PROPOSED

$PM_{2.5}$ IMPLEMENTATION/MAINTENANCE PLAN

AND REDESIGNATION REQUEST

FOR SACRAMENTO $PM_{2.5}$ NONATTAINMENT AREA

For December 3, 2013 Board Hearing

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°F -	degree Fahrenheit
°C -	degree Celsius
$\mu g/m^3$ -	microgram per cubic meter
am -	ante meridiem
APCD -	Air Pollution Control District
AQMD -	Air Quality Management District
AQS -	Air Quality System
ARB -	California Air Resources Board
ARM -	Approved Regional Method
BACT -	Best Available Control Technology
BAM -	β attenuation method
BTU -	British thermal unit
CAA -	Clean Air Act
CARB -	California Air Resources Board
CART -	Classification and Regression Tree Analysis
CCOS -	Central California Ozone Study
CCSCE -	Continuing Study of the California Economy
CEPAM -	California Emission Projection Analysis Model
CFR -	Code of Federal Regulations
CMB -	Chemical Mass Balance
CSN -	Chemical Speciation Network
DMV -	Department of Motor Vehicle
DOF -	Department of Finance
DOT -	U.S. Department of Transportation
DPM -	Del Paso Manor
DV -	Design Value
EC -	Elemental Carbon
EDCAQMD -	El Dorado County Air Quality Management District
EI -	Emissions Inventory
EMFAC -	California’s on-road motor vehicle emission factor model

EPA -	United States Environmental Protection Agency
ERCs -	Emission Reduction Credits
et seq. -	et sequens
FEM -	Federal Equivalent Method
FR -	Federal Register
FRM -	Federal Reference Method
GHG -	Greenhouse Gas
KLAS -	Las Vegas International Airport
KOAK -	Oakland International Airport
KSAC -	Sacramento Executive Airport
KSFO -	San Francisco International Airport
KSUU -	Travis Air Force Base
kt -	knot
m -	meter
m/s -	meter per second
mb -	millibar
mph -	miles per hour
MPA -	Monitoring Planning Area
MPO -	Metropolitan Planning Organization
MSA -	Metropolitan Statistical Areas
MTC -	Metropolitan Transportation Commission (Bay Area)
MTIP -	Metropolitan Transportation Improvement Program
MTP -	Metropolitan Transportation Plan
MTP/SCS2035 -	Metropolitan Transportation Plan and Sustainable Communities Strategy 2035
MVEB -	Motor Vehicle Emissions Budget
NAA -	Nonattainment Area
NAAQS -	National Ambient Air Quality Standard
NCDC -	National Climatic Data Center
NCore -	national core multi-pollutants network
NH_3 -	ammonia

NSR -	New Source Review
NOAA -	National Oceanic and Atmospheric Administration
NORCAL -	Northern California
NO_X -	nitrogen oxides
NWS	National Weather Services
OC -	Organic Carbon
OEHHA -	Office of Environmental Health Hazard Assessment
PCAPCD -	Placer County Air Pollution Control District
pm -	post meridiem
PM -	Particulate Matter
PM_{10} -	Particles 10 microns or less in diameter
$PM_{2.5}$ -	Particles 2.5 microns or less in diameter
PMF -	Positive Matrix Factorization
PSD -	Prevention of Significant Deterioration
RACM -	Reasonably Available Control Measure
RACT -	Reasonably Available Control Technology
RAOB -	Radiosonde Observation
RFP -	Reasonable Further Progress
RPP -	Regional Planning Partnership
SACOG -	Sacramento Area Council of Governments
SACSIM -	Sacramento Activity-Based Travel Simulation Model
SAFETEA-LU -	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SANDWICH -	Sulfate, Adjusted Nitrate, Derived Water, Inferred Carbonaceous mass Hybrid material balance approach
SFNA -	Sacramento Federal Nonattainment Area
SIP -	State Implementation Plan
SMAQMD -	Sacramento Metropolitan Air Quality Management District
SO_2 -	Sulfur Dioxide
SO_X -	Sulfur Oxides
SPM -	Special Purpose Monitor
SSI -	Size-Selective Inlet

STI -	Sonoma Technology Incorporated
SV -	Sacramento Valley
tpd -	tons per day
U.S.C. -	United States Code
UTC	Coordinated Universal Time
VMT -	Vehicle Miles Traveled
VOC -	Volatile Organic Compounds
WFO	Weather Forecasting Office
YSAQMD -	Yolo-Solano Air Quality Management District
Z -	Zulu time or Zero meridian time

1 Introduction

1.1 Background Information

Particulate matter (PM) is the term for the mixture of solid and liquid particles in the ambient air. Particles originate from a variety of activities and processes, and the chemical and physical compositions vary. Components of PM include nitrates, sulfates, elemental carbon, organic carbon compounds, acid aerosols, trace metals, and geologic materials. PM can be directly emitted to the air or can be produced by secondary formation in the atmosphere when precursor gaseous pollutants, such as nitrogen oxides and sulfur dioxide, chemically react to form fine aerosol particles.

Sources of PM are mainly due to human (anthropogenic) activities, such as residential fuel combustion smoke and soot, entrained road dust, and motor vehicle exhaust. PM can also be generated from natural sources such as wildfires.

For air quality monitoring purposes, PM is measured and expressed as the mass of particles in micrograms per cubic meter ($\mu g/m^3$) of air. Ambient PM concentrations can build up in the Sacramento region due to its valley geography, stagnant wintertime meteorology, and urban emission sources. PM may eventually be removed from the atmosphere by gravitational settling or deposition, rainout (attaching to water droplets as they fall to the ground), and washout (being absorbed by water molecules in clouds and later falling to the ground with rain).

Ambient air quality standards for particulate matter focus on the smaller particle sizes that are responsible for adverse health effects because of their ability to reach the lower regions of the respiratory tract. Standards that have been established to protect human health refer to the air pollutant that consists of particles 2.5 microns or less in diameter ($PM_{2.5}$).

The United States Environmental Protection Agency (EPA) promulgated a new 24-hour standard for $PM_{2.5}$ in October 2006 (71 FR 61144). This change strengthened the daily standard from $65\mu g/m^3$ to $35\mu g/m^3$ to protect the general public from health effects caused by exposure to fine particulate matter. Although the Sacramento area had attained the prior $PM_{2.5}$ standards, the EPA Administrator established $PM_{2.5}$ nonattainment designations for the 2006 standard, which became effective on December 14, 2009 (74 FR 58688). In EPA's final designation, a multi-county $PM_{2.5}$ nonattainment area was created in the Sacramento region. The Sacramento Federal $PM_{2.5}$ Nonattainment Area attained the Federal $PM_{2.5}$ health standards on December 31, 2011. This document requests that EPA re-designate the area to attainment for the federal standard.

1.2 Health Impacts

PM is a mixture of very small liquid droplets and solid particles that are suspended in the air. Studies have linked exposure to PM to a variety of significant health problems. While all particle pollution has the ability to create health impacts, $PM_{2.5}$ (fine particles) is especially serious because the particles are so small that they can penetrate deep into the lungs. Consequently, exposure to $PM_{2.5}$ can cause serious health problems and aggravate existing problems. People with heart or lung diseases, children, and older adults are the most likely to be affected by fine particle pollution. However, even if a person is healthy, they may experience temporary symptoms from exposure to elevated levels of particle pollution. (CARB, 2003)

Adverse health effects linked to $PM_{2.5}$ include:

- Increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing;
- Decreased lung function;
- Aggravated asthma;
- Development of chronic bronchitis;
- Irregular heartbeat;
- Nonfatal heart attacks; and
- Premature death in people with heart or lung disease.

Exposure to PM pollution can cause coughing, wheezing, and decreased lung function even in otherwise healthy children and adults. The California Air Resources Board (CARB) and Office of Environmental Health Hazard Assessment (OEHHA) estimate that thousands of elderly people die prematurely each year from exposure to fine particles (Dominici et al., 2006). Before the region attained the standard in 2011, CARB had estimated both the public health and economic impacts caused by exposure to $PM_{2.5}$. For the Sacramento Metropolitan Area[1], CARB estimated (Smith, 2008) that each year $PM_{2.5}$ causes:

- 90 premature deaths;
- 20 hospital admissions;
- 1,200 asthma and lower respiratory symptom cases;
- 110 acute bronchitis cases;
- 7,900 lost work days;
- 42,000 minor restricted activity days

These $PM_{2.5}$ related health effects resulted in an estimated total economic impact of over $3 million per year. (SMAQMD, 2009)

1.3 Description of the Sacramento $PM_{2.5}$ Nonattainment Area

The Sacramento Federal $PM_{2.5}$ Nonattainment Area encompasses all of Sacramento County, the eastern portion of Yolo County, the western portions of El Dorado and Placer counties, and the northeast portion of Solano County. The map (Figure 2.1) in the Chapter 2 displays the nonattainment area boundaries.

1.4 Purpose of the Maintenance Plan and Re-designation Request

Areas that have been designated as nonattainment for the federal $PM_{2.5}$ ambient air quality standard by EPA are required to submit an attainment plan no later than 3 years after the

[1] Sacramento Metropolitan Area includes: El Dorado, Mountain Counties Air Basin; Placer, Mountain Counties Air Basin and Sacramento Valley Air Basin; Sacramento, Sacramento Valley Air Basin; Solano, Sacramento Valley Air Basin; Solano, Sacramento Valley Air Basin; and Yolo, Sacramento Valley Air Basin.

effective date of the designation (December 14, 2012). EPA's recognition that our region met the standard in 2011 suspended this planning requirement.

Once the standard has been met, a nonattainment area may request re-designation to attainment for the standard. To be re-designated the area must, among other things, show that attainment was achieved by permanent and enforceable reductions and that the area will remain below the standard for 10 years after accounting for emissions growth. This document shows that the region has met these requirements and requests that EPA re-designate the area to attainment.

1.5 Maintenance Plan Development Schedule and Public Review Process

This $PM_{2.5}$ maintenance plan was developed by the four air districts that have jurisdiction over the designated Federal $PM_{2.5}$ Nonattainment Area. These air districts include the Sacramento Metropolitan Air Quality Management District (SMAQMD), the Yolo-Solano Air Quality Management District (YSAQMD), the Placer County Air Pollution Control District (PCAPCD), and the El Dorado County Air Quality Management District (EDCAQMD). In addition, CARB provided technical assistance in the development of the emissions inventory and chemical speciation analysis. The Sacramento Area Council of Governments (SACOG), which is the Metropolitan Planning Organization for most of the region, assisted with the generation of planning assumptions used to develop $PM_{2.5}$ motor vehicle emissions budgets for the region.

Prior to submittal to EPA, the Plan will be adopted by all four air district boards and CARB as a revision to the California State Implementation Plan. Prior to adoption of the Plan by any air district or the California Air Resources Board there will be an opportunity for public review and comment, as required under the Clean Air Act (CAA) (40 U.S.C. 7410).

1.6 Overview of Plan Contents

The CAA contains specific requirements that must be met before EPA will re-designate an area. This Plan includes all of the required elements. The $PM_{2.5}$ plan contents are as follows:

FEDERAL CLEAN AIR ACT REQUIREMENTS – Explains the purpose of the maintenance plan and re-designation request and provides details concerning the CAA $PM_{2.5}$ requirements for the nonattainment area. (Chapter 2)

$PM_{2.5}$ MONITORING NETWORK AND AIR QUALITY DATA – Characterizes the network of $PM_{2.5}$ monitoring sites in the nonattainment area, includes data demonstrating that the National Ambient Air Quality Standard (NAAQS) was met, and examines the trends in data collected from the monitoring sites. This section also examines the seasonal characteristics of $PM_{2.5}$ in the nonattainment area. (Chapter 3)

EMISSIONS INVENTORY AND $PM_{2.5}$ SPECIATION ANALYSIS – Discusses $PM_{2.5}$, its precursors, and the breakdown of $PM_{2.5}$ emission sources. These sections also provide a detailed accounting of $PM_{2.5}$ emissions for the base year as well as forecasts for future years. (Chapter 4)

CONTROL MEASURES – Analyze measures that were implemented to achieve attainment and that will provide for maintenance of the $PM_{2.5}$ NAAQS. (Chapter 6)

MAINTENANCE DEMONSTRATION AND MAINTENANCE CONTINGENCY PLAN – Demonstrates that the nonattainment area will be able to remain below the national $PM_{2.5}$ standards through 2024. The contingency plan specifies actions to be taken if the health standards are violated. (Chapters 7 & 8)

TRANSPORTATION CONFORMITY BUDGETS AND GENERAL CONFORMITY – Analyzes several conformity issues. The Clean Air Act requires that federal actions be consistent with the air quality goals of a region. Conformity is separated into those that deal with highway and transit projects (transportation conformity) and those that deal with all other federal actions (general conformity). This Plan establishes regional motor vehicle emission budgets for purposes of transportation conformity and discusses General Conformity, which requires that other reasonably foreseeable federal actions will not compromise the region's maintenance of the $PM_{2.5}$ standard. (Chapters 9 & 10)

REDESIGNATION REQUEST – Demonstrates that the nonattainment area has achieved the $PM_{2.5}$ standard as a result of permanent and enforceable measures. The section also demonstrates that all requirements have been met for a re-designation to attainment of the standard, including emission budgets for evaluation of future transportation planning actions by the Sacramento Area Council of Governments and the Metropolitan Transportation Commission to meet transportation conformity requirements. (Chapter 11)

SUMMARY AND CONCLUSIONS – Summarizes the contents of the Plan and presents the Plan's final conclusions. (Chapter 12)

1.7 References

CARB. Progress Report and Research Plan on the Air Resources Board's Vulnerable populations Research Program, CA: California Air Resources Board, Sacramento, CA [2003.]

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EPA, *National Ambient Air Quality Standards for Particulate Matter*, Federal Register, Volume 71, October 17, 2006, p. 61198.

EPA, *Air Quality Designations for the 2006 24-Hour Fine Particle ($PM_{2.5}$) National Ambient Air Quality Standards*, Federal Register, Volume 74, November 13, 2009, p. 58688.

Federal Clean Air Act, 42 U.S.C. 7410, *Title 1, Part A, Section 110*, [1990.], referenced January 17, 2012.

SMAQMD, *Rule 421: Amendment Fact Sheet,* CA: Sacramento Metropolitan Air Quality Management District, Sacramento, CA [2009.]

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2 Federal Clean Air Act Requirements

This chapter provides background information and a discussion of the various requirements contained in the Clean Air Act (CAA) and other relevant regulations and guidance. The section also identifies the applicable chapters within the plan that demonstrate compliance with specific requirements.

2.1 National Ambient Air Quality Standards (NAAQS) – CAA Section 109

On July 18, 1997, the United States Environmental Protection Agency (EPA) revised the National Ambient Air Quality Standards (NAAQS) for particulate matter to add new standards for fine particle pollution, using $PM_{2.5}$ as the indicator. EPA established annual and 24-hour standards for $PM_{2.5}$ (62 FR 38652). The primary and secondary annual $PM_{2.5}$ standards were set at a level of 15 micrograms per cubic meter ($\mu g/m^3$), based on a 3-year average of annual mean $PM_{2.5}$ concentrations. Primary and secondary 24-hour $PM_{2.5}$ standards were set at a level of 65 $\mu g/m^3$, based on a 3-year average of the 98^{th} percentile of 24-hour $PM_{2.5}$ concentrations.

In 2006, EPA strengthened the primary and secondary 24-hour $PM_{2.5}$ NAAQS from 65 $\mu g/m^3$ to 35 $\mu g/m^3$, but retained the primary and secondary annual $PM_{2.5}$ NAAQS at 15 $\mu g/m^3$. The revised 24-hour $PM_{2.5}$ standards were published on October 17, 2006 (71 FR 61144) and became effective on December 18, 2006. On December 14, 2012 EPA strengthened the primary annual $PM_{2.5}$ standard to 12 $\mu g/m^3$ (78 FR 3086, January 15, 2013) effective March 18, 2013.

Numerous health studies show that short-term exposure to $PM_{2.5}$ is associated with increased mortality and a range of serious respiratory and cardiovascular effects. Chapter 1 – Introduction, includes a discussion on the adverse health effects linked to $PM_{2.5}$ exposure.

2.2 Designations – CAA Section 107(d)(1)

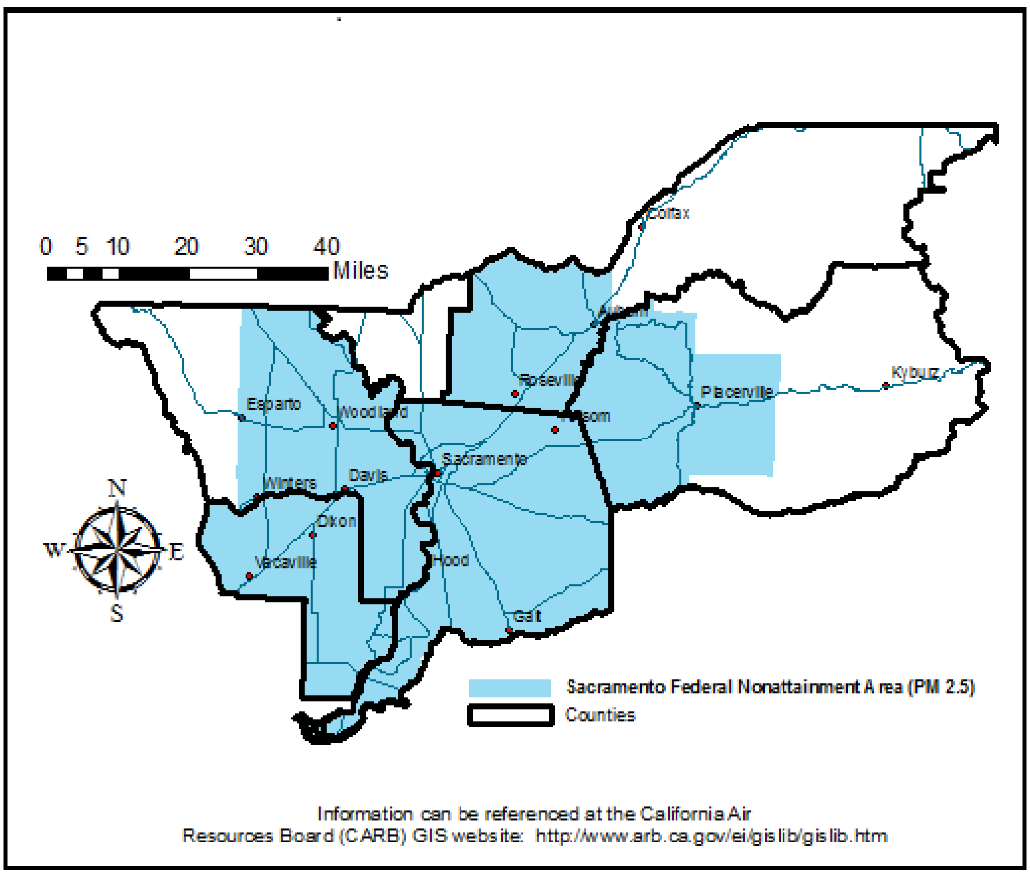
CAA Section 107(d)(1)(A)(i) defines a nonattainment area as any area that does not meet an ambient air quality standard, or that contributes to ambient air quality in a nearby area that does not meet the standard. If an area meets either prong of this definition, then EPA is required to designate the area as ‘‘nonattainment.’’ EPA designated the Sacramento Area attainment/unclassified for the 1997 annual and 24-hour $PM_{2.5}$ standard (70 FR 944, January 5, 2005) effective April 5, 2005. In December 2007, CARB recommended that EPA find that the nonattainment area only included Sacramento County (CARB, 2007). In August 2008, EPA proposed an expanded nonattainment area that included Sacramento County and portions of El Dorado, Placer, Solano, and Yolo counties. In EPA's technical analysis (EPA, 2008), it states that "the [State] recommended boundary does not include the population that would be exposed to high levels of $PM_{2.5}$ represented by the Sacramento design value, nor does it address transport that can occur from traffic and other sources within the relatively flat valley floor of the Sacramento Valley. In addition, the State relied on future mobile source controls at a statewide level to address NO_X emissions and, therefore, discounted mobile sources as an important consideration in their analysis. EPA believes that there is a significant contribution from mobile sources, both commuting and commercial truck traffic, in the Sacramento area."

EPA designated the Sacramento Area as nonattainment for the 2006 24-hour standard, effective on December 14, 2009 (40 CFR 81.305). This designation was based on air quality monitoring data from Federal Reference Method (FRM) monitors in the region for calendar years 2006 through 2008. EPA set nonattainment area boundaries using nine factors listed in their 2007 Guidance (EPA, 2007) (e.g. traffic and commuting patterns, jurisdictional boundaries, geography and topography). After an evaluation of these factors, EPA determined that the boundaries for the Sacramento nonattainment area would include all of Sacramento County and portions of Placer, Yolo, Solano, and El Dorado counties. Although EPA has not yet finalized designations for the 2013 annual $PM_{2.5}$ NAAQS, Sacramento's 2012 peak design value for the annual standard was 9.5 $\mu g/m^3$.

$PM_{2.5}$ exceedances most often occur in Sacramento during the winter months and speciation data suggest that residential wood burning and mobile source emissions are the most important sources. In fact, area source data for Sacramento and the surrounding counties, with the exception of Yolo County, show that residential wood burning is the dominant source of $PM_{2.5}$. With respect to mobile sources, Sacramento and the surrounding counties have significant mobile source emissions which, combined with the commuting patterns, suggest a link between exceedances in Sacramento and mobile source emissions from the surrounding counties.

Figure 2.1 shows the boundaries of the Sacramento Federal nonattainment area for $PM_{2.5}$.

Figure 2.1 Sacramento Federal Nonattainment Area - $PM_{2.5}$



2.2.1 Attainment of the 24-Hour $PM_{2.5}$ NAAQS

The 24-Hour $PM_{2.5}$ NAAQS is attained when the most recent three-year average of the 98^{th} percentile of the 24-hour $PM_{2.5}$ concentration is at or below 35 $\mu g/m^3$ as outlined in 40 CFR Part 50, Appendix N. Ambient air quality monitoring data from 2009 – 2011 show that the Sacramento nonattainment area has attained the standard. See Chapter 3 – $PM_{2.5}$ Monitoring Network and Air Quality Data for a more detailed discussion on the region's attainment of the 2006 $PM_{2.5}$ NAAQS.

After an area's air quality data shows that it meets the $PM_{2.5}$ NAAQS the State may request that the area be re-designated to attainment. Until the area is re-designated to attainment by EPA, CAA nonattainment area requirements apply. EPA approved a clean data finding for the Sacramento nonattainment area effective August 14, 2013 (78 FR 42018, July 15, 2013).

The remainder of this chapter summarizes some of the key CAA requirements met by this plan. It should not be considered a comprehensive list of all provisions related to approval of this re-designation request.

2.3 Re-designations – CAA Section 107(d)(3) and associated guidance and regulations

The purpose of this plan is to request re-designation to attainment. CAA Section 107(d)(3) specifies five criteria for re-designation to attainment.

1. EPA must determine that the area has met the $PM_{2.5}$ NAAQS
2. EPA must fully approve the State's implementation plan
3. EPA must determine that the improvement in air quality is due to permanent and enforceable reductions in emissions
4. EPA must fully approve a maintenance plan for the area (see Section 2.6 for further discussion)
5. EPA must find that the State has met all applicable requirements under CAA section 110 and part D (Sections 171 et seq.)

Section 2.4 of this chapter discusses in detail State Implementation Plan (SIP) requirements and Section 2.5 chapter discusses Part D requirements.

2.4 SIP requirements – CAA Section 110 (and 319 for monitoring) and associated guidance and regulations

State and air district plans for attaining and maintaining the NAAQS are outlined in a planning document known as the state implementation plan (SIP). The SIP provides for implementation, maintenance and enforcement of the NAAQS.

CAA Section 110(a) contains general requirements for State Implementation Plans regarding the content, public review, adoption, and submittal of plans. CAA Section 110(a)(2) identifies specific elements that are compiled and submitted as what is known as an "infrastructure" SIP. The California Air Resources Board submitted a comprehensive CAA Section 110(a)(2) SIP in response to CAA of 1970 which was approved by EPA in 1979 in 40 CFR 52.220. On November 16, 2007, CARB submitted a revision which fulfilled required elements for the $PM_{2.5}$

annual standard and the 24-hour standards. Additionally, on July 7, 2009, CARB submitted a revision to address one outstanding element that the previous submittals did not cover concerning emergency powers and adequate emergency episode plans for the $PM_{2.5}$ standards.

The 1990 CAA Amendment did not establish specific requirements for $PM_{2.5}$ because there were no $PM_{2.5}$ air quality standards at that time. As a result, EPA established a rule to explain how the CAA would be interpreted to implement the 1997 fine particle ($PM_{2.5}$) NAAQS. That rule, the "*Clean Air Fine Particle Implementation Rule; Final Rule*" (72 FR 20586), became effective on May 29, 2007. On January 4, 2013, in *Natural Resources Defense Council v. EPA,*[2] the DC Circuit Court of Appeals remanded EPA's "Final Clean Air Fine Particle Implementation Rule" and the "Implementation of the New Source Review Program for Particulate Matter Less than 2.5 Micrometers ($PM_{2.5}$)" to be re-promulgated pursuant to CAA Subpart 4. The Court did not address the merits of EPA's Implementation Rules. This Plan incorporates the requirements of Subpart 4 and the requirements of the Implementation Rules.

EPA's rules describe the process by which EPA will determine that an area has attained the fine particle standard and how it interprets CAA provisions with regard to:

- Precursor and other pollutants contributing to $PM_{2.5}$ formation,
- Attainment demonstrations,
- Reasonably available control measures (RACM) analysis,
- Reasonable further progress (RFP) plans,
- Contingency measures (related to meeting attainment and RFP),
- New Source Review/Prevention of Serious Deterioration (NSR/PSD),
- Transportation and General Conformity,
- Ambient Monitoring,
- Other planning requirements related to attainment of the $PM_{2.5}$ NAAQS,
- Emission inventories,
- improved source monitoring, and
- Emergency episodes.

2.4.1 Precursor and other pollutants contributing to $PM_{2.5}$ formation

The precursor gases associated with the formation of $PM_{2.5}$ are sulfur dioxide (SO_2), oxides of nitrogen (NO_X), volatile organic compounds (VOCs), and ammonia (NH_3). These precursors undergo chemical reactions in the atmosphere to form secondary particulate matter. This secondary particulate matter, along with directly emitted fine PM, makes up ambient $PM_{2.5}$ concentrations. As a result, emission inventories must include the most up-to-date information on the pollutants and their precursors[3] that contribute to $PM_{2.5}$ ambient concentrations to effectively evaluate and develop control strategies in $PM_{2.5}$ nonattainment and maintenance areas.

[2] *Natural Resources Defense Council v. EPA*, DC Circuit Court of Appeals, 2013, 706G.3d.428.

[3] 40 CFR 51.1000

Sulfur dioxide and NO_X must be evaluated when developing control strategies for all areas (nonattainment and maintenance). (72 FR 20586) VOC and NH_3 are not required unless it is shown that these precursors are a “significant contributor” to an area’s $PM_{2.5}$ ambient concentrations.

An assessment of $PM_{2.5}$ ambient concentrations using Chemical Mass Balance (CMB) modeling can be used to quantify the relative contribution for each precursor and may identify contributions from specific source categories. A detailed discussion of this assessment is contained in Chapter 7 – Maintenance Demonstration.

2.5 Nonattainment Plan Requirements

CAA Section 172 contains requirements for nonattainment plans (SIPs) including provisions regarding classification and attainment dates, plan submission schedules, and nonattainment plan provisions. A list of CAA requirements applicable to this plan is outlined in Table 1 at the end of this chapter. Some key nonattainment plan requirements are briefly described below:

2.5.1 Attainment demonstrations, RACM, RFP, and Contingency Measures

CAA Section 172(c) and 189(a)(1) require nonattainment areas to submit a nonattainment plan. This plan consists of: (1) a technical analysis that locates, identifies and quantifies sources of emissions contributing to area violations of the $PM_{2.5}$ NAAQS 172(c)(3) and (4); (2) analyses of future year emissions reductions and air quality improvement resulting from already-adopted federal, state and local control programs and from potential new local control programs to meet reasonably available control measures (RACM) requirements (189(a)(1)(C)), including reasonably available control technology (RACT) 172(c)(1) and reasonable further progress (RFP) (172(c)(2)) requirements in the area; (3) other adopted emission reduction measures required by CAA Section 172(c)(6); and (4) contingency measures required under CAA section 172(c)(9).

EPA suspends certain planning requirements for an area that has 3 consecutive years of certified air quality data showing that it meets (attained) the $PM_{2.5}$ standard. (40 CFR 51.1004(c). Although the regulation specifically references Subpart 1 provisions (in CAA Section 172), EPA suspended the attainment related planning obligations in Subpart 4, as well as Subpart 1, in making Sacramento’s Determination of Attainment (78 FR 42019 July 15, 2013). Areas that have attained the standards are not required to submit attainment and reasonable further progress demonstrations, RACM, and attainment plan contingency measures as long as the area continues to meet the standard.

2.5.2 Control Measures

The SIP must “provide for the implementation of all reasonably available control measures as expeditiously as practicable (including such reductions in emissions from existing sources…through the adoption, at a minimum, of reasonably available control technology)”. (CAA Section 172(c)(1) and 189(a)(1)(C)). EPA rules require controls to be evaluated for $PM_{2.5}$, SO_2, NO_X, but not for VOC or NH_3 unless they are demonstrated to significantly contribute to $PM_{2.5}$ concentrations. (40 CFR 51.1002). This plan does not demonstrate that VOC or NH_3 significantly contribute to $PM_{2.5}$. See Chapter 7 – Maintenance Demonstration for further information. A discussion of control measures is included in Chapter 6 – Control Measures. As noted previously, because the region had already attained, this requirement has been suspended.

2.5.3 Emissions Inventory

The SIP must include, "a comprehensive, accurate, current inventory of actual emissions from all sources of the relevant pollutant or pollutants in such area, including such periodic revisions as the [EPA] may determine necessary to assure that the requirements of this part are met." (CAA Section 172(c)(3)). The SIP needs to "identify and quantify the emissions, if any, of any such pollutant or pollutants which will be allowed, in accordance with CAA Section 173(a)(1)(B), from the construction and operation of major new or modified stationary sources in each such area." Although EPA suspends certain planning obligations, emission inventories are still required to be submitted. (40 CFR 51.1008). Emission inventories must include the best available information on all pollutants and precursors of fine particulate matter. The main precursors associated with fine particular matter are SO_2, NO_X, VOCs, and NH_3 (40 CFR 51.1000). This emission inventory must reflect growth in emissions from increases in population, motor vehicles use, and other factors. The inventory must also reflect the impact of federal, state, and local control strategies. A detailed discussion of the region's emission inventories is in Chapter 4 – Emissions Inventory.

2.5.4 New Source Review/Prevention of Significant Deterioration (NSR/PSD)

The NSR program was created to ensure that stationary sources of air pollution are constructed or modified in a manner consistent with air quality goals in the area. EPA established NSR provisions for $PM_{2.5}$ precursors of $PM_{2.5}$, including major source thresholds, significant emission rates, and offset ratios effective July 15, 2008 (73 FR 28321).

SIPs must include provisions to require permits for the construction and operation of new or modified major stationary sources in the nonattainment area (CAA Sections 172(c)(5), 173 and 189(a)(1)(A) SIPs must include preconstruction permit requirements applicable to "major" stationary sources of $PM_{2.5}$ and $PM_{2.5}$ precursors. As discussed in Section 2.5.2, the $PM_{2.5}$ precursors for emission control purposes are NO_X and SO_2.

When Sacramento is re-designated to attainment for the $PM_{2.5}$ NAAQS, $PM_{2.5}$ major stationary sources will be subject to the PSD (40 CFR 51.166) rather than the federal nonattainment NSR provisions (73 FR 28321). Chapter 6 – Control Measures, discusses the status of Sacramento regional air districts permit requirements.

2.5.5 Ambient Monitoring

CAA Sections 110(a)(2)(B), 319 and 40 CFR 58 and 50 Appendixes L & N require the establishment of an air quality monitoring network that uses standardized air quality monitoring criteria and methodologies to measure ambient air quality. These regulations also ensure air quality monitoring meets requirements outlined in implementation plans, and provides for data analysis, reporting, and recordkeeping and reporting to the general public. A detailed description of the ambient air quality monitoring network and its objectives for the Sacramento Federal

$PM_{2.5}$ Nonattainment Area are discussed in greater detail in Section 3.2 of Chapter 3 – $PM_{2.5}$ Monitoring Network and Air Quality Data.

2.5.6 Other planning requirements related to the attainment of the $PM_{2.5}$ NAAQS

To ensure this plan meets the requirements for an approvable SIP, additional planning objectives relating to attainment of the $PM_{2.5}$ NAAQS and plan submittals must be addressed.

Public Noticing requirements - provide public notice of the proposed adoption of plans and the opportunity for the public to submit written comments (CAA 110(a)). States are required to hold a public hearing or provide the public the opportunity to request a public hearing prior to any plan adoption. The specific noticing requirements are outlined in 40 CFR 51.1002 and in EPA guidance (McCabe, 2011).

Emergency Episode requirements - 40 CFR Part 51 Subpart H requires SIPs to address emergency pollution episodes and contain provisions to prevent air pollution concentrations from reaching levels determined to cause significant harm to human health. The requirement for a state to submit an emergency episode plan is based on a priority classification. This priority classification uses information on the severity of air quality in a region to determine the applicability of an emergency episode plan and the specific plan requirements. While EPA has yet to establish the specific $PM_{2.5}$ levels for the priority classifications, it did issue interim guidance (Harnett, 2009) that only required States with 24-hour $PM_{2.5}$ concentrations over $140.4 \mu g/m^3$, in the most recent three years of data, to develop an emergency episode plan for $PM_{2.5}$. States that do not meet that threshold would be classified Priority III regions and emergency episode plans would not be required[4]. CARB's analysis (CARB, 2009) of three years of recent data showed that California should be classified as a Priority III region and therefore, an emergency episode plan is not required.

2.6 Maintenance Plans

CAA Section 107(d)(3)(E)(iv) requires areas to prepare a maintenance plan to qualify for redesignation. CAA Section 175A contains planning requirements pertaining to the general framework of a maintenance plan. A maintenance plan is a SIP revision that is submitted after a nonattainment area attains the applicable primary NAAQS. CAA Section 175A requires a maintenance plan to:

- Provide for maintenance of the NAAQS for at least 10 years after re-designation. (CAA Section 175A(a))
- Contain any additional measures necessary to ensure the area stays in attainment. (CAA Section 175A(a))
- Include contingency provisions to ensure prompt correction of any violation of the standard after re-designation, including implementing all control measures contained in the nonattainment SIP before re-designation. (CAA Section 175A(d))

[4] 40 CFR 51.152

EPA may also require a SIP revision if the region fails to maintain the NAAQS (CAA Section 110(k)(5)).

2.6.1 General and Transportation Conformity

CAA Section 176(c)(1)(A) prohibits federal entities from performing actions in nonattainment or maintenance areas that do not conform to the SIP for the attainment and maintenance of the NAAQS. The purpose of conformity is to:

- Ensure actions do not cause or contribute to new violations,
- Ensure actions do not increase the frequency or severity of violations, and
- Ensure attainment and maintenance of the NAAQS.

General conformity and transportation conformity apply to all federal actions except for specified exempt projects, actions that are below established thresholds (*de minimis* emissions), and actions that are presumed to conform. Transportation conformity is the federal regulatory procedure to ensure transportation projects do not interfere with air quality goals and plans. Federal agencies must not approve or fund transportation plans and projects unless they are consistent with state implementation plans, including maintenance plans. Motor vehicle emissions budgets (MVEBs) are established in air quality plans using motor vehicle related emissions information and associated transportation activity data provided by the metropolitan transportation organization (MPO). A more detailed discussion of how conformity is addressed and can be demonstrated is included in Chapter 9 – Transportation Conformity Budgets and Chapter 10 – General Conformity.

2.6.2 Contingency Plan

The SIP needs to contain contingency provisions to assure that the region will promptly correct any violation of the standard that occurs after the re-designation of the area. (CAA Section 175A(d)). The provisions must include a requirement that the State implement all measures with respect to the control of the air pollutant concerned that were contained in the state implementation plan before re-designation. The failure of any re-designated area to maintain the national ambient air quality standard would not result in the need for the State to revise the plan unless EPA requires a revision (CAA Section 110(k)(5)). A detailed discussion of this plan's contingency provisions and how they will be applied is contained in Chapter 8 – Maintenance Contingency Plan.

CAA Section 175A(b) also specifies that a subsequent maintenance plan is required 8 years after re-designation. This second plan must provide for maintenance of the NAAQS for 10 more years after expiration of the first 10-year maintenance period.

2.7 Conclusions

CAA Section 107(d)(3)(E) contains the applicable provisions for EPA to re-designate an area to attainment. The requirements have been fulfilled and are addressed in this $PM_{2.5}$ Plan:

1. Attained the applicable NAAQS.

   Chapter 3 of this $PM_{2.5}$ plan includes air quality data showing attainment and the current $PM_{2.5}$ air quality monitoring network in the Sacramento nonattainment area in accordance with 40 CFR 58 – Ambient Air Quality Surveillance.

2. Fully approved applicable implementation plan under CAA Section 110(k).

   This plan document includes the required elements for EPA to fully approve the Sacramento Region's $PM_{2.5}$ Implementation Plan.

3. The improvement in air quality is due to permanent and enforceable reductions in emissions resulting from implementation of the applicable implementation plan and applicable Federal air pollutant control regulations and other permanent and enforceable reductions.

   Chapter 6 of this $PM_{2.5}$ Plan includes and describes the permanent and enforceable control measures implemented in the Sacramento region, which were responsible for bringing the area into attainment.

4. Fully approved maintenance plan, including a contingency plan, for the area pursuant to CAA Section 175A.

   Chapters 7 and 8 contain the maintenance plan provisions and discuss how this plan meets the required elements for EPA to fully approve this $PM_{2.5}$ Maintenance Plan.

5. Meets all relevant requirements under CAA Section 110 and Part D, including Section 172(c) nonattainment plan requirements.

   This Plan, after being considered at a noticed public hearing, and adopted, will be submitted to EPA as required under (40 CFR 51 Appendix V) and provides for maintenance of the 24-hour $PM_{2.5}$ primary standard in the Sacramento region.

   a. Chapter 3 discusses the establishment and operation of the monitoring network necessary to monitor, compile, and analyze data on ambient air quality, and how that data is made available to the other regulatory agencies and the public.
   b. Chapter 4 documents a comprehensive updated inventory of actual emissions from all sources of $PM_{2.5}$ and $PM_{2.5}$ precursor emissions of NO_X, SO_2, NH_3, and VOCs in the Sacramento nonattainment area.
   c. Chapter 6 describes the new source permit programs that require preconstruction review and permits for the construction and operation of new or modified major stationary sources of $PM_{2.5}$ and applicable $PM_{2.5}$ precursors. Upon re-designation to attainment for the $PM_{2.5}$ NAAQS, federal new source review permitting regulations for major stationary sources would no longer apply and prevention of significant deterioration requirements would be in effect.

2.8 References

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EPA. *Interpretation of the National Ambient Air Quality Standards for $PM_{2.5}$,* Code of Federal Regulations, 40 CFR 50, Appendix N. Reference. 17 October 2011.

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McCabe, Janet and Becky Weber. *Guidelines for Preparing Letter Submitting State Implementation Plans (SIPs) to EPA and for Preparing Public Notices for SIPs*. November 22, 2011. [2011.]

Table 2.1 2006 $PM_{2.5}$ Regulation/Policy Summary

Federal CAA	Requirement	Regulation	Guidance/Policies	Plan Chapter
172(b) and 189(a)(1)(B)	Attainment demonstration	51.1007 51.1004(c) –clean data		2
172(c)(1) and 189(a)(1)(C)	RACM/RACT	40CFR51.1010 51.1004(c) –clean data		2/6
172(c)(2) and 189(c)	RFP	40CFR51.1009 51.1004(c) –clean data		2
172(c)(3)	Emission inventory	40CFR51.1008 40CFR51.1000 Precursors		4
172(c)(4)	Major sources	40CFR51 Subpart A		6
172(c)(5) and 189(a)(1)(A)	Permitting	40CFR51.166 PSD	Part D NSR requirements for Areas Requesting Re-designation to Attainment (Mary D. Nichols, October 14, 1994) Revised Policy to Address Reconsideration of Inter-pollutant Trading Provisions for Fine Particles ($PM_{2.5}$) (Gina McCarthy, July 21, 2011)	6
172(c)(6) and 189(e)	Other control measures Precursor control requirements	40CFR51.1000		6

Federal CAA	Requirement	Regulation	Guidance/Policies	Plan Chapter
110(a) and 172(c)(7)	Other Planning requirements	See below	Guidance on SIP Elements Required Under Sections 110(a)(1) and (2) for the 1997 8-hour Ozone and $PM_{2.5}$ NAAQS (William T. Harnett, October 2, 2007) Guidance of SIP Elements Required Under Sections 110(a)(1) and (2) for the 2006 24 hour $PM_{2.5}$ NAAQS (William T. Harnett, September 25, 2009) Guidelines for Preparing Letters Submitting SIPS to EPA and for Preparing Public Notices for SIPs (Janet McCabe & Becky Weber, November 22, 2011)	2
172(c)(8)	Equivalent techniques			N/A
172(c)(9)	Contingency Measures for attainment/RFP	40CFR51.1012 51.1004(c) –clean data		2

Table 2.1 Cont'd - 2006 $PM_{2.5}$ Regulation/Policy Summary

Other Requirements				
107(d)(1)(A)(i)	Nonattainment designation	40CFR81.305		1
107(d)(3)(E)	Re-designation	None	Procedures for Processing Requests to Re-designate Areas to Attainment (John Calcagni, September 4, 1992)	11
109	NAAQS	71FR61144, 40CFR50.13		2
110(k)	EPA action on plan submittals	51.103 40CFR51 Appendix V	Processing of SIP Submittals (John Calcagni, June23, 1992)	See Note [5]
173	Permitting Requirements	See above 172(c)(5)		6
175A	Maintenance plans		See Re-designation above.	7 & 8
176	Conformity	40CFR93		9 & 10
179	Sanctions	40CFR52.31		N/A

[5] Note: EPA actions on the California SIP can be found at: http://yosemite.epa.gov/r9/r9sips.nsf/Casips?readform&count=100&state=California

319	Air monitoring	40CFR50: Appendix L - FRM Appendix N – Interpretation NAAQS 40CFR58 Ambient Air Quality Surveillance		3

N/A = Not applicable to this plan

3 $PM_{2.5}$ Monitoring Network and Air Quality Data

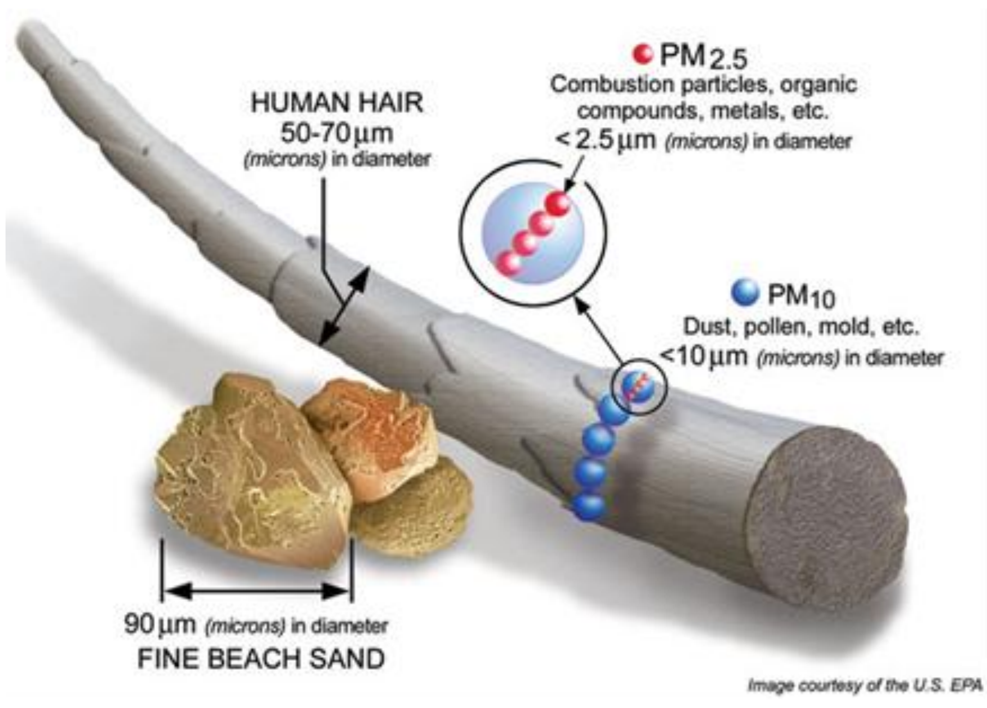
3.1 Introduction to $PM_{2.5}$ data

Chapter 3 discusses $PM_{2.5}$ air quality monitoring and air quality data. This chapter discusses the Sacramento region's $PM_{2.5}$ monitoring network and the region's current attainment status, as well as the conclusions from the EPA's "clean data" findings. This chapter also discusses the characterization of the seasonality of the $PM_{2.5}$ problems in the region and the declining trend of $PM_{2.5}$ concentrations.

Particulate matter (PM) is the term for a mixture of solid particles or liquid droplets found in the air. Particles come in many sizes and shapes and originate from a variety of sources. Some particles, known as *primary particles*, are emitted directly from a source such as motor vehicles, fireplaces, woodstoves, power plants, construction demolition, and wind-blown dust. Other particles, called *secondary particles,* are formed by complicated reactions in the atmosphere between pollutants such as sulfur dioxide (SO_2) and nitrogen oxides (NO_X).

The ambient air quality standards for PM focus on small particles that are responsible for adverse health effects. State and federal PM standards are set for: particles 10 microns or less in diameter (PM_{10}) and the smaller subset that is 2.5 microns or less in diameter ($PM_{2.5}$). Figure 3.1 illustrates the size of PM_{10} and $PM_{2.5}$ by comparison with the other substances.

Figure 3.1 Diameter Comparison: Human Hair, Sand, PM_{10}, and $PM_{2.5}$



Sacramento meets the National Ambient Air Quality Standards (or NAAQS) for PM_{10}, and was designated attainment/unclassified for the 1997 annual and 24 hour $PM_{2.5}$ NAAQS. On October

17, 2006[6], the United States Environmental Protection Agency (EPA) promulgated a new 24-hour (daily) standard for $PM_{2.5}$. This change lowered the daily standard from 65µg/m^3 to 35µg/m^3 and maintained 15µg/m^3 as the annual standard to protect the general public from short term exposure of fine particles. Table 3.1 shows the averaging times and the primary and secondary standards set forth by EPA for $PM_{2.5}$.

Table 3.1 Current federal air quality standard for $PM_{2.5}$

Pollutant	Averaging Times	Primary Standard	Secondary Standard
Particulate Matter ($PM_{2.5}$)	24 Hour	35 µg/m^3	Same as Primary
	Annual Arithmetic Mean	15 µg/m^3	Same as Primary

On November 13, 2009[7], EPA issued final area designations for the 24-hour standard for $PM_{2.5}$. EPA designated 31 areas[8], including the Sacramento area, as a “nonattainment area” for the new 24-hour $PM_{2.5}$ standard. This designation was based on the 2006-2008[9] data collected from five monitoring sites around the Sacramento area. The Sacramento $PM_{2.5}$ nonattainment area includes all of Sacramento County and portions of El Dorado, Placer, Yolo, and Solano counties as shown in Figure 3.2.

On December 14, 2012 EPA strengthened the primary annual $PM_{2.5}$ standard to 12 µg/m^3 (78 FR 3086, January 15, 2013) effective March 18, 2013. Although EPA has not yet finalized designations for the 2013 annual $PM_{2.5}$ NAAQS, Sacramento will likely attain the 2013 NAAQS with a 2012 peak design value for the annual standard of 9.5 µg/m^3.

The severity of $PM_{2.5}$ pollution and the progress towards attainment can be characterized by analyzing ambient air quality data collected over an extended period of time. The region currently has ten $PM_{2.5}$ monitoring sites, five of which are federal reference monitors used to determine if the region has attained the standard. Among these five monitoring sites, the Sacramento-Del Paso Manor (DPM) site was the peak site in the region for 8 of the past 10 years. Therefore, data trends for peak regional concentrations will mostly likely be represented by concentrations at the DPM site. Other sites in the region follow a similar historical data trend to the DPM site.

3.2 $PM_{2.5}$ Monitoring Network

As required by federal regulations, CARB and the local air districts divided California into 18 areas called Monitoring Planning Areas (MPAs)[10] for the purpose of planning and implementing a $PM_{2.5}$ monitoring network. The MPAs provide geographical divisions for $PM_{2.5}$ monitoring network planning based on an analysis of population, political boundaries, geography, and meteorology. With few exceptions, the boundaries of the MPAs correspond to the boundaries of

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[6] 40 CFR Part 50: National Ambient Air Quality Standards for Particulate Matter
[7] 40 CFR Part 81: Air Quality Designations for the 2006 24-Hour Fine Particle ($PM_{2.5}$) National Ambient Air Quality Standards
[8] 74 FR 58689
[9] 74 FR 58697
[10] 62 FR 38764

the various air basins in California. The $PM_{2.5}$ network was designed to meet the following EPA monitoring objectives[11]:

- Provide air pollution data to the general public in a timely manner,
- Support compliance with ambient air quality standards and emission strategy development, and
- Support air pollution research studies that can be used to conduct health effect assessments, atmospheric processes or monitoring methods development work.

The minimum number of monitors for each pollutant is based on the Metropolitan Statistical Areas (MSA) population as described in 40 CFR 58 Appendix D. The Sacramento-Arden-Arcade-Roseville MSA has a population of 2.1 million (U.S. Census Bureau, 2012). Three (3) Federal Reference Monitors and two (2) continuous monitors is the minimum level for a population greater than a million. The region exceeds the minimum requirements for $PM_{2.5}$ monitoring network as shown in Table 3.2.

Table 3.2 Minimum Number of Monitors Requirement

Type of Monitors	Min. # of monitor required[12]	# of active monitors in the Region	Additional monitor needed
Federal Reference Monitor	3	5	0
Continuous Monitors	2	9[13]	0

The 14 monitors are located at ten (10) monitoring sites within the Sacramento $PM_{2.5}$ Nonattainment Area and are operated by multiple agencies for use in air quality planning and to meet federal and state requirements. Two types of $PM_{2.5}$ monitors are used at nine of the monitoring sites: 1) the Federal Reference Method (FRM) filter-based mass samplers and 2) the beta attenuation monitors (BAMs), which are a category of continuous monitors. One of the monitoring sites (Sacramento - Sloughhouse) uses a $PM_{2.5}$ e-BAM[14], a special purpose monitor that runs continuously from November to February. The schedule for filter-based sampler collection is 1 in 3 days, or 1 in 6 days, depending on the purpose of the monitoring requirement. The BAMs and e-BAMS monitors operate continuously on a 24-hour basis.

