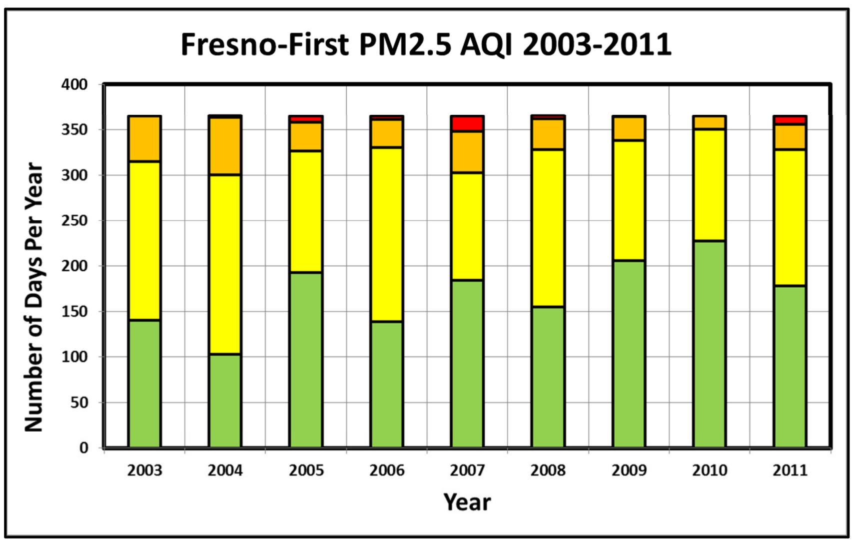


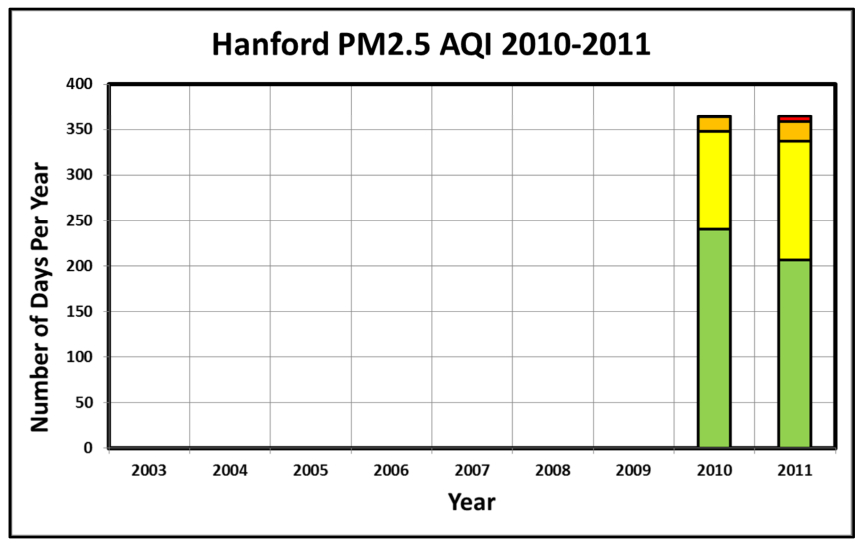


Figures A-19.5 through A-19.8: Number of Days per AQI Category per Year; Merced, Clovis, Fresno-First, and Hanford