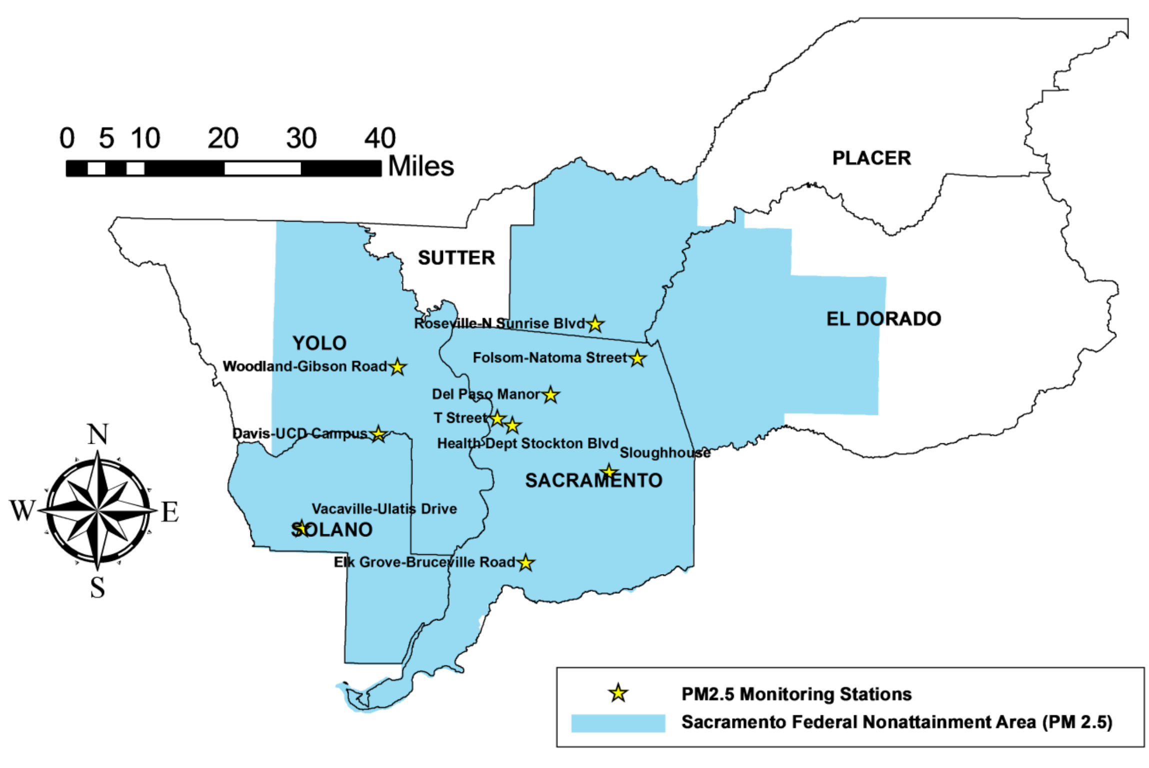
The data from different types of $PM_{2.5}$ monitors must be collected in accordance with one of three data collection methods[15] used to determine attainment status for federal air quality standards. The three methods are 1) the Federal Reference Method (FRM), 2) the Federal Equivalent Method (FEM), or 3) an Approved Regional Method (ARM). Only data collected using the FRM filter-based sampler collection method was used to analyze attainment in the Sacramento nonattainment area during the attainment period (2010-2012). The Sacramento region added FEM monitors at Auburn and Folsom in 2013 but the data collected are still under

[11] 40 CFR Part 58 Appendix D
[12] Ibid.
[13] Includes one Special Purpose Monitor (SPM) e-BAM monitor at the Sacramento - Sloughhouse Monitoring site.
[14] A portable real-time beta gauge is traceable to EPA requirements for automated $PM_{2.5}$ and PM_{10} measurement. Method is not used to meet federal or state standards.
[15] 40 CFR Parts 50 Appendix N

evaluation. The other types of $PM_{2.5}$ monitors currently operating in the region (BAMS and e-BAMS) are not FEMs or ARMs and are used only for public education and air quality forecasting purposes and cannot be used for attainment determinations.

Of the ten monitoring sites in the region (Figure 3.2), the Sacramento Metropolitan Air Quality Management District (SMAQMD) operates five sites (two sites have FRM samplers), CARB operates three sites (two sites have FRM samplers), and the Yolo-Solano Air Quality Management District operates two sites (one site has an FRM sampler). There are no $PM_{2.5}$ monitors that are located or operated in El Dorado County.

Figure 3.2 $PM_{2.5}$ Monitoring Sites in the Sacramento Nonattainment Area



SMAQMD submits annual monitoring network plans to EPA Region 9 as required by 40 CFR 58.10. These plans describe the status of the air monitoring network (operations, existing and proposed sites, statement of purpose for each monitor and evidence that the siting and operation of each monitor meets the requirements of 40 CFR 58, including Appendices A, C, D, and E, where applicable). EPA approves the annual network plans and CARB conducts audits of all the air monitoring sites and certifies and submits the air quality data to EPA. Section 3.7—

References, include the documents that pertain to the network plans, audits and data certification.

Table 3.3 provides a summary of the monitoring sites within the Sacramento $PM_{2.5}$ Nonattainment Area and Figure 3.2 shows a map of the locations of those ten (10) monitoring sites in the Sacramento area.

Table 3.3 Summary of Monitoring Sites in the SacramentoPM$_{2.5}$ Nonattainment Area[16]

List of $PM_{2.5}$ Monitoring Sites within the Sacramento $PM_{2.5}$ Nonattainment Area					
Site Name	**Site ID**	**County**	**Operating Agency**	**Types of Monitors**	**Data Record**
Del Paso Manor 2701 Avalon Drive	06-067-0006	Sacramento	SMAQMD	FRM, BAM	FRM 1999-Present BAM 2000-Present
Health Department 2221 Stockton Blvd	06-067-4001	Sacramento	SMAQMD	FRM	FRM 1999-Present
T Street 1309 T Street	06-067-0010	Sacramento	CARB	FRM, BAM	FRM 1998-Present BAM 2004-Present
Elk Grove 12490 Bruceville Road	06-067-0011	Sacramento	SMAQMD	BAM	BAM 2003-Present
Folsom 50 Natoma Street	06-067-0012	Sacramento	SMAQMD	BAM	BAM 2003-Present
Woodland 41929 E. Gibson Road	06-113-1003	Yolo	YSAQMD	FRM, BAM	FRM 1999-Present BAM 2000 - Present
Davis-UCD Campus Campbell Road	06-113-0004	Yolo	CARB	BAM	BAM 2003-Present
Vacaville 2012 Ulatis Drive	06-095-3003	Solano	YSAQMD	BAM	BAM 2000-Present
Roseville 151 N. Sunrise Blvd.	06-061-0006	Placer	CARB	FRM, BAM	FRM 1998-Present BAM 2004-Present
Sloughhouse[17] 7520 Sloughhouse Road	06-067-5003	Sacramento	SMAQMD	e-BAM*	December 2007-Present

3.3 Attainment Status

A violation of the federal 24-hour $PM_{2.5}$ standard at a monitoring site occurs if the design value exceeds the standard. The design value is defined as the average of the annual 98th percentile 24-hour values recorded over 3 consecutive years (40 CFR 50, Appendix N). Attainment must be shown at each monitoring site in the region using 3 consecutive years of complete data. CARB uploads and submits quality assured air quality data to EPA's Air Quality System (AQS). On May 19, 2010, April 28, 2011, May 9, 2012, and May 16, 2013 CARB certified that for years 2009, 2010, 2011, and 2012 all data uploaded to AQS was complete and quality assured.

On May 9, 2012, CARB submitted a clean data finding request to EPA Region 9 for the Sacramento $PM_{2.5}$ Nonattainment Area (Goldstene, 2012). This request was based upon review of ambient air quality $PM_{2.5}$ data that show attainment of the NAAQS during 2009-2011. On October 26, 2012, EPA proposed to determine that the Sacramento region attained the standard based on 2009-2011 air quality data. EPA determined that the Sacramento region

16 e-BAMS operated at other sites are not included because data from the monitors have inadequate data quality and they are not used for attainment purposes.

17 SPM operates during the months of November through February.

continued to attain in 2012, and issued a final *Determination of Attainment for the Sacramento Nonattainment Area for the 2006 Fine Particle Standard* effective August 14, 2013 (78 FR 42018, July 15, 2013).

Table 3.4 shows that the design values in 2011 and 2012 met the 35µg/m^3 federal standard at each monitoring site in the region. The region first attained in 2011, when the highest design value was 35µg/m^3, recorded at the Del Paso Manor and the Department of Health monitoring sites. Consequently this Plan treats 2011 as the attainment year. The area continued to attain in 2012 with a lower design value of 31µg/m^3. Table 3.4 is a summary of air quality in the Sacramento region between 2009 and 2012. Tables 3.5 – 3.9 summarize the 24-hour and annual statistics for the data measured at all of the sites using Federal Reference Method or Federal Equivalent Method monitors from 2002 to 2012.

Table 3.4 Summary of $PM_{2.5}$ Air Quality Data – Sacramento region 2009-2012

Monitoring Station	**Annual 98th Percentile**				**Design Value***	
	2009	**2010**	**2011**	**2012**	**2011**	**2012**
Roseville – Sunrise Blvd.	21.3	20.3	23.0	14.9	22	19
Sacramento – Del Paso Manor	38.7	27.0	39.8	27.1	35	31
Sacramento – T Street	27.2	27.3	45.1	20.5	33	31
Sacramento – Health Department	34.9	26.5	44.8	20.5	35	31
Woodland – Gibson Road	27.4	18.6	25.8	14.2	24	20
Region's Peak Value	**38.7**	**27.3**	**45.1**	**27.1**	**35**	**31**

* 2011 design value is calculated from the 98th percentile of years 2009-2011; 2012 design value is calculated from years 2010-2012.
Data Source: EPA AQS Database (http://www.epa.gov/ttn/airs/airsaqs/aqsweb/). Data downloaded on 03/29/2013.

Table 3.5 24-Hour and annual statistics at the Roseville, CA Sunrise Blvd.

Year	24-hr Standard µg/m^3		Annual Standards µg/m^3		Percent Data Capture				Number of Samples				
	Annual 98th Percentile	Design Value	Annual Average	Design Value	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Total
2002	40	44	13.2	12.4	100%	100%	100%	88%	15	15	16	16	62
2003	26	38	9.9	11.7	100%	100%	100%	100%	15	15	16	15	61
2004	30	32	9.4	10.8	93%	100%	100%	100%	15	15	16	15	61
2005	28	28	10.0	9.8	100%	100%	93%	88%	15	15	15	17	62
2006	36	31	10.5	10.0	100%	100%	100%	100%	15	16	15	16	62
2007	27	30	8.4	9.7	88%	100%	94%	100%	17	15	16	15	63
2008	26.6	30	10.0	9.6	94%	93%	100%	94%	16	15	15	16	62
2009	21.3	25	8.6	9.0	100%	100%	93%	93%	15	16	15	15	61
2010	20.3	23	6.6	8.4	100%	94%	94%	100%	15	16	16	15	62
2011	23	22	8.5	7.9	94%	100%	100%	100%	16	15	16	15	62
2012	14.9	19	6.5	7.2	100%	94%	94%	82%	15	16	17	17	65

Data Source: EPA AQS Database (http://www.epa.gov/ttn/airs/airsaqs/aqsweb/). Data downloaded on 05/28/2013.

Table 3.6 24-Hour and annual statistics at the Del Paso Manor monitor

Year	24-hr Standard µg/m^3		Annual Standards µg/m^3		Percent Data Capture				Number of Samples				
	Annual 98th Percentile	Design Value	Annual Average	Design Value	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Total
2002	62	60	12.1*	11.2	9%	87%	81%	97%	90	30	31	92	243
2003	43	48	12.3	11.5	86%	100%	87%	96%	90	30	31	92	243
2004	42	49	11.5	12.0	95%	97%	90%	100%	91	30	31	92	244
2005	49	45	11.5	11.8	96%	100%	97%	97%	90	33	30	92	245
2006	55	49	13.1	12.0	97%	100%	94%	99%	90	32	34	92	248
2007	60	55	12.3	12.3	100%	97%	97%	100%	90	31	31	30	182
2008	54.9	57	13.2	12.9	100%	97%	94%	97%	31	32	31	30	124
2009	38.7	51	10.7	12.1	91%	100%	97%	91%	33	31	31	32	127
2010	27.0	40	8.8	10.9	100%	91%	94%	91%	30	33	31	34	128
2011	39.8	35	10.5	10.0	94%	97%	100%	88%	31	30	31	33	125
2012	27.1	31	9.1	9.5	97%	97%	97%	94%	31	31	31	31	124

Data Source: EPA AQS Database (http://www.epa.gov/ttn/airs/airsaqs/aqsweb/). Data downloaded on 03/29/2013.

Table 3.7 24-Hour and annual statistics at the T-Street monitor

Year	24-hr Standard µg/m^3		Annual Standards µg/m^3		Percent Data Capture				Number of Samples				
	Annual 98th Percentile	Design Value	Annual Average	Design Value	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Total
2002	63	55	14.3	12.7*	93%	97%	90%	85%	90	91	92	92	365
2003	38	51	11.6*	12.5	93%	75%	90%	71%	90	91	92	92	365
2004	37	46	11.4*	12.4	58%	81%	97%	93%	91	91	92	92	366
2005	47	41	10.9	11.3*	88%	89%	93%	97%	90	91	92	92	365
2006	39	41	12.4*	11.6	87%	65%	97%	92%	90	91	92	92	365
2007	43	43	11.9	11.7	94%	96%	80%	87%	90	91	41	30	252
2008	46.4	43	11.0	11.8	94%	93%	79%	93%	33	30	43	30	136
2009	27.2	39	9.5	10.8	83%	94%	94%	91%	36	33	32	33	134
2010	27.3	34	8.1	9.5	91%	97%	100%	100%	32	31	31	31	125
2011	45.1	33	10.1	9.2	97%	94%	94%	94%	32	32	34	32	130
2012	20.5	31	8.3	8.8	100%	88%	94%	88%	31	32	34	32	129

Data Source: EPA AQS Database (http://www.epa.gov/ttn/airs/airsaqs/aqsweb/). Data downloaded on 03/29/2013.

Table 3.8 24-Hour and annual statistics at the Sacramento Health Department

Year	24-hr Standard µg/m³		Annual Standards µg/m³		Percent Data Capture				Number of Samples				
	Annual 98th Percentile	Design Value	Annual Average	Design Value	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Total
2002	60	46	11.3*	10.1*	26%	83%	84%	87%	90	30	31	92	243
2003	36	41	10.8	10.3	81%	97%	97%	98%	90	30	31	92	243
2004	35	44	10.5	10.9	98%	93%	90%	96%	91	30	31	92	244
2005	42	38	10.4	10.5	89%	97%	97%	95%	90	33	30	92	245
2006	39	39	10.8	10.5	99%	100%	77%	98%	90	32	31	92	245
2007	47	43	10.9	10.7	99%	100%	90%	100%	90	31	31	31	183
2008	47.6	45	12.2	11.3	97%	100%	94%	94%	31	30	31	32	124
2009	34.9	43	9.6	10.9	97%	100%	93%	97%	30	31	30	34	125
2010	26.5	36	7.8	9.9	97%	90%	100%	90%	30	31	31	31	123
2011	44.8	35	10.1	9.2	94%	100%	100%	97%	31	30	31	31	123
2012	20.5	31	8.2	8.7	100%	100%	100%	94%	31	30	31	31	123

Data Source: EPA AQS Database (http://www.epa.gov/ttn/airs/airsaqs/aqsweb/). Data downloaded on 03/29/2013.

Table 3.9 24-Hour and annual statistics at the Woodland, CA Gibson Road

Year	24-hr Standard µg/m³		Annual Standards µg/m³		Percent Data Capture				Number of Samples				
	Annual 98th Percentile	Design Value	Annual Average	Design Value	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Total
2002	31	35*	10.7	10.5	84%	100%	94%	84%	31	30	31	32	124
2003	28	31	8.4	9.8	97%	100%	94%	78%	31	30	31	32	124
2004	31	30	10.4	9.8	94%	97%	100%	90%	31	30	31	30	122
2005	24	28	8.4	9.1	77%	90%	93%	94%	30	31	30	33	124
2006	36	30	9.3	9.4	97%	97%	94%	97%	30	31	31	31	123
2007	39.5	33	8.3	8.7	100%	81%	82%	94%	30	32	22	16	100
2008	23.7*	33	9.7*	9.1	88%	87%	71%	94%	17	15	17	17	66
2009	27.4	30	7.5	8.5	100%	95%	94%	87%	15	21	17	15	68
2010	18.6	23	5.7	7.6	88%	93%	94%	93%	17	15	18	15	65
2011	25.8	24	7.6	6.9	100%	93%	94%	74%	15	15	17	19	66
2012	14.2	20	6.4	6.6	100%	100%	85%	88%	15	15	20	17	67

Data Source: EPA AQS Database (http://www.epa.gov/ttn/airs/airsaqs/aqsweb/). Data downloaded on 05/28/2013.

Note: Annual Values not meeting completeness criteria are marked with an asterisk (*). For the 24-hour and annual $PM_{2.5}$ standard, a year meets data completeness requirements when at least 75 percent of the scheduled sampling days for each quarter have valid data. (40 CFR Appendix N to Part 50)

Table 3.10 shows the top 5 concentration values at the region's peak value monitor. Since the FRM sampling frequency was one in three days, approximately 120 $PM_{2.5}$ concentration values were recorded every year. The third highest concentration represents the 98^{th} percentile concentration.

Table 3.10 Top $PM_{2.5}$ measurements during 2009-2012

Rank	Date	$PM_{2.5}$ Concentration ($\mu g/m^3$)	Comments
2009			
1	12/24/2009	49.8	The 98th percentile (3rd highest value) was recorded at the Del Paso Manor Monitor.
2	01/16/2009	45.9	
3	01/10/2009	38.7	
4	01/13/2009	35.2	
5	12/21/2009	33.6	
2010			
1	12/04/2010	30.6	The 98th percentile (3rd highest value) was recorded at the Sacramento T Street Monitor.
2	01/08/2010	27.6	
3	02/04/2010	27.3	
4	01/29/2010	27.0	
5	01/17/2010	26.7	
2011			
1	12/29/2011	50.5	The 98th percentile (3rd highest value) was recorded at the Sacramento T Street Monitor.
2	12/20/2011	47.8	
3	12/26/2011	45.1	
4	12/08/2011	36.3	
5	12/17/2011	35.6	
2012			
1	01/10/2012	35.3	The 98th percentile (3rd highest value) was recorded at the Del Paso Manor Monitor.
2	01/01/2012	35.1	
3	11/11/2012	27.1	
4	01/04/2012	26.5	
5	12/08/2012	26.5	

3.4 $PM_{2.5}$ Seasonality Analysis

$PM_{2.5}$ seasonality analysis was conducted to evaluate whether the potential for high $PM_{2.5}$ was a year round problem or a more seasonal occurrence in the Sacramento $PM_{2.5}$ non-attainment area. The results from the analysis was used to develop the emission inventory in Chapter 4 and to evaluate and develop the most effective control strategies in reducing ambient $PM_{2.5}$ concentrations. Meteorological factors[18] vary during the year and play an important role in $PM_{2.5}$ concentration levels. Seasonality was characterized based on spring/summer (referred to later as summer) being the months of April through September and fall/winter (referred to later as

[18] Average wind speed & temperature (1950-2010), precipitation (1971-2000), and atmospheric stability data for Sacramento from National Oceanic and Atmospheric Administration National Data Center website at:
http://ols.nndc.noaa.gov/plolstore/plsql/olstore.prodspecific?prodnum=C00095-PUB-A0001#OVERVIEW

winter) during the months of October through March. In general, low wind velocities, low temperatures with a strong atmospheric stability and strong inversions during the winter, when combined with low precipitation, may result in higher $PM_{2.5}$ concentrations.

Wind. Wind speed and direction are important because they are indicative of the level of pollutant dispersion. Two distinctive wind patterns, summer and winter, were identified for the Del Paso Manor Site. Predominant winds are from the south and south-west during the summer season, while during the winter, predominant winds are from the north-west and south-east. On days when $PM_{2.5}$ concentrations were high (>30µg/m^3), winter wind patterns predominated (CARB, 2011). During the winter pattern, wind speeds are lower and calm conditions result in higher pollution concentrations potential. Pollutants sometimes accumulate in the area for several days before being dispersed. Overall, the average winter wind velocity was 6.9 mph versus 8.7 mph for summer months. In general, low wind velocities, low temperatures with a strong atmospheric stability lead to strong inversions during the early morning hours, which may result in higher $PM_{2.5}$ concentrations.

Precipitation. Sacramento averages approximately 18 inches of precipitation per year with 88 percent of the annual precipitation falling between October and March. October through March averages greater than 2 inches of precipitation per month, while the summer months of April through September average less than 1/2 an inch per month.

Atmospheric Stability and Dispersion. Vertical air movement is important in the dispersion of air pollutants. A temperature inversion acts as a nearly impenetrable lid to the vertical mixing of the atmosphere and traps pollution near the ground. Inversions occur with greater frequency during the winter in the Sacramento Valley.

Temperature. Sacramento temperatures have reached a record high of 115 degrees Fahrenheit during the summer, and record low of 18 degrees during winter months. Low temperatures in the presence of increased humidity are conducive to the formation of secondary particulates. In addition, as winter temperatures drop, more residents are likely to utilize wood combustion devices such as fireplaces and woodstoves for residential heating, increasing $PM_{2.5}$ ambient concentration levels.

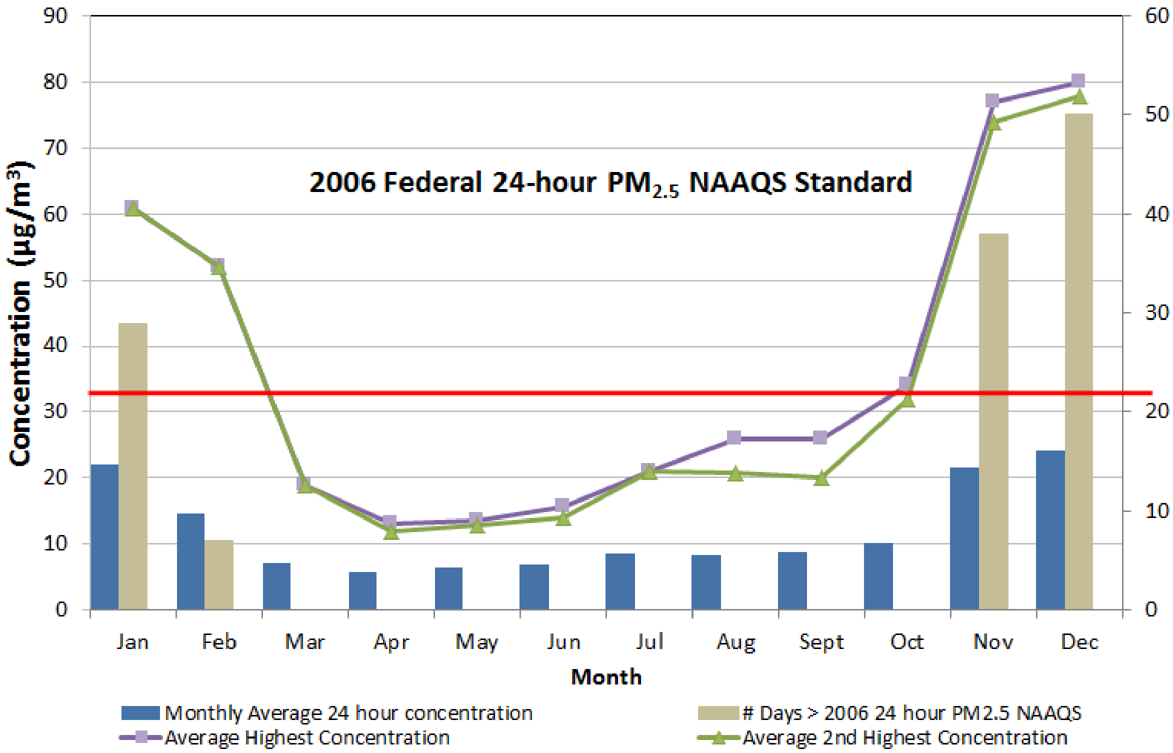
$PM_{2.5}$ Air Quality Data. Figure 3.3 illustrates the monthly variation in $PM_{2.5}$ concentrations monitored at the design value site (Del Paso Manor) for years 2002-2012. Figure 3.3 includes the following metrics:

- The 24-hour $PM_{2.5}$ concentrations monitored during the month are averaged to find a monthly average, and the monthly averages are averaged for the period 2002-2012.
- The average of the number of days monitored that were above the 35 µg/m^3 2006 24 hour standard for the month over 2002 to 2012.
- The average of the highest 24 hour concentration monitored during the month during 2002 to 2012.
- The average of the 2nd highest concentration monitored during the month, during 2002 to 2012.

Elevated concentrations generally occur in the late fall and winter and lowest concentrations during the summer.

The meteorology in the Sacramento region during winter time when compared to the summer time is conducive to $PM_{2.5}$ pollution. See Chapter 5 for additional information.

Figure 3.3 24-hour $PM_{2.5}$ Concentration* for Del Paso Manor (Design Value Site) during 2002 to 2012



*PM $_{2.5}$ FRM SSI (Size-Selective Inlet) 24-Hour filter average concentration (µg/m^3)

Data Source: EPA AQS Database (http://www.epa.gov/ttn/airs/airsaqs/aqsweb/). Data downloaded on05/28/2013

NOTE: This seasonality analysis excluded the days (June 23, 2008, June 26, 2008, and July 8, 2008) that were affected by the 2008 wildfires.

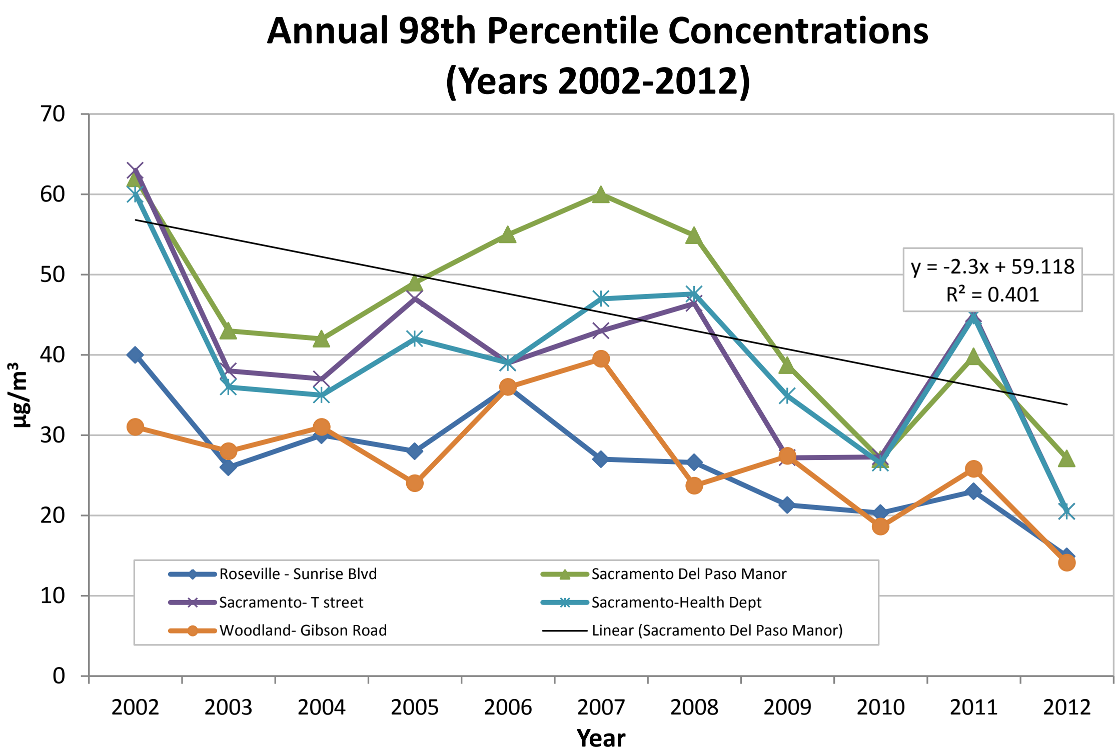
3.5 $PM_{2.5}$ Data Trends

Progress towards attainment and maintenance of the standard after attainment is measured by analyzing ambient air quality data collected at various monitoring sites over a period of many years. This section focuses on three indicators that will show the Sacramento nonattainment area continuing to meet the 2006 24-hour $PM_{2.5}$ standard in future years. The three indicators are 1) the annual peak 98th percentile concentration 2) the number of days exceeding the federal $PM_{2.5}$ standard of 35µg/m^3, and 3) the maximum 24-hour concentrations in the region over 10 years. All data tables for charts in Chapter 3 are located in Appendix A.

Figure 3.4 shows the declining trend of the peak annual 98th percentile concentration. During the past 10 years, the region has made significant progress in reducing ambient $PM_{2.5}$

concentrations. The annual 98th percentile statistic shows the year to year progress and is used in calculating the 3-year 24-hour average design value. The declining historical trend line indicates that the annual 98th percentile concentration for the region is expected to continue to meet and remain below the standard in the future.

Figure 3.4 Annual 98th percentile 24-hour Average Concentration



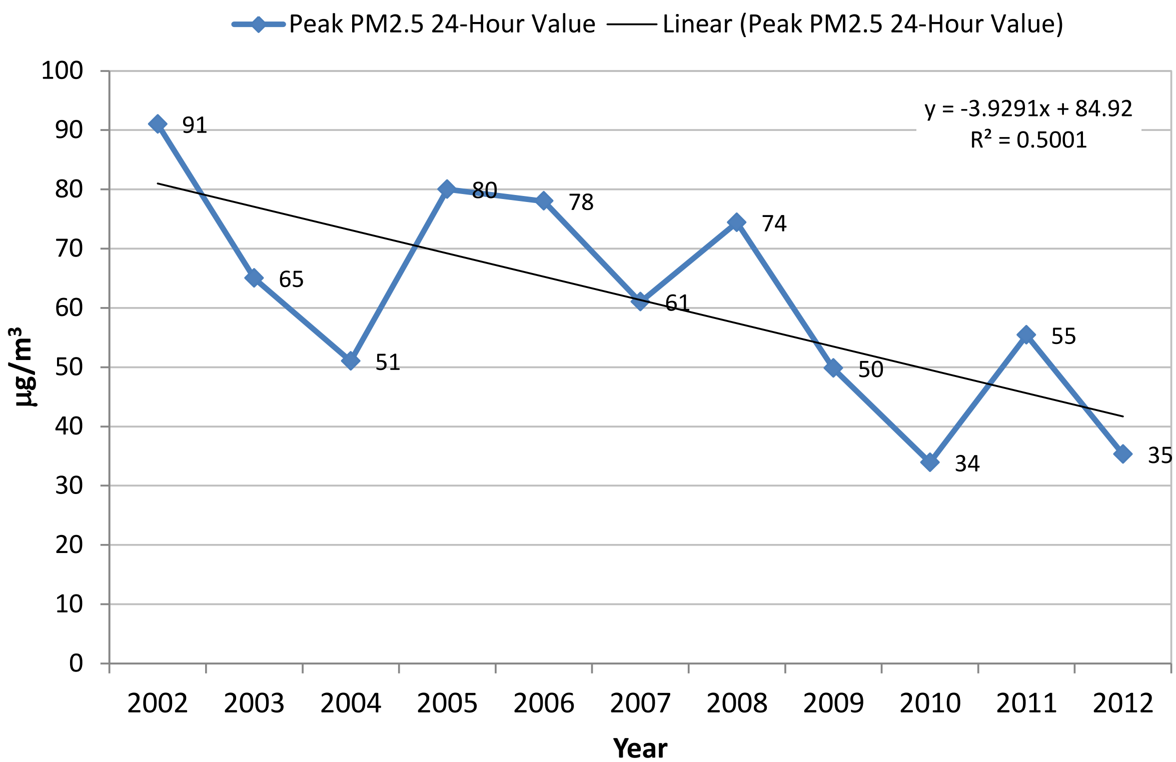
$PM_{2.5}$ FRM SSI 24-Hour filter average concentration (µg/m^3) includes days affected by 2008 wildfires (June 23, 2008, June 26, 2008, and July 8, 2008).
Data Source: EPA AQS Database (http://www.epa.gov/ttn/airs/airsaqs/aqsweb/). Data downloaded 08/16/2013.

The next indicator shows that the observed annual maximum concentration (Figure 3.5) in the region has a declining trend. The magnitudes of the maximum concentrations have decreased significantly over the last decade. In 2002, the peak 24-hour concentration was 91µg/m^3 and it declined to 54.3µg/m^3 by 2011, which indicates the overall air quality has improved throughout the years. These improvements can be attributed to the regulations and programs that have been implemented throughout the region.

There are several control strategies, rules and programs that contribute to the decline in $PM_{2.5}$ concentrations, particularly since 2007. Specific rules and regulations are discussed in Chapter 6. A significant benefit on direct $PM_{2.5}$ emissions and secondary NO_X emissions in the region is the Sacramento Metropolitan Air Quality Management District's Rule 421 (Mandatory Episodic Curtailment of Wood and Other Solid Fuel Burning) adopted October 25, 2007 and made more stringent in 2009. In EPA's Technical Supporting Document (TSD) (EPA, 2008) for the 24-hour $PM_{2.5}$ area designations, EPA acknowledges that the Sacramento region has relatively high levels of directly emitted $PM_{2.5}$, especially from wood burning, which is associated with relatively densely populated areas and their surroundings. In addition, there are substantial mobile source NO_X emissions throughout the region, which contributes to secondary aerosol $PM_{2.5}$. Rule 421 was implemented in December 2007 and restricts wood burning from November through February.

Motor vehicle fleet turn over and ARB's on- and off-road motor vehicle and equipment emissions and fuel regulations also helped reduce the ambient $PM_{2.5}$ concentrations in the region and will continue to yield emission reductions and help the region remain in attainment.

Figure 3.5 Maximum 24-hour Concentrations in the Region



Data Source: EPA AQS Database (http://www.epa.gov/ttn/airs/airsaqs/aqsweb/). FRM data only. Data downloaded 05/28/2013.

3.6 $PM_{2.5}$ Air Quality Data Conclusions

$PM_{2.5}$ includes solid and liquid particles with a diameter of 2.5 micrometers or less. EPA's health-based national ambient air quality standard for 24-hour $PM_{2.5}$ is 35µg/m^3.The nonattainment area includes Sacramento County and portions of El Dorado County, Placer County, Solano County, and Yolo County. There are currently ten (10) $PM_{2.5}$ monitoring sites within the Sacramento nonattainment area. Three types of $PM_{2.5}$ monitors are used to monitor $PM_{2.5}$ concentrations: 1) filter based mass samplers approved as the federal reference method (FRM), 2) the beta attenuation monitors (BAMS) and 3) the portable e-BAMs. There are five (5) FRM and nine (9) BAMS monitors in the $PM_{2.5}$ Nonattainment Area, which meets the federal requirements[19] of three (3) FRM and two (2) continuous monitors for a California Metropolitan Statistical Area (MSA) population greater than 1,000,000. CARB and SMAQMD submitted their required annual network plans and EPA approved these network plans. In addition, the region has met the required complete certified air quality data requirements[20] for the attainment determination years of 2009-2012.

The design value determines whether or not the area is in attainment. A violation of federal 24-hour $PM_{2.5}$ standard at a monitoring site occurs if the design value exceeds the federal 24-hour standard. An area's design value is calculated by averaging the 98th percentile concentrations for three consecutive years of complete data. The air quality monitoring data shows that the design value for the Sacramento nonattainment area has decreased from 60µg/m^3 in 2002 to 31µg/m^3 in 2012. On October 26, 2012, EPA proposed to determine that the Sacramento region attained the NAAQS based on 2011 data. Therefore, this Plan uses 2011 as the attainment year. Effective August 14, 2013, EPA determined that the Sacramento region attained the 2006 24-hour $PM_{2.5}$ NAAQS after finding the region continued to attain in 2012.(78 FR 42018).

The $PM_{2.5}$ seasonality analysis showed that winter time conditions (e.g., atmospheric stability, low wind dispersion, and colder temperatures) were more conducive to higher $PM_{2.5}$ concentrations. Winter weather conditions are favorable to direct $PM_{2.5}$ pollutant build up and increased secondary formation of particulates and historically resulted in the region's only exceedances of the $PM_{2.5}$ NAAQS. Therefore, the winter season emissions inventory and conformity budgets are appropriate metrics for maintenance demonstration purposes.

3.7 References

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19 40 CFR 58, Appendix D Section 4.7.1 and 4.7.2
20 40 CFR Appendix N to part 50 Section 4.2

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EPA. 40 CFR Part 50 National Ambient Air Quality Standards for Particulate Matter

EPA. 40 CFR 50, Appendix N: Interpretation of the National Ambient Air Quality Standards for $PM_{2.5}$

EPA. 40 CFR Part 81: Air Quality Designations for the 2006 24-Hour Fine Particle ($PM_{2.5}$) National Ambient Air Quality Standards

EPA. 40 CFR Part 58, Appendix D: Network Design Criteria for Ambient Air Quality Monitoring

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4 Emissions Inventory

4.1 Introduction to Emissions Inventory

An emissions inventory is an accounting of the amount of air pollutants discharged into the atmosphere of a geographical area during a given time period. The maintenance plan must require the submittal of attainment year (2011), interim year (2017) and maintenance year (2024) emissions inventories of directly emitted $PM_{2.5}$ and its precursors[21]. Year 2024 is designated as the maintenance plan's final year inventory based on the assumption that the United States Environmental Protection Agency (EPA) will approve the Region's re-designation request in 2014 and the requirement under Clean Air Act (CAA) Section 175A to demonstrate maintenance of the National Ambient Air Quality Standards (NAAQS) for at least 10 years. The 2017 interim year inventory is used to demonstrate that the emissions in the area are not expected to exceed the attainment year inventory between the attainment year and the final year of the maintenance plan. These three sets of emissions inventories are used to determine whether the Sacramento Federal $PM_{2.5}$ Nonattainment Area (SFNA-$PM_{2.5}$) will remain in attainment through the final year, 2024, despite growth in the area.

The emissions inventory undergoes continuous updating to improve its accuracy. The 2011, 2017 and 2024 emissions inventories use the latest planning assumptions and emissions data in California Air Resources Board's (CARB's) $PM_{2.5}$ SIP planning projections model, California Emission Projection Analysis Model (CEPAM). The emission inventories are presented in tons per day for an average winter day. Future year inventories are forecast using latest socio-economic growth indicators and applying the emission reduction benefits from adopted control strategies.

The emission inventories include emissions for the SFNA-$PM_{2.5}$, which encompasses all of Sacramento County, the eastern portion of Yolo County, the western portions of El Dorado and Placer counties, and the northeast portion of Solano County. Figure 2.1 in Chapter 2 contains the map of the SFNA-$PM_{2.5}$.

This chapter begins with a discussion of the emissions inventory by different air pollutant source categories for the SFNA-$PM_{2.5}$. Directly emitted $PM_{2.5}$, and $PM_{2.5}$ precursors of NO_X (Nitrogen Oxides), SO_2 (Sulfur Dioxide), VOC (Volatile Organic Compounds), and NH_3 (Ammonia) emissions, in tons per day for an average winter day, are then summarized for 2011, 2017 and 2024 in tabular and graphical formats. This is followed by a section analyzing the emissions inventory forecasts and emissions inventory maintenance demonstration. Final sections of this chapter include a discussion of emission reduction credits (ERCs), which are included in the emissions inventory forecasts to ensure that the potential use of ERCs is reflected in the maintenance year inventory. More detailed information and emissions inventory tables are provided in Appendix B – Emissions Inventory.

[21] CAA Sections 172(c)(3) and175A, and 40 CFR 51.1008

4.2 Emissions Inventory Requirements

Emissions are updated as part of the overall requirement for "plan revisions to include a comprehensive, accurate, current inventory of actual emissions from all sources of the relevant pollutants" under CAA sections 172(c)(3), 40 CFR 51 Subpart A, and 40 CFR 51.1008.

4.3 Precursors to $PM_{2.5}$

In accordance with SIP emission inventory requirements under 40 CFR part 51 subpart A, CAA Section 172(c)(3) and 40 CFR 51.1008, this $PM_{2.5}$ plan contains an emissions inventory for total directly emitted $PM_{2.5}$, and all precursors of $PM_{2.5}$. Emissions of NO_X, SO_2, VOC and NH_3 are precursors of $PM_{2.5}$ because these pollutants can undergo chemical reactions in the atmosphere to form secondary $PM_{2.5}$, such as ammonium nitrate and ammonium sulfate.

4.4 Emissions Inventory Source Categories

Due to the large number and wide variety of emission processes and sources, a hierarchical system of emission inventory categories was developed for more efficient use of the data. The anthropogenic (man-made) emissions inventory is divided into four broad categories: stationary sources, area-wide sources, on-road mobile sources, and other mobile sources. Each of these major categories is subdivided into more descriptive subcategory sources. Each of these subcategories is further defined into more specific emission processes.

4.4.1 Stationary Sources

The stationary source category of the emissions inventory includes non-mobile, fixed sources of air pollution. They are comprised of individual, industrial, manufacturing, and commercial facilities called "point sources". A point source which emits 10 tons or more per year of any criteria pollutant is specifically included as a facility in the inventory. Small facilities such as gas stations, dry cleaners, and concrete batch plants are grouped together under aggregated point source categories. The more descriptive subcategories include fuel combustion (e.g. power plant gas turbines), waste disposal (e.g. landfills), petroleum production and marketing, and industrial processes (e.g. rock crushing plant). The process and emissions data reported by industrial facility operators are used to calculate emissions from point sources.

4.4.2 Area-Wide Sources

The area-wide sources inventory category includes aggregated emissions data from processes that are individually small and widespread or not well-defined stationary sources. The area-wide subcategories include residential wood combustion, farming operations, construction and demolition activities, and road dust. Emissions from these sources are calculated from fuel usage, product sales, population, employment data, and other parameters for a wide range of activities that generate air pollution across the Sacramento region.

4.4.3 On-Road Motor Vehicles

The on-road motor vehicles inventory category consists of trucks, automobiles, buses, and motorcycles. EMFAC (EMission FACtor) is the California model for estimating emissions from on-road motor vehicles operating in California. It is built on decades of vehicle testing and analysis. It uses travel activity data from metropolitan planning organizations, vehicle registration data from the Department of Motor Vehicles (DMV), and data from the Smog Check program.

Motor Vehicle Emissions Model, EMFAC2011

CARB has continued to update and improve its EMFAC on-road motor vehicle emissions model. CARB's latest model, EMFAC2011, was released in September 2011. EMFAC2011 model improvements include:

- The latest information on vehicle populations and miles traveled in California.
- The impacts of recently adopted diesel regulations including the Truck and Bus Rule and other diesel truck fleet rules; the Pavley Clean Car Standard, and the Low Carbon Fuel Standard.
- The latest emissions inventory methods for heavy duty trucks and buses.

EMFAC2011 software and detailed information on the vehicle emission model can be found on the CARB website: http://www.arb.ca.gov/msei/modeling.htm.

Vehicle Activity Data

On-road motor vehicle emission estimates were developed using the latest available transportation data and California's EMFAC2011 model. The forecasted vehicle miles traveled (VMT) and speed distributions used in this plan are based on the Sacramento region's Metropolitan Transportation Plan/Sustainable Communities Strategy 2035 (MTP/SCS 2035) (Abraham, 2012a, Crow, 2012, and Abraham, 2012b), which was adopted by the Sacramento Area Council of Governments (SACOG) on April 19, 2012. Vehicle activity data for Solano County, however, is based on the Plan Bay Area Preferred Land Use Scenario/Transportation Investment Strategy (May 11, 2012) and was provided by the San Francisco Bay Area Metropolitan Transportation Commission (MTC) to SACOG (Brazil, 2012)

4.4.4 Other Mobile Sources

The emission inventory category for other mobile sources includes aircraft, trains, boats, and off-road vehicles and equipment used for construction, farming, commercial, industrial, and recreational activities. The other mobile source categories are estimated by category specific methods and inventory models that are developed for specific regulatory support projects. The diesel equipment categories using category specific method include: In-Use Off-Road Equipment (Construction, Industrial, Airport Ground Support, and Oil Drilling); Cargo Handling Equipment; In-Use Mobile Agricultural Equipment; Locomotives; Transport Refrigeration Units; Commercial Harbor Craft; Ocean Going Vessels; and Stationary Commercial Engines. The OFFROAD2007 emission model is used for estimating emissions for equipment categories that have not yet been replaced within a category specific method. In general, emissions are calculated by using estimated equipment population, engine size and load, usage activity, and emissions factors.

Off-road inventory improvements include:

- Updated estimates of equipment population,
- New data from 2009 academic studies and reducing certain load factors by 33% at engine manufacturers recommendation, and
- Decreases in construction activity and revised growth projections due to the recent economic recession.

More detailed information on the latest off-road motor vehicle emissions inventory can be found on the CARB website: http://www.arb.ca.gov/msei/categories.htm#offroad_motor_vehicles.

4.5 Attainment Year Emissions and Forecasts

4.5.1 Anthropogenic Emissions Tables by Source Category

In the SFNA-$PM_{2.5}$, peak concentrations typically occur under late fall and winter weather conditions when temperature inversions and low wind speeds trap and concentrate $PM_{2.5}$ emissions near the ground, cooler temperature and high humidity increase the secondary formation of particulates, and residential wood burning increases. Therefore, the emissions inventories for directly emitted $PM_{2.5}$ and its precursors of NO_X, SO_2, VOC, and NH_3 are compiled for an average winter day, which are the average daily emissions in the winter planning season of November to April.

The following tables (Tables 4.1, 4.2 and 4.3) show the anthropogenic emissions inventory of directly emitted $PM_{2.5}$, and its precursors of NO_X, SO_2, VOC and NH_3 by source categories for the SFNA-$PM_{2.5}$. The emissions inventory is shown for an average winter day in units of tons per day. Inventories except on-road vehicles were obtained using CEPAM: NORCAL 2012 $PM_{2.5}$ SIP Baseline Emission Projections for the attainment year 2011, the interim year 2017, and the maintenance plan year 2024[22]. On-road vehicle inventories for these years were provided by CARB (Taylor, 2012b), (Taylor, 2012c).

Targeted emission reduction benefits from SMAQMD Rule 421, Mandatory Episodic Curtailment of Wood and Other Solid Fuel Burning, on directly emitted $PM_{2.5}$ inventory are not well represented in a winter average inventory scenario. During a poor air quality day, Rule 421 is expected to reduce an additional 5 tons per day of SFNA $PM_{2.5}$ emissions in 2024 or an additional reduction of 20% in the 2024 SFNA directly emitted $PM_{2.5}$ inventory.

[22] CARB. *CEPAM. Section a1 - Emission Projections With External Adjustments*. Web 11 October, 2012 <http://www.arb.ca.gov/app/emsinv/2012pm25sip/norcal2012pm25sip/>

Table 4.1 Average Winter Day Directly Emitted $PM_{2.5}$ Emissions (tons per day) Sacramento Federal $PM_{2.5}$ Nonattainment Area

CATEGORY	$PM_{2.5}$		
	2011	**2017**	**2024**
TOTAL EMISSIONS	**26**	**27**	**26**
STATIONARY	2.8	3.4	3.7
AREAWIDE	19.6	20.4	20.2
ON-ROAD MOTOR VEHICLES	2.2	1.7	1.6
OTHER MOBILE	1.1	1.0	0.7
STATIONARY			
Fuel Combustion	1.2	1.3	1.3
Industrial Processes	1.6	2.0	2.3
Other	0.0	0.1	0.1
AREAWIDE			
Residential Fuel Combustion	13.4	13.7	13.5
Farming Operations	1.1	1.1	1.1
Construction and Demolition	2.0	2.2	2.2
Paved Road Dust	1.2	1.3	1.4
Unpaved Road Dust	0.4	0.4	0.4
Managed Burning and Disposal	0.7	0.8	0.7
Cooking	0.6	0.7	0.7
Other	0.2	0.2	0.2
ON-ROAD MOTOR VEHICLES			
Light/Medium-Duty Vehicle	1.2	1.1	1.1
Heavy-Duty Trucks	0.9	0.5	0.4
Other	0.1	0.1	0.1
OTHER MOBILE			
Aircraft	0.1	0.1	0.1
Trains	0.1	0.1	0.1
Boats/Rec Vehicles	0.2	0.2	0.1
Off-Road Equipment	0.4	0.4	0.3
Farm Equipment	0.3	0.2	0.1
Fuel Storage & Handling	0.0	0.0	0.0

Data Source: Except for on-road, CARB CEPAM: NORCAL 2012 $PM_{2.5}$ SIP Baseline Emission Projections, Section a1 - Emission Projections with External Adjustments, downloaded on October 11, 2012. On-road emissions include CARB external adjustments and are based on emissions generated by SACOG using EMFAC2011 and SACOG MTP/SCS2035 vehicle activity forecasts. ERCs plus additional adjustments from Tables B5.1 and B5.2 are included in the table. The Motor Vehicle Emission Budgets (MVEB) includes a safety margin for $PM_{2.5}$ that is not reflected in this table. The total emissions are rounded to nearest integer.

Table 4.2 Average Winter Day $PM_{2.5}$ Precursor Emissions (tons per day) Sacramento Federal $PM_{2.5}$ Nonattainment Area

CATEGORY	NO_X			SO_2		
	2011	2017	2024	2011	2017	2024
TOTAL EMISSIONS	**100**	**79**	**60**	**2**	**2**	**2**
STATIONARY	10.7	12.4	12.6	0.6	1.0	1.0
AREAWIDE	7.2	8.3	8.3	0.7	0.8	0.8
ON-ROAD MOTOR	60.3	37.1	22.1	0.3	0.3	0.4
OTHER MOBILE	21.3	20.7	16.8	0.2	0.2	0.2
STATIONARY						
Fuel Combustion	10.1	11.6	11.7	0.4	0.7	0.7
Industrial Processes	0.4	0.6	0.7	0.1	0.2	0.2
Other	0.2	0.2	0.2	0.1	0.1	0.1
AREAWIDE						
Residential Fuel	6.8	7.8	7.8	0.6	0.7	0.7
Managed Burning and Disposal	0.4	0.5	0.5	0.1	0.1	0.1
Consumer Products	0.0	0.0	0.0	0.0	0.0	0.0
Architectural Coatings	0.0	0.0	0.0	0.0	0.0	0.0
Pesticides/Fertilizers	0.0	0.0	0.0	0.0	0.0	0.0
Farming Operations	0.0	0.0	0.0	0.0	0.0	0.0
Other	0.0	0.0	0.0	0.0	0.0	0.0
ON-ROAD MOTOR VEHICLES						
Light/Medium-Duty Vehicle	23.3	12.3	7.1	0.2	0.2	0.3
Heavy-Duty Trucks	33.2	21.7	12.5	0.1	0.1	0.1
Other	3.8	3.1	2.5	0.0	0.0	0.0
OTHER MOBILE						
Aircraft	2.3	2.8	3.0	0.2	0.2	0.2
Trains	5.9	6.2	5.6	0.0	0.0	0.0
Boats/Rec Vehicles	2.1	1.6	1.5	0.0	0.0	0.0
Off-Road Equipment	6.0	6.9	4.9	0.0	0.0	0.0
Farm Equipment	5.0	3.2	1.8	0.0	0.0	0.0
Fuel Storage & Handling	0.0	0.0	0.0	0.0	0.0	0.0

Data Source: Except for on-road, CARB CEPAM: NORCAL 2012 $PM_{2.5}$ SIP Baseline Emission Projections, Section a1 - Emission Projections with External Adjustments, downloaded on October 11, 2012. On-road emissions include CARB external adjustments and are based on emissions generated by SACOG using EMFAC2011 and SACOG MTP/SCS2035 vehicle activity forecasts. ERCs plus additional adjustments from Tables B5.1 and B5.2 are included in the table. The Motor Vehicle Emission Budgets (MVEB) includes a safety margin for NO_X that is not reflected in this table. The total emissions are rounded to nearest integer.