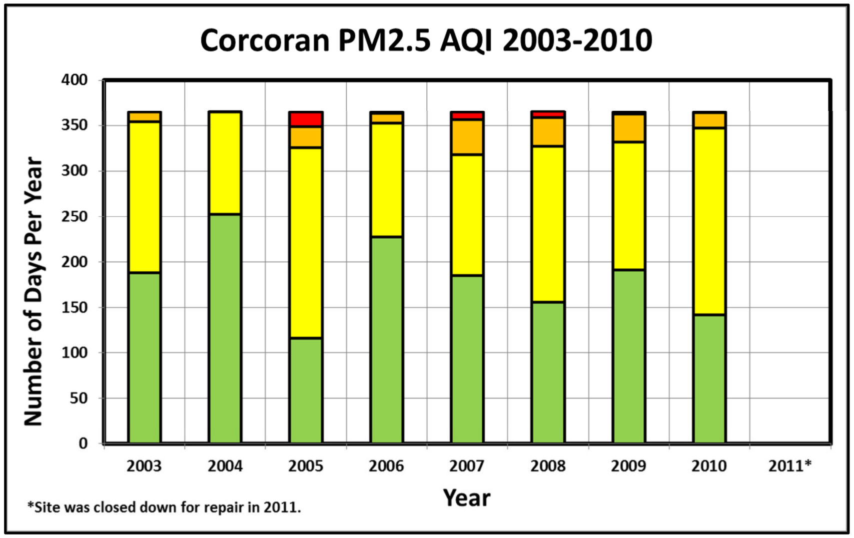


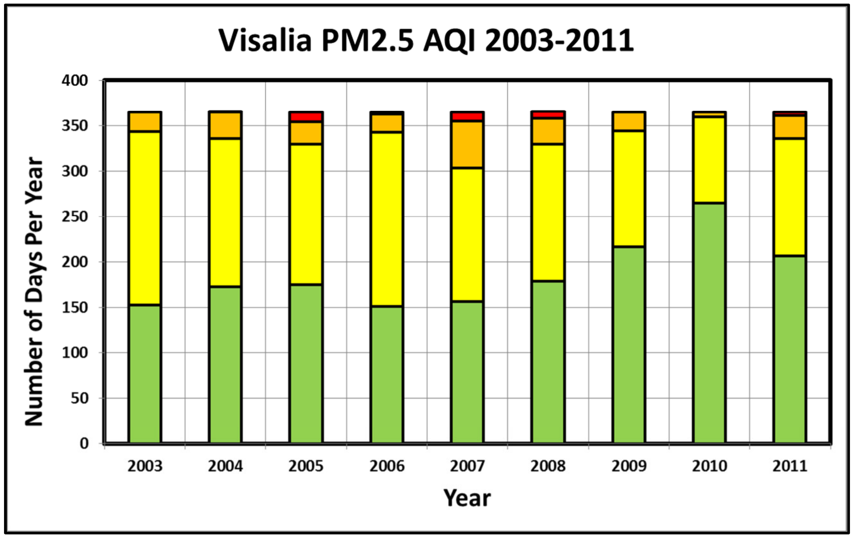


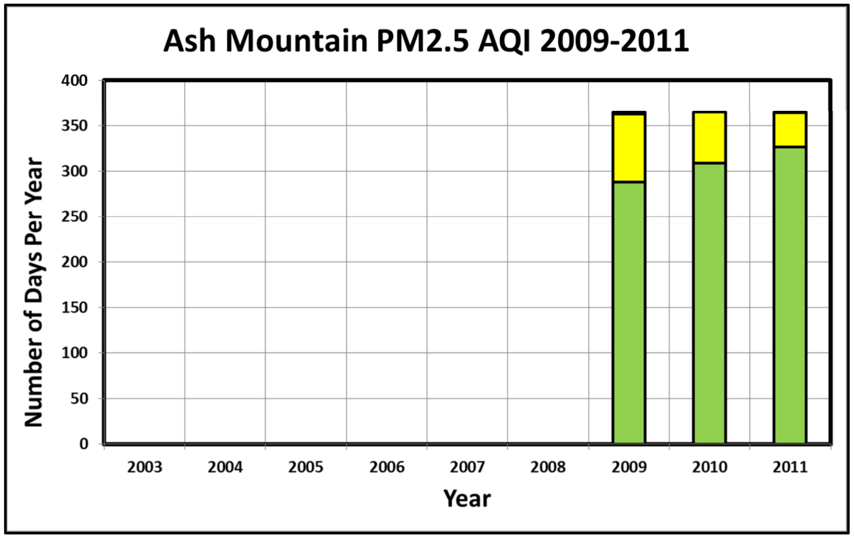


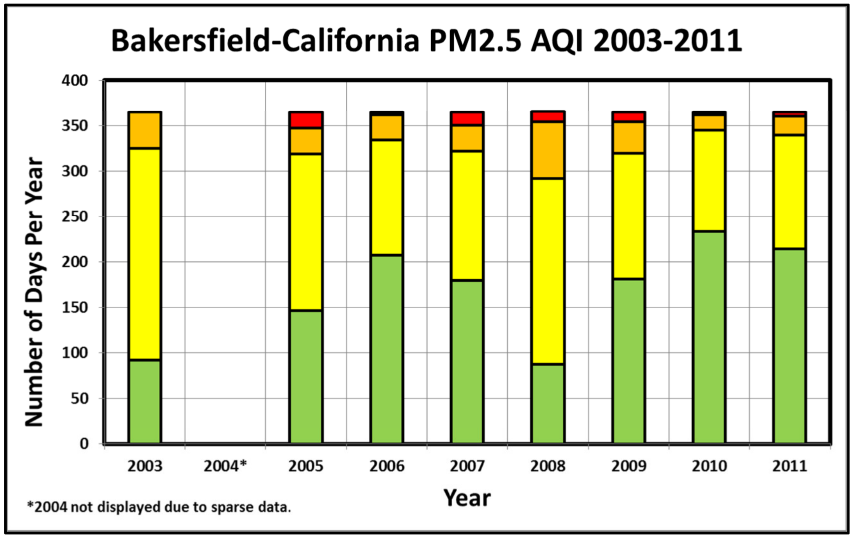


Figures A-19.9 through A-19.12: Number of Days per AQI Category per Year; Corcoran, Visalia, Ash Mountain, and Bakersfield-California







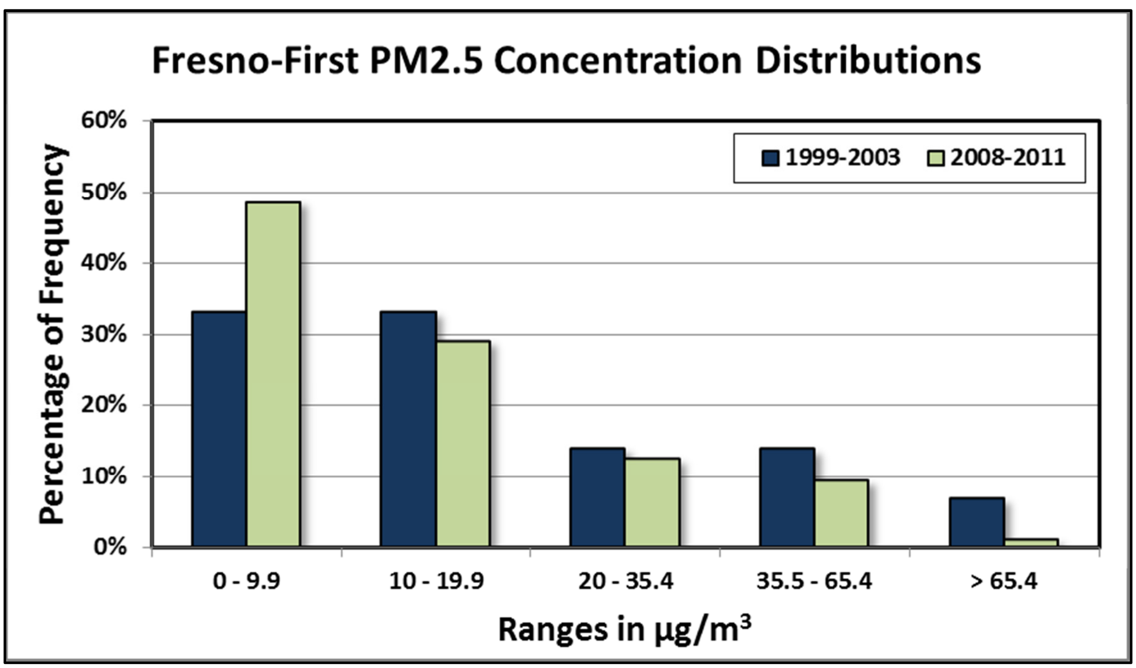


A.5.6 Concentration Frequency Distributions

The District analyzed filter-based PM2.5 data from various sites throughout the San Joaquin Valley to form histograms based on the distribution of concentrations over the time periods of 1999-2003 and 2008-2011. In this analysis, the concentrations were separated into bins of 0 – 9.9 µg/m^3, 10 – 19.9 µg/m^3, 20 – 35.4 µg/m^3, 35.5 – 65.4 µg/m^3, and greater than 65.4 µg/m^3. At each air monitoring site, the observations for each time period were grouped into the appropriate bins depending upon their concentration. The frequency of the observations in the bins were converted to a percentage of the total time period, and displayed as a bar chart, comparing the distribution of 1999-2003 against 2008-2011. The air monitoring sites included in this analysis were Modesto, Fresno-First, Corcoran, Visalia, and Bakersfield-Planz since they all had a robust set of measurements beginning in 1999.