Table 4.3 Average Winter Day $PM_{2.5}$ Precursor Emissions (tons per day) Sacramento Federal $PM_{2.5}$ Nonattainment Area

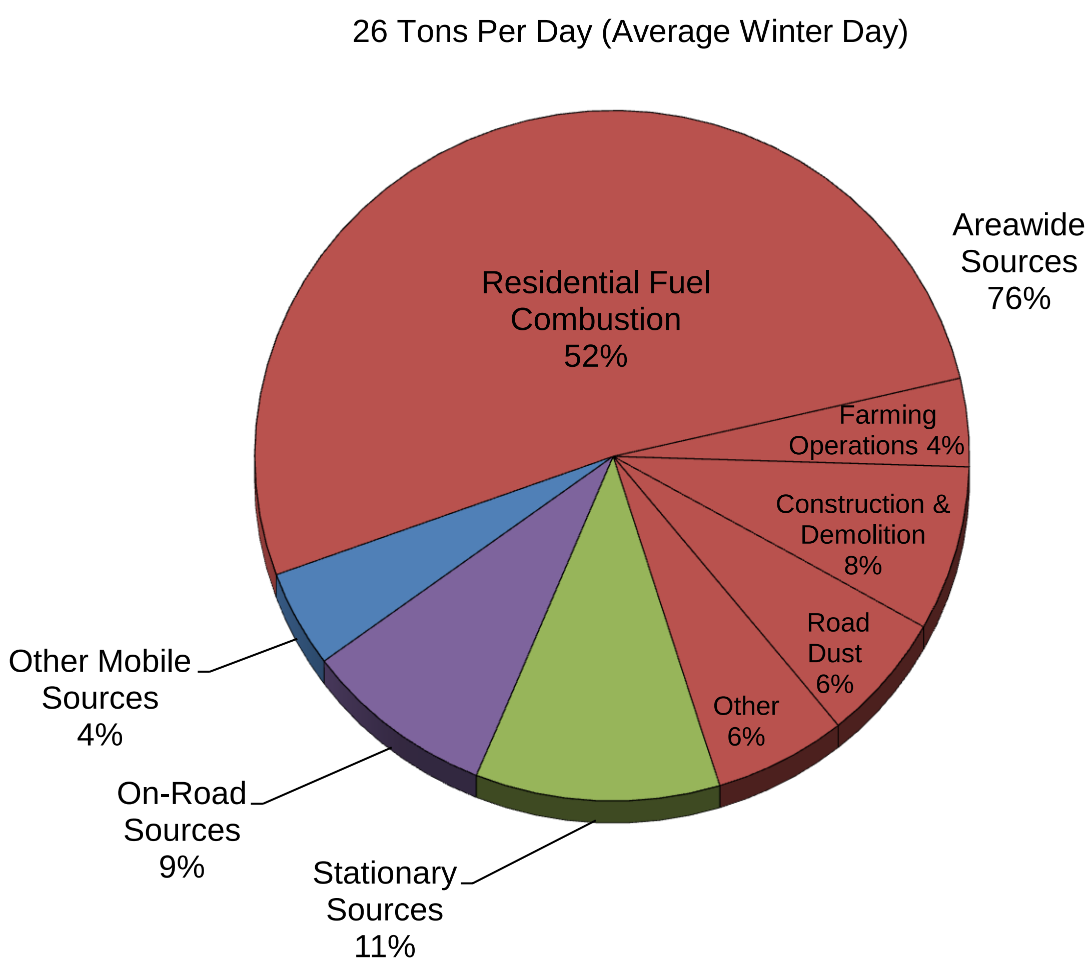
CATEGORY	VOC			NH_3		
	2011	2017	2024	2011	2017	2024
TOTAL EMISSIONS	**106**	**97**	**94**	**27**	**27**	**28**
STATIONARY	23.1	26.3	27.8	5.5	6.0	6.3
AREAWIDE	41.4	44.3	45.4	18.9	19.1	19.3
ON-ROAD MOTOR	27.4	14.4	10.8	2.8	2.3	2.1
OTHER MOBILE	14.2	11.6	10.2	0.0	0.0	0.0
STATIONARY						
Fuel Combustion	1.3	1.3	1.3	0.5	0.5	0.5
Industrial Processes	7.5	8.4	9.3	0.0	0.0	0.0
Other	14.3	16.6	17.2	5.0	5.5	5.8
AREAWIDE						
Residential Fuel	17.6	18.5	18.1	0.8	0.8	0.8
Managed Burning and Disposal	0.6	0.7	0.6	0.1	0.1	0.1
Consumer Products	12.4	13.0	14.0	0.0	0.0	0.0
Architectural Coatings	5.9	6.8	7.5	0.0	0.0	0.0
Pesticides/Fertilizers	1.1	1.2	1.1	7.1	6.9	6.7
Farming Operations	2.8	3.0	3.0	7.1	7.1	7.1
Other	1.0	1.1	1.1	3.8	4.2	4.6
ON-ROAD MOTOR VEHICLES						
Light/Medium-Duty Vehicle	20.2	9.3	6.4	2.5	2.0	1.9
Heavy-Duty Trucks	4.6	3.0	2.3	0.3	0.3	0.2
Other	2.6	2.1	2.1	0.0	0.0	0.0
OTHER MOBILE						
Aircraft	0.6	0.6	0.6	0.0	0.0	0.0
Trains	0.4	0.3	0.2	0.0	0.0	0.0
Boats/Rec Vehicles	5.0	4.1	3.5	0.0	0.0	0.0
Off-Road Equipment	6.1	5.2	4.8	0.0	0.0	0.0
Farm Equipment	1.0	0.6	0.4	0.0	0.0	0.0
Fuel Storage & Handling	1.1	0.8	0.7	0.0	0.0	0.0

Data Source: Except for on-road, CARB CEPAM: NORCAL 2012 $PM_{2.5}$ SIP Baseline Emission Projections, Section a1 - Emission Projections with External Adjustments, downloaded on October 11, 2012. On-road emissions include CARB external adjustments and are based on emissions generated by SACOG using EMFAC2011 and SACOG MTP/SCS2035 vehicle activity forecasts. ERCs plus additional adjustments from Tables B5.1 and B5.2 are included in the table. The total emissions are rounded to nearest integer. The total emissions are rounded to nearest integer.

4.5.2 2011 Attainment Year Emissions Distribution

Figure 4.1 shows the 2011 directly emitted $PM_{2.5}$ emission inventory categories as a percentage of the total inventory for SFNA-$PM_{2.5}$. Areawide sources make up 76% of directly emitted $PM_{2.5}$ emissions. At 52%, the Residential Fuel Combustion category of areawide sources dominates the $PM_{2.5}$ inventory. Other areawide sources, which include Construction & Demolition, Road Dust, Farming Operation and Other categories, contribute 24%. Mobile sources and stationary sources contribute 13% and 11%, respectively.

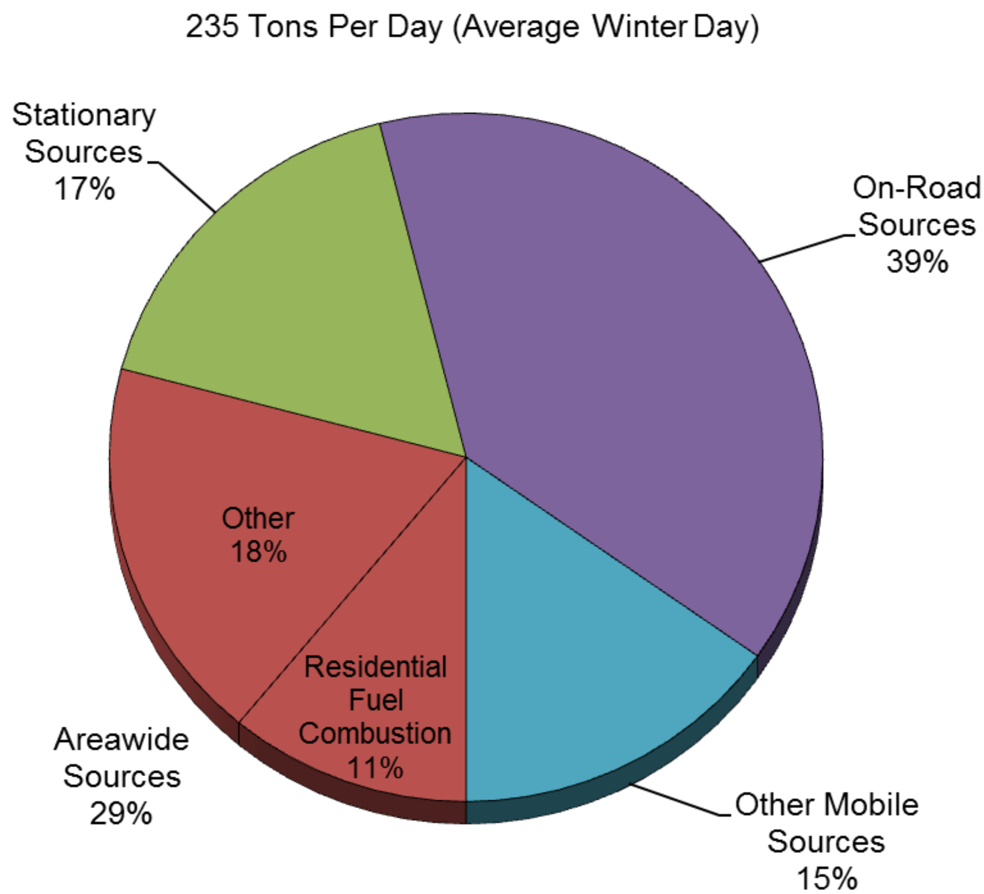
Figure 4.1 2011 Directly Emitted $PM_{2.5}$ Emissions Distribution Sacramento Federal $PM_{2.5}$ Nonattainment Area



Data Source: Table 4.1

Figure 4.2 shows 2011 $PM_{2.5}$ precursor emission inventory categories as a percentage of the total inventory for SFNA-$PM_{2.5}$. The main contribution of $PM_{2.5}$ precursors (NO_X, VOC, SO_2, and NH_3) comes from mobile sources. On-road motor vehicles account for about 39% of the $PM_{2.5}$ precursor inventory, and other mobile sources contribute 15%. Areawide Sources and stationary sources, mostly from solvent evaporation and fuel combustion, contribute 29% and 17%, respectively. Residential fuel combustion, a subset of areawide sources, contributes 11% to the total inventory.

Figure 4.2 2011 $PM_{2.5}$ Precursor (NO_X + VOC + SO_2 + NH_3) Emissions Distribution Sacramento Federal $PM_{2.5}$ Nonattainment Area



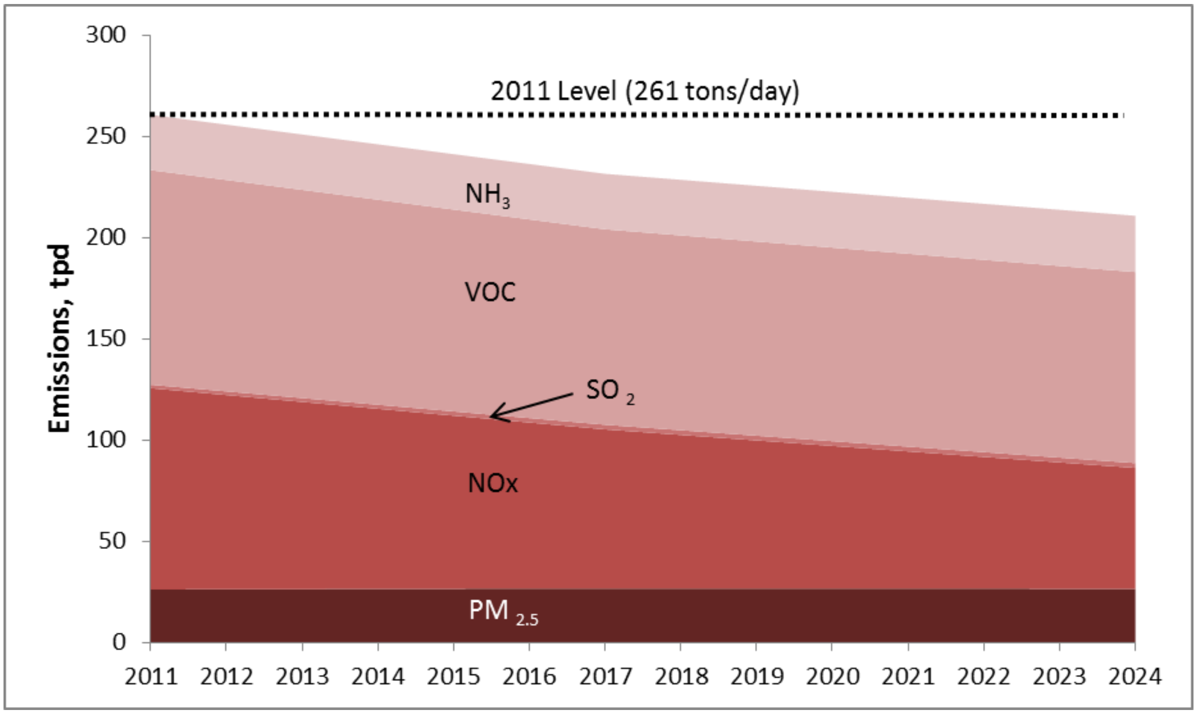
Data Source: Tables 4.2a and 4.2b.

4.6 Analysis of Emissions Inventory Forecasts

Emissions Inventory Trends

Figure 4.3 shows the attainment year inventory and forecasts through 2024 for $PM_{2.5}$ and its precursors in the SFNA-$PM_{2.5}$. These forecasts take into account anticipated population and economic growth and emission benefits from the federal, state and local control measures adopted as of mid-2011.

Figure 4.3 $PM_{2.5}$ & $PM_{2.5}$ Precursor Emissions Forecasts Sacramento Federal $PM_{2.5}$ Nonattainment Area (Average Winter Day)

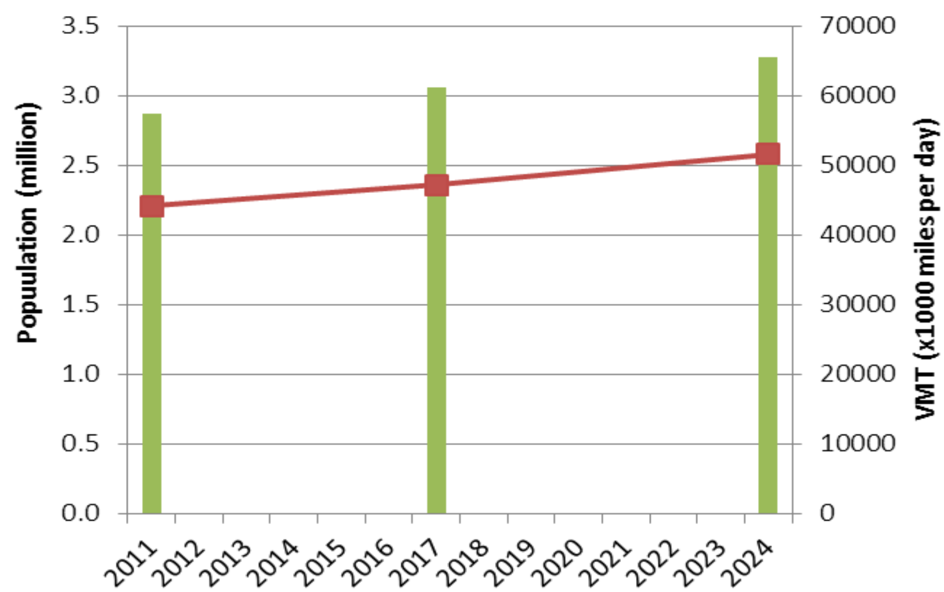


Data Source: Tables 4.1, 4.2a, and 4.2b.

The emission inventory trends show that between 2011 and 2024, the directly emitted $PM_{2.5}$ remains fairly constant at 26 tons/day with a slight increase of 0.4 ton/day while the $PM_{2.5}$ precursors steadily decline by 21%. The reductions in directly emitted $PM_{2.5}$ gained from the controls on residential wood combustion, diesel trucks and off-road equipment are offset by growth in the Sacramento region. Whereas, despite growth, the $PM_{2.5}$ precursors are projected to decrease by 50 tons per day from 2011 to 2024. The reduction in $PM_{2.5}$ precursors are predominately from cleaner vehicles and equipment replacement due to mobile fleet turnover and from the adopted NO_X and VOC control commitments in the ozone attainment plans. Chapter 6 contains a discussion on control measures which have been implemented by the local air districts of the Sacramento Region, as well as State and federal agencies. These permanent and enforceable measures, which have reduced directly emitted $PM_{2.5}$ and its precursors have decreased the region's $PM_{2.5}$ design value significantly and led to $PM_{2.5}$ attainment in 2011. These measures will continue to reduce emissions in future years so that the combined total emissions of directly emitted $PM_{2.5}$ and its precursors remain below the attainment year emission level.

The SFNA-$PM_{2.5}$ emissions inventory continues to decline despite increasing population and vehicle activity. Figure 4.4 illustrates trends in population and VMT. Based on SACOG forecasts and the U.S. Census (Glover 2012)(California Department of Finance, 2012), the population in the SFNA-$PM_{2.5}$ is projected to grow at an average of 1.3% annually from 2011 to 2024. The 2011, 2017 and 2024 VMT data are based on SACOG's adopted MTP/SCS 2035. Between 2011 and 2024, population and VMT in SFNA-$PM_{2.5}$ are expected to increase by 17% and 14%, respectively. These growth projections are used to make the 2017 and 2024 emissions inventory forecasts.

Figure 4.4 Population and Vehicle Miles Traveled (VMT) Forecasts - Sacramento Federal $PM_{2.5}$ Nonattainment Area (2011-2024)



	2011	2017	2024
VMT (x1000 miles/day)	57397	61275	65654
Population (millions)	2.2	2.4	2.6

Data sources:

- (Glover, 2012)
- Solano pop is from DOF website: http://www.dof.ca.gov/research/demographic/reports/estimates/e-5/2001-10/view.php.
- (Abraham, 2012a), (Crow, 2012), (Abraham, 2012b)

4.7 Emission Reduction Credits

Certain pollutant emission reductions due to equipment shutdown or voluntary controls may be converted to emission reduction credits (ERCs) and registered with the air district. These ERCs may then be used as "offsets" to compensate for an increase in emissions from a new or modified major emission source. In Sacramento County, ERCs may also be used as an alternative to, or bridge, to compliance with specified rules.

Since ERCs represent potential emissions, they need to be taken into account in the emission inventories. One method is to assume that the use of ERCs will already be included within the projected rate of stationary source growth in the emissions inventory. However, if the use of available ERCs exceeds anticipated emissions growth, future emissions could be underestimated. Therefore, to ensure that the use of ERCs will not be inconsistent with the future $PM_{2.5}$ maintenance goals, the amount of ERCs issued for reductions that occurred prior to the 2011 base year are added to the emission inventory forecasts in the maintenance demonstration.

Unused Banked Emission Reduction Credits

The current unused banked ERCs[23] in the SFNA-$PM_{2.5}$ are accounted for in this $PM_{2.5}$ maintenance plan. Reductions in rice burning in Yolo-Solano air district are banked under Rule 3.21 Rice Straw Emission Reduction Credits and in Placer County Air Pollution District are banked under Rule 516 Rice Straw Emission Reduction Credits, and are included under unused banked ERCs. These ERCs are included to maintain the validity of previously banked ERCs and other reductions.

Future Bankable Rice Burning Emission Reduction Credits

California legislation[24] in 1991 (known as the Connelly Bill) required rice farmers to phase down rice field burning on an annual basis, beginning in 1992. A burn cap of 125,000 acres in the Sacramento Valley Air Basin was established, and growers with 400 acres or less were granted the option to burn their entire acreage once every four years. Since the rice burning reductions were mandated by state law, they would ordinarily not be “surplus” and eligible for banking. However, the Connelly bill included a special provision declaring that the reductions are qualified for banking if they meet the State and local banking rules.

Reduction in rice burning may be banked in the future because of ERC rules[25] under development in the Sacramento Air District. Table 4-4 shows the total amount of potential bankable rice burning ERCs in the SFNA-$PM_{2.5}$.

Available Wood Stove/Fireplace Change-Out Incentive Program Emission Reduction Credits

Sacramento County’s Wood Stove/Fireplace Change-Out Incentive Program was established in June 2006 to provide financial incentives to remove or replace existing fireplaces and dirty wood stoves. Part of the funding for this incentive program comes from Sacramento County’s Solutions for the Environment and Economic Development (SEED) program. One of the SEED program requirements is that the revenue generated from ERCs be used to replenish the ERC bank. The emissions reductions generated using SEED revenue in this incentive program must be banked as ERCs. About half of the emission reductions from this program will be available for the ERC bank. These ERCs from the Wood Stove/Fireplace Change-Out Incentive Program from Sacramento County are also added to the total ERCs.

Summary of Emission Reduction Credits

ERCs issued for reductions that occurred prior to the 2011 attainment year and potential future bankable ERCs from rice burning and Wood Stove/Fireplace Change Out Incentive Program are summarized for the SFNA-$PM_{2.5}$ in Table 4.4 and are accounted for in the emissions

23 Each district provided their ERC information to CARB and is summarized in (Taylor, 2012a).
24 Connelly-Areias-Chandler Rice Straw Burning Reduction Act of 1991, section 41865 of California Health and Safety Code.
25 This rice burning ERC rule must be approved by EPA into the SIP for the rice ERCs to be used for compliance with federal air quality requirements.

forecasts in Tables 4.1, 4.2, and 4.3. These ERCs are in tons per day for average winter day and are included in the $PM_{2.5}$ maintenance demonstration for 2017 and 2024. See Appendix B6 for details.

Table 4.4 Emission Reduction Credits Added to the Maintenance Demonstration - Sacramento Federal $PM_{2.5}$ Nonattainment Area

Emissions in tons/day (winter average day)	**$PM_{2.5}$**	**SO_X**	**NO_X**	**VOC**
Emission Reduction Credits (Includes YS Rice ERC)	1.6	0.6	2.8	4.3
Future Bankable Rice Burning Emission Reduction Credits (Sac County + Placer County)	0.31	0.06	0.28	0.25
Wood Stove/Fireplace Change-Out Incentive Program (Sac County Only)	0.09	0.001	0.01	0.10
Total ERCs	**2.0**	**0.6**	**3.1**	**4.6**
Total ERCs (rounded up)	**2**	**1**	**4**	**5**

4.8 Emissions Inventory Documentation

More detailed tables of the $PM_{2.5}$, SO_2, NO_X, VOC, and NH_3 emissions inventory are provided in Appendix B. This appendix contains the estimated 2011, 2017, and 2024 emissions inventory for the SFNA-$PM_{2.5}$.

Emission inventories are constantly being updated to incorporate new and better information and methodologies. Detailed information on emission methodologies, changes and forecasts can be found on CARB websites:
http://www.arb.ca.gov/ei/ei.htm and http://www.arb.ca.gov/msei/msei.htm

4.9 Emissions Inventory Conclusions

This maintenance plan includes an emissions inventory for total directly emitted $PM_{2.5}$, and its precursors, SO_2, NO_X, VOC, and NH_3. The emissions inventory shows that residential combustion from fireplaces and woodstoves is the main contributor to the directly emitted $PM_{2.5}$ inventory at 52%. It also shows that mobile sources dominate the $PM_{2.5}$ precursor inventory at 54%.

The emission inventory trends show that between 2011 and 2024, $PM_{2.5}$ precursors steadily decline about 21% primarily due to the phase-in of cleaner vehicles and equipment subject to steadily tightening emission standards. The trends show that $PM_{2.5}$ increases slightly by 1%. Thus, the emission inventory trends demonstrate that the region will continue to attain the 24-hour $PM_{2.5}$ NAAQS through 2024 by showing that the combined total future emissions of directly emitted $PM_{2.5}$ plus its precursors for SFNA-$PM_{2.5}$ remain below the attainment year emission level.

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5 Meteorological Analysis

Overview

The purpose of this chapter is to illustrate that attainment of the 2006 National Ambient Air Quality Standard (NAAQS) for $PM_{2.5}$ in Sacramento during the 2009-2011 period was not due to "unusually favorable meteorological conditions." Three independent analyses were performed to assess whether meteorological conditions during this period were unusually favorable for low $PM_{2.5}$ concentrations:

1. Classification and Regression Tree (CART)
2. General Statistics and Hypothesis Testing
3. Air Quality Forecasting Conceptual Model

The CART analysis is an advanced statistical technique that is used to predict the value of a variable (in this case, $PM_{2.5}$ concentrations in Sacramento) using several input variables (in this case, meteorological parameters). This analysis found that reductions in $PM_{2.5}$ concentrations in Sacramento during the 2009-2011 attainment period were not attributable to unusually favorable meteorological conditions.

The General Statistics and Hypothesis Testing analysis used several techniques to assess individual meteorological parameters that impact $PM_{2.5}$ concentrations in Sacramento. This analysis showed that the meteorological conditions during the past decade and during the 2009-2011 attainment period were not unusually favorable for lower $PM_{2.5}$ concentrations.

The Air Quality Forecasting Conceptual Model analysis used established guidelines for forecasting $PM_{2.5}$ concentrations in Sacramento to assess whether daily meteorological parameters were collectively favorable for high or low $PM_{2.5}$ concentrations. This analysis found that overall meteorological conditions during the 2009-2011 attainment period were not conducive for lower $PM_{2.5}$ concentrations in Sacramento.

The three aforementioned independent analyses all illustrate that meteorological conditions during the 2009-2011 attainment period were not unusually favorable for lower $PM_{2.5}$ concentrations in Sacramento. Section 5.1 further introduces these analyses, the differences between analyses, and provides a brief overview of meteorological conditions in Sacramento during the 2009-2011 attainment period. Sections 5.2 through 5.4 describe in detail the three independent analyses and their results. Section 5.5 concludes this chapter.

5.1 Introduction

The United States Environmental Protection Agency (EPA) guidance states that "… attainment due to *unusually favorable meteorology* would not qualify as an air quality improvement due to permanent and enforceable emissions reductions" (Calcagni, 1992). The following analyses address the likelihood that "unusually favorable meteorological conditions" caused the region to attain the 2006 National Ambient Air Quality Standard (NAAQS) for $PM_{2.5}$.

Meteorology plays a major role in the formation of $PM_{2.5}$. Certain meteorological parameters such as surface temperature, inversion layer strength, wind speed, relative humidity, and precipitation can affect pollutant transport, secondary aerosol formation and, more importantly,

$PM_{2.5}$ ambient concentration levels. For example, on cold nights with no wind, a temperature inversion can trap pollutants near the surface, which could result in higher $PM_{2.5}$ concentrations in the Sacramento region (Motallebi, 1999, p1).

California Air Resources Board (CARB), the Sacramento Metropolitan Air Quality Management District, and Sonoma Technology, Inc. (STI) prepared three independent analyses to evaluate the meteorological impacts on ambient $PM_{2.5}$ concentrations. These analyses applied different methods (two statistical and one conceptual) to answer the question: Is Sacramento's attainment due to "*unusually favorable meteorology*"? Although some differences exist among these analyses, such as the period of evaluation, methodologies used, and data selection, they lead to the same conclusion that reductions in $PM_{2.5}$ concentrations in Sacramento during the 2009-2011 attainment period are not attributable to unusually favorable meteorological conditions.

Classification and Regression Tree Analysis (CART)

California Air Resources Board staff used a statistical technique, referred to as Classification and Regression Tree (CART) analysis, to help support the Sacramento Region's attainment and maintenance demonstration of the 24-hour $PM_{2.5}$ standard. CART is a non-parametric technique that produces a classification tree if the dependent (target) variable is categorical or a regression tree if the dependent variable is numeric. At each step of the tree building process, CART finds the best possible independent variable to split the values of the target variable into two groups for which the means are as different as possible (subject to certain constraints). In this analysis of $PM_{2.5}$ and meteorology, the final CART tree explains daily $PM_{2.5}$ in terms of the meteorological variables (parameters) used to make the splits. The evaluation period of the initial CART analysis did not cover 2011, one of the attainment years, and therefore could not provide a full evaluation whether the attainment of $PM_{2.5}$ was due to "unusually favorable" meteorology. STI reproduced the CART analysis prepared by CARB and applied it to data for the years 2011 and 2012, allowing for a full evaluation of meteorological conditions during the 2009-2011 attainment period.

General Statistics and Hypothesis Testing

SMAQMD staff applied the general statistics and hypothesis test to evaluate whether individual meteorological parameters might favor low ambient $PM_{2.5}$ concentrations. The general statistics include the calculation of average, median, first quartile, third quartile, minimum, and maximum. The first quartile and third quartile are also known as 25^{th} and 75^{th} percentiles. These statistical values are presented in Box-and-Whisker Plots (box plots). By comparing the data distribution, data location, data spread, and data range, we can determine any favorable meteorological conditions that may exist. The hypothesis test compares the average between the attainment year and the decade and determines whether these averages are significantly different from each other. STI also reviewed and affirms the statistical analysis performed by the SMAQMD.

Air Quality Forecasting Conceptual Model for Sacramento

STI has produced daily $PM_{2.5}$ and ozone forecasts for the Sacramento region since 1996. STI developed forecasting guidelines for SMAQMD's Check Before You Burn (CBYB) program (STI, 2012); these guidelines indicate whether meteorological conditions are conducive to high $PM_{2.5}$

concentrations. STI implemented a web-based system called AQRules (STI, 2013) that automatically runs these guidelines daily using predictions from meteorological forecast models. STI developed unique sets of guidelines specific to certain upper-air and synoptic pressure patterns identified as favorable for high $PM_{2.5}$ concentrations in Sacramento. STI used these guidelines to assess whether observed meteorological conditions during the 2002-2012 period were unusually favorable for high or low $PM_{2.5}$ concentrations. This analysis was limited to days in November, December, January, and February, as these months constitute Sacramento's CBYB program for which the forecast guidelines were developed and the time of year when high $PM_{2.5}$ values typically occur.

Differences Between Analyses

CARB's CART analysis, SMAQMD's statistical analysis, and STI's conceptual model analysis are three independent evaluations: differences exist in terms of data selection, evaluation period, and the $PM_{2.5}$ concentration averaging time (i.e. 24 Hour and Annual). The CART analysis evaluated surface temperature, surface wind speed, difference of surface temperature and 850 millibar (mb) temperature, relative humidity, daily maximum and minimum temperature, and the difference (delta) of daily maximum and minimum temperature. The general statistics and hypothesis test evaluated a similar set of meteorological parameters except it did not evaluate the difference (delta) of daily maximum and minimum temperature. In addition, since the general statistics analysis only focuses on winter seasons, SMAQMD chose to evaluate inversion strength using an upper air temperature height of 925mb, which is at a lower height than that used for CARB's CART analysis. SMAQMD also chose to evaluate dew point temperatures in the general statistics analysis instead of relative humidity, which CARB analyzed in the CART analysis. STI's conceptual model analysis uses a separate set of parameters depending on synoptic weather conditions, but these parameters are generally similar to those used in the CART and SMAQMD analyses.

As mentioned earlier, the CART analysis evaluated the meteorological parameters for all months in a year, and all parameters are considered together in the regression tree analysis and the met-adjusted trend. Note, however, that the first branch of the CART divides the data by season. SMAMQD and STI analyses only focused on the meteorological conditions of winter months (November through February). Furthermore, in SMAQMD's analyses, meteorological parameters are compared independently with the ambient $PM_{2.5}$ concentrations, whereas STI's analysis looks at meteorological conditions as a whole. Additionally, CARB's analysis evaluated the annual average $PM_{2.5}$ concentrations where SMAQMD's statistical analysis evaluated the 98^{th} percentile $PM_{2.5}$ concentrations.

Benefits and Limitations of Having Three Independent Analyses

Because data selections and evaluation methods are different, the results of the three analyses are not expected to be identical; however, the analyses collectively provide a weight of evidence because they reach the same conclusion that reductions in $PM_{2.5}$ concentrations in Sacramento during the 2009-2011 attainment period are not attributable to unusually favorable meteorological conditions.

CARB's analysis integrated all the influence of meteorological parameters and predicted the annual average $PM_{2.5}$ concentrations if emissions remained constant at the 2004-2006 level. It also predicted annual average $PM_{2.5}$ concentrations when meteorological adjustment factors are considered. This methodology evaluated the overall impacts of meteorology for the $PM_{2.5}$ concentrations in the Sacramento region.

SMAQMD's statistical analysis looked at each meteorological parameter individually and covered the period from 2002 to 2011. All the years in the attainment period were evaluated.

STI's conceptual model analysis has the benefit of examining meteorological parameters in combination and assessing whether daily conditions as a whole were favorable for high or low $PM_{2.5}$ concentrations and also considers synoptic weather patterns. However, this analysis does not directly compare predicted and observed $PM_{2.5}$ concentrations. The analysis covered the period from 2002 to 2012; thus, all the years in the attainment period were evaluated.

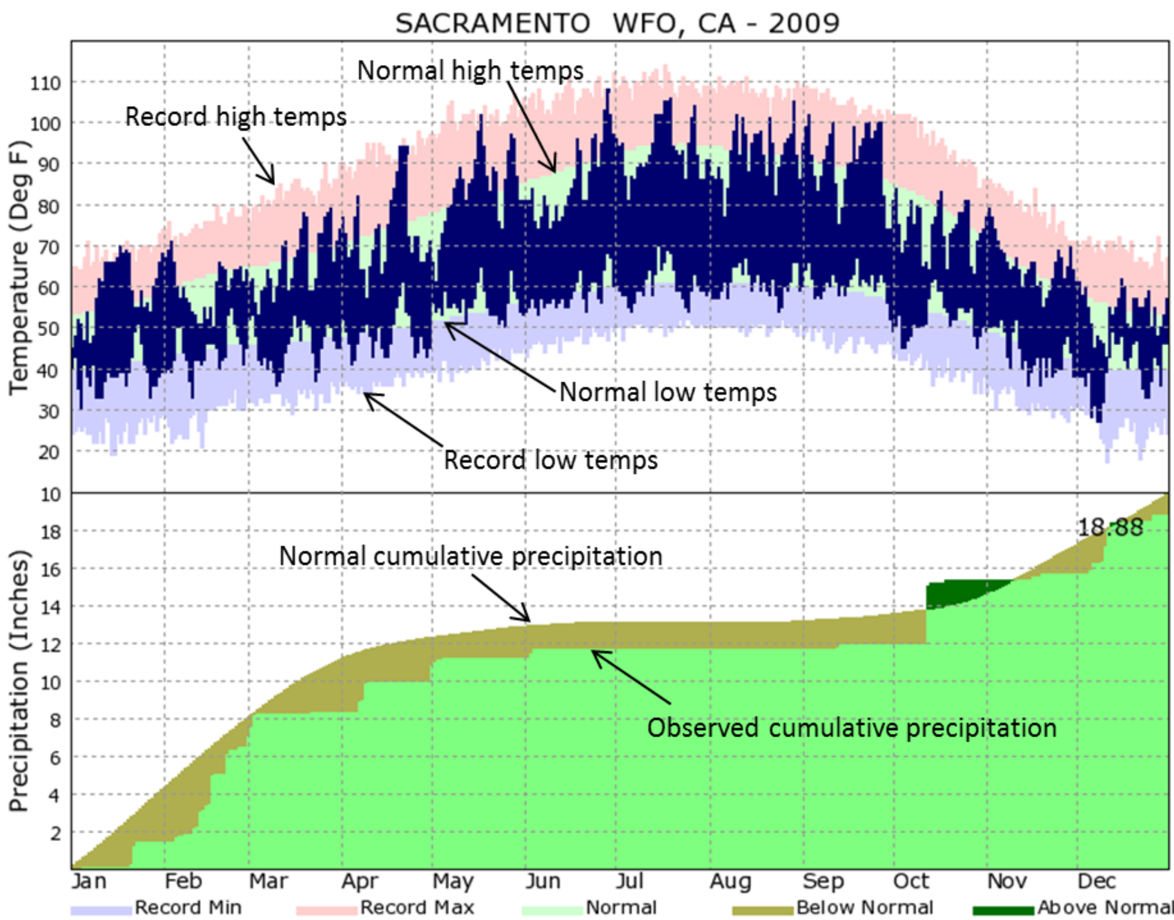
Overview of Meteorological Conditions in Sacramento, 2009-2011

The purpose of this section is to summarize temperature and precipitation patterns in Sacramento during the months of November through February in 2009, 2010, and 2011. $PM_{2.5}$ concentrations in the Sacramento region are typically highest during these months. The summary focuses on precipitation frequency and amounts, as these serve as a proxy for the frequency of storm systems moving through. Storm systems generally produce stronger winds and enhance atmospheric mixing, which disperses pollutants and results in lower $PM_{2.5}$ concentrations. Annual temperature and precipitation plots from the National Weather Service (NWS) in Sacramento (NWS, 2013) illustrate the observed weather conditions relative to normal conditions. The temperature plots show observed daily temperature ranges (dark blue), daily record high temperatures (light red), daily record low temperatures (light blue), and the normal high and low temperatures (indicated by light green area). The precipitation plots show the observed cumulative precipitation (light green). Dark green shading on the precipitation plots indicates precipitation surpluses relative to normal, and brown shading indicates precipitation deficits relative to normal. Observations shown in these plots were taken at the Sacramento NWS Weather Forecast Office (WFO). These plots are shown in this report only to provide a broad summary of weather conditions during these winter seasons; however, $PM_{2.5}$ concentrations are not solely driven by temperature and precipitation. More detailed analyses of other meteorological parameters and their effects on $PM_{2.5}$ concentrations are provided later in this chapter. This broad assessment of meteorological conditions in Sacramento during the 2009-2011 attainment period indicates that conditions overall were not unusually favorable for low ambient $PM_{2.5}$ concentrations, especially in 2009 and 2011. This assessment is consistent with the results from the more detailed analyses found in the rest of Chapter 5.

Meteorological Conditions in 2009

Overall weather conditions in Sacramento in 2009 during January, February, November, and December were drier and slightly cooler than normal. These temperature and precipitation patterns are not unusually favorable for low ambient $PM_{2.5}$ concentrations. January 2009 was slightly warmer and much drier than normal in Sacramento (Figure 5.1), with only one major wet system moving through mid-month. In contrast, February 2009 was cooler and much wetter than normal, with numerous wet systems moving through and over 5 inches of rain reported for the month. November 2009 was very dry in Sacramento, with only 0.36 inches of rain reported. Several wet systems moved through the Sacramento region in December 2009, resulting in near-normal precipitation.

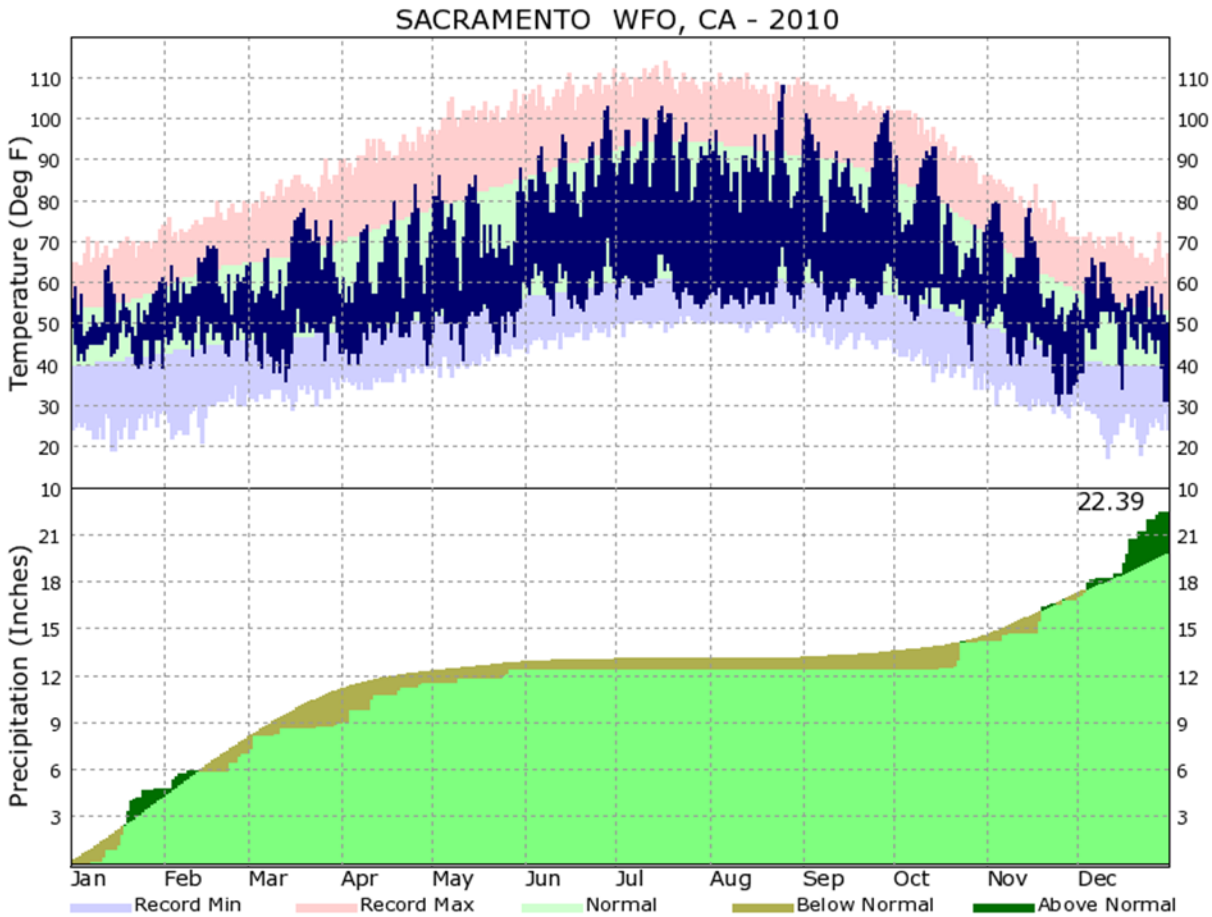
Figure 5.1 2009 climograph for downtown Sacramento (NWS).



Meteorological Conditions in 2010

Overall weather conditions in 2010 during January, February, November, and December were wetter and slightly warmer than normal. These temperature and precipitation patterns are generally favorable for lower ambient $PM_{2.5}$ concentrations. January 2010 was slightly warmer and wetter than normal in Sacramento (Figure 5.2) with several wet systems moving through during the second half of the month. February 2010 was drier than normal, with a period of warmer than normal temperatures during the middle of the month followed by cooler than normal temperatures. November 2010 began with warmer than normal temperatures but ended with much cooler than normal temperatures, resulting in overall temperatures cooler than normal. A strong system moved through Sacramento in mid-November, producing nearly 2 inches of rain over two days. December 2010 was warmer and much wetter than normal, with measureable precipitation falling on 18 days and 5.52 inches of rain total.

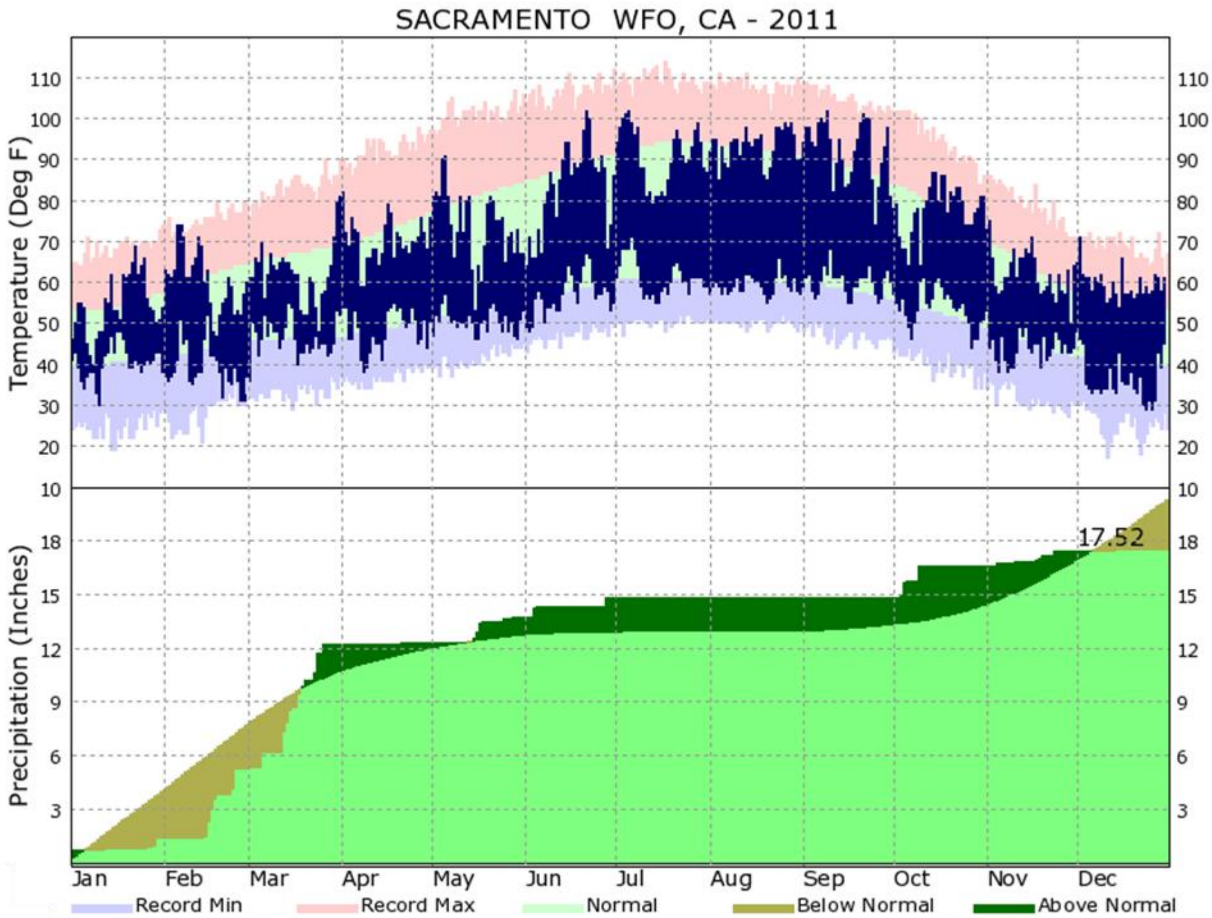
Figure 5.2. 2010 climograph for downtown Sacramento (NWS).



Meteorological Conditions in 2011

Overall weather conditions in 2011 during January, February, November, and December were cooler and much drier than normal. These temperature and precipitation patterns were not favorable for low ambient $PM_{2.5}$ concentrations. January 2011 was drier and slightly cooler than normal in Sacramento (Figure 5.3). Only two significant storm systems moved through Sacramento during this month, one at the very beginning of the month and the other at the end of the month. This resulted in an extended period of dry, cool weather for much of the month. February 2011 was cooler than normal with near normal precipitation, but all of the precipitation fell during the second half of the month. November 2011 was cooler and drier than normal in Sacramento, and December 2011 was extremely dry with near normal temperatures. A persistent upper-level ridge of high pressure along the West Coast deflected wet Pacific storms well north of Sacramento, resulting in relatively stagnant conditions and only 0.07 inches of rain for the month.

Figure 5.3. 2011 climograph for downtown Sacramento (NWS).



5.2 Classification and Regression Tree Analysis

5.2.1 Introduction

Air quality trends can help reveal the effects of emission control strategies and regulations on ambient air pollution levels. However, meteorological conditions also affect pollutant levels and can obscure the effects of changing emissions on ambient air pollution levels over time. If the meteorological effects can be identified, quantified and removed, the met-adjusted trends may reveal the emissions-induced trends with greater clarity.

For Sacramento, met-adjusted trends were prepared for annual average $PM_{2.5}$ and for $PM_{2.5}$ exceedance days. This analysis presents the methodology used to construct the met-adjusted trends.

5.2.2 Data Acquisition and Preparation

$PM_{2.5}$ mass concentrations from three air quality monitoring sites in Sacramento were collected. Meteorological data for factors that may influence $PM_{2.5}$ concentrations were also acquired from various meteorological monitoring networks. Monitors at ground level provided temperature, relatively humidity, air pressure, wind speed, wind direction, precipitation, and solar radiation data. For various reasons, surface air pressure, wind direction, precipitation, and solar radiation were not used in the final analysis. Routine rawinsondes (weather balloons) at Oakland provided data for 500 millibar (mb) heights and 850 mb temperatures. These surface and upper air factors are consistent with studies of meteorological conditions associated with daily $PM_{2.5}$ levels (EPA, 2003).

Table 5.1 lists the air quality and meteorological monitoring sites that provided data used in this analysis. The $PM_{2.5}$ and meteorological data presented are daily regional averages of the data collected from the sites in various locations in Sacramento.

Table 5.1 Air Quality and Meteorological Monitoring Sites

Air Basin	Region	Air Quality Sites	Meteorological Sites
SV	Sacramento	Sacramento-Health Dept., Stockton Bl Sacramento-Del Paso Manor Sacramento-T Street	Sacramento-Health Dept. Stockton Bl Sacramento-Del Paso Manor Sacramento-T Street Elk Grove-Bruceville Road Fair Oaks #2

A consistent analysis of met-effects on daily $PM_{2.5}$ will benefit from, and may require, the presence of all $PM_{2.5}$ and meteorological data for each daily record used in the analysis. If any values are missing, the entire day might be excluded from further consideration. Therefore, data completeness is very desirable for the analysis to be as meaningful as possible. To minimize instances of missing $PM_{2.5}$ and meteorological data, imputed values were calculated based on relationships for measured data at nearby sites. The imputed values were used when appropriate. Details concerning the imputation method (called "I-Bot") are available from the Air Quality and Statistical Studies Section of CARB.

5.2.3 Analytical Method: Classification and Regression Trees

CART is a statistical exploratory technique for uncovering structures in the data, which is sometimes called "data mining" (Breiman, 1984; Thompson, 2001; Slini, 2007). CART is a non-parametric decision tree learning technique that produces a classification tree if the dependent (target) variable is categorical or a regression tree if the dependent variable is numeric. At each step of the tree building process, CART finds the best possible independent variable (or linear combination of independent variables) to split the values of the target variable into two groups for which the means are as different as possible (subject to certain constraints). Each of the new groups is called a "child" node. The process of node splitting is repeated for each child node, continued recursively until a stopping criterion is satisfied, and a set of terminal nodes is reached (Breiman, 1984; Xu, 2005). In this way, the nodes of the final CART tree explain the values of the dependent variable in terms of the independent variables used to make splits.

In this analysis of $PM_{2.5}$ and meteorology, the final CART tree explains daily $PM_{2.5}$ in terms of the meteorological variables (parameters) used to make the splits. Table 5.2 lists all the parameters used in this particular analysis. The parameters used are much the same as those listed in EPA Guidelines for Developing an Air Quality (Ozone and $PM_{2.5}$) Forecasting Program (EPA, 2003).

Table 5.2 Meteorological Parameters in CART Analysis

Common predictor variables used to forecast $PM_{2.5}$

Variable	Usefulness	Condition for High $PM_{2.5}$ [a]	Used in Our Analysis
500-mb height	Indicator of the synoptic-scale weather pattern	High	Yes
Surface wind speed	Associated with dispersion and dilution of pollutants	Low	Yes
Surface wind direction	Associated with transport of pollutants	-	No[b]
Pressure gradient	Causes wind/ventilation	Low	No[b]
Previous day's peak $PM_{2.5}$ concentration	Persistence, carry-over	High	No[c]
850-mb temperature	Surrogate for vertical mixing	High	Yes
Precipitation	Associated with clean-out	None or small	No[d]
Relative Humidity	Affects secondary reactions	High	Yes
Holiday	Additional emissions	-	Yes
Day of week	Emissions differences	-	Yes
Season	Transport patterns / Chemistry		Yes
Surface Temperature	Chemistry / Photochemistry		Yes
Difference of Surface T and 850-mb T	Surrogate for stability		Yes
Difference of max and min T	Diurnal variability		Yes

[a] Relative condition is location- and season- dependent
[b] Transport patterns are characterized either by clustering the pressure gradients or by seasons
[c] Since we are investigating the impact of meteorology on $PM_{2.5}$ (not forecasting), the change of emissions should not play a role in the analysis
[d] Precipitation data are not used in this analysis due to the data quality and completeness issues

To prepare a CART tree, CARB selected the years 2004-2006 as base years, assuming that the relevant emissions did not change greatly during these few years. When emissions are reasonably stable, day-to-day differences in $PM_{2.5}$ concentrations are mostly due to differences in meteorology. CARB then applied CART analysis to the base years to define a relationship ("tree") between daily $PM_{2.5}$ and daily meteorological conditions.

First, the tree was split by season so that an independent sub-tree was generated for each season. Each sub-tree consisted of one or more terminal nodes representing different meteorological classes. The CART system makes the differences in $PM_{2.5}$ between the met-classes as large as possible and the differences in $PM_{2.5}$ within the met-classes as small as possible. CARB's CART tree diagram (CARB, 2012) shows the CART defined relationship between the daily $PM_{2.5}$ concentration and the daily meteorological conditions for Sacramento. The $PM_{2.5}$ concentration representing each met-class (terminal node) is the average concentration of all the days assigned to that met-class in the base years. For each day assigned to a met-class, the average $PM_{2.5}$ for the met-class serves as a "predicted $PM_{2.5}$" for that day. Days with high-predicted values have met-conditions that are more conducive to $PM_{2.5}$ formation compared to days with low predicted values.

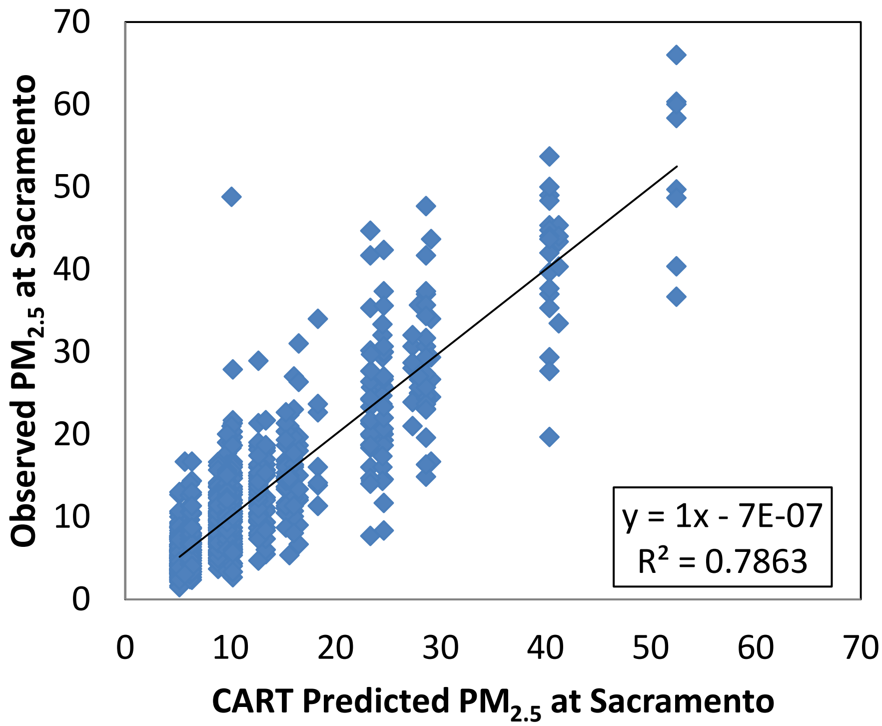
The CART-defined relationship between meteorology and $PM_{2.5}$ in the base years was then used to assign days in the other years to their appropriate met-classes based on their day-specific meteorological data. The predicted $PM_{2.5}$ values for all the days are then used to adjust $PM_{2.5}$ trends up or down to compensate for each year's $PM_{2.5}$-conduciveness relative to "normal."

5.2.4 Results and Discussion

Based on daily air quality and meteorological data in 2004-2006, a CART tree with 26 met-classes was constructed for Sacramento. Figure 5.4 indicates that this CART tree accounts for approximately 80 percent of the variation in daily $PM_{2.5}$ during the base years.

It is worth mentioning that this CART model treats each day independently and does not directly characterize met-conditions over a sequence of days that may result in long-term buildup and transport of $PM_{2.5}$.

Figure 5.4 Observations vs. CART Predictions during the Base Years in Sacramento

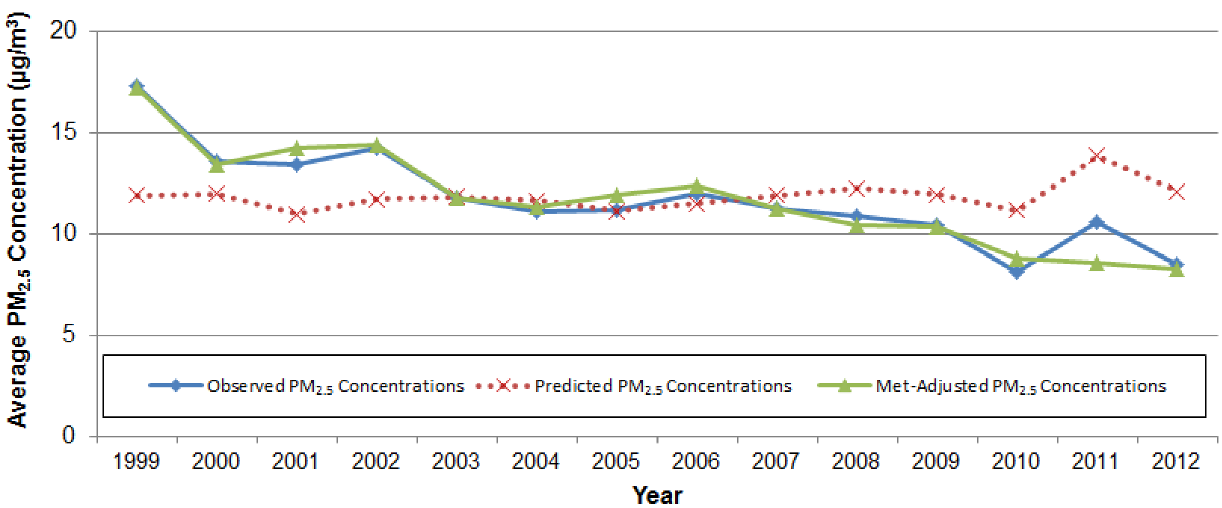


A sensitivity analysis was also done to explore the impact of the selected base years on the CART results for Sacramento. For this purpose, different sets of base years (2003-2005, 2004-2006, and 2006-2008) were used with CART to develop relationships between meteorology and $PM_{2.5}$. The met-adjusted annual average $PM_{2.5}$ concentrations proved to be quite similar regardless of the base years used in the CART analysis.

Annual average $PM_{2.5}$ trends for observed data and for CART-predicted values (2004-2006 used as base years) were analyzed in Sacramento. In Sacramento, observed $PM_{2.5}$ levels decreased significantly from 1999 to 2003, were relatively flat from 2003 to 2006, decreased again from 2007 to 2010, and increased in 2011 then dropped again in 2012. As described throughout Chapter 5, meteorological conditions in 2011 were particularly unfavorable for low $PM_{2.5}$ concentrations in Sacramento. Otherwise, for Sacramento, the CART-predicted annual average $PM_{2.5}$ concentrations trend (the red dotted line in Figure 5.5) is relatively flat, which indicates that met-conditions have been stable and have had relatively small impacts on observed $PM_{2.5}$ trends from 1999 through 2012. Additionally, the CART-predicted $PM_{2.5}$ concentrations are higher than the observed annual average $PM_{2.5}$ concentrations (blue line) beginning in 2008, demonstrating that emissions reductions, not weather conditions, caused the reductions in observed $PM_{2.5}$ annual average concentrations.

The CART-predicted trend information was merged with the observed trends to produce met-adjusted trends for annual average $PM_{2.5}$. Figure 5.5 shows the observed and met-adjusted trends for Sacramento and indicates that the met-adjusted and observed trends are very similar, both showing significant decreases in Sacramento. Met-adjusted $PM_{2.5}$ decreased by approximately 0.64µg/m^3 per year from 1999 through 2012. Comparing the met-adjusted trend line (green) to the observed trend line (blue) to examine the effect of meteorology during the 2009-2012 attainment period, the met-adjusted annual average $PM_{2.5}$ concentration in 2010 is slightly higher than what was observed, reflecting that weather conditions caused the observed annual average $PM_{2.5}$ concentration to be slightly lower than expected in 2010. In 2011, the met-adjusted annual average $PM_{2.5}$ concentration is lower than what was observed, reflecting that weather conditions caused the observed annual average $PM_{2.5}$ concentration to be higher than expected. The 2009 and 2012 met-adjusted and observed annual average $PM_{2.5}$ concentrations are roughly the same, indicating that weather conditions were relatively normal in those years. Overall, the met-adjusted trends indicate that annual average $PM_{2.5}$ decreased by over 50 percent in Sacramento from 1999 through 2012 because of ongoing emission reductions.

Figure 5.5 Trends of Observed and Meteorologically Adjusted $PM_{2.5}$ Concentrations in Sacramento



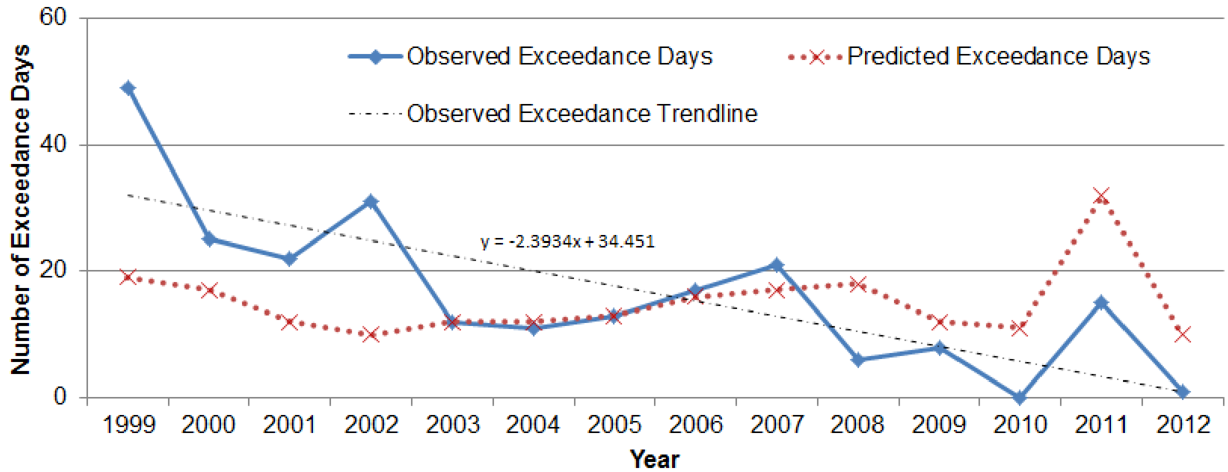
Trends for exceedance days were also prepared for Sacramento. For this work, an exceedance day meant that the regional average daily $PM_{2.5}$ concentration was greater than or equal to 35 µg/m^3. Trends for the observed $PM_{2.5}$ data and for the CART-predicted $PM_{2.5}$ data (representing meteorological effects) were prepared.

In Sacramento, the impact of meteorology on $PM_{2.5}$ exceedance days was relatively small, again similar to the annual averages. Figure 5.6 shows that the observed $PM_{2.5}$ exceedance days were greater than the CART-predicted $PM_{2.5}$ exceedance days from 1999 through 2002. The two trends were similar from 2003 through 2006. From 2007 through 2012, observed $PM_{2.5}$ exceedance days dipped below the CART-predicted exceedance days. In 2011, the number of observed $PM_{2.5}$ exceedance days increased but remained below the number of CART-predicted exceedance days. As is described in Section 5.2, meteorological conditions in 2011 were particularly favorable for higher $PM_{2.5}$ concentrations. The number of observed exceedance days decreased at a rate of approximately 3 days per year from 1999 through 2012. The implication of these results is that emission reductions played a significant role in decreasing the $PM_{2.5}$ exceedance days from 1999 through 2012. The number of observed $PM_{2.5}$ exceedance days remains below the number of CART predicted days.

It should be noted that the annual averages and exceedance days calculated in this analysis are not the same as the official annual averages and exceedance days for Sacramento. This is true for several reasons:

1. imputed data were used,
2. the exceedance days shown on the plots are the counts of days when the average (not the maximum) of the three Sacramento sites was greater than 35µg/m^3, and
3. the exceedance days were adjusted to account for the missing days (although there were not many because of data imputation).

Figure 5.6 Trends of Observed and CART-Predicted $PM_{2.5}$ Exceedance Days in Sacramento



5.2.5 CART Analysis Summary

Overall, CART analysis can help us to define the relationship between $PM_{2.5}$ mass concentrations and meteorological conditions and to calculate meteorologically adjusted trends. Such trends can help reveal the impact of emission changes on air pollutant levels, and promote the development of effective air pollution control strategies and regulations. Of course, as with any statistical analysis, there are uncertainties and limitations in CART analysis. Therefore, caution is needed when interpreting the resulting air quality trends, especially when small differences occur within short time periods.

The annual average $PM_{2.5}$ concentrations and the number of exceedances of the 24-hour $PM_{2.5}$ standard followed similar trends in Sacramento from 1999-2012. During that time, the meteorological conditions seem to have been relatively stable, so met-adjusted trends were similar to the observed trends.

The analyses indicate that the met-adjusted annual average $PM_{2.5}$ concentrations decreased at a rate of approximately 0.64µg/m^3 per year between 1999 and 2012. This corresponds to a decrease in met-adjusted $PM_{2.5}$ of approximately 50 percent in Sacramento as a result of emission reductions during this period. The observed number of $PM_{2.5}$ exceedance days per year in Sacramento also decreased significantly, at a rate of approximately 3 days per year between 1999 and 2012. This corresponds to a decrease in observed number of $PM_{2.5}$ exceedance days of approximately 98 percent. The implication of these results is that the downward trend in $PM_{2.5}$ concentrations in the Sacramento region is due to federal, state, and local emission reduction strategies rather than meteorological differences.

5.3 General Statistical Analysis and Hypothesis Testing

Meteorological parameters that are known to influence $PM_{2.5}$ concentrations in Sacramento were evaluated by year using various statistical techniques. For this analysis, each meteorological parameter was evaluated independently of the other parameters. Section 5.3.1 describes the meteorological parameters used in this analysis, why they were selected for this analysis, and the statistical methods used in this analysis. Sections 5.3.2 through 5.3.7 contain more detailed information on the statistical analyses and results for each meteorological parameter.

5.3.1 Background and Methodology

Forecasting Guidelines and meteorological research studies identified several meteorological parameters, which are important to ambient $PM_{2.5}$ concentrations. EPA forecasting program guidelines (EPA, 2003, Table 2-5) identified eight meteorological phenomena that can affect $PM_{2.5}$ concentrations: aloft pressure pattern, wind speed and direction, temperature inversions, rain, moisture, temperature, cloud/fog, and season[26]. Two scientific studies, which focus on particulate matter formation in the Sacramento region, evaluated most of EPA's meteorological phenomena and concluded that these factors play a role in the region's ambient $PM_{2.5}$ concentrations.

Motallebi's wintertime PM source apportionment study (Motallebi, 1999, p.7) examined 24-hour average wind speed, wind direction, temperature, and relative humidity and suggested that low temperatures in the presence of increased humidity are conducive to the formation of secondary particles. Motallebi also claimed that more residents are likely to utilize fireplaces, a source of $PM_{2.5}$, for residential heating as winter temperatures drop.

A study conducted by the University of California, Davis (Palazoglu, 2012, p.25) identified six different upper air pressure patterns using the technique of cluster analysis. It evaluated temperature, wind speed, wind direction, relative humidity, and precipitation. The cluster analysis shows that scenarios with cool midnight surface temperature and low wind speed recorded higher ambient $PM_{2.5}$ concentrations. This study also found that the scenario with significant daily average precipitation has the lowest ambient $PM_{2.5}$ concentration.

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[26] Season includes events that change by seasons such as agricultural activities, construction, and sun angle.

Sonoma Technology, Inc. (STI) developed forecasting guidelines for SMAQMD's Check Before You Burn program (STI, 2012). The guideline identifies four different upper air pressure patterns that are conducive to high $PM_{2.5}$ concentrations. STI uses these meteorological patterns and associated meteorological parameters to forecast ambient $PM_{2.5}$ concentrations in Sacramento County.

This analysis evaluates the meteorological parameters that scientific studies and forecasting guidelines commonly recognize as meteorological factors contributing to high ambient $PM_{2.5}$ concentrations. The purpose of the analysis is to demonstrate that the attainment year meteorology was not statistically different from earlier, nonattainment year meteorology.

The above forecasting guidelines and scientific studies recognized several factors relevant to $PM_{2.5}$ formation and concentration levels. The meteorological parameters evaluated in this analysis are based on STI's Forecasting Guidelines with some variations. For example, STI uses the morning temperature at Sacramento Executive Airport (KSAC) for forecasting and this analysis uses the 4am surface temperature at the Del Paso Manor (DPM) monitoring site.

Table 5.3 summarizes the meteorological parameters evaluated in the above guidelines and studies, and the parameters used in this analysis.

Table 5.3 Contributing Meteorological Parameters

Meteorological Parameters	EPA Forecasting Program Guidelines	Motallebi's PM Source Apportionment Study	Palazoglu's $PM_{2.5}$ Cluster Analysis	STI Check Before You Burn Forecasting Guidelines	This analysis
Aloft Pressure Pattern	X		1800 UTC 500-hPa and 1000-hPa pressure pattern over the western North America and Pacific	* KSAC 12Z 500mb height * 4 different pressure scenarios	OAK 4am 500mb height
Winds (wind speed)	X	24-hr average resultant wind speed at Sacramento T Street	1pm & 5am surface wind field at the Sacramento Valley and Bay Area	* KSAC morning, afternoon, & overnight wind speed * KSAC 12Z 950mb wind speed	DPM afternoon and overnight wind speed
Winds (wind direction)	X	24-hr average resultant wind direction at Sacramento T Street	24-hr wind direction at Elk Grove, Sacramento, Folsom, and Roseville	* KSUU wind direction	DPM afternoon and overnight wind direction
Temperature Inversion	X			* KSAC 12Z and 00Z 950mb – surface temperatures	4am/4pm OAK 925mb temperature –DPM surface temperature
Rain (precipitation)	X		Hourly rainfall at Davis		Total winter rainfall at KSAC
Moisture (Relative Humidity /Dew Point Temperature)	X	24-hr average relative humidity at Sacramento T Street	2pm and hourly relative humidity at Davis	* KSAC 6am-6pm average dew point temperature	DPM 6am-6pm dew point temperature
Surface Temperature	X	24-hr average temperature at Sacramento T Street	Midnight surface temperature in the Sacramento Valley	* KSAC morning low temperature and afternoon high temperature	DPM 4am and 4pm temperature
Cloud/Fog	X				
Seasons	X				
Solar Radiation			Solar Radiation at Davis		
Pressure Gradient				*KSAC to KLAS 12Z pressure gradient *KSAC to KSAC 12Z pressure gradient *KSAC to KSAC 00Z pressure gradient	

Note to abbreviations:
DPM: Del Paso Manor
KSAC: Sacramento Executive Airport
KSFO: San Francisco International Airport
mb: millibars
hPa: hectare Pascal
OAK: Oakland International Airport
KSUU: Travis Air Force Base
KLAS: Las Vegas International Airport
Z: Zulu Time (Greenwich Mean Time) 12Z= 4 a.m. 00Z= 4pm
UTC: Coordinated Universal Time

Table 5.4 lists the meteorological parameters documented in STI's CBYB Forecasting Guidelines and the parameters evaluated in this analysis. STI forecasting parameters are based on the region's historical meteorological data and ambient $PM_{2.5}$ concentrations defined by four scenarios that are conducive to high ambient $PM_{2.5}$ concentrations. These four scenarios are the Great Basin High, Pacific Northwest High, Pre-cold front/Pre-trough, and 500mb cut-off South. These are the upper air pressure patterns over the Western United States and Northeast

Pacific Ocean. Graphical expressions of these pressure scenarios can be found in STI's Sacramento $PM_{2.5}$ CBYB Forecasting Guidelines (STI, 2012).

Table 5.4 CBYB Forecasting Guidelines Forecast Exceedance Criteria.

Meteorological Parameter	Great Basin High	Pacific Northwest High	Pre-Cold Front/Pre-trough	500mb Cut-off Low South	Parameters used in this analysis
Surface Temperature KSAC Moring low temperature	<42°F	None	None	None	DPM 4am temperature
Surface Temperature KSAC Afternoon High Temperature	None	None	50°F-62°F	None	DPM 4pm temperature
Temperature Inversion: KSAC 12Z 950mb – surface temperature	>8°C	>10°C	>6°C	None	OAK 4am 925mb temperature – 4am DPM surface temperature
Temperature Inversion: KSAC 00Z 950mb – surface temperature	>-2°C	None	None	>-2°C	OAK 4pm 925mb temperature – 4pm DPM surface temperature
KSAC afternoon wind speed	< 3kts	< 3kts	< 6kts	< 3kts	DPM 4pm wind speed
KSAC morning wind speed	< 2kts	None	None	None	Not evaluated
KSAC overnight wind speed	None	<1 kt	< 3kts	< 3kts	DPM 12am wind speed
KSAC 12Z 950mb wind speed	None	None	< 4 m/s	None	Not evaluated
KSUU afternoon wind speed	None	None	< 9kts	< 6kts	Not evaluated
KSUU wind direction	< 100°	None	None	None	DPM wind rose diagram
KSAC 12Z 500mb Height	None	> 5670m	> 5630m	None	OAK 4am 500mb Height
KSAC 6am to 6pm average dew point temperature	< 48°F	34°F – 48°F	None	None	DPM dew point temperature
KSAC to KLAS 12Z pressure gradient	< 4mb	-1mb to 5mb	-6mb to 0mb	None	Not evaluated. Not mentioned in other research
KSFO to KASC 12Z pressure gradient	None	< 0mb	-1.5mb -1mb	None	
KSFO to KSAC 00Z pressure gradient	None	None	None	< 0mb	

CBYB is a control strategy in Sacramento County that prohibits residents and businesses from using indoor or outdoor fireplaces, wood stoves, fire pits, and chimneys that burn wood, pellets, manufactured logs or other solid fuels unless they are in exempted categories (i.e. a household's sole source of heat, ceremonial fires, cook stoves, or economic hardship). A forecast exceedance day occurs when 24-hour $PM_{2.5}$ concentrations are predicted to exceed the level of the federal health standard (35 $\mu g/m^3$). For convenience, we refer to this as a "forecast exceedance." In the following analysis, we examine the meteorological parameters, which are used for $PM_{2.5}$ ambient concentration forecasting.

5.3.1.1 Seasonality Analysis

Higher ambient concentrations of $PM_{2.5}$ are a wintertime issue for the Sacramento Region. As discussed in Section 3.4, low wind speed, low temperatures, and a strong temperature inversion, combined with low precipitation during winter could result in higher $PM_{2.5}$ concentrations. Figure 3.3 shows that days exceeding the 35µg/m^3 standard have occurred only in the winter season (November-February). It is unusual to have exceedances during the remaining months, with the exception of summer wildfire events. This analysis will focus on the meteorological parameters and ambient $PM_{2.5}$ concentrations during winter months.

5.3.1.2 Parameter Selection

EPA's forecasting guidelines, Motallebi's study, Palazoglu's cluster analysis, and STI's Forecasting Guidelines identified six different meteorological parameters that relate to high ambient $PM_{2.5}$ concentrations. These factors are surface temperature, temperature inversion (the temperature difference between upper air and surface air), wind speed and direction, aloft pressure pattern (500mb height), relative humidity/dew point temperature, and rainfall. We used STI's parameters for this meteorological evaluation with modifications of measurement time and location. For example, STI selected the overnight wind speed at KSAC for the exceedance days forecasting but this analysis evaluates the 12am wind speed at the Del Paso Manor monitor. This section discusses the selection of each meteorological parameter, and the selection of data sources is discussed in Section 5.3.1.3 below.

Surface Temperature

EPA's and STI's forecasting guidelines and the Motallebi and Palazoglu studies recognized that surface temperature is an important factor relating to the formation of high $PM_{2.5}$ concentrations. Motallebi evaluated the 24-hour average temperature at the Sacramento T Street monitor and Palazoglu evaluated the midnight surface temperature at various locations in the Sacramento Valley. STI's Forecasting Guidelines used the morning low and afternoon high temperatures at Sacramento Executive Airport (KSAC) as criteria for calling a forecast exceedance day. In this analysis, the 4am and 4pm surface temperatures were chosen to represent the morning and afternoon temperatures. These times are also used in the temperature inversion analysis. This analysis evaluated the general statistics and hypothesis testing results for morning and afternoon temperatures.

Temperature Inversion

Temperature inversion describes the vertical movement of air. The temperature difference between 925mb and the surface is used to quantify the temperature inversion and vertical mixing. Since $PM_{2.5}$ is a winter problem in the Sacramento region, the inversion layer is usually below the 925mb level; therefore, the 925mb level was chosen for our analysis. The 850mb level is commonly used for year round or summer season analyses, which is why it was selected in CARB's analysis.

STI's Forecasting Guidelines used the morning and afternoon forecasting temperatures at Sacramento Executive Airport (KSAC) as criteria for a forecast exceedance day. Since no continuous upper air temperature data is available within the Sacramento Region, this analysis used the upper air temperature from Oakland International Airport (OAK) and surface temperature at the Del Paso Manor monitor. Upper air measurement equipment is launched twice daily at 4am and 4pm. Therefore, this analysis evaluated the temperature inversions at these hours.

Wind Speed and Direction

Wind speed and direction is another parameter that is commonly recognized in the above-referenced research papers and forecasting guidelines. However, these studies and guidelines focused on different times of the day in their evaluation. Motallebi uses 24-hour average wind speed and wind direction at Sacramento T Street, Palazoglu uses 1 pm and 5am surface wind field in the Sacramento Valley, and STI uses morning, afternoon, and overnight wind speed and direction at KSAC. In this analysis, we chose the 4pm and midnight wind speed and direction.

Aloft Pressure Patterns

Aloft pressure pattern indicates the vertical flow of air. Meteorologists usually use the 500mb height as a simplified indicator to determine the vertical airflow direction. Upper air pressure patterns are the important factors identified in both Palazoglu's cluster analysis and STI's Forecasting Guidelines. Palazoglu's study identified six different clusters based on 500mb pressure patterns over the Western United States and the Northeast Pacific Ocean. STI identified four upper air pressure patterns and used their model-forecasted 4am 500mb height at KSAC to determine the possibility of exceedance days. Again, weather conditions at upper elevations are not available, so the OAK 500mb height was used as a surrogate in this analysis.

Rainfall

Rainfall is another factor associated with ambient $PM_{2.5}$ concentration levels. EPA's guidelines and Palazoglu's cluster analysis suggested that rainfall removes pollutants from the air. This analysis evaluates the total winter rainfall measured during January, February, November, and December at Sacramento Executive Airport. The total winter rainfall and the percentage of days when rainfall was greater than 0.05 inches are compared to the 98^{th} percentile $PM_{2.5}$ concentrations.

Relative Humidity

Relative humidity or dew point temperature is the measurement of water vapor content in the air. Humidity can enhance $PM_{2.5}$ aerosol formation. Motallebi's study uses 24-hour average relative humidity and Palazoglu's study uses 2pm and hourly relative humidity to evaluate water vapor content in their studies. STI uses daytime (6am-6pm) dew point temperature.

Other Factors

Other factors mentioned in the guidelines and research studies include cloud/fog, solar radiation, and pressure gradient. However, these factors are not commonly identified among the literature reviewed and were not evaluated in this analysis.

5.3.1.3 Data Sources

Four regional monitoring sites were selected as the source of meteorological data for this analysis: Del Paso Manor (DPM), Sacramento T Street, Sacramento Executive Airport (KSAC), and Oakland International Airport (OAK). Table 5.5 lists the meteorological parameters and their data source.

Table 5.5 Data Sources

Meteorological parameters	Details of the parameters	Data source and download date
Surface Temperature	4am surface temperature at DPM	https://aqs.epa.gov/aqs/ on 09/19/2012
	4pm surface temperature at DPM	
Temperature Inversion	4am 925mb Temperature at OAK– 4am surface temperature at DPM	http://www.ncdc.noaa/oa/climate/igra/index.php on 05/29/2012
	4pm 925mb Temperature at OAK – 4pm surface temperature at DPM	
Wind Speed and Direction	4am surface wind speed and direction at DPM	https://aqs.epa.gov/aqs/ on 09/19/2012
	4pm surface wind speed and direction at DPM	
Aloft pressure 500mb Height	4am 500mb Height	http://www.ncdc.noaa/oa/climate/igra/index.php on 05/29/2012
Rain	Number of days with rainfall ≥ 0.05in at Sacramento Executive Airport	http://www.ncdc.noaa.gov/cdo-web/#t=secondTabLink on 09/27/2012
Moisture	6am to 6pm average dew point temperature at DPM	https://aqs.epa.gov/aqs/ on 09/19/2012

The Del Paso Manor site, located at the core of the urbanized area of the Sacramento region, is the peak design value site. Del Paso Manor is also one of the 52 national core multi-pollutants network (NCore) sites. It is the primary source of surface meteorological data in this study. This analysis uses Federal Reference Method (FRM) $PM_{2.5}$ concentration data, surface temperature, wind speed, wind direction, and relative humidity from this site[27]. The data was downloaded from the EPA Air Quality Systems (AQS) database.

The Sacramento T-Street monitor is also a design value site located in downtown Sacramento. It has similar weather equipment configuration as the Del Paso Manor site. These two sites are 7.3 miles apart. Evaluation of the Del Paso Manor site wind data revealed a large gap in wind data between November 13, 2004, and January 6, 2005, which was due to equipment maintenance. Therefore, the T Street data was used to replace the wind speed and direction data during that period. The Sacramento T Street meteorological data was also downloaded from the EPA AQS database.

Neither Del Paso Manor nor T Street monitors measure rainfall. As an alternative, this analysis used the rainfall data from the Sacramento Executive Airport. The National Oceanic and Atmospheric Administration (NOAA) operates this site. The rainfall data was downloaded from National Climatic Data Center's (NCDC) website[28].

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27 On May 19, 2010, April 28, 2011, and May 9, 2012, CARB certified and submitted the air quality data to EPA as complete and quality assured. The 2012 data has not been certified, but district staff perform daily and monthly data review to ensure data quality.

28 NCDC performs data quality check by both automated and manual methods. The details of their procedures are listed in

The upper air profiler located at the air quality monitoring site on Bruceville Road in Sacramento County measures temperature and wind speed up to 900-1000 meters above the ground surface. However, due to equipment issues at this site, data gaps exist for 2002, 2003, 2004, and 2009. As an alternative, this analysis used the upper air radiosonde data measured at the Oakland International Airport. The radiosonde data was downloaded from the NCDC's website[29]. The Oakland International Airport is the nearest available upper air data source for the region. It is approximately 75 miles away from the Del Paso Manor monitor. The Oakland International Airport upper air data is considered representative of the Sacramento Region and was used to evaluate modeling episode selection in support of the development of the Sacramento Region 8-hour Ozone Attainment Plan (CARB, 2007, p.14).

5.3.1.4 Statistical Methods

This analysis applies two different statistical methods to demonstrate that meteorological conditions in the attainment years were not "unusually favorable" to low ambient $PM_{2.5}$ concentrations. The statistical methods include simple statistics of average values, five-number summary (minimum, first quartile, median, third quartile, and maximum), standard deviation, and hypothesis testing. As described in Section 5.3.1.1, the majority of the days with 24-hour $PM_{2.5}$ concentrations over 35µg/m^3 occur during winter seasons; therefore, this analysis only evaluates the meteorological data for winter months (November–February). Winter data was extracted from the raw data downloaded from EPA's AQS and NOAA databases and evaluated using spreadsheet software.

5.3.1.4.1 General Statistics

The simple statistics method includes the calculations of average, standard deviation, and five-number summary. The five-number summary is the minimum, first quartile, median, third quartile, and maximum values. The summary gives information on data distribution, data location (distance from the median), spread (location of quartiles), and range (distance between minimum and maximum). Box-and-Whisker Plots (box plots) are used to visualize the five-number summary statistics and show the trend of each meteorological parameter. The two ends of the box plot are the minimum and maximum values. The bottom of the box is the first quartile (25th percentile), the middle of the box is the median, and the top of the box is the third quartile (75th percentile). A line is included in each graph to illustrate the trend, using the average value. A second line, showing $PM_{2.5}$ concentration, is included in each graph to allow the reader to directly compare the meteorological parameter to the 98th percentile $PM_{2.5}$ concentration for each year.

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http://www1.ncdc.noaa.gov/pub/data/cdo/documentation/PRECIP_HLY_documentation.pdf as 08/16/2013.

[29] NCDC performs eight steps to ensure the upper air data meets their data quality standards. Their quality control procedures can be found under http://www.ncdc.noaa.gov/oa/climate/igra/index.php?name=quality

To ensure a robust dataset of the parameters evaluated, each parameter dataset was evaluated for completeness and had to pass a 75% completeness threshold[30]. For example, to calculate the average dew point temperatures between 6am-6pm for a given day, nine hourly data points are required during that period. In another example, to compute the average 4am wind speed for 2004, at least 90 daily wind speed records are required. If the data completeness rate of a year is below 75%, data from an alternate representative site is used to substitute or replace the missing data for that year.

5.3.1.4.2 Hypothesis Testing

Hypothesis testing was used to determine whether there is a statistically significant difference between the mean of the meteorological parameters recorded in the attainment year and the data recorded during nonattainment years. When there is not a statistically significant difference, the meteorology is not considered to have an unusually favorable impact on the attainment year $PM_{2.5}$ concentration.

In this analysis, we used the method "Tests of Hypotheses on the Equality of Two Means, Variances Known" to compute the standard score Z_0 (Hines, 1990, p.301-303).

$$Z_0 = \frac{\overline{X_1} - \overline{X_2}}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

Where: Z_0 = Standard Score
$\overline{X_1}$ = Average Meteorological Data—Attainment Year (2009 or later)
$\overline{X_2}$ = Average Meteorological Data—Nonattainment Year (before 2009)
σ_1^2 = Variance of Meteorological Data—Attainment Year
σ_1^2 = Variance of Meteorological Data—Nonattainment Year
n_1 = Total Number of Data—Attainment Year
n_2 = Total Number of Data—Nonattainment Year
* Variance is the square of standard deviation

The standard score Z_0 represents how far the statistical averages are away from each other. In the analysis, we established a significance level of 0.05 for the standard score, which provides a 95% level of confidence that the hypothesis is true. In other words, a standard score between -1.96 and 1.96 suggests there is a 95% level of confidence that no significant differences exist between two averages. A positive standard score means the attainment year meteorological average is greater than the nonattainment year meteorological average; a negative standard score means the nonattainment year is greater than the attainment year.

Table 5.6 displays an example of the hypothesis testing results. For example, the comparison of attainment year 2011 and the decade (2002-2011) morning temperature averages was -6.64,

30 There is no universal standard for data completeness for meteorological data evaluation. However, EPA uses 75% data completeness to calculate 8-hour ozone or 24-hour $PM_{2.5}$ concentration. This standard will be applied throughout this analysis.

which is less than -1.96. Therefore, the 2011 average morning temperature is significantly cooler than the decade average morning temperature.

Hypothesis test results also displays the standard scores comparing individual attainment vs. nonattainment years—e.g., the 2009 attainment year compared to the 2002 nonattainment year—and are for information purposes only. The conclusions for each parameter are based on whether the attainment year is statistically more favorable to low $PM_{2.5}$ concentrations than the decade.

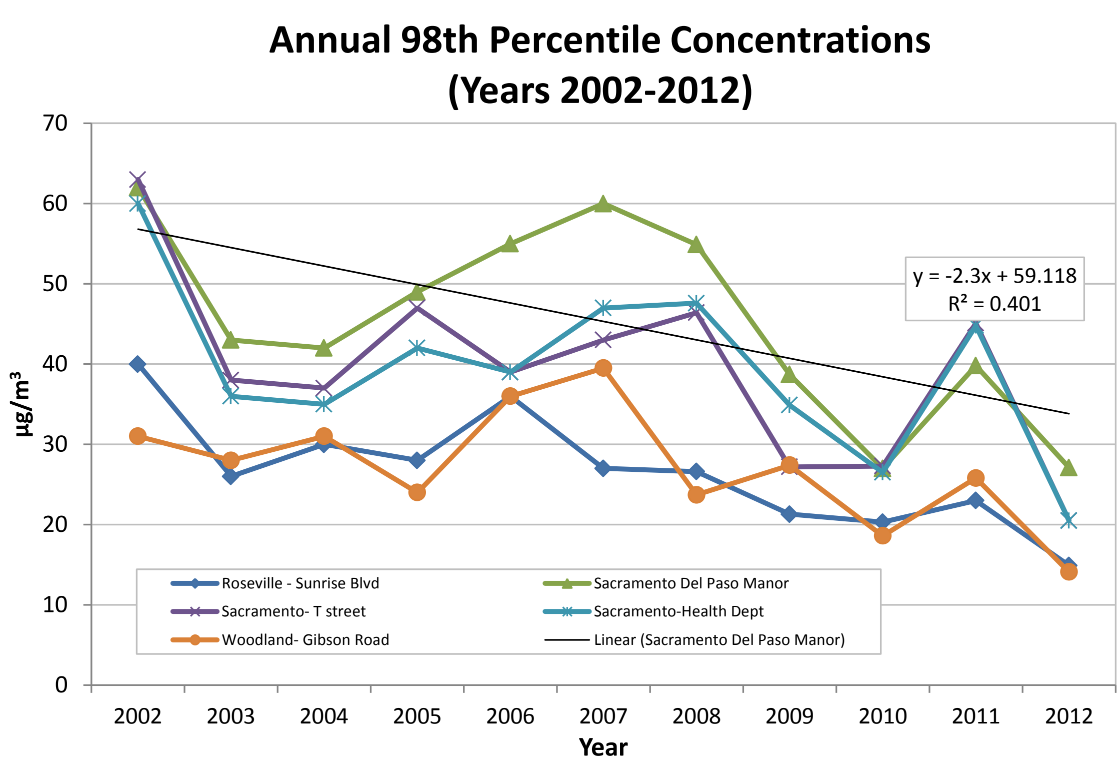
Table 5.6 Sample Results for Hypothesis Testing—Morning (4am) Temperature at Del Paso Manor Monitor

Analysis Years	Attainment Year		
	2009	2010	2011
2002-2011	-2.12	2.38	-6.64

5.3.1.5 Peak $PM_{2.5}$ Monitoring Site

In this analysis, the $PM_{2.5}$ concentration data at the Del Paso Manor monitor was selected as reference for this meteorological analysis. As described earlier, Del Paso Manor was the peak monitoring site for the region until 2011. The Sacramento Health Department and Sacramento T Street monitoring sites were the peak sites in 2011. Note that the peak sites have been in Sacramento County since 2001. Figure 5.7 shows the annual 98th percentile for all monitors in the Sacramento region.

Figure 5.7 (Figure 3.4) Annual 98th Percentile Concentration—All Monitors



5.3.2 Surface Temperature

Surface temperature can indirectly influence $PM_{2.5}$ concentrations (i.e., home heating on winter nights) (EPA, 2003, Table 2-5). During cold winter nights, people tend to use fireplaces for home heating[31] (Motallebi, 1999, p6). Residential wood combustion contributes 51% of the Sacramento Region's directly emitted wintertime $PM_{2.5}$ emissions (Section 4.5.2, Figure 4.1). If the region experiences a cold winter, more emissions from residential wood burning can be expected. Conversely, warm temperatures suggest less wood burning and lower $PM_{2.5}$ concentrations, and would favor $PM_{2.5}$ attainment.

Surface temperatures also play multiple roles in the secondary aerosol formation, similar to the role of relative humidity or dew point temperature. Secondary aerosol formation is a two-step process: condensation of the gas particle into water droplets and chemical reaction. Under cold temperature conditions, more gas phase particles can condense into water droplets in the air and these water droplets act as chemical reactors. Next, dissolved gas particles react with other chemicals to form secondary particulate matter. Higher temperatures may speed up the chemical reactions. However, the rate-determining step for the secondary aerosol formation is the gas phase particle condensation. As a result, cold surface temperatures can be conducive to secondary aerosol formation. A scientific study conducted by the Paul Scherrer Institute (Barmpadimos, 2012, p.1) stated, "Temperature has a negative relationship to $PM_{2.5}$ for low temperatures and a positive relationship for high temperatures. The stationary point of this relationship varies between 5°C and 15°C depending on the location." (The 2002-2011 median morning surface temperature of Sacramento was 5°C.) This statement confirms that cooler temperatures mean less favorable weather for low ambient $PM_{2.5}$ concentrations.

In this analysis, we used the morning temperature at 4am and the afternoon temperature at 4pm as our time reference to determine whether unusual temperature conditions resulted in low ambient $PM_{2.5}$ concentrations. Different studies used different time references for their meteorological analyses. Motallebi used the 24-hour average temperature, Palazoglu used the midnight temperature, and STI used morning and afternoon temperatures with no specified hours. Since the upper air morning and afternoon temperatures are measured at 4am and 4pm in the region, these two hours were selected as the time reference for the temperature analysis. The selection of the specific time is consistent with the temperature inversion analysis.

Hypothesis testing can determine whether there is a statistically significant difference in the attainment years' temperatures compared to the rest of the decade. Section 5.3.1.4.2 has a detailed discussion of the methodology used.

5.3.2.1 General Statistical Analysis

5.3.2.1.1 Morning (4am) Temperature

Table 5.7 shows the statistical summary of the morning (4am) temperature measured at the Del Paso Manor site and the 98th percentile $PM_{2.5}$ concentration. Figure 5.8 is a box plot visualizing

[31] In Sacramento County, 83% of homes had wood burning fireplaces and half of those fireplaces are used.

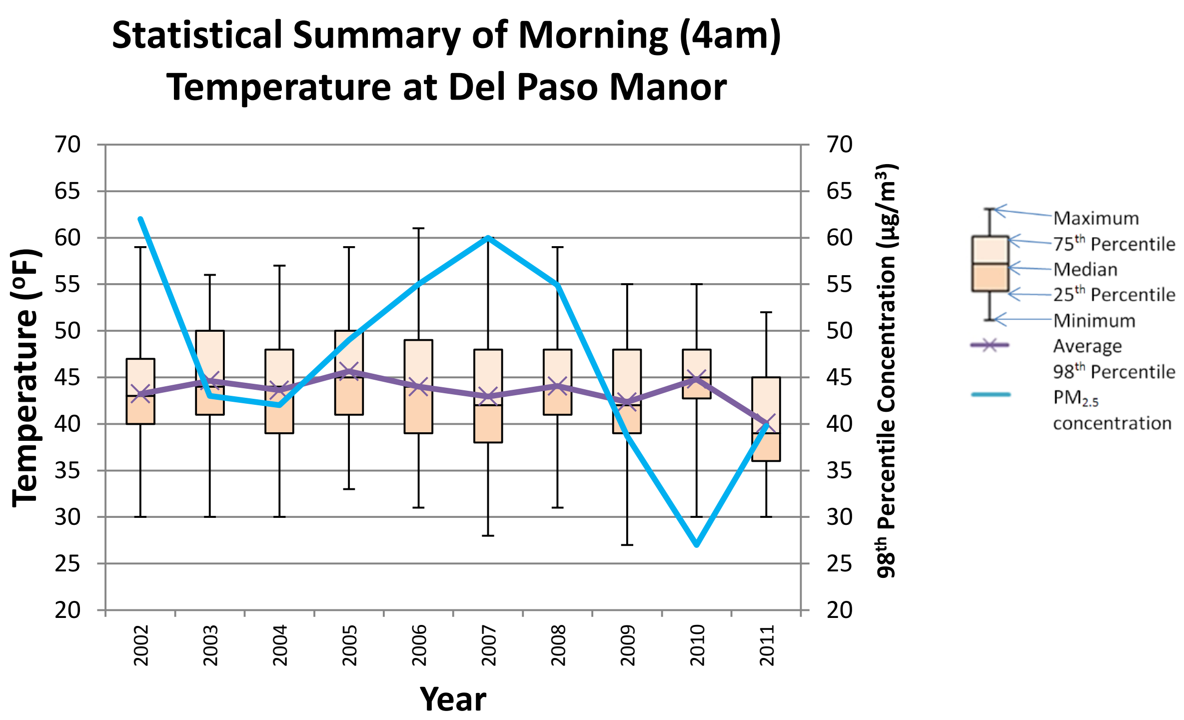
the statistical five-number summary of the 4am temperature with the 98th percentile $PM_{2.5}$ concentrations.

Table 5.7 Statistical Summary of Morning (4am) Temperature (°F) at Del Paso Manor Monitor and 98th Percentile Concentration

Year	Minimum	First Quartile	Median	Third Quartile	Maximum	Average ($\bar{x}$)	Standard Deviation (σ)	Count (n)	98th percentile concentration (µg/m³)
2002	30.0	40.0	43.0	47.0	59.0	43.2	5.9	111	62
2003	30.0	41.0	44.0	50.0	56.0	44.6	5.8	120	43
2004	30.0	39.0	44.0	48.0	57.0	43.6	6.0	121	42
2005	33.0	41.0	45.0	50.0	59.0	45.7	5.9	120	49
2006	31.0	39.0	44.0	49.0	61.0	44.0	6.7	120	55
2007	28.0	38.0	42.0	48.0	60.0	43.0	7.1	120	60
2008	31.0	41.0	44.0	48.0	59.0	44.1	5.3	121	54.9*
2009	27.0	39.0	42.0	48.0	55.0	42.4	5.8	120	38.7*
2010	30.0	42.8	45.0	48.0	55.0	44.8	5.5	120	27.0*
2011	30.0	36.0	39.0	45.0	52.0	40.1	5.4	120	39.8*
2002 - 2011	27.0	39.0	43.0	48.0	61.0	43.5	6.1	1193	N/A

* Note: EPA changed the $PM_{2.5}$ concentration reporting accuracy requirement from nearest integer to one decimal point in mid-2007; as a result, the 98th percentile concentration is shown to one decimal point beginning in 2008.

Figure 5.8 Statistical Summary of Morning (4am) Temperature at Del Paso Manor Monitor



The morning temperature data had more than a 90% data completeness rate for all individual years, satisfying our 75% minimum data completeness rate. The median morning temperatures for all years were between 39°F and 45°F and the median morning temperatures for the decade was 43°F.

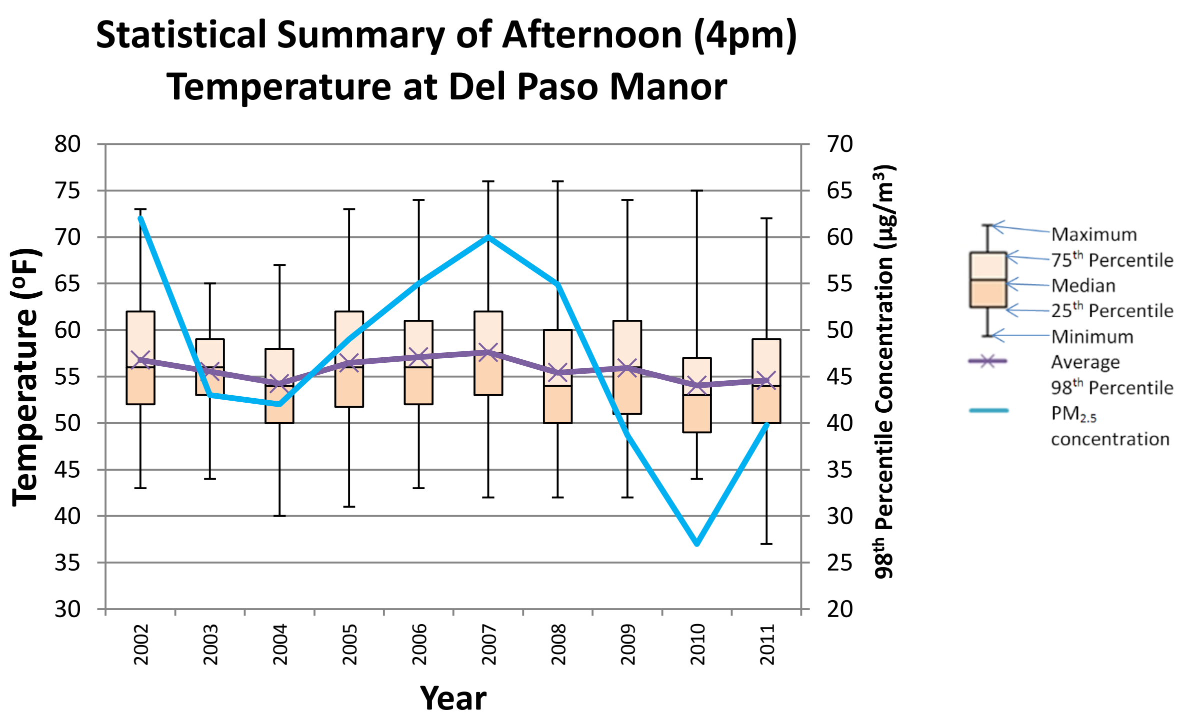
5.3.2.1.2 Afternoon (4pm) Temperature

Table 5.8 shows the statistical summary of the afternoon (4pm) temperatures measured at the Del Paso Manor site and the 98th percentile $PM_{2.5}$ concentration. Figure 5.9 is a box plot of the statistical five-number summary of afternoon temperature.

Table 5.8 Statistical Summary of Afternoon (4pm) Temperature (°F) at Del Paso Manor Monitor

Year	Minimum	First Quartile	Median	Third Quartile	Maximum	Average ($\bar{x}$)	Standard Deviation (σ)	Count (n)	98th percentile concentration ($\mu g/m^3$)
2002	43.0	52.0	56.0	62.0	73.0	56.8	6.7	111	62
2003	44.0	53.0	56.0	59.0	65.0	55.5	4.5	120	43
2004	40.0	50.0	54.0	58.0	67.0	54.2	5.2	121	42
2005	41.0	51.8	56.0	62.0	73.0	56.5	7.4	120	49
2006	43.0	52.0	56.0	61.0	74.0	57.1	6.3	120	55
2007	42.0	53.0	57.5	62.0	76.0	57.6	7.3	120	60
2008	42.0	50.0	54.0	60.0	76.0	55.4	7.7	121	54.9
2009	42.0	51.0	56.0	61.0	74.0	55.9	6.9	120	38.7
2010	44.0	49.0	53.0	57.0	75.0	54.1	6.9	119	27.0
2011	37.0	50.0	54.0	59.0	72.0	54.6	6.6	120	39.8
2002 - 2011	37.0	51.0	55.0	60.0	76.0	55.8	6.7	1192	N/A

Figure 5.9 Statistical Summary of Afternoon (4pm) Temperature at Del Paso Manor Monitor



The afternoon data completeness rates for individual years were at least 92%, satisfying our 75% minimum data completeness rate. The median afternoon temperatures ranged from 53.0°F to 57.5°F between 2002 and 2011, and the decade's median was 55.0°F.

5.3.2.2 Hypothesis Testing Results

Hypothesis testing can determine whether the attainment years' temperatures were significantly different than average temperatures over the decade.

Table 5.9 and Table 5.10 show the hypothesis test results for the morning and afternoon temperatures at Del Paso Manor. If the number is greater than 1.96, the attainment year is significantly warmer than the 10-year average, a favorable weather condition for low $PM_{2.5}$ concentrations. If the number is less than -1.96, the year is significantly cooler, a favorable condition for higher $PM_{2.5}$ concentrations than the 10-year period. If the number is between -1.96 and 1.96, there is no statistical difference between the attainment year and the 10-year period.

Table 5.9 Hypotheses Test Results for Morning (4am) Temperature at Del Paso Manor Monitor

Analysis Years	Attainment Year		
	2009	2010	2011
2002	-1.12	2.11	-4.21
2003	-3.03	0.23	-6.30
2004	-1.66	1.61	-4.83
2005	-4.37	-1.16	-7.68
2006	-2.02	1.02	-4.98
2007	-0.71	2.26	-3.53
2008	-2.40	1.06	-5.82
2002-2011	-2.12	2.38	-6.64

Table 5.10 Hypotheses Test Results for Afternoon (4pm) Temperature at Del Paso Manor Monitor

Analysis Years	Attainment Year		
	2009	2010	2011
2002	-0.95	-3.04	-2.49
2003	0.50	-1.98	-1.31
2004	2.13	-0.24	0.45
2005	-0.58	-2.60	-2.06
2006	-1.37	-3.56	-3.00
2007	-1.83	-3.87	-3.35
2008	0.53	-1.46	-0.91
2002-2011	0.24	-2.59	-1.85

5.3.2.3 Conclusions of Surface Temperature Analysis

The hypothesis test results show that morning temperatures in 2009 were statistically cooler than the 10-year average. Therefore, the morning (4am) temperature was unfavorable for low $PM_{2.5}$ concentrations in 2009.

The hypothesis test results show that morning temperatures in 2010 were statistically warmer than the 10-year average. Therefore, the morning (4am) temperature was favorable for low $PM_{2.5}$ concentrations in 2010.

The hypothesis test results show that morning temperatures in 2011 were statistically cooler than the 10-year average. Therefore, the morning (4am) temperature was unfavorable for low $PM_{2.5}$ concentrations in 2011.

The hypothesis test results show that afternoon temperatures in 2009 were statistically no different compared to the 10-year average. Therefore, the afternoon (4pm) temperatures were not considered as favorable conditions for low $PM_{2.5}$ concentrations in 2009.

The hypothesis test results show that afternoon temperatures in 2010 were statistically cooler than the 10-year average. Therefore, the afternoon (4pm) temperature was unfavorable for low $PM_{2.5}$ concentrations in 2010.

The hypothesis test results show that afternoon temperatures in 2011 were statistically no different compared to the 10-year average. Therefore, the afternoon (4pm) temperatures were not considered as favorable conditions for low $PM_{2.5}$ concentrations in 2011.

5.3.3 Temperature Inversion

A temperature inversion is a layer of warm air above a layer of relatively cooler air in the atmosphere, which acts to limit the vertical mixing of pollutants (EPA, 2003, p2-23). The temperature difference between the 925mb level and the surface is a simplified way to quantify the strength of the temperature inversion in winter seasons for the Sacramento region (Ching, 2010). If the difference is a positive number, it represents a stable atmosphere. If the upper atmosphere is warmer than the surface air, denser cooler air is trapped near the surface and higher pollutant concentrations can develop. Conversely, if the difference is negative, strong vertical circulation of the air (vertical mixing) disperses the pollutants. This analysis examines whether strong vertical mixing or weak temperature inversions occurring during the attainment years favored low ambient $PM_{2.5}$ concentrations.

In the Forecasting Guidelines, STI uses the model-forecasted morning and afternoon temperature differences between 950mb and the surface as criteria for determining a forecast exceedance. Three scenarios in STI's Forecasting Guidelines include morning temperature inversion as forecast exceedance criteria. In the Great Basin High scenario, the temperature difference criterion is 8°C (14.4°F); in the Pacific Northwest High scenario, the temperature difference is 10°C (18°F); and in the Pre-cold front/Pre-trough scenario, the temperature difference is 6°C (10.8°F). One scenario in STI's Forecasting Guidelines includes afternoon temperature inversion as forecast exceedance criteria. STI uses the afternoon (4pm) temperature differences as one of the forecast exceedance criteria for the 500mb Cut-off Low South scenario. If the temperature difference between 950mb and the surface is greater than -2°C (-3.8°F), it favors higher ambient $PM_{2.5}$ concentrations.

A temperature difference greater than any of these criteria may trigger a forecast exceedance. However, 950mb sounding data is not available daily because it is not a mandatory reporting level[32] for radiosonde measurement. The closest mandatory level is 925mb. This analysis used the 925mb temperature at Oakland International Airport to compare with the surface temperature at Del Paso Manor.

Upper air temperature data used in this analysis was collected at Oakland International Airport. Radiosonde balloons were launched twice daily to collect upper atmospheric data, usually at 4am and 4pm local standard time. We matched the 925mb sounding temperatures with the surface temperature data at the Del Paso Manor monitor for the same hour and calculated the temperature differences. If either temperature was missing, the temperature inversion was not calculated and was considered as missing data. The data completeness rates were better than 75% for all individual years, which met our 75% data completeness rate.

The morning temperature difference between 925mb and the surface represents the strength of vertical mixing in the nighttime when the surface cools due to heat loss. A positive number means less vertical mixing in the attainment years compared to nonattainment years, and a negative value represents increased vertical mixing during the attainment years compared to nonattainment years.