The data shows that in the most recent four years there has been a significant increase in the percentage of days with low PM2.5 concentrations (under 10 µg/m^3) when compared to 1999-2003. This increase can be observed among all of the sites in this analysis, as seen in figure A-20 below representing Fresno-First. Figure A-20 also reveals a dramatic decrease in the percentage of days that exceed the 1997 24-hour PM2.5 standard of 65 µg/m^3.

Figure A-20: Histogram Comparison for Fresno-First



This was also observed among all of the sites, which shows a Valley-wide downward shift in concentrations. This would also explain why some of the sites show an increase in the frequency of concentrations in the middle bin ranges when comparing the most recent four years to the earliest four years. As progress continues to be made in reducing PM2.5, the curve of this distribution will become more sharply pushed to the left as higher concentrations become less frequent and lower concentrations become more frequent. The distributions for the other sites included in this analysis are shown below in figures A-21 through A-24. Note that the most recent four years for Corcoran were 2007-2010 since the site was non-operational in 2011.

Figure A-21: Histogram Comparison for Modesto

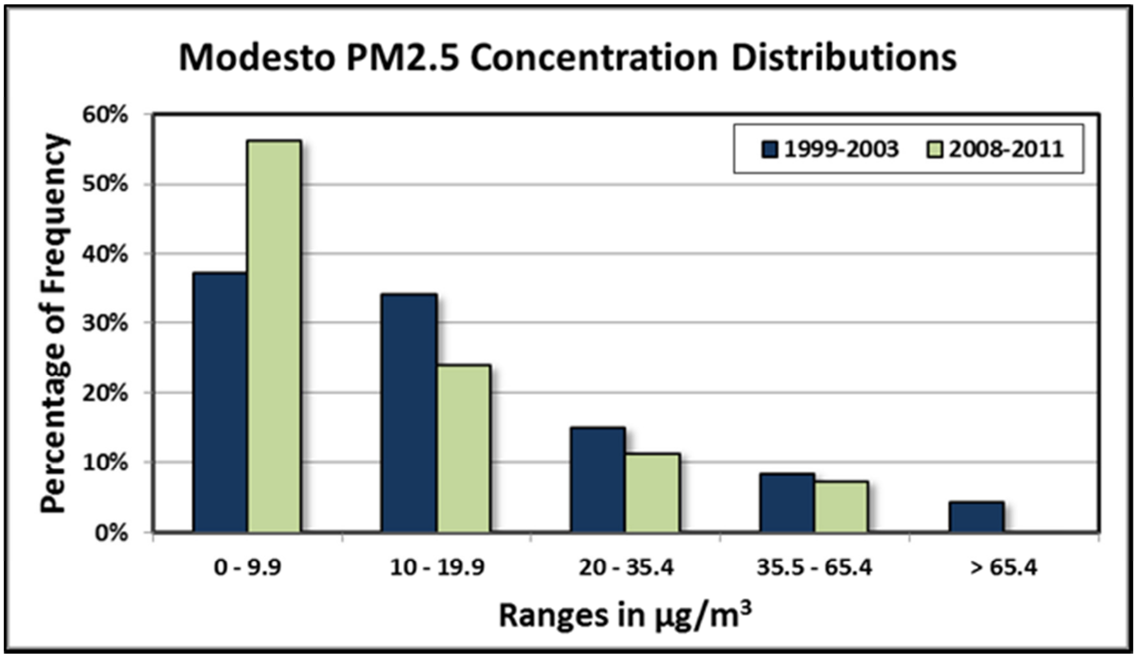


Figure A-22: Histogram Comparison for Corcoran

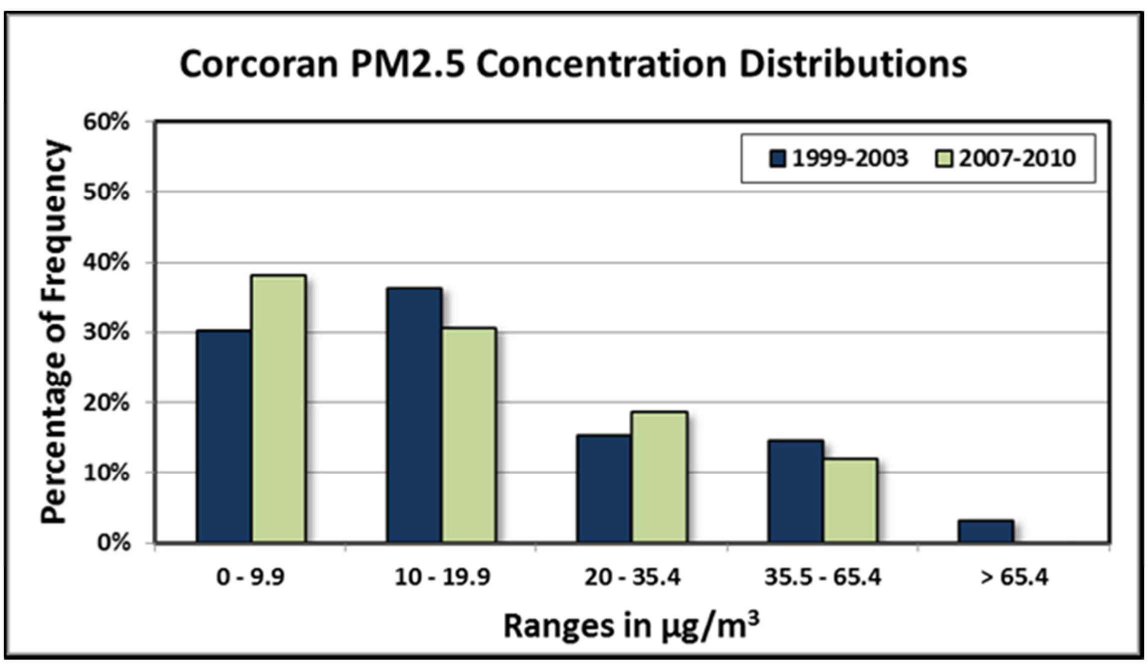


Figure A-23: Histogram Comparison for Visalia

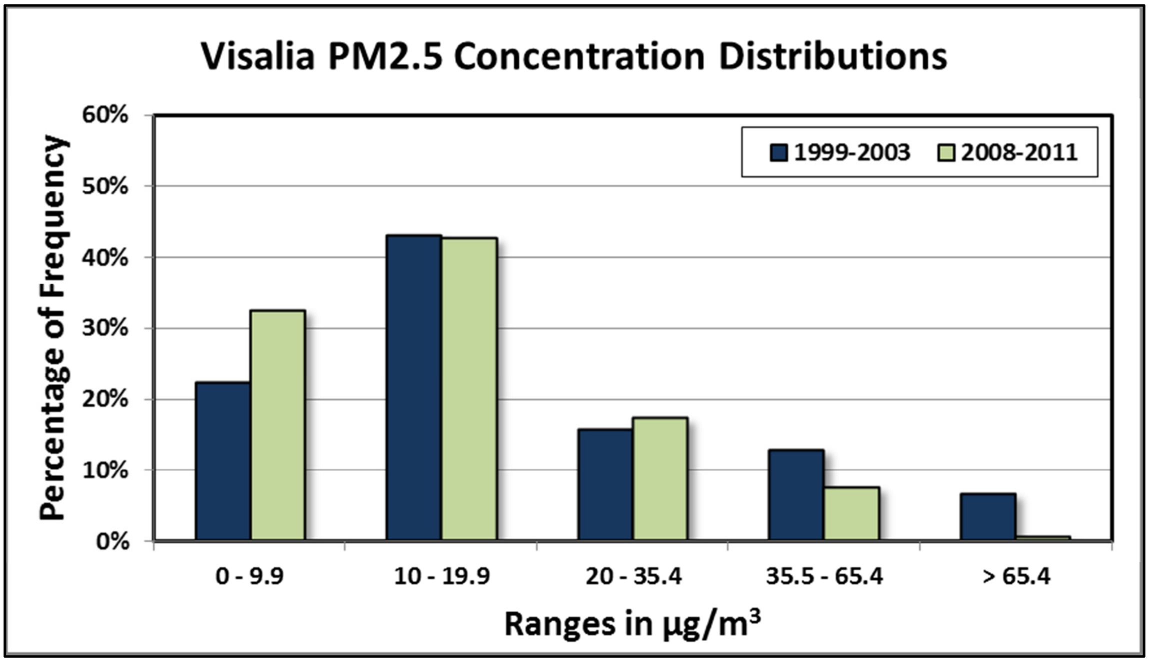
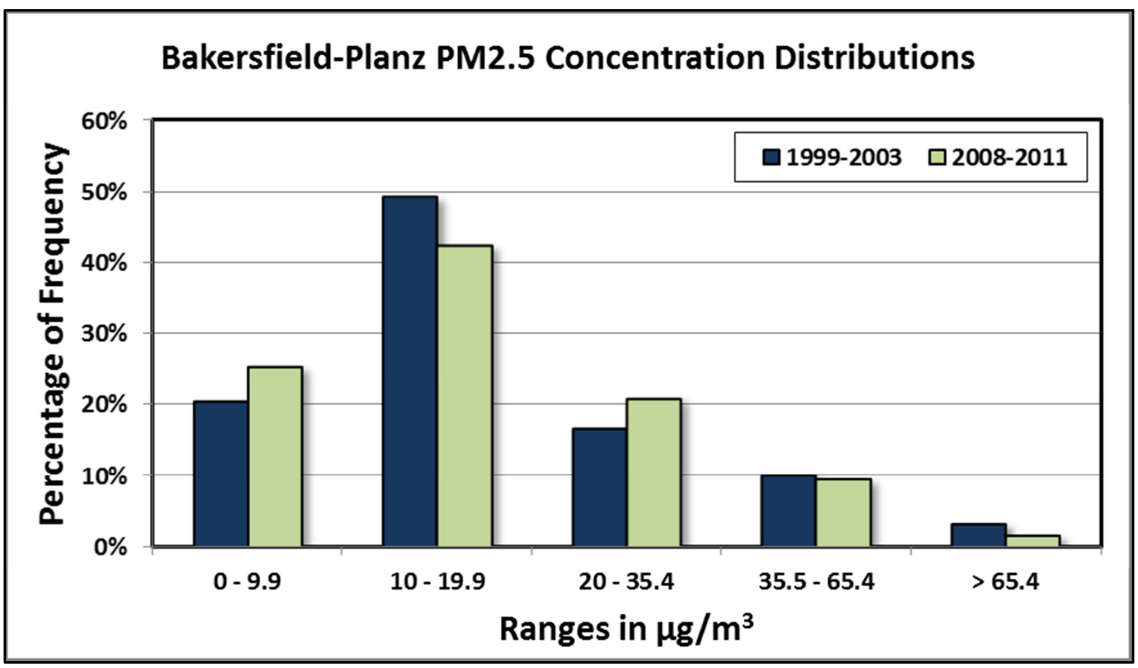


Figure A-24: Histogram Comparison for Bakersfield-Planz



A.6 Forthcoming Analyses

As this plan continues to be developed, a number of additional analyses will be conducted to further explore the trend and nature of the change in air quality within the San Joaquin Valley. These forthcoming analysis efforts may include data distribution comparisons, trends among the species of PM2.5, comparison between weekday and weekend PM2.5 concentrations, and the effectiveness of District's residential wood-burning rule.

In addition, an analysis focusing on the Valley population's exposure to concentrations over the federal PM2.5 standard will also be developed. Even though the District is currently designated as non-attainment of the federal PM2.5 standard, not all areas of the San Joaquin Valley are equally challenged. As time progresses and further emission reductions are achieved, some areas of the Valley will be in attainment of the standard ahead of the rest. The journey to attainment for the San Joaquin Valley will not be an immediate achievement for the entire air basin, but will rather be progression among the population centers.

To address this issue, a population-weighted exposure analysis will be conducted to better project how many residents of the San Joaquin Valley are breathing clean air versus unhealthy air, and how this ratio has changed and will change over time. The District's completed population-weighted exposure analysis will appear in a later draft, including the details and assumptions behind the methodology