5.3.3.1 General Statistics

5.3.3.1.1 Morning (4am) Temperature Inversion

Heat loss by radiation after sunset causes temperatures to drop overnight. If the heat loss is faster near the surface than in the upper atmosphere, cooler and denser air traps pollutants near the surface due to buoyance force and prohibits vertical air circulation. This causes more pollutants to stay near the surface, which can result in higher ambient $PM_{2.5}$ concentrations.

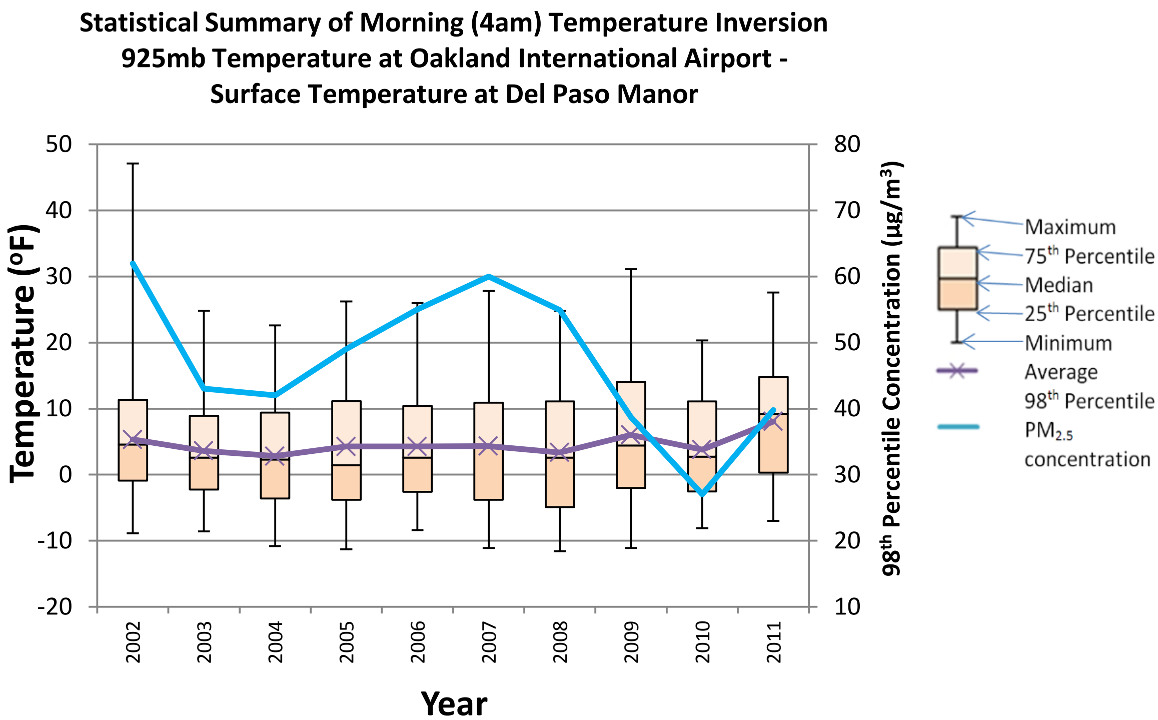
Table 5.11 shows the five-number statistical summary, average temperature, standard deviation of the morning temperature difference, and 98^{th} percentile $PM_{2.5}$ concentrations. Figure 5.10 is the box plot of the statistical summary, average trend, and 98^{th} percentile $PM_{2.5}$ concentrations trend.

[32] Mandatory reporting levels are the surface, 1000, 925, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, and 10 mb. These radiosonde pressure levels were set by international convention and must be reported in the radiosonde message. (Hopkins, 1996)

Table 5.11 Statistical Summary of Morning (4am) Temperature (°F) Inversion

Year	Minimum	First Quartile	Median	Third Quartile	Maximum	Average ($\bar{x}$)	Standard Deviation (σ)	Count (n)	98th percentile concentration (µg/m³)
2002	-8.9	-0.9	4.6	11.4	47.1	5.3	8.9	105	62
2003	-8.6	-2.3	2.6	8.9	24.8	3.6	7.2	119	43
2004	-10.8	-3.6	2.3	9.4	22.6	2.8	7.8	117	42
2005	-11.3	-3.8	1.4	11.1	26.2	4.3	9.4	115	49
2006	-8.4	-2.6	2.6	10.4	26.0	4.3	8.8	120	55
2007	-11.1	-3.8	4.1	10.9	27.8	4.3	9.0	114	60
2008	-11.6	-4.9	2.6	11.1	24.8	3.4	9.4	101	54.9
2009	-11.1	-2.0	4.4	14.1	31.1	6.0	9.9	106	38.7
2010	-8.1	-2.6	2.7	11.1	20.3	3.8	7.3	102	27.0
2011	-7.0	0.3	9.2	14.8	27.6	8.1	8.4	119	39.8
2002 - 2011	-11.6	-2.7	3.6	11.2	47.1	4.6	8.8	1118	N/A

Figure 5.10 Statistical Summary of Morning (4am) Temperature Inversion



The morning temperature differences data had better than 80% data completeness rate for all individual years, satisfying our 75% minimum data completeness rate. The median morning temperature differences for individual years ranged from 1.2°F to 9.2°F and the decade's median temperature difference was 3.6°F.

5.3.3.1.2 Afternoon (4pm) Temperature Inversions

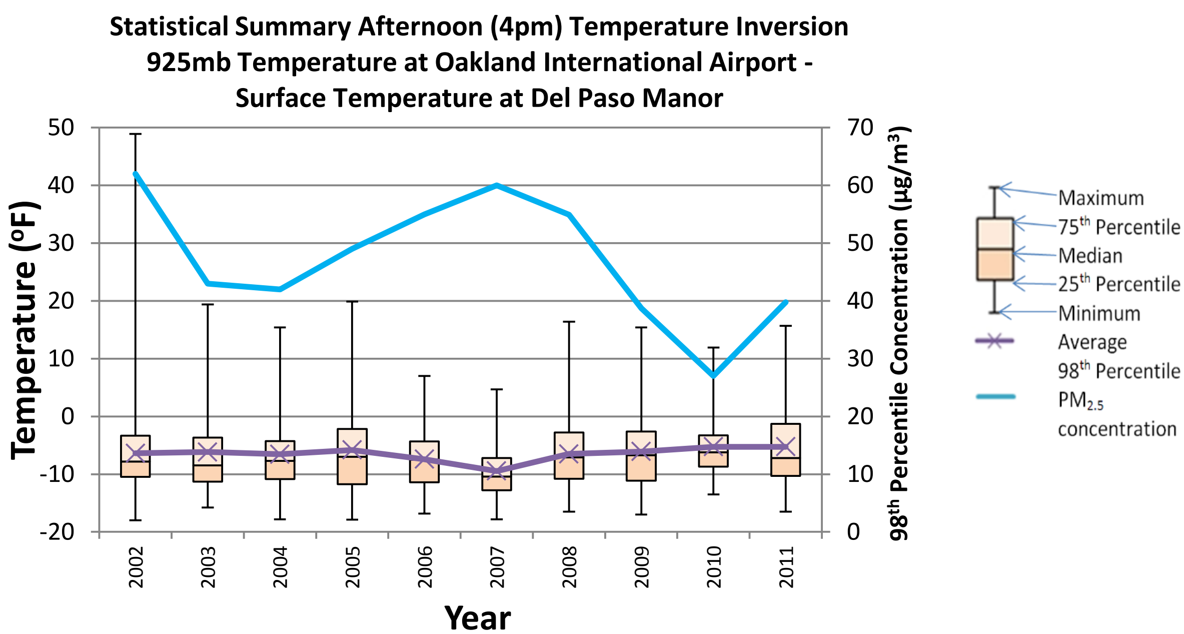
As the sun heats up the earth's surface during the daytime, warmer air near the surface brings pollutants to higher elevations in the upper atmosphere, resulting in lower surface pollutant concentrations. If the surface temperature is much warmer than the upper air temperature (more negative for the temperature difference), more pollutants are transported into the upper atmosphere.

Table 5.12 shows the five-number summary, average temperature, standard deviation of the afternoon temperature difference, and the 98th percentile concentrations. Figure 5.11 is the box plot of the five-number summary, average trend, and the 98th percentile $PM_{2.5}$ concentration trend.

Table 5.12 Statistical Summary of Afternoon (4pm) Temperature (°F) Inversion

Year	Minimum	First Quartile	Median	Third Quartile	Maximum	Average ($\bar{x}$)	Standard Deviation (σ)	Count (n)	98th percentile concentration (μg/m^3)
2002	-18.0	-10.5	-7.8	-3.4	48.9	-6.4	7.5	115	62
2003	-15.8	-11.3	-8.5	-3.7	19.4	-6.2	7.3	119	43
2004	-17.8	-10.9	-7.7	-4.3	15.4	-6.6	6.3	120	42
2005	-17.9	-11.8	-7.0	-2.2	19.9	-5.8	8.2	118	49
2006	-16.8	-11.4	-7.5	-4.3	7.0	-7.4	5.5	119	55
2007	-17.8	-12.8	-10.4	-7.2	4.7	-9.5	4.8	118	60
2008	-16.5	-10.8	-7.1	-2.8	16.4	-6.5	6.2	100	54.9
2009	-17.0	-11.2	-6.7	-2.6	15.4	-6.1	6.4	106	38.7
2010	-13.5	-8.7	-6.2	-3.3	11.9	-5.3	5.8	100	27.0
2011	-16.5	-10.3	-7.2	-1.3	15.7	-5.3	7.3	120	39.8
2002 - 2011	-18.0	-11.1	-7.8	-3.3	48.9	-6.5	6.7	1135	N/A

Figure 5.11 Statistical Summary of Afternoon (4pm) Temperature Inversion



The afternoon temperature differences data had more than an 80% data completeness rate for all individual years, satisfying our 75% minimum data completeness rate. The median afternoon temperature differences for individual years ranged from -6.2°F to -10.4°F, and the decade's median temperature difference was -7.8°F.

5.3.3.2 Hypothesis Testing Results

Hypothesis testing was used to determine whether the morning and afternoon temperature differences of the attainment years were the results of statistically stronger vertical mixing. Table 5.13 and Table 5.14 show the hypothesis results for the morning and afternoon 925mb and surface temperature differences. If the number is greater than 1.96, the average temperature difference of the attainment year is significantly higher than the 10-year average difference, which means stronger temperature inversions with less vertical mixing. If the number is less than -1.96, the average temperature difference of the attainment year is significantly lower than the 10-year average difference, which means weaker temperature inversions with increased vertical mixing. If the number is between -1.96 and 1.96, there was no statistical difference between the attainment year and the decade.

Table 5.13 Hypothesis Test Result: Morning (4am) 925mb and Surface Temperature Difference

Analysis Years	Attainment Year		
	2009	2010	2011
2002	0.55	-1.34	2.36
2003	2.07	0.21	4.39
2004	2.66	0.97	4.97
2005	1.36	-0.40	3.27
2006	1.40	-0.43	3.42
2007	1.33	-0.47	3.27
2008	1.98	0.37	3.89
2002-2011	1.43	-1.02	4.27

Table 5.14 Hypothesis Test Result: Afternoon (4pm) 925mb and Surface Temperature Difference

Analysis Years	Attainment Year		
	2009	2010	2011
2002	0.32	1.24	1.18
2003	0.09	1.03	0.98
2004	0.55	1.60	1.49
2005	-0.31	0.56	0.54
2006	1.64	2.80	2.58
2007	4.41	5.77	5.25
2008	0.47	1.47	1.38
2002-2011	0.64	2.05	1.81

5.3.3.3 Conclusions of Temperature Inversion Analysis

The hypothesis test results show that in 2009 there was no statistical difference compared to the 10-year average. Therefore, the morning temperature inversion was not considered as favorable conditions for low $PM_{2.5}$ concentrations in 2009.

The hypothesis test results show that in 2010 there was no statistical difference compared to the 10-year average. Therefore, the morning temperature inversion was not considered as favorable conditions for low $PM_{2.5}$ concentrations in 2010.

The hypothesis test results show that the temperature difference in 2011 was statistically greater than the 10-year average. Therefore, the morning temperature inversion was unfavorable for low $PM_{2.5}$ concentrations in 2011.

The hypothesis test results show that in 2009 there was no statistical difference compared to the 10-year average. Therefore, the afternoon temperature inversion was not considered as favorable conditions for low $PM_{2.5}$ concentrations in 2009.

The hypothesis test results show that the temperature difference in 2010 was statistically greater than the 10-year average. Therefore, the afternoon temperature inversion was unfavorable for low $PM_{2.5}$ concentrations in 2010.

The hypothesis test results show that the temperature difference in 2011 was statistically greater than the 10-year average. Therefore, the afternoon temperature inversion was unfavorable for low $PM_{2.5}$ concentrations in 2011.

5.3.4 Surface Wind Speed and Direction

Surface wind represents the horizontal movement of air. Moderate to strong winds can act to disperse pollutants, transporting these constituents to other locations (EPA, 2003, p2-26). Motallebi suggests that light winds and calmer conditions lead to high ambient pollutant concentrations because pollutants can accumulate in the area for several days before being dispersed (Motallebi, 1999, p.4). This analysis examines the wind speed and direction at the Del Paso Manor site to determine whether low wind speed or unusual wind direction patterns existed during the attainment years.

Surface wind data (speed and direction) were collected at the Del Paso Manor site. Parameter and data selection was discussed in Section 0. STI evaluates the forecasted morning, afternoon, and overnight wind speed as forecast exceedance criteria. STI evaluates the afternoon wind speed in all four scenarios (Great Basin High, Pacific Northwest High, Pre-cold front/Pre-trough, and 500mb Cut-off Low South), overnight temperature in three scenarios (Pacific Northwest High, Pre-cold front/Pre-trough, and 500mb Cut-off Low South), and morning temperature in one scenario (Great Basin High) for determining a forecast exceedance day.

Overnight wind speed is one of the criteria for predicting a forecast exceedance day under the Pacific Northwest High, Pre-Cold Front/Pre-trough, and 500mb Cut-off Low South scenarios. If the overnight wind speed is less than 3 knots (kt) (1.54 meter per second (m/s)), it favors a forecast exceedance day for the Pre-cold front/Pre-trough and 500mb Cut-off Low South scenarios. If the overnight wind speed is less than 1kt (0.51m/s), it satisfies forecast exceedance criteria during the Pacific Northwest High weather pattern.

Afternoon wind speed is a criterion common to all scenarios in STI's Forecasting Guidelines. If the afternoon wind speed is under 3kt (1.54m/s) for the Great Basin High, Pacific Northwest High, and 500mb Cut-off Low South scenarios, it satisfies one of the criteria for predicting a forecast exceedance day. If the afternoon wind speed is below 6kt (3.08/s) under the Pre-Cold

Front/Pre-trough scenario, it satisfies one of the criteria for predicting a forecast exceedance day.

The overnight and afternoon wind data were selected for this analysis because it was evaluated for the majority of forecasting scenarios. No specific time was defined in STI's Forecasting Guidelines, and the time definition of morning, afternoon, and evening for meteorological measurements varies in different literatures. In this analysis, wind speed and direction at 12am and 4pm were chosen to represent overnight and afternoon time points. The selection of 4pm for the afternoon time is also consistent with the upper air measurement described in Section 5.3.3.

The data completeness requirement was not met in 2004 because of a large data gap between November 13, 2004, and January 6, 2005. The Sacramento T Street data was used to substitute the missing wind data for that period. Both Del Paso Manor and T Street monitors are located in urbanized areas of Sacramento County and the Sacramento T Street data is a representative site for the region. The Sacramento T Street monitor is located in downtown Sacramento and is 7.6 miles west-southwest of the Del Paso Manor site.

5.3.4.1 General Statistics

5.3.4.1.1 Overnight (12am) Wind Speed

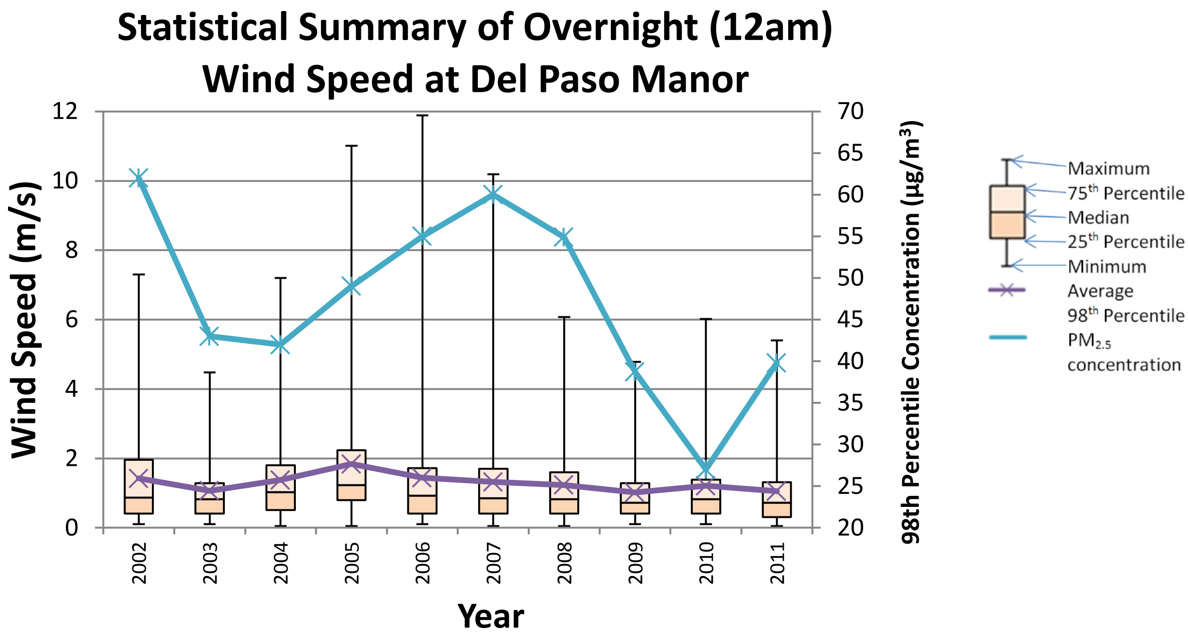
Table 5.15 shows the statistical summary of the overnight wind speed and the 98th percentile $PM_{2.5}$ concentration. Figure 5.12 shows the box plot diagram and statistical trends.

Table 5.15 Statistical Summary of Overnight Surface Wind Speed (m/s) at Del Paso Manor Monitor

Year	Minimum	First Quartile	Median	Third Quartile	Maximum	Average ($\bar{x}$)	Standard Deviation (σ)	Count (n)	98th percentile concentration (µg/m³)
2002	0.10	0.41	0.87	1.95	7.31	1.42	1.39	0.10	62
2003	0.10	0.41	0.82	1.29	4.48	1.07	1.00	0.10	43
2004	0.10	0.62	0.87	1.49	4.01	1.16	0.80	0.10	42
2005	0.05	0.84	1.54	3.16	11.99	2.30	2.13	0.05	49
2006	0.10	0.41	0.93	1.72	11.88	1.44	1.75	0.10	55
2007	0.05	0.41	0.85	1.70	10.19	1.32	1.44	0.05	60
2008	0.05	0.41	0.82	1.59	6.07	1.23	1.20	0.05	54.9
2009	0.10	0.41	0.72	1.29	4.78	1.01	0.91	0.10	38.7
2010	0.10	0.41	0.82	1.39	6.02	1.21	1.23	0.10	27.0
2011	0.05	0.31	0.72	1.31	5.40	1.05	1.09	0.05	39.8
2002 - 2011	0.05	0.41	0.87	1.70	11.99	1.32	1.41	0.05	N/A

Note: The Sacramento T Street data was used to replace the missing Del Paso Manor data between November 13, 2004 and January 5, 2005

Figure 5.12 Statistical Summary of Overnight (12am) Wind Speed at Del Paso Manor Monitor



The overnight wind speeds measured in the Sacramento urbanized area were usually calm. Large differences between the maximum and the 75th percentile were due to occasional high wind speed events such as storms.

The median overnight wind speeds for all individual years ranged between 0.72m/s and 1.54m/s, and the decade's median wind speed was 0.87m/s. As described above, slow surface wind speed allows pollutants to stay in the region and may result in high ambient $PM_{2.5}$ concentrations.

5.3.4.1.2 Afternoon (4pm) Wind Speed

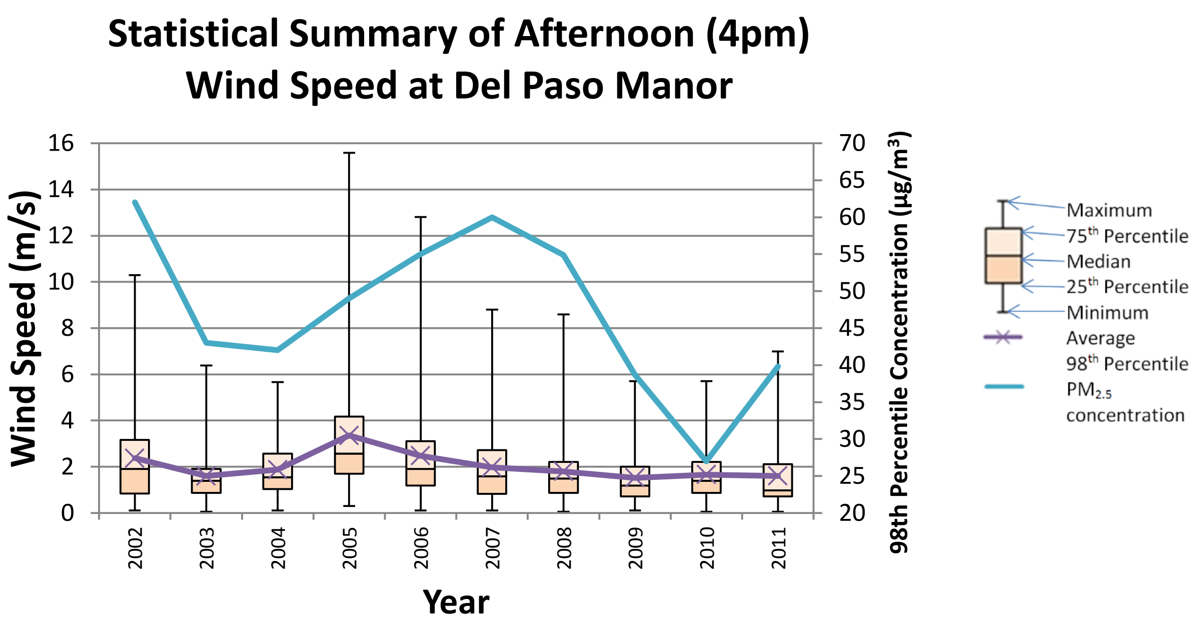
Table 5.16 shows the statistical summary of the afternoon wind speed and the 98th percentile $PM_{2.5}$ concentrations. Figure 5.13 shows the box plot and trends for these statistics.

Table 5.16 Statistical Summary of Afternoon Surface Wind Speed (m/s) at Del Paso Manor Monitor

Year	Minimum	First Quartile	Median	Third Quartile	Maximum	Average ($\bar{x}$)	Standard Deviation (σ)	Count (n)	98th percentile concentration (µg/m^3)
2002	0.10	0.84	1.90	3.16	10.29	2.37	1.99	114	62
2003	0.05	0.87	1.39	1.90	6.38	1.60	1.14	120	43
2004	0.10	1.03	1.54	2.57	5.66	1.88	1.18	121	42
2005	0.31	1.70	2.57	4.17	15.59	3.36	2.48	119	49
2006	0.10	1.18	1.90	3.11	12.81	2.47	2.05	120	55
2007	0.10	0.82	1.59	2.73	8.80	1.98	1.50	120	60
2008	0.05	0.87	1.49	2.21	8.59	1.80	1.34	118	54.9
2009	0.10	0.72	1.18	2.01	5.71	1.52	1.08	117	38.7
2010	0.05	0.87	1.39	2.21	5.71	1.66	1.03	119	27.0
2011	0.05	0.72	0.98	2.11	7.00	1.60	1.45	120	39.8
2002 - 2011	0.05	0.87	1.54	2.57	15.59	2.02	1.68	1188	N/A

Note: The Sacramento T Street data was used to replace the missing Del Paso Manor data between November 13, 2004, and January 5, 2005

Figure 5.13 Statistical Summary of Afternoon (4pm) Wind Speed at Del Paso Manor Monitor



The afternoon wind speeds measured in the Sacramento urbanized area were usually calm. Large differences between the maximum and the 75th percentile were due to occasional high wind speed events such as storms.

The afternoon median wind speed ranged between 0.98m/s and 2.57m/s, and the decade's median was 1.54m/s. Again, slow surface wind speed allows accumulation of pollutants in the region and may cause high $PM_{2.5}$ ambient concentrations.

5.3.4.2 Hypothesis Testing Results

Hypothesis testing is a statistical tool comparing the meteorological conditions between two years. The test results determine whether the attainment years' average wind speeds were significantly stronger than the decade. Section 5.3.1.4.2 has a detailed discussion of the hypothesis testing methodology. Table 5.17 and Table 5.18 show the hypothesis test results for the overnight (12am) and afternoon (4pm) wind speed at Del Paso Manor. If the number is greater than 1.96, the year's wind speed is considered significantly faster than the decade's. If the number is less than -1.96, the year is considered to be experiencing statistically slower winds compared to the decade. If the number is between -1.96 and 1.96, no significant differences exist between the wind speeds of the years compared.

Table 5.17 Hypothesis Test Result for Overnight (12am) Wind Speed at Del Paso Manor Monitor

Analysis Years	Attainment Year		
	2009	2010	2011
2002	-2.61	-1.22	-2.25
2003	-0.41	1.00	-0.10
2004	-1.26	0.42	-0.84
2005	-6.06	-4.84	-5.71
2006	-2.36	-1.17	-2.07
2007	-1.97	-0.64	-1.64
2008	-1.56	-0.13	-1.21
2002-2011	-3.30	-0.94	-2.53

Note: Sacramento T Street was used to replace the Del Paso Manor data between November 13, 2004 and January 5, 2005

Table 5.18 Hypothesis Test Result for Afternoon (4pm) Wind Speed at Del Paso Manor Monitor

Analysis Years	Attainment Year		
	2009	2010	2011
2002	-4.02	-3.41	-3.36
2003	-0.54	0.43	0.03
2004	-2.42	-1.52	-1.60
2005	-7.40	-6.90	-6.67
2006	-4.50	-3.89	-3.80
2007	-2.68	-1.90	-1.95
2008	-1.73	-0.88	-1.06
2002-2011	-4.52	-3.41	-2.96

Note: Sacramento T Street was used to replace the Del Paso Manor data between November 13, 2004 and January 5, 2005

The hypothesis test results show that the average overnight wind speed in 2009 was statistically slower than the 10-year average wind speed. Therefore, the overnight wind speed was unfavorable for low $PM_{2.5}$ concentrations in 2009.

The hypothesis test results show that in 2010 there was no statistical difference compared to the 10-year average wind speed. Therefore, the overnight wind speed was not considered as favorable conditions for low $PM_{2.5}$ concentrations in 2010.

The hypothesis test results show that the average overnight wind speed in 2011 was statistically slower than the 10-year average wind speed. Therefore, the overnight wind speed was unfavorable for low $PM_{2.5}$ concentrations in 2011.

The hypothesis test results show that the average afternoon wind speed in 2009 was statistically slower than the 10-year average wind speed. Therefore, the afternoon wind speed was unfavorable for low $PM_{2.5}$ concentrations in 2009.

The hypothesis test results show that the average afternoon wind speed in 2010 was statistically slower than the 10-year average wind speed. Therefore, the afternoon wind speed was unfavorable for low $PM_{2.5}$ concentrations in 2010.

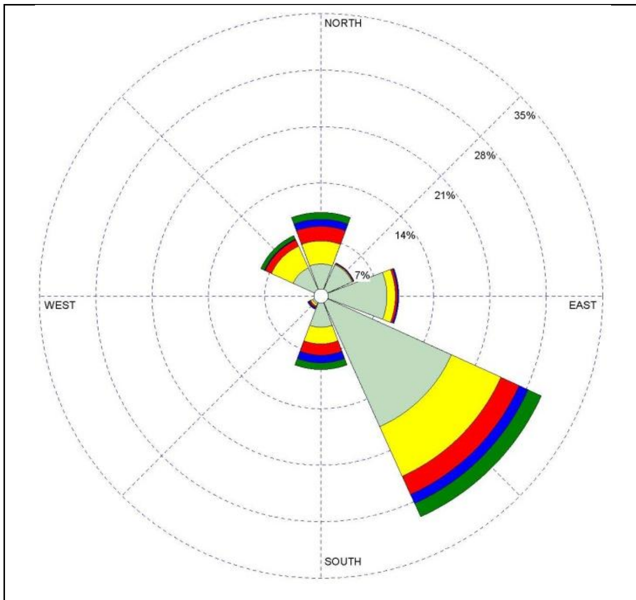
The hypothesis test results show that the average afternoon wind speed in 2011 was statistically slower than the 10-year average wind speed. Therefore, the afternoon wind speed was unfavorable for low $PM_{2.5}$ concentrations in 2011.

5.3.4.3 Wind Direction

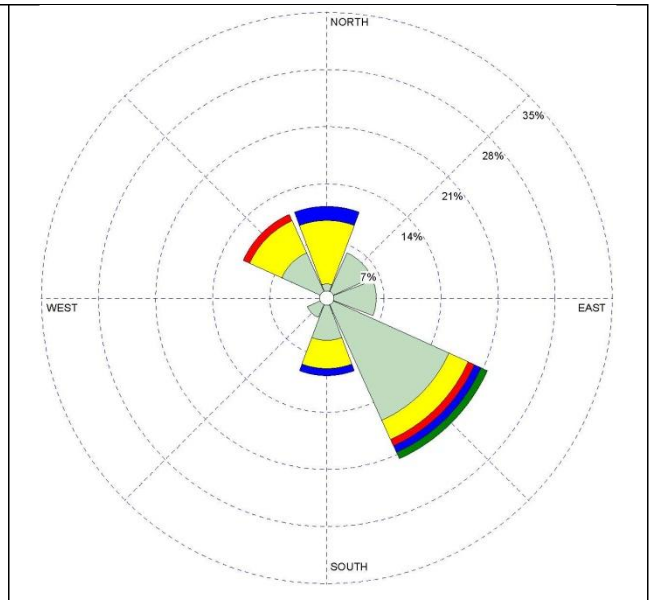
Wind direction at Del Paso Manor was also evaluated. Significant upwind emission sources can transport pollutants to downwind areas. In addition, particular wind directions are common to certain meteorological events, such as storms that usually come from the south into the Sacramento region. Palazoglu's cluster analysis (Palazoglu, 2012, p.31) found that the wind directions experienced during high $PM_{2.5}$ concentration scenarios were predominately from the northwest, while low $PM_{2.5}$ concentration scenarios experienced winds predominately from the southwest. In this section, we evaluate the 12am and 4pm wind rose diagrams for the decade (2002-2011) and individual attainment years and determine whether unusual wind direction patterns occurred during the attainment period.

Figure 5.14 and Figure 5.15 show the wind rose diagrams for 12am and 4pm for nonattainment years (2002-2011) and individual attainment years. Note that the missing November 13, 2004, to January 5, 2005 wind data were substituted by the Sacramento T Street data.

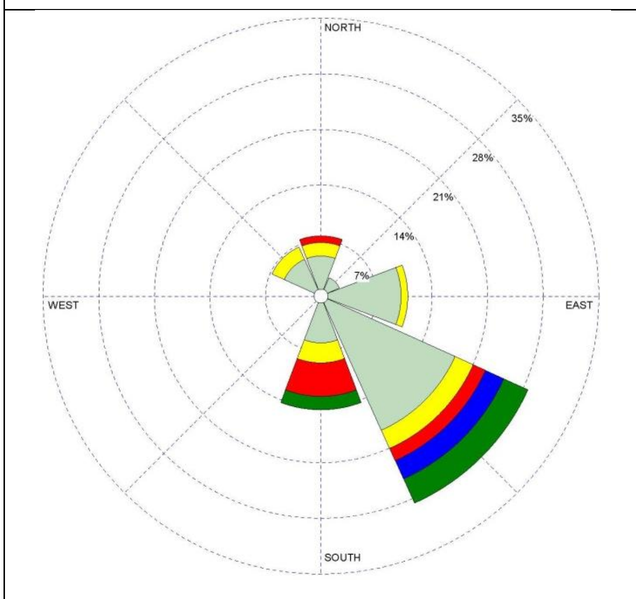
Figure 5.14 Overnight (12am) Wind Rose Diagrams for Del Paso Manor Monitor



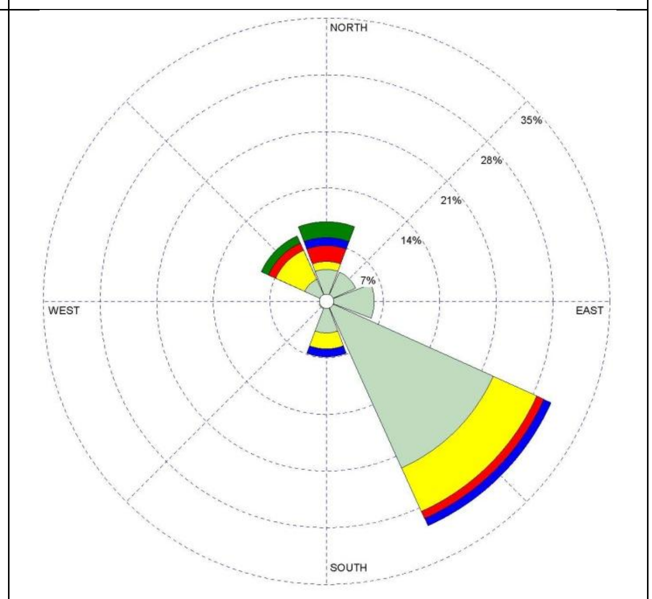
Winter months from 2002-2011



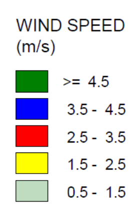
Winter months of 2009



Winter months of 2010



Winter months of 2011



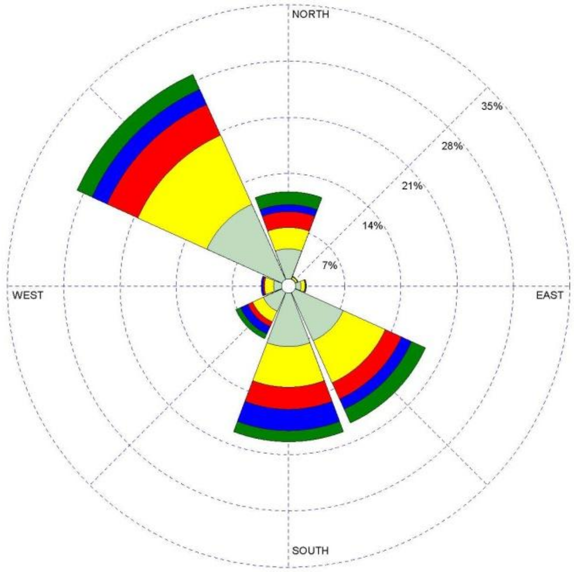
The decade's overnight (12am) wind directions measured at the Del Paso Manor site were predominately (approximately 30%) from the southeast, 18.5% came from the northwest and north, and 9% came from the south.

In 2009, the dominant overnight wind direction was from the southeast direction, occurring on approximately 22% of the days. The next dominant wind directions were from the north and northwest directions and they combined for 22% of the days. The general shape of the wind rose diagram is similar to the decade's diagram. The diagrams did not show any unusual variations.

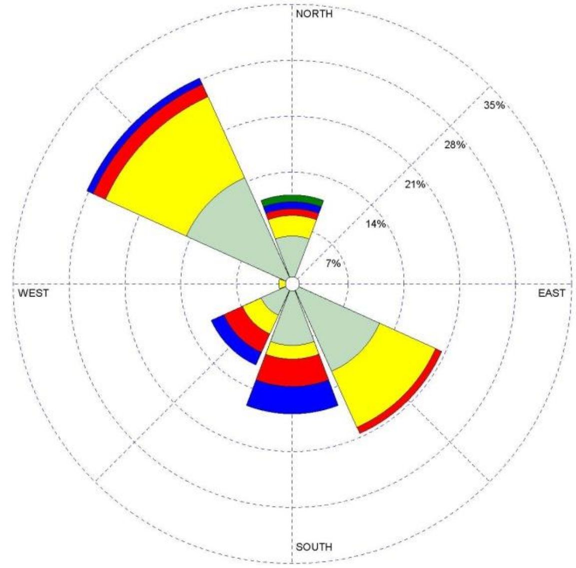
In 2010, the dominant overnight wind direction also came from the southeast, with 29% of the days experiencing wind from that direction. However, the year had a higher percentage (14%) of overnight wind that came from the south. Another 14% of 2010 winds came from the north and northwest.

In 2011, 30% of the days with overnight wind came from the southeast, similar to the decade's average wind direction. 18.6% of 2011 winds came from the north and northwest and 7% came from the south. The overnight wind rose diagrams do not show significant variations of wind direction that may contribute to low ambient $PM_{2.5}$ concentrations.

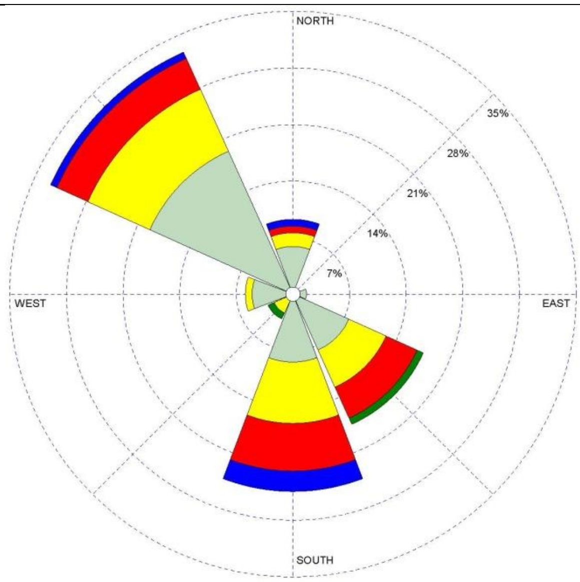
Figure 5.15 Afternoon (4pm) Wind Rose Diagrams for Del Paso Manor Monitor



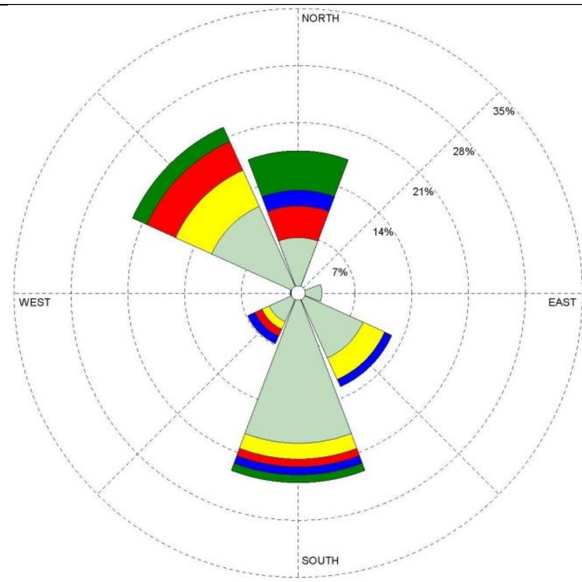
Winter months from 2002-2011



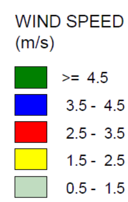
Winter months of 2009



Winter months of 2010



Winter months of 2011



The decade's afternoon (4pm) wind directions measured at Del Paso Manor were predominately from the northwest, south, and southeast. Approximately two thirds of the afternoon winds came from these directions. 29% came from the northwest, 19% came from the southeast, 19% came from the south, 12% came from the north, and 7% came from the southwest.

The dominant wind directions for attainment years were also from the northwest, south, and southeast. In 2009, approximately 28% and 21% of the days with afternoon wind came from the northwest and southeast, respectively. There were no significant variations compared to the decade's wind rose diagram.

The afternoon wind direction of 2010 was predominately from the northwest and south on approximately 33% and 24% of the days with afternoon wind, respectively. Compared to the decade's predominate wind directions, 2010 experienced a slightly higher percentage of days with southerly wind, but less wind came from the southwest.

The predominant afternoon wind directions of 2011 were from the south and northwest. Approximately 23% of the days with afternoon wind came from the south and 22% came from the northwest. The next most predominant 2011 wind direction shows 17% of the afternoon winds came from the north. Although a relatively higher percentage of days with afternoon wind came from the north, the northwestern wind may slightly shift to a north wind.

In general, the overnight and afternoon winds in the Sacramento Region came from the northwest and southeast directions. No significant variations were present in attainment years. The wind rose diagrams did not demonstrate any unusual wind direction patterns that might favor low ambient $PM_{2.5}$ concentrations.

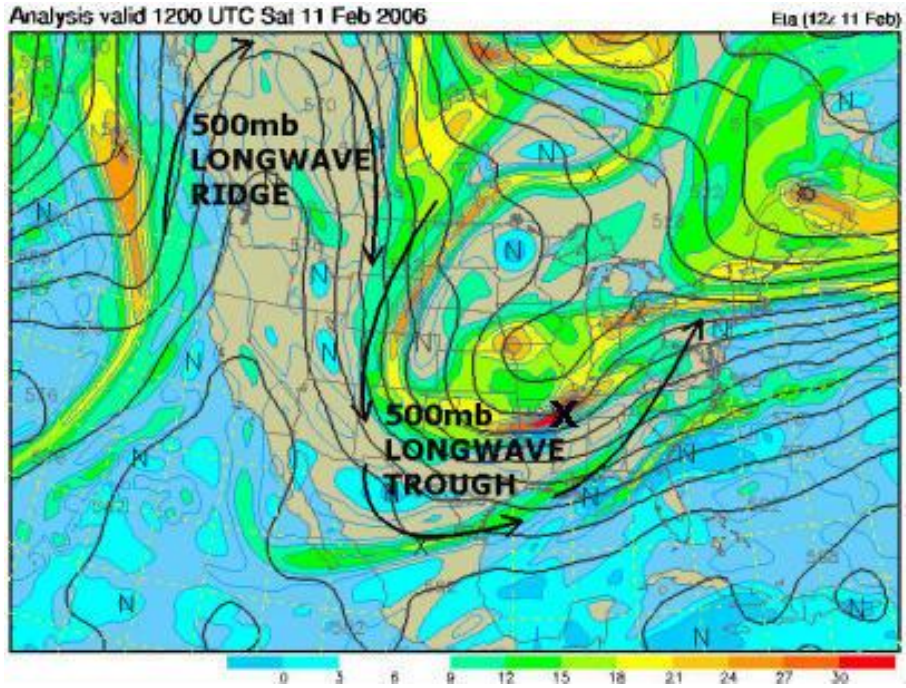
5.3.4.4 Conclusion from the Surface Wind Analysis

The wind speed statistics demonstrate that the attainment years experienced slower and calmer wind conditions. These conditions favor high $PM_{2.5}$ concentrations as described in the beginning of Section 5.3.4. The attainment years' wind rose diagrams show no significant differences in wind direction compared to the decade. It is reasonable to conclude that wind conditions of 2009-2011 were not more favorable to low ambient $PM_{2.5}$ concentrations than average.

5.3.5 500mb Height

Aloft atmospheric circulations have a strong influence on regional weather conditions. Meteorologists generally focus on the so-called "500mb level" to evaluate the aloft large-scale pressure systems. In particular, they focus on the location, size, intensity, and movement of 500mb high-pressure ridges and low-pressure troughs (mountains of warm air and cold air, respectively). (EPA, 2003, p2-23) Specifically, ridges tend to produce conditions conducive to the accumulation of $PM_{2.5}$ and troughs tend to produce conditions conducive to the dispersion (greater vertical mixing) and removal (rainfall deposition) of $PM_{2.5}$. Figure 5.16 is a 500mb height diagram, which shows an example of a ridge over the Western United States and a trough near Oklahoma and Texas.

Figure 5.16 Example of 500mb Height Diagram (courtesy Lutzak, 2008)



An advanced cluster analysis study, conducted by the University of California, Davis, evaluated the 500mb pressure pattern over the Northeastern Pacific Ocean and the Western part of North America. The study concluded that certain pressure patterns favored high ambient $PM_{2.5}$ concentrations (Palazoglu, 2012). STI used a similar approach, but defined different upper air pressure patterns to identify high ambient $PM_{2.5}$ scenarios in their Forecasting Guidelines. That type of analysis is too difficult to replicate for this study. Two scenarios in STI's Sacramento $PM_{2.5}$ Forecasting Guidelines use the 500mb height as the criterion to determine if there will be a forecast exceedance. In the Pre-cold front/Pre-trough scenario, if the morning 500mb height is over 5630 meters, it satisfies one of the forecast exceedance criteria. If the height is over 5670 meters, it satisfies the criteria for the Pacific Northwest High Scenario. This analysis used a simplified approach, using 500mb height, to examine the aloft pressure pattern over the region. This allowed us to determine whether the region experienced a low 500mb height during the attainment years.

A 500mb height indicates whether a high-pressure or low-pressure system is over the region. A high-pressure system drives air downward, trapping pollutants near the surface. The 500mb height value describes the condition of a high-pressure system: the higher the 500mb height, the stronger the high-pressure system, thus more trapping of pollutants at the surface. If the region experiences a low 500mb height, it represents a low-pressure system that drives air upward and disperses pollutants away from the surface. This analysis examines the 500mb height and determines whether $PM_{2.5}$ attainment was due to low 500mb height.

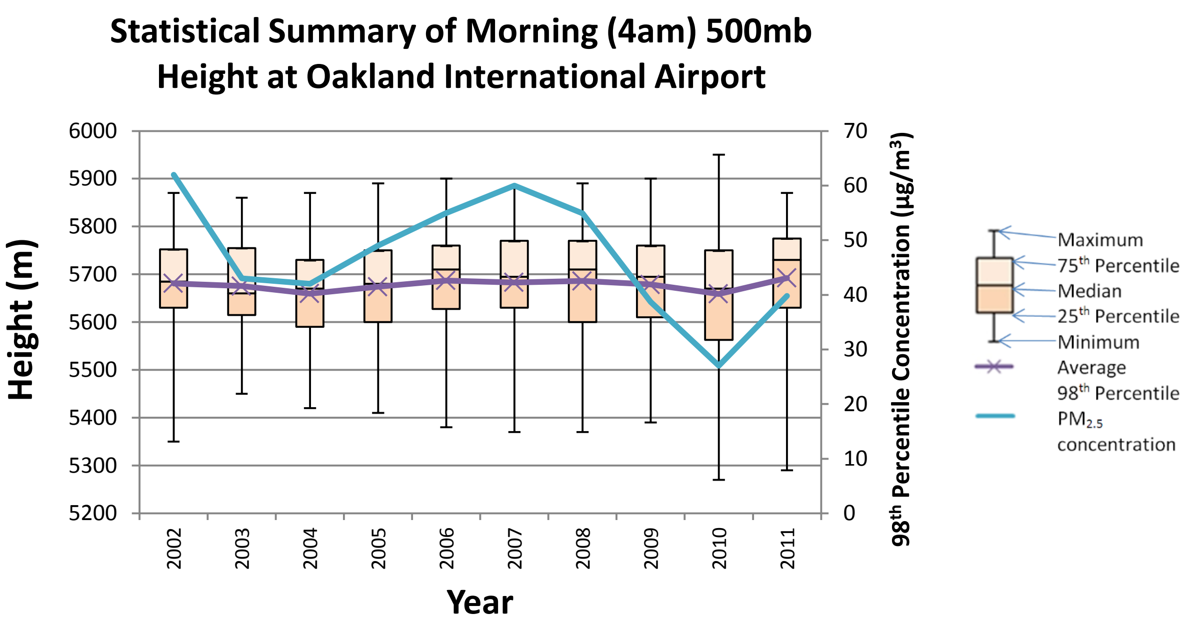
5.3.5.1 General Statistics

The data completeness rates for all the years were over 80%, satisfying our 75% minimum data completeness rate. Table 5.19 shows the five-number statistical summary, average, standard deviation of the morning 500mb height at Oakland International Airport, and the 98th percentile $PM_{2.5}$ concentration. Figure 5.17 is the box plot and chart visualizing the statistical trends.

Table 5.19 Statistical Summary of Morning (4am) 500mb Height (m) at Oakland International Airport

Year	Minimum	First Quartile	Median	Third Quartile	Maximum	Average ($\bar{x}$)	Standard Deviation (σ)	Count (n)	98th percentile concentration ($\mu g/m^3$)
2002	5350	5630	5685	5753	5870	5681	106	104	62
2003	5450	5615	5660	5755	5860	5675	97	119	43
2004	5420	5590	5670	5730	5870	5660	105	115	42
2005	5410	5600	5680	5750	5890	5674	106	113	49
2006	5380	5628	5710	5760	5900	5687	109	120	55
2007	5370	5630	5695	5770	5880	5683	113	112	60
2008	5370	5600	5710	5770	5890	5686	126	101	54.9
2009	5390	5610	5695	5760	5900	5679	118	104	38.7
2010	5270	5563	5670	5750	5950	5659	133	102	27.0
2011	5290	5630	5730	5775	5870	5692	120	119	39.8
2002 - 2011	5270	5610	5690	5760	5950	5677	114	1109	N/A

Figure 5.17 Statistical Summary of Morning (4am) 500mb Height at Oakland International Airport



A high 500mb height usually favors elevated ambient $PM_{2.5}$ concentrations. The range in median 500mb heights was 5660 meters to 5730 meters, and the decade's median was 5690 meters.

5.3.5.2 Hypothesis Testing Results

Hypothesis testing was applied to determine whether the attainment year's 500mb height was statistically different from the decade. Table 5.20 shows the hypothesis test results for the morning (4am) 500mb height at Oakland International Airport. If the number is greater than 1.96, the average 500mb height is significantly higher than the decade's average. If the number is lower than -1.96, the average 500mb height is significantly lower than the decade's average, which is a favorable condition for low ambient $PM_{2.5}$ concentrations. If the number is between -1.96 and 1.96, there is no significant difference.

Table 5.20 Hypothesis Test Result for Morning (4am) 500mb Height at Oakland International Airport

Analysis Years	Attainment Year		
	2009	2010	2011
2002	-0.15	-1.32	0.74
2003	0.24	-1.03	1.20
2004	1.27	-0.04	2.21
2005	0.31	-0.92	1.23
2006	-0.55	-1.71	0.35
2007	-0.27	-1.43	0.60
2008	-0.43	-1.50	0.37
2002-2011	0.14	-1.34	1.31

5.3.5.3 Conclusions of 500mb Height Analysis

The hypothesis test results show that in 2009 there was no statistical difference compared to the 10-year average. Therefore, the 500mb height was not considered a favorable condition for low $PM_{2.5}$ concentrations in 2009.

The hypothesis test results show that in 2010 there was no statistical difference compared to the 10-year average. Therefore, the 500mb height was not considered a favorable condition for low $PM_{2.5}$ concentrations in 2010.

The hypothesis test results show that in 2011 there was no statistical difference compared to the 10-year average. Therefore, the 500mb height was not considered a favorable condition for low $PM_{2.5}$ concentrations in 2011.

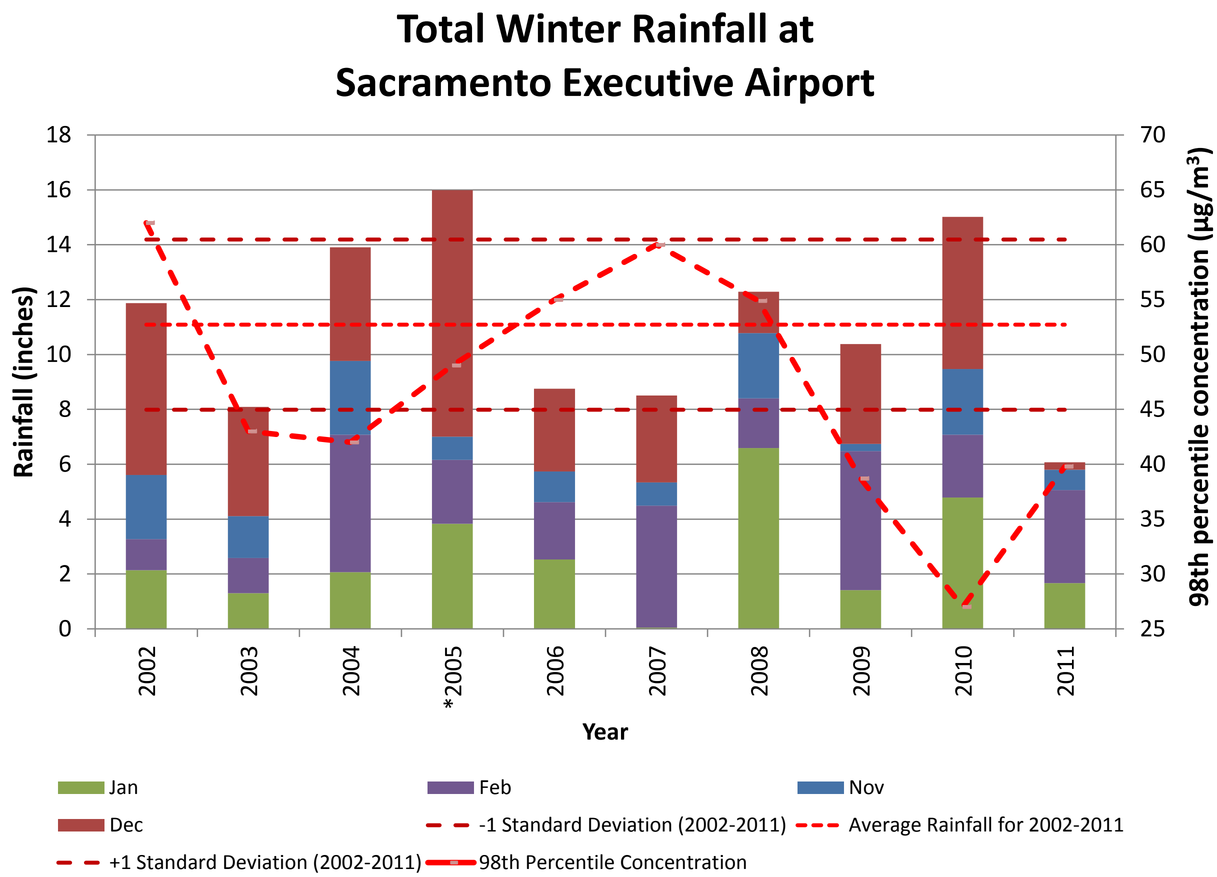
5.3.6 Rainfall

Rainfall can remove particulate matter emissions and its precursors from the air through wet deposition and result in lower $PM_{2.5}$ ambient concentrations (EPA, 2003, Table 2-5). Rainfall amounts are not measured at air quality monitoring sites in the Sacramento region. Therefore, this analysis uses rainfall data measured at the Sacramento Executive Airport. The Sacramento Executive Airport is the best available site in the Sacramento region with complete rainfall data for the past 10 years. It is located 10 miles to the southwest of the Del Paso Manor site. Table 5.21 shows the total winter rainfall at the Sacramento Executive Airport and the 98th percentile concentration at Del Paso Manor. Figure 5.18 shows a stacked bar chart of monthly rainfall for each year over the past decade.

Table 5.21 Summary of Winter Rainfall at Sacramento Executive Airport and 98th Percentile $PM_{2.5}$ Concentration

Year	Total Rainfall (inches)	98th Percentile $PM_{2.5}$ Concentrations ($\mu g/m^3$)
2002	11.87	62
2003	8.09	43
2004	13.91	42
2005	15.99	49
2006	8.75	55
2007	8.51	60
2008	12.29	54.9
2009	10.38	38.7
2010	15.02	27.0
2011	6.07	39.8

Figure 5.18 Total Winter Rainfall at Sacramento Executive Airport.



* In Fig 5.18, 2005 had the highest total winter rainfall in the decade but also had the highest 98th percentile ambient $PM_{2.5}$ concentration. This observation seems contradictory to the scientific claims discussed earlier that high rainfall would lower ambient $PM_{2.5}$ concentrations. We found three possible reasons: 1) although 2005 had the highest total amount of winter rainfall, there were fewer rain days compared to other wet years. A few days with heavy rainfall were recorded in late December 2005. Table 5.22 shows that 31 rain days were recorded in 2005 while 38 days were recorded in 2010; 2) Not many exceedance days were recorded in 2005 compared to other nonattainment years, but a dry five-day high concentration episode that occurred in mid-December 2005 drove high 98th percentile $PM_{2.5}$ concentrations in the region. The Del Paso Manor monitor recorded the decade's 1st, 4th, 8th, and 10th highest $PM_{2.5}$ concentrations in 2005.

5.3.6.1 General Statistics Results

The total winter rainfall of 2009 (10.38 inches) was slightly less than the decade's average rainfall (11.06 inches), and the 98th percentile $PM_{2.5}$ concentration was 38.7µg/m^3. 2010 was a wet year. The Sacramento region recorded total rainfall of 15.02 inches, which was one standard deviation above the decade's average, and it recorded the lowest 98th percentile $PM_{2.5}$ concentration of 27.0µg/m^3. 2011 was the driest year in the past decade with only 6.07 inches of rain, more than one standard deviation below the decade's average. If the winter of 2011 had had normal rainfall, we would expect 98th percentile $PM_{2.5}$ concentrations to be lower than what were observed.

5.3.6.2 Hypothesis Testing Results

Winter rainfall data is presented as total annual rainfall and cannot be represented by averages and standard deviations like other meteorological parameters; therefore, the "tests for hypotheses on the equality of two means, variances known" are not applicable here. We applied another method—"tests of hypothesis on two proportions" (Hines et al, 1990, p.323-325)—to compare the ratios of rainy days between the attainment year and the decade. In this method, we compare the ratio of days with rainfall greater than 0.05 inches and calculate the standard score. The interpretation of the standard score results is identical to the hypothesis test method introduced in Section 5.3.1.4.2. If Z_0 is greater than 1.96, the number of rain days in attainment years is significantly more than the nonattainment years. If the standard score is between -1.96 and 1.96, there is no significant difference of rain days between attainment and nonattainment years. If Z_0 is less than -1.96, the attainment year had significantly fewer rain days compared to nonattainment years. The equations for the standard score are below.

$$p = \frac{x_1+x_2}{n_1+n_2} \text{ and } Z_0 = \frac{\frac{x_1}{n_1}-\frac{x_2}{n_2}}{\sqrt{p(1-p)(\frac{1}{n_1}+\frac{1}{n_2})}}$$

Where: Z_0 = Standard Score
x_1 = the number of days with rainfall more than 0.05 inches (attainment year, 2009 or later)
x_2 = the number of days with rainfall more than 0.05 inches (nonattainment year/decade)
n_1 = total number of days (attainment year)
n_2 = total number of days (nonattainment year/decade)
and $0 \le x_i \le n_i$

Table 5.22 Hypotheses Test Result for Rainfall at Sacramento Executive Airport

Year	*x*	*n*
2002	27	120
2003	30	120
2004	33	121
2005	31	120
2006	26	120
2007	22	120
2008	29	121
2009	23	120
2010	38	120
2011	18	120
2002-2011	277	1202

Analysis Years	Attainment Year		
	2009	2010	2011
2002	-0.64	1.60	-1.49
2003	-1.09	1.15	-1.94
2004	-1.49	0.75	-2.33
2005	-1.24	1.00	-2.08
2006	-0.48	1.75	-1.33
2007	0.17	2.39	-0.69
2008	-0.91	1.33	-1.76
2002-2011	-0.97	2.11	-2.02

Positive Z_0 value means more rainfall days than nonattainment year and favors low $PM_{2.5}$ concentrations

5.3.6.3 Conclusions of the Rainfall Analysis

The hypothesis test results show that in 2009 there was no statistical difference in rainfall compared to the 10-year average. Therefore, winter rainfall was not considered a favorable condition for low $PM_{2.5}$ concentrations in 2009.

The hypothesis test results show that 2010 was statistically wetter than the 10-year average. Therefore, the winter rainfall was a favorable condition for low $PM_{2.5}$ concentrations in 2010.

The hypothesis test results show that 2011 was statistically drier than the 10-year average. Therefore, the winter rainfall was an unfavorable condition for low $PM_{2.5}$ concentrations in 2011.

The total rainfall analysis and hypothesis test indicated that 2009 was a year with average rainfall, 2010 was a wet year, and 2011 was a dry year.

5.3.7 Dew Point Temperature

Dew point is the temperature below which water vapor in a volume of humid air, at a constant pressure, will condense into liquid water. Water vapor or droplets in the air play various roles in $PM_{2.5}$ formation and chemistry. Scientific studies (Brown, 2006) state that "fog droplets served as both aqueous reactors for production of secondary sulfate and nitrate and facilitated wet removal of PM ammonium, sulfate, and nitrate." Motallebi also suggests that low temperatures in the presence of increased humidity are conducive to the formation of secondary particles (Motallebi, 1999, p.7). For most meteorological parameters, the relationship between the parameter and $PM_{2.5}$ concentrations is generally one directional; for example, high wind speeds always disperse pollutants and reduce $PM_{2.5}$ concentrations. With water vapor, as represented by dew-point temperature, some moisture increases $PM_{2.5}$ formation, but if the moisture level is a bit higher, the water droplets remove $PM_{2.5}$. The threshold when moisture changes from favorable to unfavorable is complex. STI's Forecasting Guidelines suggest that if the 6am to 6pm average dew point temperature is between 34°F and 48°F under the Pacific Northwest High scenario (Criterion 1) or lower than 42°F under the Great Basin High scenario (Criterion 2), it would satisfy one of the forecast exceedance criteria. Since there is no absolute correlation between dew point temperature and ambient $PM_{2.5}$ concentration, high or low dew point temperature alone does not indicate a favorable or unfavorable condition. Therefore, we present the dew-point temperature information to complete the analysis, but do not draw any conclusions from that data.

The Del Paso Manor site does not collect direct dew point temperature measurements but it measures surface temperature and relative humidity. The dew point temperature can be calculated using the Arden Buck equation (Buck, 1981) with the Del Paso Manor site surface temperature and humidity data.

Below is the Arden Buck equation converting relative humidity and surface temperature to dew point temperature.

$$T_C = (T_F - 32) \times \frac{5}{9}$$

$$\gamma = \ln(RH \times e^{(b - \frac{T_C}{d}) \times \frac{T_C}{c + T_C}})$$

$$T_{dp} = \frac{c\gamma}{b - \gamma}$$

Where T_C = *Temperature in degree Celsius (°C)*

T_F = *Temperature in degree Fahrenheit (°F)*

T_{dp} = *Dew Point Temperature in degree Celsius (°C)*

b = *18.678*

c = *257.14°C*

d = *234.5°C*

RH = *Relative Humidity (%)*

Additional steps were performed to compute the average 6am–6pm dew point temperatures before performing simple statistics. If either surface temperature or relative humidity is missing, the dew point temperature of that hour was described as missing. The hourly dew point temperatures from 6am to 6pm were extracted and then the total number of valid hourly data was determined. If the number of valid records for a day is less than 9 (less than 75% completeness), the average 6am to 6pm dew point temperature was described as missing.

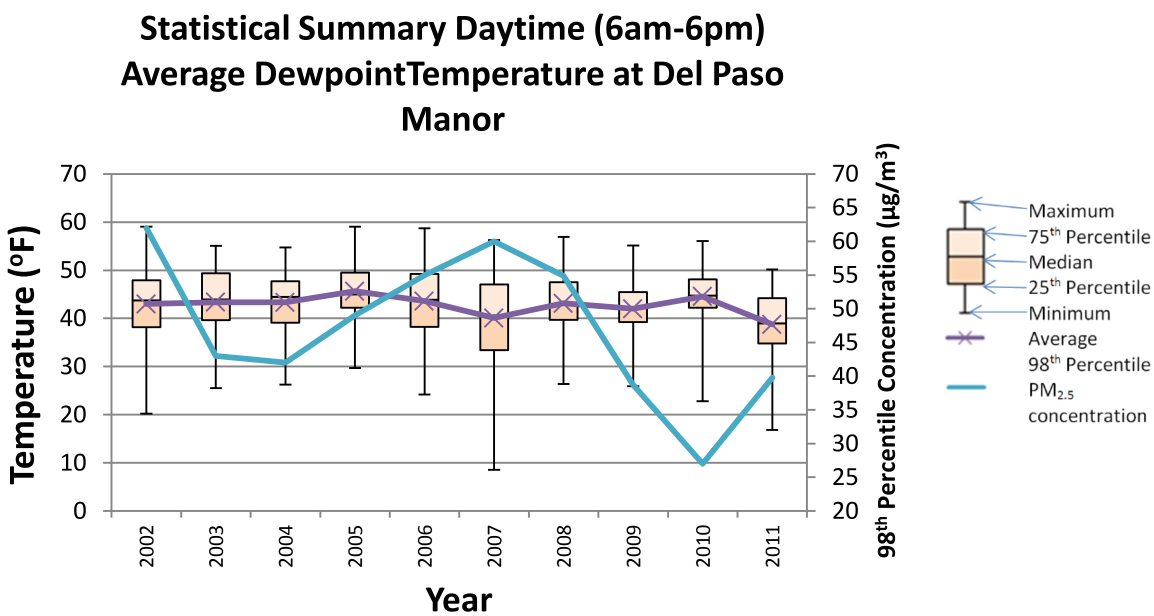
5.3.7.1 General Statistics

Table 5.23 shows the statistical summary of dew point temperatures at Del Paso Manor and the 98th percentile $PM_{2.5}$ concentrations. Figure 5.19 is the box plot and trend lines visualizing the statistical results.

Table 5.23 Statistical Summary of Daytime (6am–6pm) Average Surface Dew Point Temperature (°F) at Del Paso Manor Monitor

Year	Minimum	First Quartile	Median	Third Quartile	Maximum	Average ($\bar{x}$)	Standard Deviation (σ)	Count (n)	98th percentile concentration (μg/m^3)
2002	20.2	38.2	43.7	47.9	59.1	43.0	7.0	111	62
2003	25.5	39.7	43.9	49.4	55.1	43.4	7.0	89	43
2004	26.2	39.1	44.5	47.7	54.8	43.3	6.2	120	42
2005	29.7	42.2	45.0	49.5	59.0	45.7	5.4	120	49
2006	24.2	38.2	43.9	49.2	58.7	43.6	7.7	120	55
2007	8.5	33.4	40.6	47.1	56.2	40.1	9.7	120	60
2008	26.4	39.7	43.0	47.5	56.9	43.1	6.0	120	54.9
2009	25.9	39.2	42.1	45.5	55.2	42.0	6.0	120	38.7
2010	22.8	42.2	44.7	48.1	56.0	44.5	5.8	120	27.0
2011	16.8	34.8	38.9	44.2	50.1	38.7	6.7	119	39.8
2002 - 2011	8.5	38.9	43.3	47.5	59.1	42.7	7.1	1149	N/A

Figure 5.19 Statistical Summary of Daytime (6am – 6pm) Average Surface Dew Point Temperature at Del Paso Manor Monitor



The data had better than a 90% completeness rate except for 2003. The data completeness rate for 2003 was 74%, which was slightly less than our established criterion of 75%. Since the data completeness rate is not significantly lower than the threshold, we included 2003 data in this analysis.

The statistical data shows that the dew point temperature during the nonattainment years ranged from 8.5°F to 59.1°F and the decade's median was 43.3°F.

5.3.7.2 Conclusions from the Dew Point Temperature Analysis

Since dew point temperature or water vapor moisture has multiple roles in secondary aerosols formation and $PM_{2.5}$ removal, no conclusion can be clearly drawn from the general statistics.

5.4 Air Quality Forecasting Conceptual Model for Sacramento

5.4.1 Introduction

STI developed forecasting guidelines for SMAQMD's CBYB program as a tool to help forecasters assess whether meteorological conditions are conducive to high $PM_{2.5}$ concentrations. Observed meteorological parameters were compared to $PM_{2.5}$ concentrations, and meteorological parameters with stronger correlations to $PM_{2.5}$ concentrations were identified. Thresholds for these meteorological parameters were then chosen on the basis of historical data on days with high $PM_{2.5}$ concentrations (in this case, above 35 $\mu g/m^3$). For example, one guideline in STI's conceptual model is for afternoon average wind speed at Sacramento Executive Airport to be less than 5.5 knots, meaning that on most historical days with high $PM_{2.5}$ concentrations in Sacramento, the afternoon average wind speed was less than 5.5 knots. STI developed unique sets of guidelines specific to certain upper air and synoptic pressure patterns identified as favorable for high $PM_{2.5}$ concentrations in Sacramento. STI used these guidelines to assess whether observed meteorological conditions during the 2002-2012 period were unusually favorable for high or low $PM_{2.5}$ concentrations. This analysis was limited to days in November, December, January, and February, as these months constitute SMAQMD's CBYB program for which the forecast guidelines were developed. The specific guidelines by synoptic pattern are shown in Tables 5.24 through 5.28.

Table 5.24. General forecast guidelines for high $PM_{2.5}$ concentration in Sacramento

Parameter	Criteria
OAK 12Z 500 mb height (m)	> 5530 m
SAC morning low temperature (°F)	< 9°C
SFO to SAC 00Z pressure gradient (mb)	Between -1.7 and 1.0 mb
SAC average morning wind speed (kts)	< 3 kts
SUU average morning wind speed (kts)	< 10 kts
SFO to SAC 12Z pressure gradient (mb)	Between -2.3 and 1.0 mb
SFO average morning wind speed (kts)	< 8 kts
OAK 12Z 850 mb wind direction (deg)	< 225 deg
OAK 12Z 850 mb wind speed (kts)	< 10 kts
SAC to RNO 12Z pressure gradient (mb)	-9.0 to 3.0 mb
SAC 12Z 925 mb – surface temp difference (°C)	> 5°C
SAC average afternoon wind direction (deg)	> 125 deg
SAC average afternoon wind speed (kts)	< 5.5 kts
SAC average daytime dew point temperature (°C)	< 9°C
SAC average morning wind direction (deg)	Between 100 and 200 deg or between 340 and 360 deg

Table 5.25. Great Basin surface high forecast guidelines for high $PM_{2.5}$ concentrations in Sacramento.

Parameter	Criteria
SAC 12Z 950 mb – surface temp difference (°C)	> 8°C
SAC average afternoon wind speed (kts)	< 3 kts
SAC 00Z 950 mb – surface temp difference (°C)	> -2°C
SAC average daytime dew point temperature (°C)	< 9°C
SAC morning low temperature (°C)	< 5.5°C
SAC to LAS 12Z pressure gradient (mb)	< 4 mb
SUU average morning wind direction (deg)	< 100 deg
SAC average morning wind speed (kts)	< 2 kts

Table 5.26. Pacific Northwest surface high forecast guidelines for high $PM_{2.5}$ concentrations in Sacramento.

Parameter	Criteria
SAC 12Z 950 mb – surface temp difference (°C)	> 10°C
SAC average afternoon wind speed (kts)	< 3 kts
SAC average overnight wind speed (kts)	< 1 kt
SFO to SAC 12Z pressure gradient (mb)	< 0 mb
SAC to LAS 12Z pressure gradient (mb)	Between -1 and 5 mb
SAC 12Z 500 mb height (m)	> 5670 m
SAC average daytime dew point temperature (°C)	Between 1 and 9°C

Table 5.27. Pre-cold front/Pre-trough forecast guidelines for high $PM_{2.5}$ concentrations in Sacramento.

Parameter	Criteria
SAC afternoon high temperature (°C)	Between 10 and 16°C
SAC average afternoon wind speed (kts)	< 6 kts
SAC 12Z 950 mb – surface temp difference (°C)	> 6°C
SFO to SAC 12Z pressure gradient (mb)	Between -1.5 and 1.0 mb
SAC to LAS 12Z pressure gradient (mb)	Between -6.0 and 0.0 mb
SAC 12Z 925 mb wind speed (kts)	< 8 kts
SAC 12Z 500 mb height (m)	> 5630 m
SUU average afternoon wind speed	< 9 kts
SAC average overnight wind speed (kts)	< 3 kts

Table 5.28. 500 mb Cutoff Low south forecast guidelines for high $PM_{2.5}$ concentrations in Sacramento.

Parameter	Criteria
SAC average overnight wind speed (kts)	< 3 kts
SAC average afternoon wind speed (kts)	< 3 kts
SFO to SAC 00Z pressure gradient (mb)	< 0 mb
SUU average afternoon wind speed (kts)	< 6 kts
SAC 00Z 950 mb – surface temp difference (°C)	> -2°C

5.4.2 Data Acquisition and Analysis

STI collected surface and upper air meteorological data for all days in November, December, January, and February for the 2002-2012 period using the same stations, times, and averaging periods as described in Tables 5.24 through 5.28. Each day was synoptically typed and placed into one of five categories according to the five sets of forecast guidelines. Days that did not fit into the four specific synoptic patterns identified as favorable for high $PM_{2.5}$ concentrations were assessed using the general forecast guidelines. The general forecast guidelines were originally developed without synoptic typing. All of the guidelines contain parameter-specific thresholds according to the CBYB program. Stage 2 corresponds to daily average $PM_{2.5}$ concentrations above 35 $\mu g/m^3$, which is in exceedance of the NAAQS. Thus, the Stage 2 thresholds were used in this analysis to determine the predicted number of exceedance days.

The data used to create the forecast guidelines encompasses the attainment period in question (2009-2011), and the forecast guidelines were developed with the intention that all or nearly all meteorological parameters must be satisfied in order to have observed $PM_{2.5}$ concentrations above 35 $\mu g/m^3$. Thus, for the purposes of this analysis, an exceedance day is defined as a day in which all meteorological parameters in the appropriate set of forecast guidelines are satisfied. Days that were missing data for any of the required parameters in the appropriate set of forecast guidelines were not considered in this analysis. To achieve as complete a data set as possible, upper air data were at times estimated using synoptic weather maps and model analysis data when raw observed data were not available.

Figure 5.20 shows the annual predicted number of exceedance days for 2002-2012 using the forecast guidelines, and Figure 5.21 illustrates these results broken down by synoptic weather pattern. There is considerable variation in the number of predicted exceedance days from year to year over the 2002-2012 period and over the 2009-2011 attainment period. The guidelines suggest that weather conditions in 2010 were favorable for lower $PM_{2.5}$ concentrations in Sacramento, but that weather conditions in 2011 were very unfavorable for lower $PM_{2.5}$ concentrations. In fact, the forecast guidelines predicted 35 exceedance days in 2011, which is similar to the results from the CART analysis and is the highest predicted number of exceedances for any year in the 2002-2012 period. The forecast guidelines also predicted 23 exceedances for 2009, which is the second highest number of exceedances for any year in this analysis. Thus, overall meteorological conditions during the 2009-2011 attainment period as a whole were not unusually favorable for low $PM_{2.5}$ concentrations in the Sacramento region, corroborating the results from the CART analysis and the general statistics analysis.

Figure 5.20. Predicted number of exceedance days per year using STI's forecast guidelines, 2002-2012.

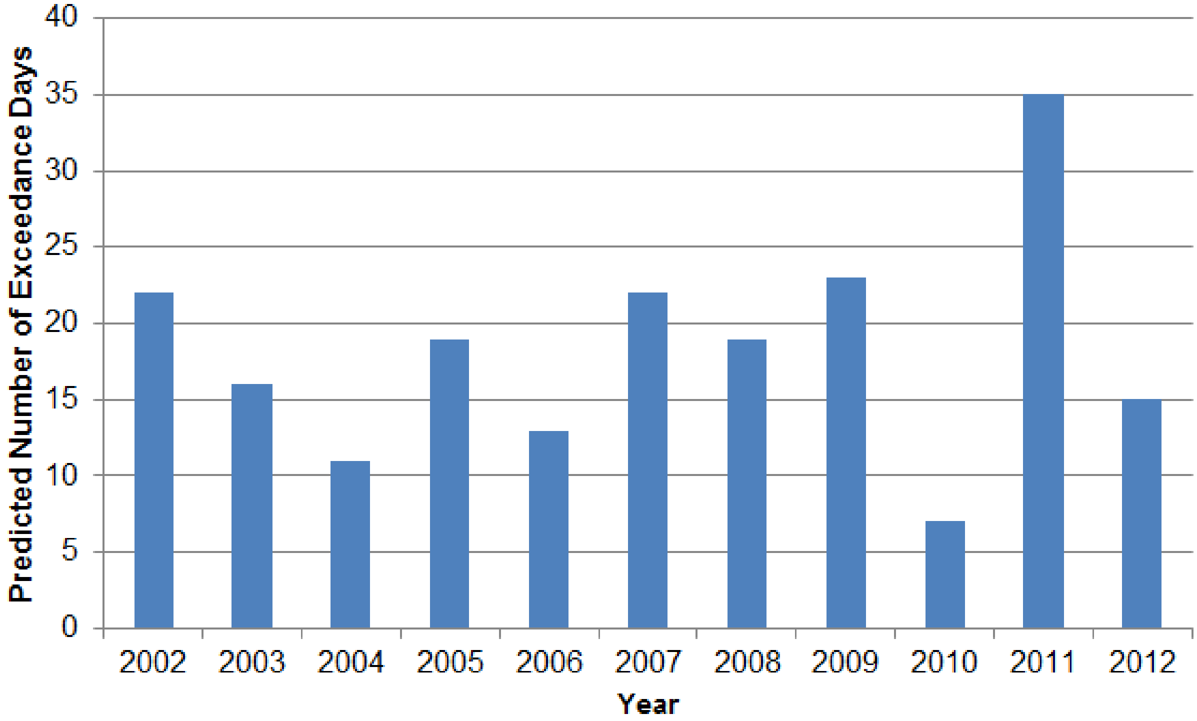
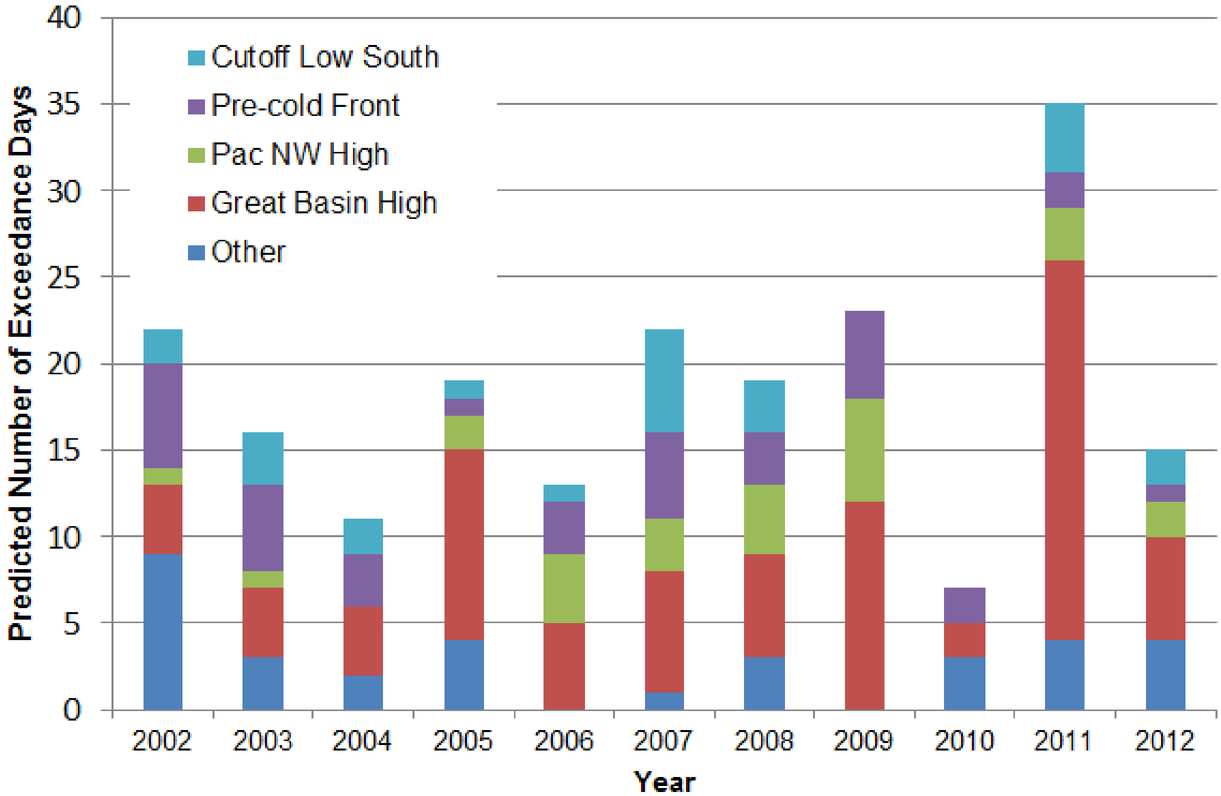


Figure 5.21. Predicted number of exceedance days per year by synoptic weather pattern using STI's forecast guidelines, 2002-2012.



5.5 Conclusions

This chapter details the findings of three separate and independent analyses which were prepared to determine the influence of meteorology on $PM_{2.5}$ concentrations in the Sacramento Region. These analyses were spurred by USEPA guidance that states "… attainment due to unusually favorable meteorology would not qualify as an air quality improvement due to permanent and enforceable emissions reductions." (Calcagni, 1992) While the Region has made significant emission reductions through permanent and enforceable control strategies, and has attained the $PM_{2.5}$ standard, the region must demonstrate that meteorology did not have a significant influence on lowering $PM_{2.5}$ concentrations during the attainment years of 2009-2011.

In the first analysis, CARB and STI applied the Classification and Regression Tree (CART) technique to evaluate the trends of $PM_{2.5}$ annual averages and number of exceedance days from 1999-2010. In order to cover the attainment years of 2009-2011, STI reproduced this CART analysis to determine trends in $PM_{2.5}$ annual averages and number of exceedance days in 2011 and 2012. The findings from this analysis indicate that the actual observed and meteorologically adjusted $PM_{2.5}$ trends decline. The fact that the observed and met-adjusted trend lines are lower than the CART-predicted $PM_{2.5}$ concentrations (beginning in 2008) demonstrate that the $PM_{2.5}$ concentrations were declining because of emission reductions and not meteorology. In 2010, the met-adjusted annual average $PM_{2.5}$ concentration is higher than the observed concentration, showing that meteorological conditions in 2010 were slightly favorable for low $PM_{2.5}$ concentrations. The CART analysis shows that 2011 had the most unfavorable meteorological conditions for low $PM_{2.5}$ concentrations over all the years investigated (1999-2012) because the CART-predicted annual average $PM_{2.5}$ concentration and number of exceedance days were notably higher than the other years. In addition, the met-adjusted annual average $PM_{2.5}$ concentration (the concentration expected if weather conditions were normal) for 2011 was lower than observed. Despite these very unfavorable meteorological conditions, the number of observed $PM_{2.5}$ exceedances days was still less than the CART-predicted number of $PM_{2.5}$ exceedances. These facts further illustrate that $PM_{2.5}$ concentrations were declining because of emission reductions and not meteorology.

In the second analysis, SMAQMD examined the relationship between $PM_{2.5}$ concentrations and meteorology in the region, statistically comparing each attainment year with the 10-year average for several meteorological parameters. The meteorological parameters analyzed were surface temperature, temperature inversion, surface wind speed and direction, 500mb height, dew point temperature, and rainfall. Warm surface temperature, strong vertical mixing (temperature inversion), strong surface wind speed, low 500mb height, and rainfall are conducive to low ambient $PM_{2.5}$ concentrations based on scientific studies of the region. Table 5.29 summarizes SMAQMD's findings on the impacts of each meteorological parameter and its propensity to favor low ambient $PM_{2.5}$ concentrations.

Table 5.29 Summary of Impacts of Meteorological Parameters to Favor Low Ambient $PM_{2.5}$ Concentrations.

Meteorological Parameter	2009	2010	2011
Surface Temperature-Morning	Unfavorable	Favorable	Unfavorable
Surface Temperature-Afternoon	No impact*	Unfavorable	No impact
Temperature Inversion – Morning	No impact	No impact	Unfavorable
Temperature Inversion – Afternoon	No impact	Unfavorable	Unfavorable
Wind Speed – Overnight/Midnight	Unfavorable	No impact	Unfavorable
Wind Speed – Afternoon	Unfavorable	Unfavorable	Unfavorable
500 mb Height – Morning	No impact	No impact	No impact
Winter Rainfall	No impact	Favorable	Unfavorable

* No impact means that there was not a statistically significant difference in the value for the attainment year and the data over the entire 10-year data record.

The statistical analysis found that despite some variability of meteorological conditions during the past decade, the conditions could not be considered as "unusually favorable" for low ambient $PM_{2.5}$ concentrations. Among SMAQMD's findings is that surface temperature and winter rainfall in 2010 are the only two meteorological parameters that favored low ambient $PM_{2.5}$ concentrations. It is not reasonable to conclude that unusually favorable meteorological conditions were present during the attainment years when only two favorable conditions were present for one of the three attainment years.

The third analysis used STI's forecasting conceptual model to assess whether daily meteorological conditions were unusually favorable for low $PM_{2.5}$ concentrations. STI's forecasting conceptual model for $PM_{2.5}$ in Sacramento consists of five sets of meteorological parameters customized to different synoptic weather patterns. This analysis has the benefit of assessing multiple meteorological parameters in combination. This analysis showed considerable variability in the number of predicted exceedances from year to year over the 2002-2012 period, with the most predicted exceedances occurring in 2011, the second most in 2009, and the fewest number of exceedances in 2010. Thus, while this analysis indicates that meteorological conditions in 2010 were favorable for lower $PM_{2.5}$ concentrations, meteorological conditions were unfavorable for low $PM_{2.5}$ concentrations in 2009 and were very unfavorable for low $PM_{2.5}$ concentrations in 2011. Therefore, this analysis demonstrates that meteorological conditions during the 2009-2011 attainment period as a whole were not unusually favorable for low $PM_{2.5}$ concentrations.

From CARB/STI's CART analysis, we have strong evidence that the low ambient $PM_{2.5}$ concentrations were a result of emission reductions. SMAQMD's statistical analysis and STI's conceptual model analysis concluded that the overall meteorological conditions during the attainment years could not be considered as "*unusually favorable*" for low ambient $PM_{2.5}$ concentrations. It is reasonable to conclude that attainment of the 2006 $PM_{2.5}$ National Ambient Air Quality Standards (NAAQS) for the Sacramento region was due to permanent and enforceable emissions reductions and not "*unusually favorable*" meteorological conditions.

5.6 References

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6 Control Measure Analysis

6.1 Introduction and Background

The control measures chapter describes the permanent and enforceable control measures that enabled the Sacramento Federal Nonattainment Area (SFNA) to attain the 24-hour $PM_{2.5}$ National Ambient Air Quality Standard (NAAQS) in 2011. The control measures include a combination of actions taken by local, state, and federal agencies to reduce $PM_{2.5}$ and applicable $PM_{2.5}$ precursor emissions from various source categories. Because the SFNA has already attained the 2006 NAAQS, new measures and a Reasonably Available Control Measure (RACM) analysis are not required[33]. The maintenance demonstration in Chapter 7 showed that no new control measures are required to maintain the $PM_{2.5}$ NAAQS through 2024. Rules implemented in 2008 or later are the measures that led to attainment and are identified in this chapter. CAA Section 107(d)(3)(E)(iii) requires a demonstration that attainment is the result of permanent and enforceable measures as a condition of re-designation. This chapter reviews permanent and enforceable measures that contribute to attainment and the status of CAA Part D permit requirements.

6.2 Existing Local $PM_{2.5}$ Control Measures

$PM_{2.5}$ concentrations were reduced by controlling direct emissions of $PM_{2.5}$ and $PM_{2.5}$ precursors. Under the United States Environmental Protection Agency's (EPA) final $PM_{2.5}$ implementation rule, $PM_{2.5}$ precursors include nitrogen oxides (NO_X) and sulfur dioxide (SO_2). (72 FR 20591) Volatile organic compounds (VOC) and ammonia are excluded from the $PM_{2.5}$ control evaluation, unless it is demonstrated that VOC or ammonia is a significant contributor to the formation of $PM_{2.5}$. The sources of $PM_{2.5}$, NO_X, and SO_2 have been controlled in the nonattainment area by the local air districts, as well as by the California Air Resources Board (CARB) and EPA.

The majority of directly emitted $PM_{2.5}$ in the nonattainment area is the result of fuel combustion, including wood burning. The local air districts of the nonattainment area have rules to control directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors. The chart below shows rules implemented to control residential wood burning, and other rules implemented in 2008 or later for each air district by source type. Rules adopted or implemented following 2008 collectively contributed to attainment and/or continued attainment of the 2006 24-hour $PM_{2.5}$ NAAQS in the Sacramento region. Following this table, for each District, are tables which include adoption dates[34], implementation dates, current State Implementation Plan (SIP) approval status, and brief narratives of the rules.

[33] 40 CFR 51.1004(c)
[34] Adoption or amendment dates of the version that was implemented 2008 or later.

Table 6.1 Summary of Wood Burning Rules and Rules Implemented 2008 or Later

	Pollutant	EDCAQMD	PCAPCD	SMAQMD	YSAQMD
Wood Burning Appliances	$PM_{2.5}$		X	X	X
Mandatory Episodic Burn Restrictions	$PM_{2.5}$, NO_X, SO_2			X	
Boilers, Process Heaters, and Steam Generators	NO_X			X	
Water Heaters, Boilers, Process Heaters < 1,000,000 BTU/hr	NO_X			X	X
Central Furnaces	NO_X				X
Biomass Boilers	NO_X		X		X
Burn Management	$PM_{2.5}$		X		

EDCAQMD: El Dorado County Air Quality Management District
PCAPCD: Placer County Air Pollution Control District
SMAQMD: Sacramento Metropolitan Air Quality Management District
YSAQMD: Yolo-Solano Air Quality Management District

El Dorado County Air Quality Management District

No District rules for wood burning and no other rules that began implementation in 2008 or later.

Placer County Air Pollution Control District

Table 6.2 PCAPCD Control Measures

Rule #	Pollutant	Title	Adoption (Amendment) Date	Implementation Date	SIP Submittal Date	SIP Approval Date
225	$PM_{2.5}$	Wood Burning Appliances	12/13/2007	1/1/2009		
233	NO_X	Biomass Boilers	6/14/2012	6/14/2012	6/26/2012	8/29/2013
301	$PM_{2.5}$	Non-Agricultural Burning Smoke Management	2/9/2012	2/9/2012	2/29/2012	1/31/2013
302	$PM_{2.5}$	Agricultural Waste Burning Smoke Management	2/9/2012	2/9/2012	2/29/2012	1/31/2013
303	$PM_{2.5}$	Prescribed Burning Smoke Management	2/9/2012	2/9/2012	2/29/2012	1/31/2013
304	$PM_{2.5}$	Land Development Burning Smoke Management	2/9/2012	2/9/2012	2/29/2012	1/31/2013
305	$PM_{2.5}$	Residential Allowable Burning	2/9/2012	2/9/2012	2/29/2012	1/31/2013
306	$PM_{2.5}$	Open Burning of Non-Industrial Wood Waste at Designated Disposal Sites	2/9/2012	2/9/2012	2/29/2012	1/31/2013

- The amendment of Rule 225 Wood Burning Appliances was approved by the Board of Directors on December 13, 2007. The rule requires that 1) after January 1, 2009 the sale, offer for sale, supply, or installation of new wood-burning appliance in Placer County should meet the EPA Phase II woodstove emission standard, and 2) after January 1, 2012 no person shall sell or transfer any real property which contains an operable free standing woodstove which is not EPA Phase II certified.
- The amendment of Rule 233 Biomass Boilers was approved by the Board of Directors on June 14, 2012 to address EPA comments and remove the limited approval by EPA

on January 19, 2012. This rule was fully approved into the SIP on August 29, 2013 (78 FR 53249-53250).

- On February 10, 2011, six (6) burn management rules were adopted which replace the District's 25 prior burn rules. The 25 prior rules were adopted in or before 1993. Those rules were restructured into a new format, language was clarified or deleted as applicable, and changes to Title 17 of the California Code of Regulations, adopted by CARB in 2000 and 2002, were added. The new rules are more stringent for outdoor burning and allow the District to manage the burning program more efficiently to reduce smoke and associated PM impacts. The rules were submitted to EPA for SIP approval in September 2011. However, EPA had additional comments that required changes. The rules were amended in February 2012 to incorporate those changes and received approval on January 31, 2013 (78 FR 6736-6740).

Sacramento Metropolitan Air Quality Management District

Table 6.3 SMAQMD Control Measures

Rule #	Pollutant	Title	Adoption (Amendment) Date	Implementation Date	SIP Submittal Date	SIP Approval Date
417	$PM_{2.5}$	Wood Burning Appliances	10/26/2006	10/26/2007	9/21/2012	4/11/2013
421	$PM_{2.5}$, NO_X, SO_2	Mandatory Episodic Curtailment of Wood and Other Solid Fuel Burning	10/25/2007 (9/24/2009)	12/1/2007 (11/1/2009)	5/2012	
411	NO_X	Boilers. Process Heaters, and Steam Generators	8/23/2007	10/27/2009	3/7/2008	5/6/2009
414	NO_X	Water Heaters. Boilers, Process Heaters <1,000,000 BTU/hr	3/25/2010	1/1/2013	4/5/2011	11/1/2011

Wood Burning Control Measures: The largest single source of Sacramento County's wintertime direct $PM_{2.5}$ emissions is wood, pellet, and other solid fuel burning in fireplaces, inserts, wood, and pellet stoves. In 2005, SMAQMD began developing a three-prong approach to reducing emissions from wood burning: providing financial incentives to install cleaner burning device, regulating new wood burning installations, and reducing burning from existing fireplaces and wood stoves. The following rules were adopted to reduce $PM_{2.5}$ emissions from residential wood combustion. These emission reductions are permanent and enforceable as they are implemented through District adopted rules.

- Rule 417, Wood Burning Appliances, was approved by the Board of Directors on October 26, 2006 to prohibit installing new fireplaces and limiting the sale or installation of wood burning devices. The sale and installation requirements in the rule became effective on October 26, 2007. This rule was submitted for SIP approval in May 2012.
- Rule 421, Mandatory Episodic Curtailment of Wood and Other Solid Fuel Burning, was approved by the Board of Directors on October 25, 2007 to restrict wood burning on forecasted high $PM_{2.5}$ days during November through February and was first implemented during the 2007/2008 winter season. It was amended on September 24, 2009 to lower the forecast thresholds for burning restrictions which went into effect for

the 2009/2010 winter season. This rule was submitted for SIP approval in May 2012. This rule also provides $PM_{2.5}$ precursor benefits.

- Rule 411, Boilers, Process Heaters, and Steam Generators, was amended by the Board of Directors on August 23, 2007 to establish lower NO_X limits for boilers and process heaters that are 1 mmBTU/hr or greater. The new limits were fully implemented by October 27, 2009. This rule was approved into the SIP on May 6, 2009 (74 FR 20880-20882).
- Rule 414, Water Heaters, Boilers, Process Heaters <1,000,000 BTU/hr, was amended by the Board of Directors on March 25, 2010 [see 2009 Ozone Plan (SMAQMD, 2011) for a narrative on this control measure.] Implementation of the 2010 amendments began January 1, 2011 and additional NO_X limits were implemented in January 2013. This rule was approved into the SIP on November 1, 2011 (76 FR 67366-67369).

<u>Yolo/Solano Air Quality Management District</u>

Table 6.4 YSAQMD Control Measures

Rule #	Pollutant	Title	Adoption (Amendment) Date	Implementation Date	SIP Submittal Date	SIP Approval Date
2.11	PM	Particulate Matter	1/13/2010	1/13/2010	7/20/2010	4/8/2012
2.12	PM	Specific Contaminants	1/13/2010	1/13/2010	7/20/2010	4/8/2012
2.3	PM	Ringelmann Chart	1/13/2010	1/13/2010	7/20/2010	4/8/2012
2.37	NO_X	Natural Gas-Fired Water Heaters and Small Boilers	4/8/2009	1/1/2010	9/15/2009	5/10/2010
2.40	$PM_{2.5}$	Wood Burning Appliances	12/8/2004	12/8/2004		
2.42	NO_X	Nitric Acid Production	5/13/2009	7/1/2009	9/15/2009	5/10/2010
2.44	NO_X	Central Furnaces	5/13/2009	1/1/2010		
11.2	PM	Confined Animal Facilities	6/14/2006	12/14/2006	10/5/2006	
11.3	PM/NO_X	Agricultural Engine Registration	7/9/2008	7/9/2008		

The following rules have been adopted by the YSAQMD to either directly control $PM_{2.5}$ emissions or to control the emissions of $PM_{2.5}$ precursors. Rules developed for the control of directly-emitted $PM_{2.5}$ focus on residential wood-burning. Rules that control $PM_{2.5}$ precursors were originally written as NO_X-reduction measures for the purposes of limiting ozone concentrations.

- Rule 2.40, Wood Burning Appliances, was approved by the YSAQMD Board of Directors on December 8, 2004. The rule prohibits the sale, offer for sale, supply, or installation of any wood-burning appliance in a new or existing development that is not:
  - A pellet-fueled wood-burning heater
  - A U.S. EPA Phase II Certified wood-burning heater
  - An appliance or fireplace determined to meet U.S. EPA particulate matter emission standards and approved in writing by the YSAQMD Air Pollution Control Officer.
- Rule 2.37, Natural Gas-Fired Water Heaters and Small Boilers, prohibits the manufacture, sale, offer for sale, or installation of any natural gas fired water heater with a rated heat input capacity of less than 1,000,000 BTU's that does not meet specified

NO_X limits, thereby reducing $PM_{2.5}$ precursor emissions. This rule was approved into the SIP by EPA on May 10, 2010 (75 FR 25778-25780).

- Rule 2.44, Central Furnaces, limits NO_X emissions from the use of natural gas-fired, fan-type central furnaces. NO_X reductions associated with this rule will reduce $PM_{2.5}$ precursor emissions.

6.3 Existing State and Federal $PM_{2.5}$ Control Measures

In addition to the local controls implemented by the air districts, controls are also adopted by federal and State authorities to regulate directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors. Typically, these controls are focused on emissions sources over which air districts do not have authority. Federal and State control measures are especially important for the Sacramento Region's continuing attainment of the federal $PM_{2.5}$ standard because some sources that are major contributors to the Region's $PM_{2.5}$ and NO_X inventories are not subject to air district control.

In 2007, CARB adopted a State Strategy for California's State Implementation Plan. The strategy included measures necessary to bring the state into compliance with federal $PM_{2.5}$ and ozone standards, concentrating on the control of emissions from mobile sources. Mobile sources are the largest contributor of NO_X in the Sacramento Region's emissions inventory. In its original nonattainment designation (EPA, 2008) for the Sacramento Region, EPA identified mobile sources as one of the categories responsible for violations of the federal $PM_{2.5}$ standard in the Sacramento Region.

CARB's 2007 State Strategy contains mobile source control measures to achieve reductions in both directly emitted $PM_{2.5}$ as well as NO_X. The measures in Table 6.5 were: (i) adopted, (ii) implemented between 2008 and 2011, and (iii) involve reductions of $PM_{2.5}$ and/or NO_X emissions in the SFNA (CARB, 2009)(CARB, 2011).

Table 6.5 CARB adopted control measures

Measure/Waiver	Date submitted to EPA	Implementation
Smog Check Improvements	10-28-09	2008-2013
Cleaner In-Use Heavy-Duty Trucks	09-21-11	2011-2015
Clean Up Existing Harbor Craft waiver	granted on 12-13-11	2009-2018
Cleaner In-Use Off-Road Equipment waiver	08-12-08	2009

Since the adoption of the 2007 Strategy, CARB has also adopted two additional rules that were not identified as specific measures in the original Strategy, but do have NO_X emission benefits. Both of these measures began implementation between 2008 and 2011.

- Light-duty Vehicle Catalyst Replacement
- Greenhouse Gas Emissions from Heavy-Duty Vehicles

<u>CARB Scoping Plan – California Global Warming Solutions Act</u>

In 2008, CARB adopted a scoping plan as mandated by the provisions of AB 32, the California Global Warming Solutions Act of 2006. AB 32 requires California to reduce emissions of greenhouse gases (GHG) to 1990 baseline levels by 2020. Many of the actions outlined in the scoping plan assist with reducing $PM_{2.5}$ pollution. Several of the scoping plan measures are measures that were originally developed for attainment of federal criteria pollutant standards.

The Light-Duty Vehicle Greenhouse Gas Standards measure in the Scoping Plan was adopted and later implemented between 2008 and 2011. That measure reduces directly emitted $PM_{2.5}$ and NO_X.

6.4 Public Education and Outreach

Some air districts in the Sacramento Region have developed public outreach to encourage voluntary efforts to reduce $PM_{2.5}$ emissions and engage with the public to educate residents concerning proper wood-burning techniques. Some districts have also developed public education campaigns that encourage residents not to burn on days when meteorological conditions indicate that $PM_{2.5}$ levels could be elevated. These outreach programs can directly assist with reducing $PM_{2.5}$ generating activity on days when a violation of the federal standard would be most likely. Some districts also administer grant programs that provide financial incentives for individuals to replace older wood burning appliances with newer, more efficient appliances.

6.5 New Source Review Program

Clean Air Act Section 161 requires SIPs to include emission limitations and other measures necessary to prevent significant deterioration of air quality in an attainment or unclassified area. Section 172(c)(5) and 173 of the Clean Air Act requires the SIP to include provisions to require permits for the construction and operation of new or modified major stationary sources anywhere in the nonattainment area. These requirements are referred to as the New Source Review (NSR) program. EPA issued final rules governing the implementation of the NSR program for $PM_{2.5}$ in 2008 (73 FR 28321-28350). $PM_{2.5}$ can be emitted directly or formed secondarily in the atmosphere from the emission of precursor compounds. EPA's final rule requires NSR programs to address directly emitted $PM_{2.5}$ and pollutants responsible for secondary $PM_{2.5}$ formation as follows:

- SO_2 – regulated
- NO_X – regulated unless it is demonstrated that NO_X is not a significant contributor to $PM_{2.5}$ for the area
- VOC – not regulated unless it is demonstrated that VOC is a significant contributor to $PM_{2.5}$ for the area
- Ammonia – not regulated unless it is demonstrated that ammonia is a significant contributor to $PM_{2.5}$ for the area

On January 4, 2013, in *Natural Resources Defense Council v. EPA,* the DC Circuit Court of Appeals remanded EPA's "Implementation of the New Source Review Program for Particulate Matter Less than 2.5 Micrometers ($PM_{2.5}$)" to be re-promulgated pursuant to CAA Subpart 4. The Court did not address the merits of EPA's rules, which have not yet been re-promulgated. We will interpret the permitting requirements in Subpart 4 regarding $PM_{2.5}$ precursors as described in EPA's prior Implementation Rule (EPA, 2013). See Chapter 7 for additional details.

CAA Section 188(a) classifies nonattainment areas initially as “moderate” with an attainment date no later than the sixth calendar year following a nonattainment designation. The Sacramento Region was designated nonattainment effective December 14, 2009. The CAA specifies that an area be reclassified to “serious” if it cannot practically attain by the moderate area attainment date. Because Sacramento attained the standard prior to the sixth year deadline, this Plan complies with the moderate nonattainment area permitting program requirements.

The nonattainment area NSR requirements apply to any major stationary source that directly emits, or has the potential to emit, 100 tons per year or more of $PM_{2.5}$. $PM_{2.5}$ precursors must also be considered when determining if a stationary source is considered a major stationary source for $PM_{2.5}$. Stationary sources that emit, or have the potential to emit, 100 tons per year or more of nitrogen oxides or sulfur oxides as $PM_{2.5}$ precursors are subject to $PM_{2.5}$ NSR requirements.

EPA has determined (Nicholas, 1994) that although PSD requirements apply after re-designation, and areas being re-designated are not required to establish a nonattainment NSR program prior to re-designation, if the area demonstrates that it can maintain $PM_{2.5}$ attainment without NSR. This Plan does not include emission reduction benefits from nonattainment NSR and demonstrates that NSR is not required to maintain the standard.

The requirements of Prevention of Significant Deterioration (PSD) affect certain new or modified major stationary sources that emit, or have the potential to emit, 100 tons per year or of any regulated NSR pollutant in an attainment or an unclassifiable area; the threshold is 250 tons per year for all other sources[35]. PSD requirements include: installation of Best Available Control Technology (BACT), air quality monitoring and modeling analyses to ensure a project will not cause or contribute to a violation of any air quality standard, and additional public involvement (including opportunity for public comment).

El Dorado Air Quality Management District PSD Rule Status

The EDCAQMD does not have a SIP approved PSD Rule and has not been delegated authority for implementing PSD. The PSD requirements for $PM_{2.5}$ are met through EPA’s implementation of 40 CFR 52.21.

Placer County Air Pollution Control District PSD Rule Status

The PCAPCD’s Prevention of Significant Deterioration Rule (Rule 518) requirements meet or exceed those required for a $PM_{2.5}$ attainment area. Rule 518 was approved by the Board of Directors on February 10, 2011 and was fully approved into the SIP on December 10, 2012 (77 FR 73316-73320).

[35] Sources belonging to the list of source categories in 40 CFR 51.166(b)(1)(i)(a) are subject to the 100 tons per year threshold. All other sources must emit, or have the potential to emit, of 250 tons per year or more of a regulated NSR pollutant.

Sacramento Metropolitan Air Quality Management District PSD Rule Status

The SMAQMD's Prevention of Significant Deterioration Rule (Rule 203) requirements meet or exceed those required for a $PM_{2.5}$ attainment area. Rule 203 was fully approved into the SIP effective August 19, 2011 (76 FR 43183-43185).

Yolo-Solano Air Quality Management District PSD Rule Status

The YSAQMD's Prevention of Significant Deterioration Rule (Rule 3.24) requirements meet or exceed those required for a $PM_{2.5}$ attainment area. Rule 3.24 was approved by the Board of Directors on February 10, 2011 and was approved into the SIP effective February 8, 2013.

6.6 Conclusions

Measures to reduce directly-emitted $PM_{2.5}$ and $PM_{2.5}$ precursors have been implemented by all the local air districts of the Sacramento Region, as well as State and federal agencies. These measures have regulated $PM_{2.5}$ and $PM_{2.5}$ precursors and have significantly decreased its $PM_{2.5}$ design value. These permanent and enforceable measures led to attainment in 2011.

6.7 References

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7 Maintenance Demonstration

7.1 Introduction to Maintenance Demonstration

The maintenance plan must include a demonstration showing that the area will continue to meet the National Ambient Air Quality Standard (NAAQS) for at least 10 years. (Clean Air Act Section 107(d)(3)(E)(iv)). This chapter describes the basic requirements for a maintenance demonstration, provides a maintenance demonstration analysis, and discusses methods for implementing verification and tracking procedures.

7.2 Maintenance Demonstration Requirements

The Clean Air Act (CAA) Section 175A contains maintenance plan requirements. The region attained the NAAQS in 2011 and anticipates formal redesignation in 2014. Therefore, the maintenance plan horizon year is 2024. Transportation Conformity rules require the region to designate an interim year for reassessing conformity budgets so that there is never more than 10 years between conformity analysis years (40CFR93.118(d)(2)). The interim year selected is 2017.

CAA Section 175A also specifies that the maintenance plan contain any additional measures necessary to ensure maintenance. EPA guidance for re-designation requests and maintenance plans (Calcagni, 1992) requires the following be included in a maintenance demonstration plan:

- Demonstrate that the NAAQS will be maintained through the horizon year either by showing that future emissions will not exceed the attainment level emissions or by modeling to show future emissions will not cause a violation of the NAAQS.
- Verify continued attainment through operation of an appropriate air quality monitoring network.
- Track progress of the maintenance demonstration by a periodic review or update of the factors and assumptions used in the maintenance demonstration.

A revision of the SIP is required 8 years after the original re-designation request is approved to demonstrate continuing maintenance of the NAAQS for an additional 10 years following the first 10-year period.

7.3 Demonstration of Maintenance

This Plan relies primarily on the first of EPA's two maintenance demonstration options, showing that the emissions in the interim year (2017) and maintenance plan horizon year (2024) are less than the emissions in the attainment year. The results of this test are summarized in Table 7.1. This analysis shows that the combined total future emissions of directly emitted $PM_{2.5}$ and its precursors remain below attainment year emission levels. Directly emitted $PM_{2.5}$ is projected to increase slightly, 1 tons per day (tpd) in 2017, and 2 tpd in 2024, after including the motor vehicle emissions budget safety margin. $PM_{2.5}$ precursors, sulfur dioxide (SO_2) emissions do not change, and ammonia (NH_3) emissions are projected to increase up to 1 tpd. The combined increase of these pollutants is small compared to the substantial reductions of 49 tpd in other $PM_{2.5}$ precursors, nitrogen oxides (NO_X) and volatile organic compound (VOC).

Table 7.1 Comparison of 2011, 2017, and 2024 $PM_{2.5}$ and Its Precursors Emissions[1]

	SFNA-$PM_{2.5}$ Emissions (Tons/Day)			Net Change From Attainment Year (Tons/Day)	
	2011	2017	2024	(2017-2011)	(2024-2011)
Total Emissions ($PM_{2.5}$ & Precursors)	**261**	**233**	**215**	**-28**	**-46**
Directly Emitted $PM_{2.5}$[2]	26	27	28	1	2
Total Precursors	235	206	187	-29	-48
NO_x[1]	100	80	63	-20	-37
SO_2	2	2	2	0	0
VOC	106	97	94	-9	-12
NH_3	27	27	28	0	1

1 Data Source: Emissions Inventory is from Tables 4.1-4.3 and included Motor Vehicle Emissions Budgets Safety Margins. The Safety Margin values can be found in Table 9.1 and Appendix D.
2 The emissions inventory is rounded to the nearest integer.

Emission Reductions

The directly emitted $PM_{2.5}$ emissions inventory projections are conservatively high for residential wood burning emissions, which represents 52% of the inventory in 2024. Significant improvement in particulate matter air quality occurred following implementation of SMAQMD Rule 421, Mandatory Episodic Curtailment of Wood and Other Solid Fuel Burning. The emission reductions from that rule are not well represented in a winter average inventory scenario because the rule prohibits wood burning only on poor air quality days, while the emission inventory averages all days, substantively diluting the true impact of the rule. On a no burn day, Rule 421 reduces up to 70% of directly emitted $PM_{2.5}$ emissions from residential wood combustion in Sacramento County or an additional reduction of about 5 tons per day (or 20%) in the 2024 SFNA directly emitted $PM_{2.5}$ inventory. In the inventory, Rule 421 emissions reductions are averaged over an entire winter season, only a fraction of which are no burn days, resulting in emission reduction benefits that are not apparent in Table 7.1, Rule 421 plays a significant role in the Sacramento Federal Nonattainment Area's (SFNA) attainment and maintenance of the 24-hour $PM_{2.5}$ NAAQS.

Ozone and $PM_{2.5}$ have two precursors in common, VOC and NO_X. The reductions in these precursor emissions are associated with implementation of NO_X and VOC controls in the ozone SIP. Between 2011 and 2024, the NO_X emissions inventory is expected to reduce from 100 tpd to 63 tpd, a 37% reduction. Most of the NO_X reductions are from on-road and off-road mobile source controls. The VOC emissions forecast shows significant reductions of 11% from 2011 to 2024, with most of the reductions from mobile sources. The SFNA remains an ozone nonattainment area, so future ozone planning will likely result in additional NOx and VOC emissions reductions. As discussed in Section 7.5, the relationship between VOC reductions and ambient $PM_{2.5}$ concentration reductions is complex. Although VOC reductions are included in this analysis, even without VOC reductions, total $PM_{2.5}$ and precursor emissions remain below attainment year levels through 2024.

7.4 Maintenance Demonstration Analysis – Chemical Mass Balance Analysis

Although the total emissions are declining, the future emissions inventory of directly emitted $PM_{2.5}$ and NH_3 are slightly higher than the 2011 attainment level. Consequently, to be conservative, a chemical mass balance (CMB) modeling analysis was performed to confirm these small emissions increases will not cause a violation of the standard. This analysis supplements the emissions analysis for the maintenance demonstration. CMB modeling of 2009–2012 wintertime ambient $PM_{2.5}$ data is used to determine $PM_{2.5}$ concentrations by emissions source categories in 2011. Next, we used the forecasted changes in emissions by source category, obtained from Sacramento's emissions inventory (EI) as described in Chapter 4, to forecast the future contributions of each source category to ambient wintertime $PM_{2.5}$ for 2024 (the end of the first maintenance period). The modeling assumes that there is a 1:1 relationship between emissions reductions and $PM_{2.5}$ concentration reductions. For example, if CMB results showed that motor vehicle emissions contributed 10 $\mu g/m^3$ in the current year, and the forecasted change in these emissions for 2024 was a reduction of 10%, then the forecasted contribution to $PM_{2.5}$ mass from motor vehicles in 2024 would be 9 $\mu g/m^3$. Wintertime data were selected because ambient $PM_{2.5}$ concentrations are highest during this season in the Sacramento region (see Section 3.4 for details), and resulting calculations would thus represent a conservative base-year estimate for future-year projections.

Ammonium nitrate is not emitted directly, but is produced in the atmosphere through chemical reactions of ammonia (NH_3) and NO_X. It is a large fraction of particulate matter in the Sacramento region, as measured by monitors at Del Paso Manor and T St, where nitrate is 30% and 39% ambient $PM_{2.5}$ concentration on an average winter day, respectively. Generally ammonia is plentiful in the Sacramento and San Joaquin Valleys (Kleeman, 2005) (MacDonald et al, 2006), therefore ammonium nitrate formation is limited only by the availability of NO_X in the atmosphere. Since the atmosphere has a sufficient amount of ammonia, ammonium nitrate is expected to vary proportionally to changes in NO_X emissions. For example, a 10% increase in NO_X would result in a proportional increase the ambient ammonium nitrate concentration by 10% (1:1). This situation is also known as a NO_X limited condition. Modeling in the California Regional Particulate Air Quality Study (CRPAQS) (Pun et al, 2009), found that a 50% reduction in NO_X emissions reduced ammonium nitrate by approximately 50% at rural sites and between 30-45% at Bakersfield. These results suggest a 1:1 ratio of ammonium nitrate response to NO_X is a reasonable assumption.

CMB is a source-receptor model used to identify and characterize the mixture and magnitude of sources contributing to ambient pollutant concentrations. Known source profiles are linearly fit to ambient data using a least squares solution. Model outputs represent the contributions of various emission sources to the observed ambient concentrations. In CMB, source profiles (i.e., the fraction of each species emitted from each source type), and ambient data collected at the receptor are required as model inputs. Underlying CMB assumptions include (1) accurate identification of source types and abundances (source profiles); (2) independent source compositions (i.e., species abundances are unique to each profile); and (3) consistent profiles between source and receptor (i.e., no mass removal and constant emissions) throughout the sampling period. In this analysis, the degree of conformance to these assumptions was similar to that commonly found in published literature (Watson, 1997) (Watson, 2004)(Coulter, 2004)(Chow, et al, 2002). The most recent version of EPA's CMB model (EPA CMB v. 8.2) was used in this analysis.

Ambient $PM_{2.5}$ mass and speciation data for November–February in the years 2009–2012 (selected as years that are representative of current ambient conditions) were obtained from the EPA Air Quality System (AQS) for two sites in Sacramento: Del Paso Manor (DPM) and T Street (T St.). In addition, data for levoglucosan, an important chemical marker for residential wood burning, was available for the T St. monitoring site.

The DPM site is in a neighborhood park about 7 miles east-northeast of downtown Sacramento and is operated as part of EPA's Chemical Speciation Network (CSN). The T St. site is in a residential area in downtown Sacramento and is operated as part of the California Air Resources Board (CARB) $PM_{2.5}$ speciation network. Data at DPM were collected every third day and data at T St. every sixth day. Daily composition information is provided in Appendix C.

Wintertime $PM_{2.5}$ in the Sacramento region is composed mostly of organic carbon (OC) and ammonium nitrate, with minor contributions from ammonium sulfate, elemental carbon (EC), soil, and trace metals (Figure 7.1). To be conservative and to target the days that would most likely affect attainment, a subset of 12 days with the highest 24-hour $PM_{2.5}$ concentrations (above 18 $\mu g/m^3$)—referred to here as "high days"—was also used to forecast future-year concentrations on high $PM_{2.5}$ days. Meteorological conditions on all of the days analyzed were representative of conditions conducive for high $PM_{2.5}$ in the Sacramento region. Therefore, the results from this analysis are representative of the day types of concern for maintenance demonstration.

With ambient data, the sum of measured species does not equal the total measured mass because, in addition to other issues, the hydrogen and oxygen associated with OC are not measured. In order to match Federal Reference Method (FRM) measurements of $PM_{2.5}$ mass, and to attempt to account for the difference between the measured species and measured mass, ambient data were also modified via the SANDWICH[36] method, which reconciles the speciation measurements with the collocated FRM $PM_{2.5}$ mass measurements (Frank, 2006). The SANDWICH method attempts to account for nitrate losses from the FRM and for OC sampling artifacts on the FRM and speciation monitors; other parameters are unchanged from the ambient measurements.

On average, OC and ammonium nitrate account for two-thirds of the mass at DPM and three-quarters of the mass at T St. Day-to-day variability was relatively low, with ammonium nitrate and OC together accounting for at least half of the mass at DPM on 84% of the days and at T St. on 98% of the days. Sources of these species were the major contributors to $PM_{2.5}$ in the CMB analysis, discussed below.

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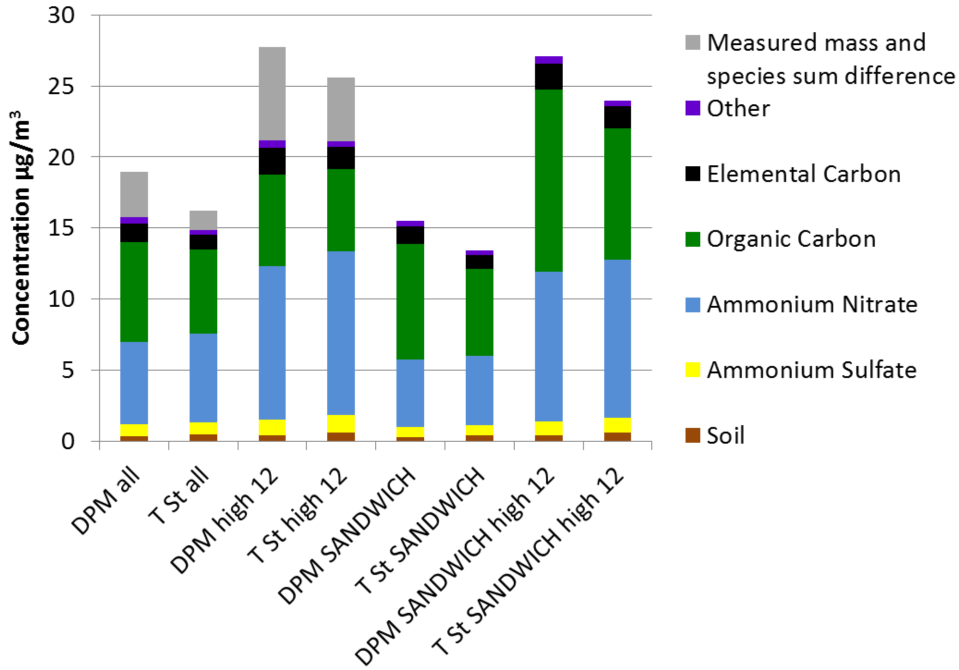
[36] SANDWICH is the Sulfate, Adjusted Nitrate, Derived Water, Inferred Carbonaceous mass Hybrid material balance approach.

Figure 7.1 Average $PM_{2.5}$ composition at DPM and T St. during winter months of 2009–2012 overall, for the 12 highest $PM_{2.5}$ concentration days, via the SANDWICH method on average, and via the SANDWICH method for the 12 highest $PM_{2.5}$ concentration days.



CMB modeling fits ambient data to known source profiles; however, source identification is limited by the ambient species that are measured, the quality of the data, and the availability and quality of source profiles. Since the ambient speciation data are limited in terms of unique species/source type combinations, only a handful of CMB source types can be quantified: ammonium sulfate, ammonium nitrate, motor vehicles (combined gasoline and diesel exhaust), dust, wood burning, and other OC (i.e., OC attributed to secondary formation from VOC emissions). The following source profiles were prepared for the likely CMB source types: ammonium sulfate, ammonium nitrate, motor vehicles (combined gas/diesel exhaust), dust, wood burning, and organic carbon. The mobile sources, dust, ammonium nitrate, and ammonium sulfate profiles, as well as the associated uncertainties, were provided by CARB via SMAQMD (Lam, 2009). These profiles compare reasonably well with the key sources of $PM_{2.5}$ and $PM_{2.5}$ precursors in the EI.

CMB was applied to the ambient and SANDWICH data sets described above. In addition to calculating source contribution and uncertainty values, the CMB model calculates various performance measures including percent of mass apportioned, chi-square, and r-square values. Standard goodness-of-fit criteria were used. To estimate future-year (2024) $PM_{2.5}$ concentrations by accounting for expected reductions by source category, we assigned the CMB source types to corresponding source categories in the EI.

CMB mobile sources were assigned to primary PM emissions from on-road and off-road vehicles. Soil was the CMB source type assigned to all crustal, soil, and dust sources in the EI. It also includes paved road dust, unpaved road dust, and highway and transit construction dust and accounts for 50% of the total $PM_{2.5}$ dust, soil, and crustal (Appendix B-7). Total road dust is 1.7% - 2.1% of the total $PM_{2.5}$ mass shown in Figure 7.2. Ammonium nitrate and ammonium sulfate are not primarily emitted, but are formed in the atmosphere by reactions of the gaseous precursors ammonia, nitrogen oxides (NO_X), and sulfur oxides (SO_X). Ammonium nitrate was assigned to all NO_X sources in the EI, and ammonium sulfate was assigned to all SO_X sources; in the atmosphere, there is no chemical difference between NO_X emissions from different sources, so the amount of nitrate by source cannot be determined. There is abundant ammonia in the Sacramento region, so ammonium nitrate and ammonium sulfate formation are limited by (1) the availability of nitrate and sulfate precursors, and (2) meteorologically conducive conditions (Pun et al, 2001)(Lurmann et al, 2006). Thus, the changes in ammonium nitrate and ammonium sulfate are affected more by changes in NO_X and SO_X precursor emissions than by changes in ammonia concentrations, and we did not use the ammonia emission inventory in this demonstration.

CMB wood burning contributions were assigned to residential and open burn emissions. Since the focus of this work is on wintertime, wildfires were not included in the wood-burning category, as they typically do not occur during the winter. The “other OC” source type was assigned to all VOC emissions in the EI. Since the ambient measured species do not necessarily account for all the $PM_{2.5}$ mass measured — in particular, the hydrogen and oxygen associated with the OC — there is some amount of unaccounted mass; this CMB unaccounted mass was assigned to all other direct $PM_{2.5}$ emissions sources that did not fit the sources described above, such as stationary fuel combustion, food processing, and cooking.

7.5 Results of Maintenance Demonstration

CMB was applied to ambient and SANDWICH data at both sites; the results are summarized in Figures 7.2 through 7.4. Model performance metrics were generally within tolerances, as summarized in Appendix C. Sensitivity tests were also performed to evaluate whether results are sensitive to different fitting species and wood burning profiles; the results were similar, i.e., within 10%, during these sensitivity tests, as discussed in Appendix C. Results are provided for average wintertime CMB source contributions (all 44 winter days combined) and for high mass concentration days (i.e., the 12 days with the highest $PM_{2.5}$ concentrations, when $PM_{2.5}$ was above 18 $\mu g/m^3$) and include days used to calculate the region’s design value. These days are typical of wintertime high $PM_{2.5}$ concentration days, with relatively stable, stagnant conditions and temperatures between 0°C and 10°C.

On average and on high days, ammonium nitrate and wood burning accounted for most of the $PM_{2.5}$ mass at both sites. At DPM, nitrate constituted 30% of the mass on average and 38% of the high-day mass, and wood burning was 24% of the mass on average and 21% of the high-day mass. At T St., nitrate constituted 39% of the mass on average and 45% of the high-day mass, and wood burning was 42% of the mass on average and 41% of the high-day mass. Other OC was significant at DPM (12% of the total), but was not considered at T St., since mass closure was achieved without it; on average, 21% of the mass was unapportioned at DPM on all analysis days; unapportioned refers to the difference in mass between the measured total mass and the total mass estimated by CMB. At T St., 4% was unapportioned in the results for the non-SANDWICH-adjusted dataset. Note that the reason for the differences between the sites in wood burning contributions and amounts of unapportioned mass is that levoglucosan data, a better tracer for wood burning than potassium, was available only at T St., and potassium was used at DPM. If either “other OC” or the unapportioned mass were attributed to wood burning at DPM, wood burning would account for 36% to 44% of the $PM_{2.5}$, similar to the value at T St. Dust, ammonium sulfate, and primary $PM_{2.5}$ from mobile sources each constituted, on average, less than 15% of the mass combined. SANDWICH data results were broadly similar to the ambient data results, with ammonium nitrate and wood burning the main contributors to $PM_{2.5}$. For the T St. SANDWICH dataset, CMB overestimates the total $PM_{2.5}$ mass by 0.37 µg/m^3 on average; therefore the “unapportioned” source contribution, or the difference between the measured and calculated total mass, in Figure 7.2 is slightly negative.

Figure 7.2 CMB apportionment of $PM_{2.5}$ and SANDWICH $PM_{2.5}$ at Del Paso Manor and T St. for all 44 wintertime samples and 12 selected high $PM_{2.5}$ concentration days for data collected during December–February in 2009–2012.

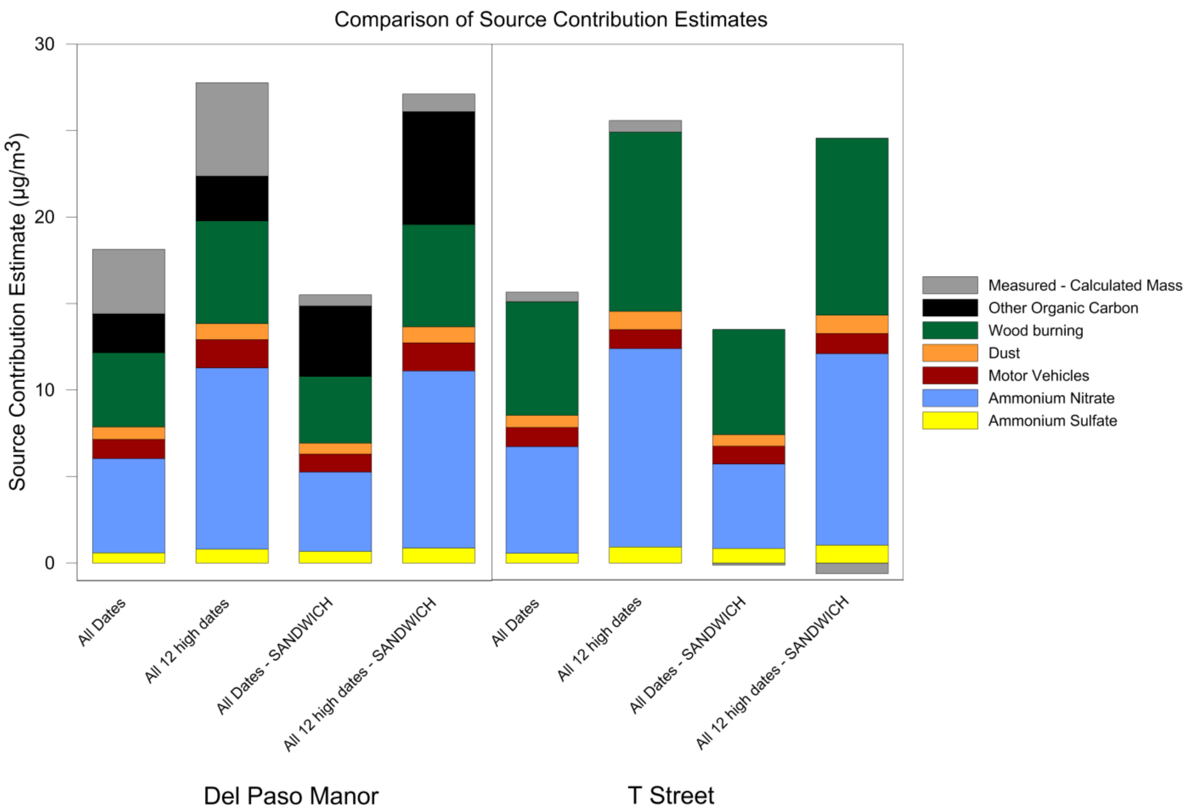
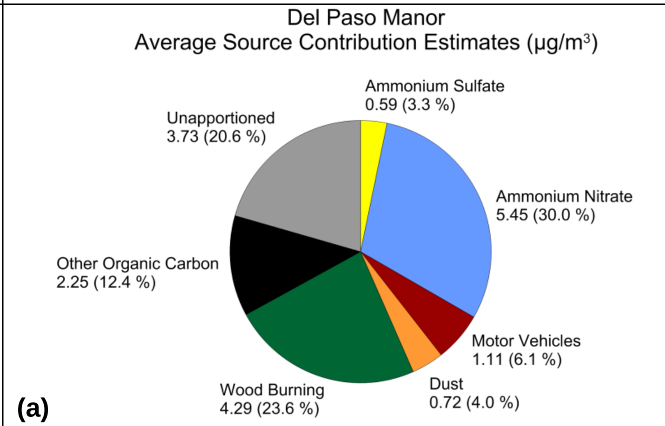
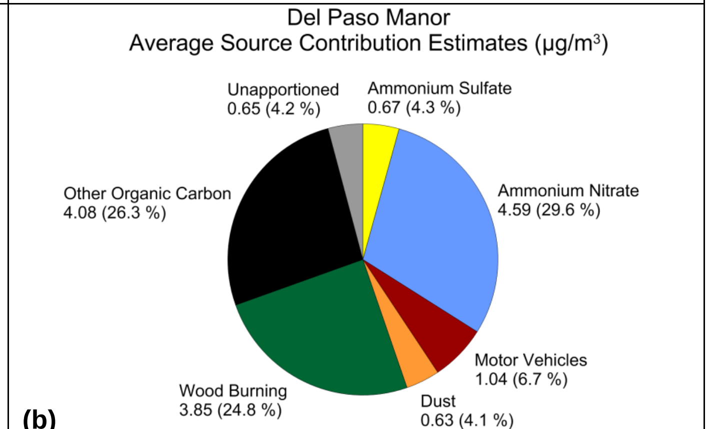


Figure 7.3 Pie charts of average contribution by CMB source type for Del Paso Manor: (a) ambient data on all analysis days; (b) SANDWICH data on all analysis days; (c) ambient data on high $PM_{2.5}$ days; and (d) SANDWICH data on high $PM_{2.5}$ days.

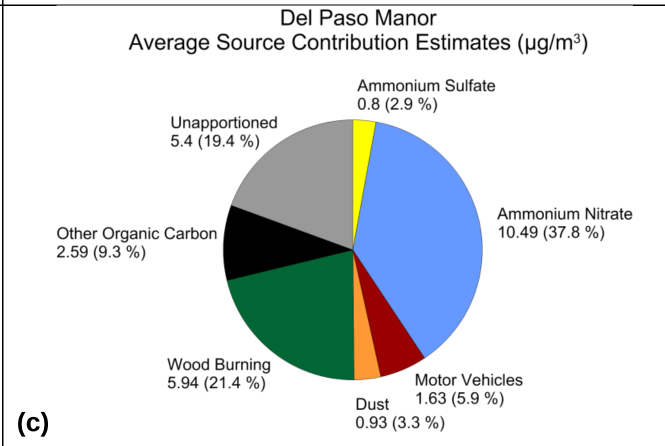
Del Paso Manor — *Ambient data* — *SANDWICH data*

All Days





12 High $PM_{2.5}$ Days



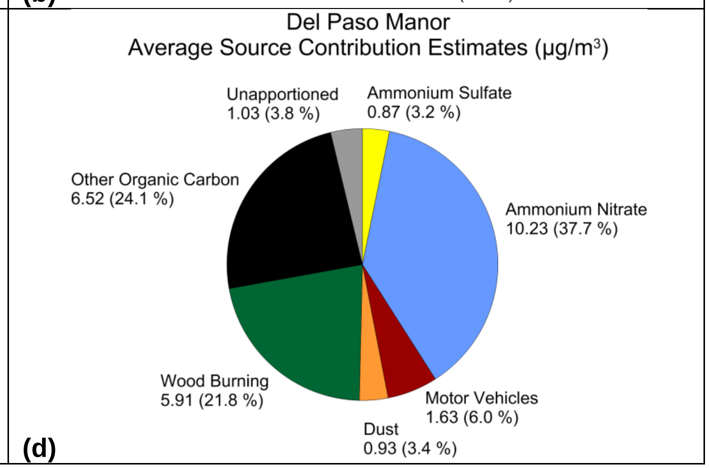
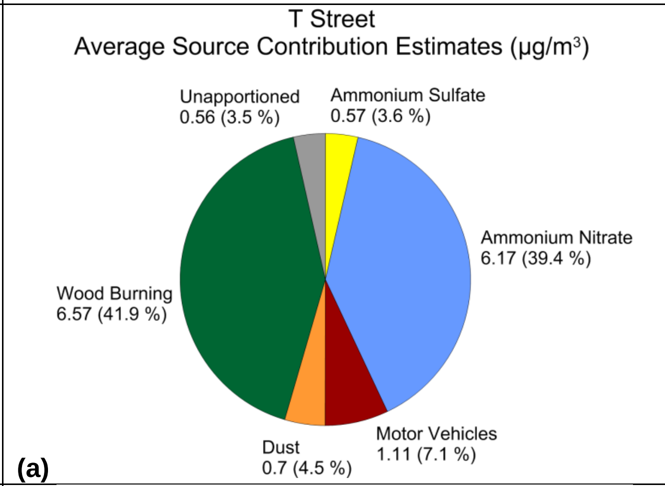
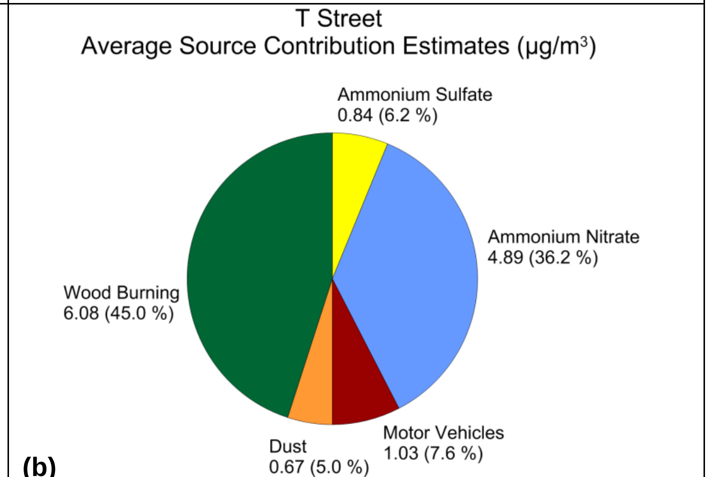


Figure 7.4 Pie charts of average contribution by CMB source type for T St: (a) ambient data on all analysis days; (b) SANDWICH data on all analysis days; (c) ambient data on high $PM_{2.5}$ days; and (d) SANDWICH data on high $PM_{2.5}$ days.

<table>
<tr><td>T St.</td><td>Ambient data</td><td>SANDWICH data</td></tr>
<tr><td>All Days</td><td>
</td><td>
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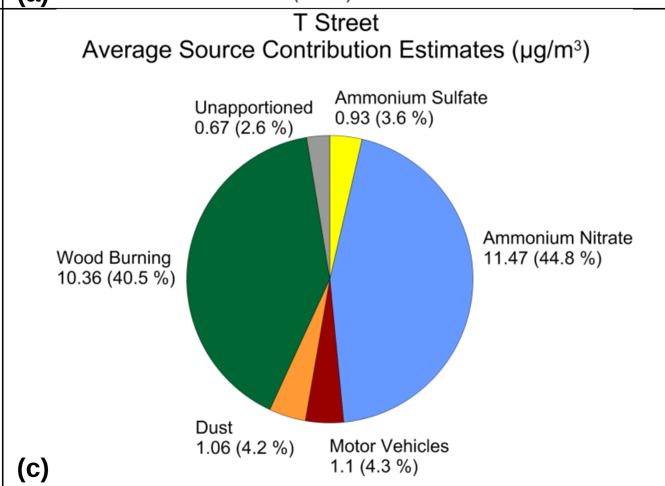
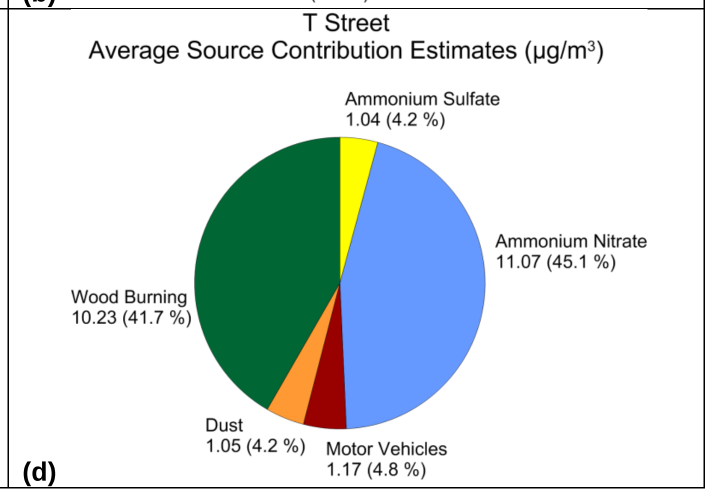
<tr><td>12 High $PM_{2.5}$ Days</td><td>
</td><td>
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</table>

The percent change in emissions from 2011 to 2024 by source category was applied to the average current-year concentration value for both sites to estimate future-year (2024) $PM_{2.5}$ mass, using all wintertime samples and using high ambient $PM_{2.5}$ days only, for both ambient and SANDWICH-modified measurements. Reconciliation of measured current-year data with EI forecasts are presented in Tables 7.3 through 7.8. These tables also include the "safety margin" discussed in Chapter 9 (Section 9.7). The EI shows decrease in NO_X emissions (-37%) and VOC emissions (-11%) and increases in mobile source $PM_{2.5}$ emissions (+33%) from 2011 levels to 2024. These source categories correspond to ambient ammonium nitrate, "other OC," and mobile source $PM_{2.5}$, respectively, of which the ammonium nitrate constitutes the largest fraction of $PM_{2.5}$. The other major part of the ambient $PM_{2.5}$ is wood burning (on average, 24% and 42% at DPM and T St., respectively), which is forecast to increase by 1%. Other source categories include Dust and "Other Emissions." The Dust category includes $PM_{2.5}$ dust, crustal material and soil. The Other Emissions category includes unaccounted mass from the CMB analysis because monitored species do not necessarily account for all the $PM_{2.5}$ mass measured.

Based on the 44 samples used here, forecasts of future-year wintertime average concentrations are 17.0 $\mu g/m^3$ and 14.1 $\mu g/m^3$ at DPM and T St., respectively, down from current-year averages of 18.1 $\mu g/m^3$ and 15.7 $\mu g/m^3$. Concentrations on high days are forecast to decrease from 27.8 $\mu g/m^3$ to 25.4 $\mu g/m^3$ at DPM and from 25.6 $\mu g/m^3$ to 22.0 $\mu g/m^3$ at T St. Results from SANDWICH data were broadly similar to results from ambient data, suggesting future average concentrations of 14.0 $\mu g/m^3$ at DPM and 12.2 $\mu g/m^3$ at T St., and high-day concentrations of 23.6 $\mu g/m^3$ at DPM and 21.1 $\mu g/m^3$ at T St.

Predictions shown in Tables 7.3, 7.5, 7.6, and 7.7 are based on high $PM_{2.5}$ days used in this analysis, i.e., days where speciation data were available at both DPM and T St. However, the goal is to forecast the likely source contributions for days used in design value calculations. Since the fraction of $PM_{2.5}$ by source category was similar across all high days here, and indeed similar across all days analyzed, it is reasonable to assume that this high day composition is similar to the composition on days used in design value calculations during the same time period. To that end, Tables 7.6 and 7.7 show results for a similar exercise as presented in Tables 7.2 through 7.5, but instead of starting with the current-year average concentrations or high-day concentrations, we used the 2011 design value for each site, as described in Chapter 3. These values are 35 $\mu g/m^3$ (35.2 before applying the required rounding convention) for DPM and 33 (33.2) $\mu g/m^3$ for T St. We use the design values with one decimal place in the calculations then apply the rounding convention to projected 2024 design values. The contribution of each CMB source on high $PM_{2.5}$ concentration days is taken from Figures 7.3(d) and 7.4(d). The design value is projected by applying the following equations:

$$contribution\ of\ source\ i\ to\ 2011\ design\ value = (2011\ design\ value) \times \left(\frac{high\ day\ concentration\ of\ source\ i}{\sum_i high\ day\ source\ concentrations}\right) \quad (1)$$

$$predicted\ 2024\ design\ value\ concentration\ of\ source\ i = contribution\ of\ source\ i\ to\ 2011\ design\ value \times (1 + \%\ change\ in\ emissions\ of\ source\ i) \quad (2)$$

The design-value equivalent CMB source contribution in Tables 7.6 and 7.7 used the percent change in the corresponding emission inventory source category from 2011 to the 2024 horizon, similar to the process shown in Tables 7.2 through 7.5, yielding a new predicted design-value CMB source contribution for each site. Both equations are applied to SANDWICH data. The projected future design values are 31 μg/m^3 (30.6 before rounding) for DPM and 29 μg/m^3 (28.5) for T St.

7.6 Maintenance Demonstration Conclusions

VOCs have the potential to contribute to the formation of two $PM_{2.5}$ components, secondary organic aerosols and nitrates. Speciation analysis indicates that organic carbon represents 30-40%, and nitrates 30-40% of filters. EPA's 2007 assessment (72 FR 20593) and EPA's final rule on the San Joaquin Valley's 2008 $PM_{2.5}$ SIP found that VOCs were not $PM_{2.5}$ precursors requiring control. (EPA, 2011, p166-169) The San Joaquin Valley Air Pollution Control District updated their review and again concluded that VOC control would have an "insignificant benefit" as a $PM_{2.5}$ precursor (SJVAPCD, 2012). VOC precursor conclusions for the Sacramento region are uncertain because it has not been studied as extensively; however, Sacramento's proximity to, and similar air quality problems as, the San Joaquin Valley lead us to conclude that VOC reductions likely have an insignificantly effect on $PM_{2.5}$ concentrations in Sacramento. VOCs were not included as $PM_{2.5}$ control measures in Chapter 6 because we cannot conclude that they 'led to attainment.'

In spite of the uncertainties about benefit, VOC reductions are included in the projection of future $PM_{2.5}$ concentrations at DPM (Table 7.6) to reflect the reality that as ozone nonattainment control measures, the VOC reductions are certain to occur. The CMB analysis assumed that $PM_{2.5}$ concentrations will reduce in a 1:1 relationship with VOC emissions reductions. Because this may overestimate reductions in $PM_{2.5}$ concentrations, then we also analyzed projected $PM_{2.5}$ concentration reductions in the absence of any VOC reductions (0.9 μg/m^3), and concluded that "NOx-only" reductions would result in projected future design value at DPM of 31.5 μg/m^3, well below the NAAQS.

The maintenance demonstration uses the method described in EPA Guidance (Calcagni, 1992) showing that the projected total $PM_{2.5}$ and its precursor emissions in the horizon are less than the attainment year inventory. The NO_X and VOC emissions are expected to decrease by 37 tons/day and 12 tons/day respectively between 2011 and 2024. The projected future emissions of directly emitted $PM_{2.5}$, SO_2, and NH_3 show slight increases compared to attainment year levels. Consequently, Chemical Mass Balance modeling was applied to confirm that the small future emission increases would not cause a standard violation. The modeling results show that the future ambient concentrations and design values are lower than the attainment year levels. Specifically, the design values are forecast to decrease from 2011 levels, from 35 μg/m^3 to 31 μg/m^3 in 2024 at DPM and from 33 μg/m^3 to 29 μg/m^3 at T St. The largest reduction comes from the forecasted change in NO_X emissions and the corresponding change in ambient ammonium nitrate concentrations (-37%).

The other maintenance plan requirements; verification of continued attainment, tracking progress, and committing to revise the SIP, are discussed in Sections 7.7 through 7.9. In summary, the air districts in the nonattainment area will continue to operate an appropriate air quality monitoring network to verify attainment and track progress and take corrective action if needed, review the assumptions and data used to demonstrate maintenance, and commit to prepare a subsequent maintenance plan in 2022.

Table 7.2 Del Paso Manor – All Days.

Emissions (tons per year) in current year and future year, with percent change from 2011 to 2024 by aggregated source category, plus current- and predicted future-year ambient concentration by source category at Del Paso Manor. Ambient data are for data collected during November–February in 2009–2012, when both speciation and FRM $PM_{2.5}$ measurements were available; all ambient units are µg/m^3.

Ammonium sulfate and ammonium nitrate emission inventories are from Table 4.2; Motor Vehicle emissions is from Table 4.1 and with the Table 9-1 MVEB replacing the on-road motor vehicle inventory; and Dust, Wood burning, Other OC, and Unaccounted mass are from Appendix B7.

CMB Source Type	EI Source Category	Base-Year (2011) Emissions	Future-Year (2024) Emissions	% Change	CMB Winter 2009-2012 Concentration	CMB Winter 2009-2012 SANDWICH Concentration	Predicted 2024 Concentration	Predicted 2024 SANDWICH Concentration
Ammonium sulfate	SO_X	2	2	0%	0.59	0.67	0.6	0.7
Ammonium nitrate	NO_X	100	63	-37%	5.45	4.59	3.4	2.9
Motor vehicles	$PM_{2.5}$ for on- and off-road mobile sources	3	4	33%	1.11	1.04	1.5	1.4
Dust	$PM_{2.5}$ dust, crustal, soil	5.26	6.00	14%	0.72	0.63	0.8	0.7
Wood burning	$PM_{2.5}$ residential and open burning	14.10	14.20	1%	4.29	3.85	4.3	3.9
Other OC	VOC emissions	106.04	94.42	-11%	2.25	4.08	2.0	3.6
Unaccounted mass	Other emissions	3.03	3.60	19%	3.73	0.65	4.4	0.8
Totals					*18.14*	*15.51*	17.0	14.0

Table 7.3. Del Paso Manor - High $PM_{2.5}$ days

Emissions (tons per year) in current year and future year, with percent change from 2011 to 2024 by aggregated source category, plus current- and predicted future-year ambient concentration for high concentration days by source category at Del Paso Manor. Ambient data are for high concentration days (N=12, concentrations greater than 18 µg/m^3) during November–February in 2009–2012, when both speciation and FRM $PM_{2.5}$ measurements were available; all ambient units are µg/m^3.

Ammonium sulfate and ammonium nitrate emission inventories are from Table 4.2; Motor Vehicle emissions is from Table 4.1 and with the Table 9-1 MVEB replacing the on-road motor vehicle inventory; and Dust, Wood burning, Other OC, and Unaccounted mass are from Appendix B7.

CMB Source Type	EI Source Category	Base-Year (2011) Emissions	Future-Year (2024) Emissions	% Change	CMB Winter 2009-2012 Concentration	CMB Winter 2009-2012 SANDWICH Concentration	Predicted 2024 Concentration	Predicted 2024 SANDWICH Concentration
Ammonium sulfate	SO_X	2	2	0%	0.80	0.87	0.8	0.9
Ammonium nitrate	NO_X	100	63	-37%	10.49	10.23	6.6	6.4
Motor vehicles	$PM_{2.5}$ for on- and off-road mobile sources	3	4	33%	1.63	1.63	2.2	2.2
Dust	$PM_{2.5}$ dust, crustal, soil	5.26	6.00	14%	0.93	0.93	1.1	1.1
Wood burning	$PM_{2.5}$ residential and open burning	14.10	14.20	1%	5.94	5.91	6.0	6.0
Other OC	VOC emissions	106.04	94.42	-11%	2.59	6.52	2.3	5.8
Unaccounted mass	Other emissions	3.03	3.60	19%	5.40	1.03	6.4	1.2
Totals					*27.77*	*27.12*	*25.4*	*23.6*

Table 7.4. T Street – All Days.

Emissions (tons per year) in current year and future year, with percent change from 2011 to 2024 by aggregated source category, plus current- and predicted future-year ambient concentration by source category at T St. Ambient data are for data collected during November–February in 2009–2012, when both speciation and FRM $PM_{2.5}$ measurements were available; all ambient units are µg/m^3.

Ammonium sulfate and ammonium nitrate emission inventories are from Table 4.2; Motor Vehicle emissions is from Table 4.1 and with the Table 9-1 MVEB replacing the on-road motor vehicle inventory; and Dust, Wood burning, Other OC, and Unaccounted mass are from Appendix B7.

CMB Source Type	EI Source Category	Base-Year (2011) Emissions	Future-Year (2024) Emissions	% Change	CMB Winter 2009-2012 Concentration	CMB Winter 2009-2012 SANDWICH Concentration	Predicted 2024 Concentration	Predicted 2024 SANDWICH Concentration
Ammonium sulfate	SO_X	2	2	0%	0.57	0.84	0.6	0.8
Ammonium nitrate	NO_X	100	63	-37%	6.17	4.89	3.9	3.1
Motor vehicles	$PM_{2.5}$ for on- and off-road mobile sources	3	4	33%	1.11	1.03	1.5	1.4
Dust	$PM_{2.5}$ dust, crustal, soil	5.26	6.00	14%	0.70	0.67	0.8	0.8
Wood burning	$PM_{2.5}$ residential and open burning	14.10	14.20	1%	6.57	6.08	6.6	6.1
Other OC	VOC emissions	106.04	94.42	-11%	n/a	n/a	0.0	0.0
Unaccounted mass	Other emissions	3.03	3.60	19%	0.56	-0.12	0.7	0.0
Totals					*15.66*	*13.51*	*14.1*	*12.2*

Table 7.5. T Street – High $PM_{2.5}$ Days

Emissions (tons per year) in current year and future year, with percent change from 2011 to 2024 by aggregated source category, plus current- and predicted future-year ambient concentration for high concentration days by source category at T St. Ambient data are for high concentration days (N=12, concentrations greater than 18 µg/m^3) during November–February in 2009–2012, when both speciation and FRM $PM_{2.5}$ measurements were available; all ambient units are µg/m^3.

Ammonium sulfate and ammonium nitrate emission inventories are from Table 4.2; Motor Vehicle emissions is from Table 4.1 and with the Table 9-1 MVEB replacing the on-road motor vehicle inventory; and Dust, Wood burning, Other OC, and Unaccounted mass are from Appendix B7.

CMB Source Type	EI Source Category	Base-Year (2011) Emissions	Future-Year (2024) Emissions	% Change	CMB Winter 2009-2012 Concentration	CMB Winter 2009-2012 SANDWICH Concentration	Predicted 2024 Concentration	Predicted 2024 SANDWICH Concentration
Ammonium sulfate	SO_X	2	2	0%	0.93	1.04	0.9	1.0
Ammonium nitrate	NO_X	100	63	-37%	11.47	11.07	7.2	7.0
Motor vehicles	$PM_{2.5}$ for on- and off-road mobile sources	3	4	33%	1.10	1.17	1.5	1.6
Dust	$PM_{2.5}$ dust, crustal, soil	5.26	6.00	14%	1.06	1.05	1.2	1.2
Wood burning	$PM_{2.5}$ residential and open burning	14.10	14.20	1%	10.36	10.23	10.4	10.3
Other OC	VOC emissions	106.04	94.42	-11%	n/a	n/a	0.0	0.0
Unaccounted mass	Other emissions	3.03	3.60	19%	0.67	-0.61	0.8	0.0
Totals					*25.58*	*24.56*	*22.0*	*21.1*

Table 7.6 Del Paso Manor – High $PM_{2.5}$ Days with Design Value

For Del Paso Manor, 2011 and 2024 emissions by source category, the percent change in emissions between 2011 and 2024, the fraction of $PM_{2.5}$ by source category on high $PM_{2.5}$ concentration days during winter 2009–2012 from the CMB analysis – SANDWICH data, the calculated concentration by source category for the 2011 design value concentration of 35.2 µg/m^3, and the predicted 2024 design value. The predicted 2024 design value concentrations = (2011 design value concentration) + (2011 design value concentration × % change in emissions).

Additionally, SMAQMD performed calculations based on a conservative ratio assumption from Pun 2009 study, 1:0.6, which also showed the region will continue to maintenance of the standard. The predicted ammonium nitrate concentration will be 8.3 and the total 2024 designed value concentration will be 31.8.

Ammonium sulfate and ammonium nitrate emission inventories are from Table 4.2; Motor Vehicle emissions is from Table 4.1 and with the Table 9-1 MVEB replacing the on-road motor vehicle inventory; and Dust, Wood burning, Other OC, and Unaccounted mass are from Appendix B7.

CMB Source Type	EI Source Category	Base-Year Emissions	2024 Emissions	% Change	CMB Winter 2009-2012 SANDWICH Concentration	Concentration Based on Fraction of Total and Design Value	Predicted 2024 Design Value Concentration
Ammonium sulfate	SO_X	2	2	0%	3.2%	1.1	1.1
Ammonium nitrate	NO_X	100	63	-37%	37.7%	13.3	8.4
Motor vehicles	$PM_{2.5}$ for on- and off-road mobile sources	3	4	33%	6.0%	2.1	2.8
Dust	$PM_{2.5}$ dust, crustal, soil	5.26	6.00	14%	3.4%	1.2	1.4
Wood burning	$PM_{2.5}$ residential and open burning	14.10	14.20	1%	21.8%	7.7	7.8
Other OC	VOC emissions	106.04	94.42	-11%	24.1%	8.5	7.6
Unaccounted mass	Other emissions	3.03	3.60	19%	3.8%	1.3	1.5
Totals						*35.2*	30.6

Table 7.7 T-St - High $PM_{2.5}$ Days with Design Value

For T St, 2011 and year 2024 emissions by source category, the percent change in emissions between 2011 and 2024, the fraction of $PM_{2.5}$ by source category on high $PM_{2.5}$ concentration days during winter 2009–2012 from the CMB analysis – SANDWICH data, the calculated concentration by source category for the 2011 design value concentration of 33.2 µg/m^3, and the predicted 2024 design value. The predicted 2024 design value concentrations = (2011 design value concentration) + (2011 design value concentration × % change in emissions).

Additionally, SMAQMD performed calculations based on a conservative ratio assumption from Pun 2009 study, 1:0.6, which also showed the region will continue to maintenance of the standard. The predicted ammonium nitrate concentration will be 11.6 and the total 2024 designed value concentration will be 30.4.

Ammonium sulfate and ammonium nitrate emission inventories are from Table 4.2; Motor Vehicle emissions is from Table 4.1 and with the Table 9-1 MVEB replacing the on-road motor vehicle inventory; and Dust, Wood burning, Other OC, and Unaccounted mass are from Appendix B7.

CMB Source Type	EI Source Category	Base-Year Emissions	2024 Emissions	% Change	CMB Winter 2009-2012 SANDWICH Concentration	Concentration Based on Fraction of Total and Design Value	Predicted 2024 Design Value Concentration
Ammonium sulfate	SO_X	2	2	0%	4.2%	1.4	1.4
Ammonium nitrate	NO_X	100	63	-37%	45.1%	15.0	9.5
Motor vehicles	$PM_{2.5}$ for on- and off-road mobile sources	3	4	33%	4.8%	1.6	2.1
Dust	$PM_{2.5}$ dust, crustal, soil	5.26	6.00	14%	4.2%	1.4	1.6
Wood burning	$PM_{2.5}$ residential and open burning	14.10	14.20	1%	41.7%	13.8	13.9
Other OC	VOC emissions	106.04	94.42	-11%	0.0%	0.0	0.0
Unaccounted mass	Other emissions	3.03	3.60	19%	0.0%	0.0	0.0
Totals						*33.2*	28.5

7.7 Future Monitoring Network

Federal Regulations state that once an area has been re-designated, the area should continue to operate an appropriate air quality monitoring network, in accordance with 40 CFR Part 58, to verify the attainment status of the area. The maintenance plan should contain provisions for continued operation of air quality monitors that will provide such verification.

As mentioned in Chapter 3 of this plan, there are two types of $PM_{2.5}$ monitors currently used in the monitoring network: 1) the Federal Reference Method (FRM) filter-based mass samplers, and 2) the beta attenuation monitors (BAMs).

The Air Districts will assure the on-going quality of the measured data by performing the operational procedures for data collection, including routine calibrations, pre-run and post-run test procedures, and routine service checks. An annual review of the entire air quality monitoring network is required by federal regulations as a means to determine if the network is effectively meeting the objectives of the monitoring program. If relocation or a closure is recommended in the annual network review, reports will be submitted to EPA and CARB to document compliance with siting criteria. The data collection procedures already in place, in conjunction with the annual review program, will ensure that the future $PM_{2.5}$ ambient monitoring network in the SFNA meets or exceeds the minimum monitoring requirements and that those ambient $PM_{2.5}$ concentrations are monitored appropriately to verify the attainment status of the area. The air districts will continue to operate an appropriate $PM_{2.5}$ ambient monitoring network in the Sacramento region to track maintenance of the $PM_{2.5}$ standard and monitor the indicator for triggering the maintenance contingency plan.

7.8 Verification and Tracking the Maintenance Demonstration

EPA guidance states that the maintenance plan submittal should indicate how the progress of the maintenance plan would be tracked. “This is necessary due to the fact that the emission projections made for the maintenance demonstration depend on assumptions of point and area source growth” (Calcagni, 1992). Options for tracking the progress of the maintenance demonstration would be periodically (typically every 3 years) review and update the emissions inventory, if needed, and reevaluate the assumptions and inputs used in the demonstration. The indicators for triggering contingency measures (specified in Chapter 8) will be monitored as well. The air districts will review the assumptions and data for the $PM_{2.5}$ maintenance demonstration in 2017 (3 year after re-designation) to fulfill the verification and tracking requirements.

7.9 Subsequent Maintenance Plan

Two years prior to the end of the maintenance planning period, CAA Section 175A(b) specifies that a subsequent maintenance plan is required. This subsequent plan must provide for maintenance of the NAAQS for 10 more years after expiration of the first 10-year maintenance period. Therefore, the air districts in the nonattainment area will prepare and submit another maintenance plan in 2022 to demonstrate continued maintenance of the $PM_{2.5}$ standard through 2034.

7.10 References

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8 Maintenance Contingency Plan

This chapter describes the federal requirements for a $PM_{2.5}$ maintenance contingency plan and discusses the proposed contingency plan for the Sacramento $PM_{2.5}$ area once the area is re-designated as attainment.

8.1 Introduction to Maintenance Contingency Plan

This contingency plan includes indicators used to evaluate $PM_{2.5}$ concentrations and take actions to evaluate and implement, if needed, measures to reduce emissions and maintain the 2006 $PM_{2.5}$ 24-hour NAAQS.

8.2 Contingency Plan Requirements

Section 175A (d) of the Clean Air Act requires a maintenance plan to:

- contain contingency provisions, as necessary, to promptly correct any violation of the standard that occurs after re-designation of the area as an attainment area.

The contingency plan must identify specific indicators or triggers which will be used to determine when the contingency measures need to be implemented (Calcagni, 1992, p.12). A contingency plan is considered to be an enforceable part of the SIP and should ensure that the contingency measures are adopted expediently once they are triggered. In addition, Section 175A(d) of the Clean Air Act specifies that the failure of any re-designated area to maintain the national ambient air quality standard is a concern but will not result in a requirement for a SIP revision unless EPA, in its discretion, requires such submittal. The contingency plan should identify a schedule and procedures for selection and adoption of the corrective measures (Calcagni, 1992, p.12).

8.3 Maintenance Contingency Plan

This contingency plan identifies specific indicators or triggers that will be used to determine when the contingency measures need to be implemented. The contingency measures will be implemented if any site in the Sacramento Maintenance area has a $PM_{2.5}$ concentration, recorded with an FRM, FEM, or ARM, where the 3 year average of the 98^{th} percentile is greater than $35 \mu g/m^3$ and is not due to a natural or exceptional event.

After verification of a monitoring violation of the $PM_{2.5}$ NAAQS, which includes sufficient time for sample weighing and processing, the following steps will be implemented.

1. First, the air district will examine the event and determine if the violation was a natural or exceptional event in accordance with EPA requirements. If so, the data will be flagged, and the air district or CARB will proceed with preparing and submitting the necessary documentation for a natural or exceptional event, as required by EPA's "Treatment of Data Influenced by Exceptional Events" Rule (72 FR 13560). The flagged data would not be considered to trigger the maintenance contingency plan.
2. Second, if EPA rejects an exceptional event request or the event does not qualify as a natural or exceptional event, the air district would then analyze the event to

determine its possible causes. Any applicable emission reductions from already adopted rules that have not yet been implemented will be evaluated to determine if these new emissions reductions would be sufficient to prevent future violations. These already adopted controls could include control measures adopted as part of the most recent 8-hour ozone attainment plan, State or local nitrogen oxides (NO_X), sulfur oxides (SO_X), and $PM_{2.5}$ measures adopted outside the Sacramento area, if they could prevent future violations.

3. Third, if the additional emission reductions from already adopted rules are insufficient, the air district would proceed with selecting control measures for adoption and implementation to realize sufficient reductions to avoid future $PM_{2.5}$ violations.

Details of the potential rules will be developed when the contingency plan is activated. This process will allow sufficient time for public review of new control measures and will be adopted at a public hearing. When needed, new rules will be adopted and submitted to EPA within 18 months. Collectively, the three steps will be completed within 24 months after a violation of the $PM_{2.5}$ is certified.

8.4 Contingency Plan Conclusions

The proposed contingency plan is expected to ensure prompt correction of any violation of the $PM_{2.5}$ NAAQS that occurs after re-designation and provide continued maintenance of the standard. The plan identifies indicators and specific procedures/steps to determine if the contingency plan should be activated and corrective actions taken to return the area to attainment.

8.5 References

Calcagni, John. *Memorandum, Procedures for Processing Requests to Re-designate Areas to Attainment.* United States Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC. September 4, 1992, p.12.

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9 Transportation Conformity Budgets

This chapter describes the federal requirements for transportation conformity and proposed new motor vehicle emissions budgets (MVEB) for the Sacramento $PM_{2.5}$ Nonattainment Area. Transportation conformity deals with highway and transit projects. The Clean Air Act (CAA) requires that federal actions be consistent with the air quality goals of a region.

9.1 Introduction to Transportation Conformity

Transportation conformity is the federal regulatory procedure for linking and coordinating the transportation and air quality planning processes. In accordance with the 1990 CAA Amendments, conformity requirements are intended to ensure that transportation activities do not interfere with air quality progress. The quantification and comparison of on-road motor vehicle emissions is the method for determining transportation conformity between air quality and transportation planning. MVEBs are established in air quality plans using motor vehicle related emissions information from the California Air Resources Board (CARB) and transportation activity data provided by the metropolitan transportation organization (MPO). The MPOs with jurisdiction over the area, which includes the Sacramento $PM_{2.5}$ nonattainment area, are the Sacramento Area Council of Governments (SACOG) and the Bay Area Metropolitan Transportation Commission (MTC).

Currently, the Sacramento Region has no federally approved budget for $PM_{2.5}$. In the interim, federal regulations allow MPOs to use a “build vs. no build” test to determine transportation conformity for the region’s transportation plans and programs for $PM_{2.5}$ (40 CFR 93.119). If the proposed MVEBs are determined to be adequate by the United States Environmental Protection Agency (EPA), future transportation plans will need to conform to these MVEBs in any future transportation plan amendment and updates. The MPOs must ensure that the aggregate transportation emissions in the Sacramento Region (including, but not limited to, vehicle emissions, dust from paved and unpaved roads and road construction), rounded up to the nearest integer, do not exceed these levels when approving new metropolitan transportation plans and transportation improvement programs, even if the mix of projects changes or growth increases. Following EPA action, these new NO_X and $PM_{2.5}$ MVEBs will remain in effect until other budgets are proposed and approved by EPA.

9.2 Transportation Conformity Requirements

CAA Section 176 specifies that transportation plans, programs, and projects cannot cause new air quality violations, worsen existing violations, or delay timely attainment of a national ambient air quality standards (NAAQS) (42 USC 7506). To implement this requirement, EPA adopted the Transportation Conformity Rule (40 CFR 93). This Rule:

- Establishes criteria and procedures for determining whether long range metropolitan transportation plans (MTPs), short range metropolitan transportation improvement programs (MTIPs), and projects conform to the SIP.
- Ensures that transportation plans and projects are consistent with the applicable SIP, such that associated transportation emissions are less than or equal to motor vehicle

emissions budgets established for demonstrating reasonable further progress, attainment or maintenance of health-based air quality standards.

- Ensures that transportation plans, programs, and other individual projects do not cause new air quality violations, exacerbate existing ones, or delay attainment of air quality standards.

9.3 $PM_{2.5}$ MVEB Pollutants

The transportation conformity rule requires an MVEB for $PM_{2.5}$ and nitrogen oxides (NO_X) as a $PM_{2.5}$ precursor pollutant[37]. Chapter 7, Section 7.4 discusses the results of Chemical Mass Balance (CMB) modeling which shows NO_X being a major precursor for $PM_{2.5}$. The CMB modeling also concluded that Volatile Organic Compounds (VOC) and ammonia (NH_3) are not appropriate to control, and sulfur oxides (SO_X) is not a significant contributor to the Sacramento $PM_{2.5}$ Non-attainment Area problem[38]. As a result, MVEBs need only be established for $PM_{2.5}$ and NO_X.

9.4 Emissions Sources

Motor vehicle emissions included in the MVEB are tailpipe emissions, brake wear, and tire wear, and must include re-entrained paved and unpaved road dust, and highway and transit construction dust if they are significant contributors.[39] The Maintenance Demonstration (Chapter 7, Section 7.4) shows that dust (which includes paved and unpaved road dust, highway and transit construction dust) do not represent a significant portion of the $PM_{2.5}$ ambient concentrations and therefore are not included in the MVEB.

9.5 Criteria for approval

Several criteria must be satisfied for EPA to find the MVEB to be adequate for transportation conformity purposes.[40] These criteria include:

i. The maintenance plan is endorsed by the Governor's designee and was subjected to a State public hearing;
ii. Before the maintenance plan was submitted to EPA, consultation among federal, State, and local agencies occurred; full implementation plan documentation was provided to EPA; and EPA's stated concerns, if any, were addressed;
iii. The MVEB is clearly identified and precisely quantified;
iv. The MVEB, when considered together with all other emissions sources, is consistent with applicable requirements for maintenance;
v. The MVEB is consistent with and clearly related to the emissions inventory and the submitted maintenance plan.

This MVEB and the maintenance plan will be reviewed and adopted by all the air districts' Boards of Directors in the Sacramento $PM_{2.5}$ Nonattainment Area during public hearings, and

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37 40 CFR 93.102(b)(2)(iv)
38 Chapter 7.4. Maintenance Demonstration Analysis – Chemical Mass Balance Analysis.
39 40 CFR 93.102(b)(3) and 40 CFR 93.122(f)
40 40 CFR 93.118(e)(4)(i-v)

subsequently will be submitted to CARB for adoption as a revision to the California State Implementation Plan. As required by 40 CFR 93.105, the regional air districts consulted with metropolitan planning organizations, state agencies, Department of Transportation and the U.S. Environmental Protection Agency during the development of the MVEBs proposed in the Maintenance Plan. On March 20, 2013, a meeting of SACOG's Regional Planning Partnership (RPP) was held to review the MVEBs. By consensus vote, members of the RPP approved that the proposed MVEBs be included in the Plan. The proposed budgets were also presented to the Land Use and Natural Resources Committee of the SACOG Board on April 4, 2013. The MVEBs listed on Table 9-1 are consistent with the baseline on-road motor vehicle emissions in Chapter 4 (Emissions Inventory) and incorporate baseline adjustments not included in EMFAC2011 and a nominal "safety margin."

9.6 SACOG's MTP and Latest Planning Assumptions

The latest planning assumptions were used to establish the MVEB[41]. Current and forecasted vehicle miles traveled (VMT) are from SACOG-supplied activity data based on transportation modeling conducted during development of SACOG's most recent Metropolitan Transportation Plan and Sustainable Communities Strategy 2035 (MTP/SCS 2035)(SACOG, 2012a) update. In addition, the vehicle activity levels for the eastern part of Solano County in the Sacramento $PM_{2.5}$ nonattainment area are based on data obtained by SACOG from the Bay Area Metropolitan Transportation Commission, which is the MPO responsible for the eastern portion of Solano County.

The SACOG long range MTP for the Sacramento region forecasts land use development and vehicle activity through 2035 using the most recent planning assumptions and an activity-based travel model. The new MTP/SCS 2035 will reflect development patterns consistent with SACOG's "Blueprint" initiative program (SACOG, 2012a), which defines a growth scenario through 2050. The Blueprint emphasizes higher population densities, preservation of open space, and reductions in vehicle miles traveled.

In order to estimate future traffic volumes in the Sacramento region SACOG used its SACSIM[42] travel demand model, which incorporates data on population, employment, and the transportation system. Using the SACSIM model, SACOG forecasts that the increase in VMT in the Sacramento region will be slower than the overall increase in population through 2035. (SACOG, 2011)

9.7 Proposed Motor Vehicle Emission Budgets

The Center for Continuing Study of the California Economy (CCSCE) developed the growth projections for SACOG, which included projections for future employment, population, and household growth at the regional scale. The CCSCE estimated 34% growth in numbers of jobs, 39% increase in population, and 35% increase in number of households from 2008 to 2035 for the Sacramento region. These factors are applied to the MTP/SCS 2035 and generate the

41 As required by 40 CFR 93.110(a)
42 SACSIM is the abbreviation of "Sacramento Activity-Based Travel Simulation Model."

forecasted activity and VMT for the Sacramento $PM_{2.5}$ Nonattainment Area (Chapter 3 of SACOG, 2011).

Once VMT for future years have been estimated with a travel demand model, mobile-source emissions are calculated using the CARB's motor vehicle emissions model, called EMFAC. The current version of the EMFAC model is referred to as EMFAC 2011 (CARB, 2011). EMFAC incorporates vehicle populations and emission factors for various vehicle types. Vehicle emissions for a given year are generated using VMT estimates supplied by SACOG. The proposed $PM_{2.5}$ MVEB for the Sacramento Region were supplied by CARB (Taylor, 2012).

The Transportation Conformity Regulation (40 CFR Part 93, §93.124) allows an area to increase the MVEB in its implementation or maintenance plan provided the area can demonstrate compliance with applicable milestone, attainment, or maintenance requirements with the higher motor vehicle emissions budget. The plan must explicitly state that this additional amount is available to the MPO (i.e. SACOG) and Department of Transportation (DOT) in the emissions budget for conformity purposes.

The MVEB incorporate a "safety margin," which includes an additional 1.88 tons per day of NO_X and 0.09 tons per day of direct $PM_{2.5}$ in 2017 and 2.10 tons per day of NO_X and 0.36 tons per day of direct $PM_{2.5}$ in 2024.

The additional increase in NO_X and $PM_{2.5}$ emissions are accounted for in the maintenance demonstration emission forecasts and the maintenance demonstration analysis using the chemical mass balance receptor modeling discussed in Chapter 7.

Table 9-1 shows the proposed MVEB for $PM_{2.5}$ and NO_X for the Sacramento $PM_{2.5}$ Nonattainment Area for an interim year (2017) and the maintenance year (2024). The numbers are rounded up to the nearest integer. Future transportation plans must show that regional motor vehicle emissions will be less than the budgets shown in order to demonstrate conformity.

Table 9-1: Proposed Motor Vehicle Emissions Budgets for Maintenance of $PM_{2.5}$ NAAQS

Sacramento $PM_{2.5}$ Nonattainment Area (tons per day)	2017		2024	
	NO_X	$PM_{2.5}$	NO_X	$PM_{2.5}$
Baseline On-Road emission from EMFAC2011	37.62	1.78	23.32	1.82
Adjustment to Baseline	-0.55	-0.05	-1.21	-0.16
Net Inventory	37.07	1.73	22.11	1.66
Safety Margin	1.88	0.09	2.10	0.36
Total	38.95	1.82	24.21	2.02
Conformity Budget*	**39**	**2**	**25**	**3**

* Budgets established by rounding emissions to the next highest integer.

9.8 References

CARB, *Mobile Source Emission Inventory,* CA: California Air Resources Board, Sacramento CA [2011.] Web February 21, 2011 < http://www.arb.ca.gov/msei/msei.htm>

EPA, *Clean Air Fine Particle Implementation Rule,* Federal Register, Volume 72, April 25, 2007, p. 20586-20667.

EPA. *Transportation Conformity Rule Amendments for the New $PM_{2.5}$ National Ambient Air Quality Standard: $PM_{2.5}$ Precursors,* Federal Register, Volume 70, May 6, 2005, p. 24280-24292.

EPA. *Transportation Conformity Rule Amendment To Implement Provisions Contained in the 2005 Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU),* Federal Register, Volume 73, January 24, 2008, p. 4420.

Taylor, Jonathan. "Sacramento 24hr $PM_{2.5}$ Transportation Conformity Budgets" Message to Charles Anderson. 17 October 2012. E-mail.

Federal Clean Air Act, 42 U.S.C. 7506, Title 1, Part D, Section 176 (c)(B)), [1990.], referenced on February 6, 2012.

SACOG, *Sacramento Region Blueprint: Transportation and Land use Plan, Special Report, Blueprint's Impact on the Region and Residents' Quality of Life*, Sacramento Area Council of Governments: Sacramento, CA [2010.]

SACOG. Draft of *Sacramento Region Metropolitan Transportation Plan and Sustainable Communities Strategy for 2035*, Sacramento Area Council of Governments: Sacramento, CA [2011]

SACOG, *Factsheet – Metropolitan Transportation Plan and Sustainable Communities Strategy for 2035 Update.* Sacramento Area Council of Governments: Sacramento, CA [2012.]

SACOG. Sacramento Region Metropolitan Transportation Plan and Sustainable Communities Strategy for 2035, Sacramento Area Council of Governments. Sacramento, CA [2012a] p.4

United States Environmental Protection Agency:

Conformity to State or Federal Implementation Plans of Transportation Plans, Programs, and Projects Developed, Funded or Approved Under Title 23 U.S.C. or the Federal Transit Laws, 40 CFR 93.102 (2010), reference on February 21, 2012.

Determining Conformity Of Federal Actions To State Or Federal Implementation Plans, 40 CFR 93 (2010), reference on February 9, 2012.

Criteria and procedures: Interim emissions in areas without motor vehicle emissions budgets, 40 CFR 93.119 (2005), reference on February 21, 2012.

10 General Conformity

This chapter summarizes basic general conformity requirements and emission criteria for demonstrating general conformity.

10.1 Introduction to General Conformity

Clean Air Act (CAA) Section 176(c) contains requirements for the federal regulatory process known as Conformity. Conformity requires that actions taken by federal agencies, including actions[43] receiving federal funding, be consistent with air quality implementation and maintenance plans. Transportation plans, programs, and projects are covered under the provisions of the Federal Transportation Conformity rule (See Chapter 8 - Transportation Conformity). The United States Environmental Protection Agency (EPA) established a separate rule for all other federal actions referred to as General Conformity.

10.2 General Conformity Requirements

EPA revised the General Conformity regulations in 2010 (75 FR 17254). Federal regulations require that federal agencies use the emission inventory from an approved SIP's attainment or maintenance plan to support a conformity determination. Chapter 4 establishes an emission inventory for general conformity purposes.

Federal agencies typically implement General Conformity requirements by preparing an applicability analysis that is used to support a draft and final conformity determination, which is subject to agency consultation and public review.

10.3 Applicability analysis

Only actions that produce emissions in designated nonattainment and maintenance areas are subject to the general conformity provisions. Federal agency actions in a nonattainment or maintenance area are exempted from the conformity requirement if their emissions are below the de minimis threshold. The $PM_{2.5}$ de minimis thresholds[44] for maintenance areas are listed in Table 10.1 below.

Table 10.1 *de minimis* threshold for $PM_{2.5}$ Maintenance Area

Pollutants or Precursors	***de minimis* threshold (tons per year)**
$PM_{2.5}$	100
Sulfur dioxide (SO_2),	100
nitrogen oxides (NO_X)	100
Volatile Organic Compounds (VOC)	100
Ammonia (NH_3)	100

43 Federal actions are defined as any activity engaged in by a department, agency, or instrumentality of the Federal government, or any activity that they support, fund, license, permit, or approve, other than activities related to transportation plans, programs, and projects that are applicable to transportation conformity requirements. (40 CFR 93.152)

44 40 CFR 93.153(b)(2)

Federal agencies may also publish lists of actions that are "presumed to conform".[45] A federal activity on a presumed to conform list is assumed to have emissions that will not exceed the de minimis threshold. One type of action that is presumed to conform[46] is a specified prescribed fire.

10.4 Conformity Determination

If a federal action cannot be shown to be below applicable de minimus levels or presumed to conform, a conformity determination is required. The federal agency responsible for the project must demonstrate that the action does not:

- cause or contribute to any new violations of a federal standard; or
- increase the frequency or severity of any existing violation of a standard.

In order to make this demonstration, the agency must show that the total direct and indirect emissions associated with the action will not exceed the emissions budget in the appropriate air quality plan. Typically, this demonstration is made in cooperation with the state or local air district. If emissions from the action cannot be shown to be consistent with the emissions budget, the agency must reduce fully offset the total direct and indirect emissions. The emissions shown in the inventory (Chapter 4) represents the emission budget for this plan.

Direct emissions of a criteria pollutant or its precursors[47] are emissions that are caused or created by the federal action, and occur at the same time and place as the action. Indirect emissions are reasonably foreseeable emissions that are further removed from the federal action in time and/or distance, and can be practicably controlled by the federal agency due to a continuing program responsibility (40 CFR 93.152).

10.5 Types of Federal Actions Subject to General Conformity Requirements

Examples of general federal actions that may require a conformity determination include, but are not limited to, the following: leasing of federal land, private construction on federal land, reuse of military bases, airport construction and expansions, and construction of federal office buildings.

10.6 References

EPA. *Revisions to the General Conformity Regulations*. Federal Register. Volume 75, April 5, 2010, p.17254-17279.

EPA. 40 CFR 93.152, *Reference: Definitions*.

EPA. 40 CFR 93.153. *Reference: Applicability*

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45 40 CFR 93.153(f)
46 40 CFR 93.153(i)
47 Precursors for $PM_{2.5}$ in the Sacramento $PM_{2.5}$ Nonattainment Area include NO_X pollutants (40 CFR 93.153).

11 Re-designation Request

This section documents that all requirements for re-designation to attainment of the 24-hour $PM_{2.5}$ standard have been addressed, including a demonstration that future transportation planning actions meet transportation conformity requirements. It also demonstrates that the nonattainment area has achieved the $PM_{2.5}$ standard as a result of permanent and enforceable measures.

11.1 Introduction to Criteria for Re-designation

The Sacramento Metropolitan Air Quality Management District, El Dorado County Air Quality Management District, Placer County Air Pollution Control District, and Yolo-Solano Air Quality Management District are requesting that the United States Environmental Protection Agency (EPA) re-designate the Sacramento $PM_{2.5}$ Nonattainment Area to attainment for the 2006 24-hour $PM_{2.5}$ National Ambient Air Quality Standard (NAAQS). The Air Districts have met the criteria for the EPA Administrator tore-designate as outlined in the Federal Clean Air Act (CAA) Section 107(d)(3)(E).

The EPA Administrator may not re-designate a nonattainment area (or portion thereof) to attainment unless the:

- Administrator determines that the area has attained the NAAQS;
- Administrator has fully approved the applicable implementation plan for the area under CAA Section 110(k);
- Administrator determines that the improvement in air quality is due to permanent and enforceable reductions in emissions resulting from implementation of the applicable implementation plan and applicable federal air pollution control regulations and other permanent and enforceable reductions;
- Administrator has fully approved a maintenance plan for the area as meeting the requirements of CAA Section 175A; and
- State containing such area has met all requirements applicable to the area under CAA Section 110 and Part D.

Table 11.1 includes the compliance statements for each of the above re-designation criteria.

Table 11.1 Compliance with CAA Section 107(d)(3)(E) Criteria for Re-designation to Attainment

Criterion	Compliance
Attainment of the $PM_{2.5}$ NAAQS	**Section 11.2** contains a summary discussion of the 24-hour $PM_{2.5}$ air quality data used to demonstrate attainment of the NAAQS. A more detailed discussion of air quality data, trend analyses and the monitoring network is documented in **Chapter 3**.
State Implementation Plan (SIP) Approval under CAA Section 110(k)	**Section 11.3** summarizes the $PM_{2.5}$ Implementation Plan elements discussed in **Chapter 2,** Sections 2.4 to 2.7. **Chapter 3** describes the $PM_{2.5}$ air quality monitoring network; **Chapter 4** documents the emissions inventory; and **Chapter 6** discusses the permit program.
Permanent and Enforceable Improvement in Air Quality	**Section 11.4** of this chapter demonstrates that the Sacramento $PM_{2.5}$ Nonattainment Area's improvement in $PM_{2.5}$ air quality was due to permanent and enforceable emissions reductions. **Chapter 6** discusses air district and CARB rules and regulations that collectively resulted in attainment. **Chapter** 4 shows long term trends demonstration that emissions will continue to decrease even though the region's population and vehicle miles traveled are projected to increase.
Fully Approved Maintenance Plan	In accordance with CAA Section 175A, the $PM_{2.5}$ Maintenance Plan is included and submitted as part of this Plan with the request for re-designation. **Section 11.6** summarizes information contained in **Chapters 7 and 8** and includes the necessary elements to satisfy the requirements of the attainment inventory, maintenance demonstration, monitoring network, verification of continued attainment, and contingency plan requirements. EPA approval of this $PM_{2.5}$ Implementation/Maintenance Plan and the Motor Vehicle Emission Budgets (MVEB)(**Chapter 9**), would satisfy CAA Section 110 and Part D requirements.
CAA §110 and Part D Requirements	**Chapter 2** discusses the public noticing procedures and other CAA Section 110 and Part D requirements (**Section 11.7**).

11.2 Attainment of the $PM_{2.5}$ NAAQS

The first condition for re-designation is to show that the Sacramento Federal Nonattainment Area has attained the 2006 24-hour $PM_{2.5}$ NAAQS (CAA Section 107(d)(3)(E)(i)). The Sacramento region is in attainment for the annual $PM_{2.5}$ standard. There are currently ten monitors which collect ambient $PM_{2.5}$ air quality data in the Sacramento Nonattainment Area. The 2009-2012 $PM_{2.5}$ data were quality-assured and certified by the California Air Resources

Board (CARB)[48]. Table 11.2 includes a summary of $PM_{2.5}$ air quality data for the Sacramento region's monitoring sites for the three attainment years, 2009-2012. The $PM_{2.5}$ design value, which determines whether an area is in attainment, is derived from this data. To attain the 24-hour $PM_{2.5}$ NAAQS, each monitoring site must have a design value at or below 35µg/m^3. A design value is calculated by averaging the 98th percentile concentration for three consecutive years of complete data. The highest three-year average of the 98th percentile concentration was 35µg/m^3, recorded at the Del Paso Manor and the Department of Health monitoring sites. Based on the data for 2009-2011, the region has attained the 2006 24-hour $PM_{2.5}$ NAAQS. The air quality monitoring data shows that the design value for the Sacramento Nonattainment Area has decreased from 60µg/m^3 in 2002 to 35µg/m^3 in 2011 (see also Chapter 3, Section 3.3). The region continued to attain in 2012 with a design value of 31 µg/m^3. EPA approved a clean data finding request for the Sacramento $PM_{2.5}$ Nonattainment Area (78 FR 42018) effective August 14, 2013. Table 11.2 summarizes the air quality data for all monitoring sites with Federal Reference Method or Federal Equivalent Method monitors. Chapter 3 includes a detailed discussion of the adequacy of the $PM_{2.5}$ monitoring network and provides the certified air quality data used to document attainment of the $PM_{2.5}$ NAAQS.

Table 11.2 Summary of $PM_{2.5}$ Air Quality Data – Sacramento region 2009-2012

Monitoring Station	Annual 98th Percentile				Design Value*	
	2009	2010	2011	2012	2011	2012
Roseville – Sunrise Blvd.	21.3	20.3	23.0	14.9	22	19
Sacramento – Del Paso Manor	38.7	27.0	39.8	27.1	35	31
Sacramento – T Street	27.2	27.3	45.1	20.5	33	31
Sacramento – Health Department	34.9	26.5	44.8	20.5	35	31
Woodland – Gibson Road	27.4	18.6	25.8	14.2	24	20
Region's Peak Value	**38.7**	**27.3**	**45.1**	**27.1**	**35**	**31**

* 2011 design value is calculated from the 98th percentile of years 2009-2011; 2012 design value is calculated from years 2010-2012.

11.3 State Implementation Plan (SIP) Approval

CAA Section 107(d)(3)(E) (ii) requires, and EPA guidance (Calcagni, 1992) states, that "The SIP for the area must be fully approved under CAA Section 110(k) and must satisfy all requirements that apply to the area" before re-designation to attainment is approved. The guidance noted that "approval action on SIP elements and the re-designation request may occur simultaneously." This Plan contains the additional required SIP elements, including a maintenance plan. The required SIP elements are summarized in Table 11.4 below.

The guidance also states that "An area cannot be re-designated if a required element of its plan is subject of disapproval; …; or partial, conditional, or limited approval." There have been no previous disapprovals, partial, conditional, or limited approvals of required elements of the $PM_{2.5}$ State Implementation Plan for the Sacramento Region.

[48] On May 19, 2010, April 28, 2011, May 9, 2012, and May 16, 2013 CARB certified and submitted the air quality data to EPA AQS as complete and quality assured.

11.4 Permanent and Enforceable Improvement in Air Quality

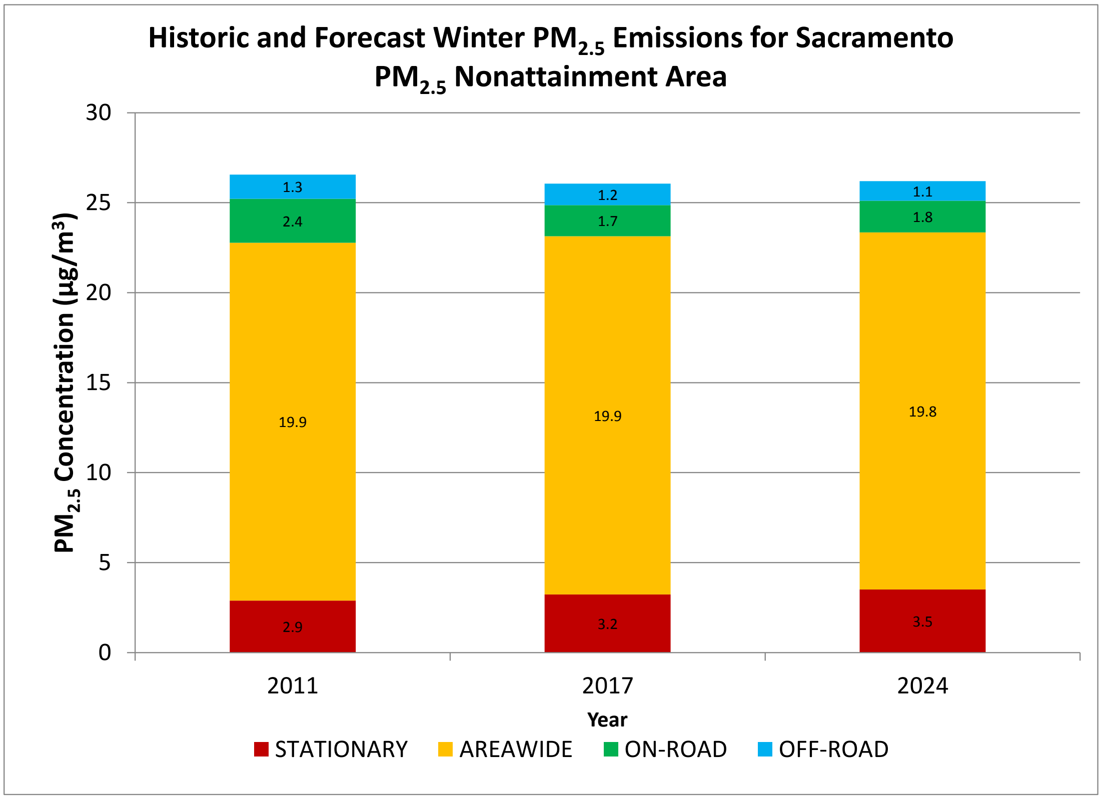
CAA Section 107(d)(3)(E)(iii) and EPA re-designation guidance (Calcagni, 1992) specifies that "The State must be able to reasonably attribute the improvement in air quality to emission reductions which are permanent and enforceable."

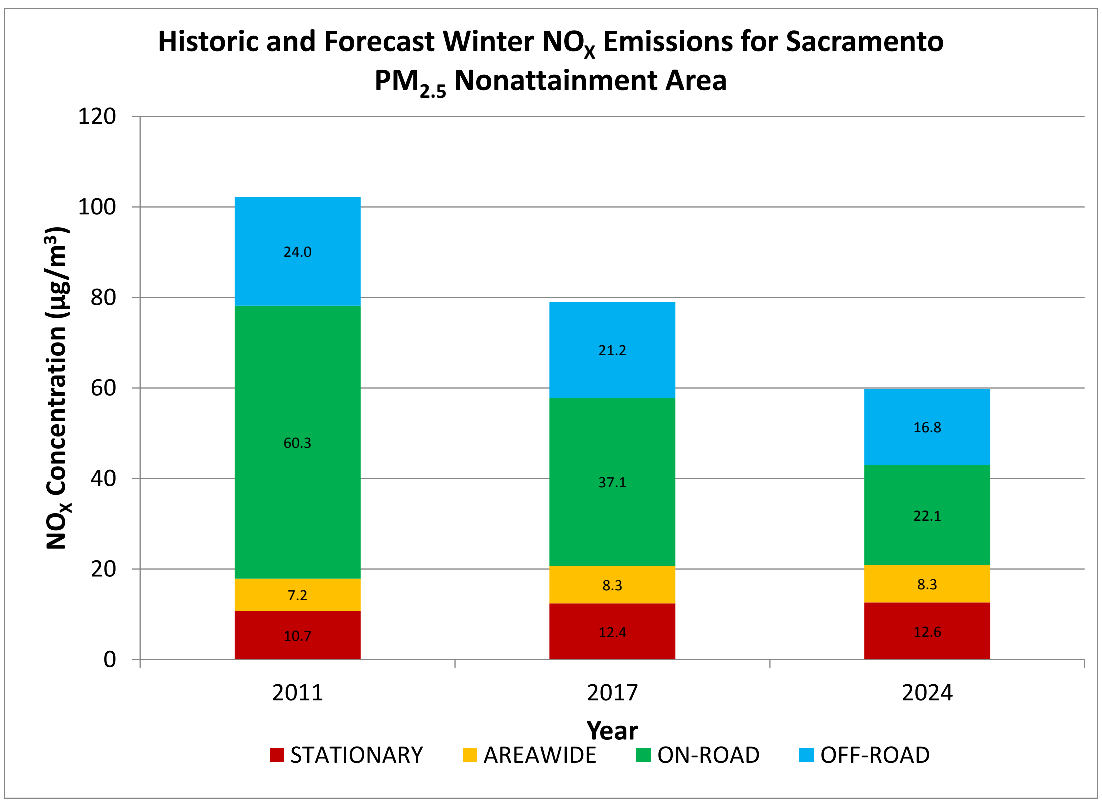
Local Air Districts in the Sacramento $PM_{2.5}$ Nonattainment Area and the California Air Resources Board have adopted 17 control measures to reduce $PM_{2.5}$ and its precursors since the implementation of the 2006 $PM_{2.5}$ standards. These measures listed in Table 11.3 include local and statewide $PM_{2.5}$ and NO_X rules. The measures regulate $PM_{2.5}$ and its precursors and significantly reduce ambient $PM_{2.5}$ concentrations. Figure 11.1a and Figure 11.1b show the historical and projected $PM_{2.5}$ and NO_X emissions for the Sacramento region. In addition, various statewide mobile measures have lowered NO_X emissions. These emission reductions are the result of permanent and enforceable measures that led to attainment of the $PM_{2.5}$ standards in the Sacramento region. See Chapter 6 for additional details on the control measures.

Table 11.3 $PM_{2.5}$ and NO_X Control Measures Adopted in the Sacramento Region Since 2006

Rule Title	Agency	Adoption Date
Rule 417: Wood Burning Appliances	SMAQMD	10/26/2006
Rule 421: Mandatory Episodic Curtailment of Wood and Other Solid Fuel Burning	SMAQMD	10/25/2007
Rule 411: Boilers, Process Heaters, and Steam Generators	SMAQMD	08/23/2007
Rule 414: Water Heaters, Boilers, Process Heaters < 1 million BTU/hr	SMAQMD	03/25/2010
Rule 233: Biomass Boilers	PCAPCD	12/10/2009
Rule 301: Non-Agricultural Burning Smoke Management	PCAPCD	02/09/2012
Rule 302: Agricultural Waste Burning Smoke Management	PCAPCD	02/09/2012
Rule 303: Prescribed Burning Smoke Management	PCAPCD	02/09/2012
Rule 304: Land Development Burning Smoke Management	PCAPCD	02/09/2012
Rule 305" Residential Allowable Burning	PCAPCD	02/09/2012
Rule 306: Open Burning of Non-Industrial Wood Waste at Designated Disposal Sites	PCAPCD	02/09/2012
Rule 2-37: Natural Gas-Fired Water Heaters and Small Boilers	YSAQMD	04/08/2009
Rule 2-44: Central Furnaces	YSAQMD	05/13/2009
Smog Check Improvements	CARB	10/28/2009
Cleaner In-Use Heavy Duty Trucks	CARB	09/21/2011
Clean Up Existing Harbor Craft waiver	CARB	12/13/2011
Cleaner In-Use Off-Road Equipment waiver	CARB	08/12/2008

Figure 11.1a and 11.1b $PM_{2.5}$ and NO_X Emissions for the Sacramento $PM_{2.5}$ Nonattainment Area 2011-2024





Economic Conditions

EPA guidance also precludes redesignation if attainment is "due to temporary adverse economic conditions." (Calcagni, 1992) Since 2008, the Sacramento region has experienced adverse economic conditions similar to many other areas of the state and nation. The recession created significant downward pressure on economic activity in the region, causing many businesses to reduce employment, extend workforce hours, and sell assets, including part of their motor vehicle fleets. In some sectors, the adjustments resulting from the recession are expected to continue for some time. Two of the sectors hit the hardest by the recession are the construction industry and goods movement, including the trucking and shipping industries. These impacts, as well as recovery scenarios, were reflected in CARB's 2010 amendments to the statewide truck and construction regulations[49,50].

CARB's revised emissions inventory incorporated the effects of the recent economic recession. It considered the future economic growth, new vehicle sales, reduced vehicle activity, and their combined effect on the emission inventory and forecasts.

<u>Reduced vehicle activity</u>
Trucking activity in California decreased by nearly 20 percent between 2007 and 2010. Construction-related activity declined by 50 percent between 2005 and 2010. These declines were dramatic, and in many cases unprecedented (CARB, 2011b). As discussed below, emissions decreases from declining use would also be reflected in reduced diesel and gasoline sales, yet overall emissions are declining at a steeper rate than fuel sales. This indicates that the decline in truck activity is not solely responsible for decreased emissions. The reductions from truck activity would also tend to be offset by the decrease in new truck sales (see below).

<u>Rate of future economic growth</u>
Several economic forecasting groups (University of California – Los Angeles, the University of the Pacific, and the California Department of Finance) forecast that economic recovery and expansion, and rising employment levels will occur relatively slowly over the next five years. ARB used these estimates to reduce its forecasted vehicle activity levels from previously anticipated levels.

<u>New Vehicle Sales</u>
The recession had a major impact on new vehicle sales, which in many cases fell by 80-90 percent from the peak levels seen in 2005-2007. Sales volumes are projected to increase gradually, and are not forecast to reach previous levels for several years. This has also reduced the penetration of the newest, cleanest vehicles into the California market, leaving fleets older than they would have been without the recession (CARB, 2011b).

While reduced trucking activity discussed above reduces emissions, the slower turnover of old vehicles increased emissions by delaying emission reductions resulting from

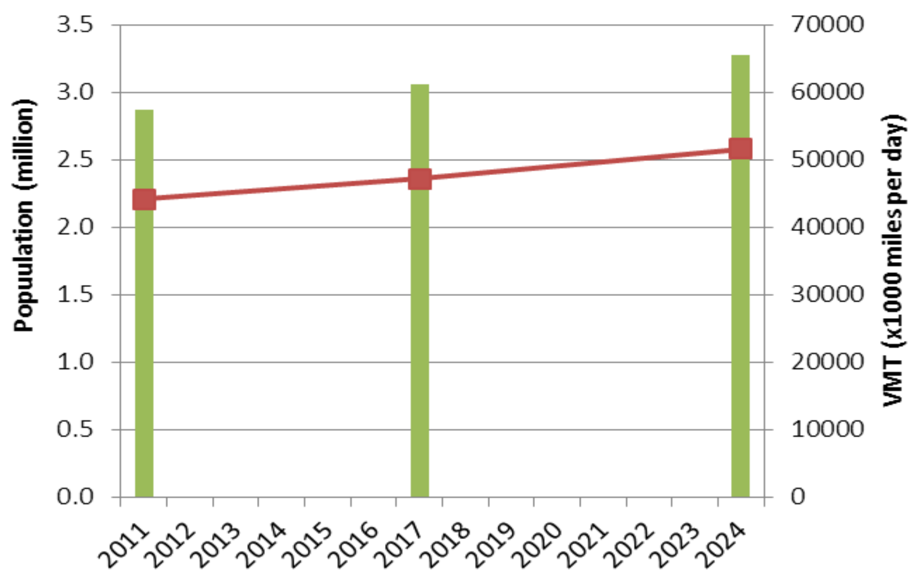
49 Amendments to the Regulation to Reduce Emissions of Diesel Particulate Matter, Oxides of Nitrogen and Other Criteria Pollutants from In-Use On-Road Diesel-Fueled Vehicles (12/14/2011).

50 Regulation for In-Use Off-Road Diesel-Fueled Fleets (12/14/2011).

replacement of older vehicles with newer cleaner vehicles. It is not possible to single out the emission change from either factor from the emissions inventory.

Other factors support the conclusion that the emission reductions are not due to the recession. The emission inventory from Chapter 4 shows that the major emission sources for $PM_{2.5}$ are residential fuel combustion and motor vehicles, sources dependent on the region's population and vehicle miles travelled (VMT). As population or transportation activities increase, emissions are expected to increase. Figure 11.4 shows the historical and projected population and VMT growth in the Sacramento Region (SACOG, 2012). The trend shows steady growth in population and VMT over the last decade and there is no indication that the recent economic recession is leading to a significant outflow of population from the region or a decrease in VMT.

Figure 11.4 Population and VMT for Sacramento $PM_{2.5}$ Nonattainment Area 1990-2024

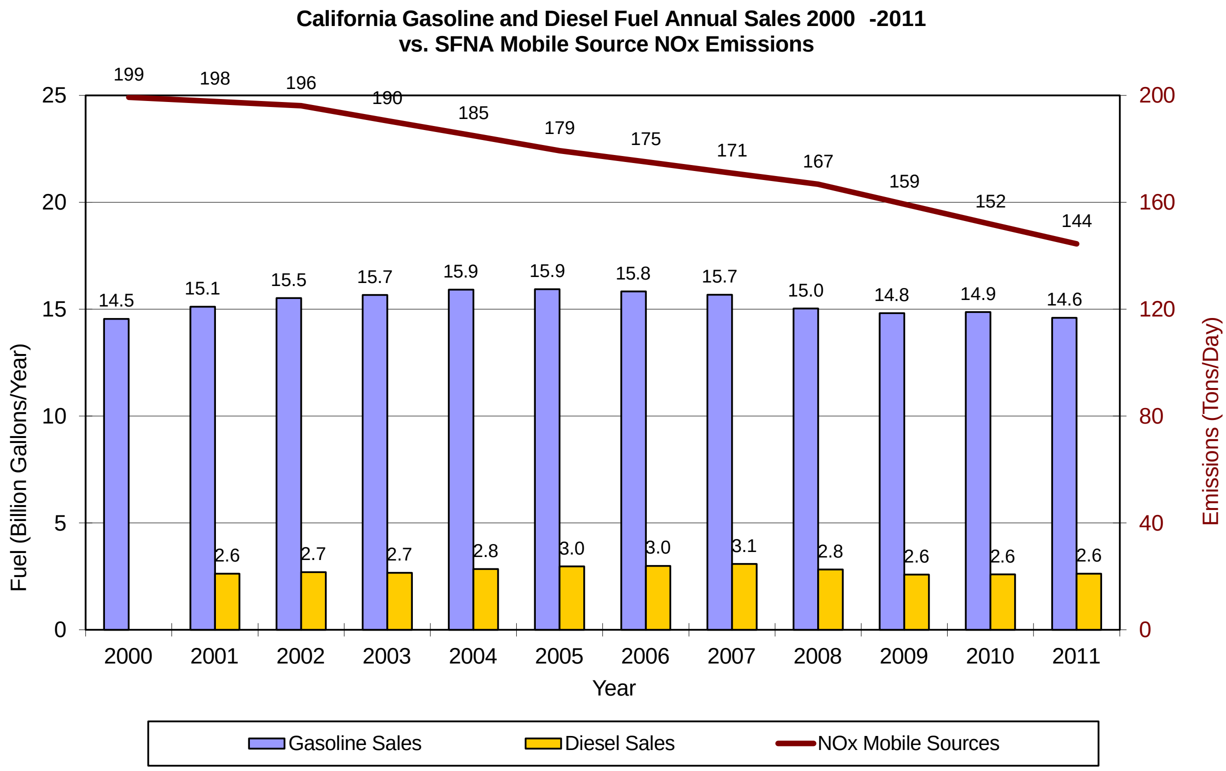


	2011	2017	2024
VMT (x1000 miles/day)	57397	61275	65654
Population (millions)	2.2	2.4	2.6

Statewide sales data of gasoline and diesel fuel is another indicator of economic conditions. Figure 11.5 shows slow growth in sales in the first half of the last decade, which peaked in 2005, and slowly returned to 2000 levels by 2011. The overall trend in statewide fuel sales remained relatively constant for the last 12 years, averaging 15 billion gallons of gasoline and 2.8 billion gallons of diesel sales per year. Improvements in vehicle fuel economy and technology can explain, in part, the declining trend in fuel sales.

The region experienced a decline in mobile NO_X emissions on an average of 2% per year for the past decade, despite the steady increase in population and VMT. Residential fuel combustion $PM_{2.5}$ emissions have been consistent at about 13.5 tons per winter day. While the recent economic recession has played a role in reducing VMT, which will cause a reduction in some emissions, many of the reductions are due to existing controls. The recession may potentially exacerbate progress toward attainment within a few emission inventory subsectors; however existing controls and future regulations affect a much larger part of the inventory and will ensure emissions remain low. Therefore, we conclude that attainment did not result from temporary adverse economic conditions.

Figure 11.5 California Gasoline and Diesel Fuel Annual Sale 2002-2011 and Sacramento $PM_{2.5}$ Nonattainment Area Mobile Source Emissions.



Data source: California State Board of Equalization - Fuel Taxes Division Statistics and Reports

Meteorological Conditions

CARB and STI prepared a Classification and Regression Tree Analysis (CART) (Chapter 5, Section 5.1), which analyzed meteorologically-adjusted air quality trends. The met-adjusted trend analysis shows that observed ambient $PM_{2.5}$ concentrations and exceedance days are consistently below projected meteorologically adjusted levels during the attainment years (2009-2012). The met-adjusted trends are independent of meteorological influence; therefore one can conclude that attainment was due to emission reductions, not unusual weather conditions.

Scientific studies (Motallebi, 1999) and (Palazoglu, 2012), EPA forecasting guidelines (EPA, 2003), and STI's Forecasting Guidelines identified several meteorological parameters that could affect the ambient $PM_{2.5}$ concentrations in the Sacramento Area. These factors include the surface temperature, temperature inversion, wind speed and direction, 500mb height, dew point temperature/humidity, and rainfall. These studies and forecasting guidelines suggested that warm surface temperature, strong vertical mixing, strong surface wind, low 500mb height, and a significant amount of rainfall are meteorological factors that favor low $PM_{2.5}$ ambient concentrations for the Sacramento Region.

In addition, the general statistical analysis and hypothesis test in Section 5.2 further confirmed that Sacramento region's attainment was not due to *unusually favorable* meteorological conditions. The analyses found that variability occurred in meteorological conditions and a couple of parameters that favor low ambient $PM_{2.5}$ concentrations in 2010. However, other meteorological parameters in 2010 either had no impact or were favor ambient $PM_{2.5}$ concentrations. In total, these observations were not sufficient to conclude that attainment was due to *unusually favorable* meteorological conditions. Moreover, the statistical analysis demonstrated that the low ambient $PM_{2.5}$ concentrations of 2009 and 2011 were achieved under adverse meteorological conditions that generally favor high ambient $PM_{2.5}$ concentrations.

Considering the control measures implemented, the economy, and meteorological conditions in the region, it is reasonable to conclude that the improvement in air quality is due to permanent and enforceable emissions reductions and not temporary reductions or unusually favorable meteorological conditions.

11.5 Fully Approved Maintenance Demonstration

In accordance with CAA Section 175A, for an area to be re-designated, EPA must fully approve a maintenance plan that meets the requirements of CAA Section 175A. A State can submit the re-designation request and the maintenance plan at the same time. CAA Section 175A defines the general framework of a maintenance plan. The maintenance plan should constitute a SIP revision and must provide for maintenance for at least 10 years. In addition, the maintenance plan must contain a contingency plan to ensure prompt correction of any violations. EPA guidance (Calcagni, 1992) states that a maintenance plan should include five core provisions: an attainment inventory, maintenance demonstration, monitoring network, verification of continued attainment, and contingency plan.

- Chapter 4 includes the emission inventory, which documented the attainment year and forecast emission inventories for the maintenance period. The projected level of the emissions during the maintenance years is lower than the attainment year emissions.
- Chapter 7 describes the maintenance demonstration, which shows that the area will continue to meet the NAAQS.
- Chapter 3 contains a commitment to continue to operate a monitoring network as required by federal regulations.
- Chapter 7 describes the local air districts' commitments to review the assumptions and data for the $PM_{2.5}$ maintenance demonstration to fulfill the verification and tracking requirements of a maintenance demonstration.
- Chapter 8 described the maintenance contingency plan to ensure prompt correction of any violation of the NAAQS.

11.6 CAA Section 110 and Part D requirements

With the approval of this Plan and the Motor Vehicle Emission Budgets discussed in Chapter 8, the Sacramento $PM_{2.5}$ Nonattainment area will meet the CAA requirements for re-designation and approval of the maintenance plan. EPA may rely on the plan to proceed with re-designation of the Sacramento region to attainment for the 24-hour $PM_{2.5}$ NAAQS. Table 11.4 summarizes the required plan elements, the current status/conclusions, and the location of the discussion in the plan.

Table 11.4 CAA Required Plan Elements, Conclusions, and Current Status.

Required Plan Element	Actions or Conclusions	Location in Plan
Plan adoption and Submittal [Section 110(a)(1)] and California: $PM_{2.5}$ (2006) Infrastructure SIP Requirements [Section 110(a)(2)]. State shall adopt and submit the State Implementation Plan after reasonable notice and hearings within three years after the promulgation of the NAAQS.	This Plan provides maintenance and enforcement of the primary 2006 24-hour $PM_{2.5}$ standard. Also, CARB submitted the Infrastructure SIP on 09/21/2009 which EPA found to be complete on 01/07/2010.[51]	Chapter 2
Emergency Episode requirements Included under the Infrastructure SIP requirements [Section 110(a)(2)]	CARB's analysis (CARB, 2009) of three years of recent data showed that California should be classified as a Priority III region. A Priority III region is defined as having no 24-hour $PM_{2.5}$ concentration was over 140.4µg/m^3. Therefore, an emergency episode plan is not required.	Section 2.4.6
Public Noticing Requirements [Section 110(a)(2)]	Local Air Districts and California Air Resources Board will hold public hearings prior to the Plan adoption as outlined in 40CFR51.1002 and EPA guidance. (McCabe, 2011)	Section 2.4.6
Reasonably Available Control Measures (RACM) [Sections 172(c)(1) and 189(a)(1)(C)]	This Plan does not include a RACM analysis. EPA's final Clean Data Finding (78FR42018) suspended the planning requirements to submit a reasonably available control measure analysis as long as the area continues to meet the standard or the area is re-designated to attainment.	Section 2.4.2
Reasonable Further Progress [Sections 172(c)(2) and 189(c)]	This Plan does not include an RFP demonstration. EPA's Clean Data Finding suspended RFP demonstration requirement because the area has already attained the NAAQS prior to the SIP due date.	Section 2.4.2.
Emissions Inventory [Section 172(c)(3)]	This Plan includes a comprehensive, accurate, current inventory of actual emissions from all sources of the relevant pollutant or pollutants in the Sacramento $PM_{2.5}$ area. The emissions inventory is updated regularly. There is a comprehensive update every three years. The next comprehensive revision is due December 31, 2015 for the 2014 inventory.	Chapter 4 & Appendix B.
Identification and Quantification and Permitting requirements [Sections 172(c)(4), 173(a)(1)(B), and 189(a)(1)(A)]	This Plan quantifies main precursor gases associated with fine particular matter (72FR20585). Emission inventories include the best available information for all pollutants and precursors of fine particulate matter to effectively evaluate and develop control strategies needed to demonstrate attainment of the NAAQS.	Chapters 4 & 6 & Appendix B.

[51] EPA. Status of State SIP Infrastructure Requirements <http://www.epa.gov/air/urbanair/sipstatus/reports/ca_infrabypoll.html > Web. Last View May 14, 2012.

Permits for new and modified stationary sources [Sections 172(c)(5), 173 and 189(a)(1)(A)]	After the Sacramento Region is re-designated attainment for the $PM_{2.5}$ NAAQS, major stationary sources will be subject to the PSD (40CFR51.166) rather than the Federal Nonattainment provisions (73 FR 28231).	Section 6.5.
Other Measures [Sections 172(c)(6) and 189(e)]	This Plan includes control measures, means or techniques (including economic incentives such as fees, marketable permits, and auctions of emission rights), as well as schedules and timetables for compliance, as may be necessary or appropriate to provide for attainment by the applicable date.	Chapter 6.
Noticing [Section 172(c)(7)]	Compliance with section 110(a)(2).- the Sacramento Region will hold public hearings or provide the public opportunity to request a public hearing prior to any plan adoption. – includes reasonable notice and public hearing requirements for plan adoptions.	Section 2.4.6
Equivalent Techniques [Section 172(c)(8)]	EMFAC 2011 was used to develop mobile emissions inventory and Mobile Vehicle Emissions Budget. CARB submitted a request to EPA Region 9 for approval of EMFAC 2011 (Goldstene 2012a)	Chapter 4.
Contingency Measures [Section 172(c)(9)]	40 CFR 51.1004(c) states the requirements of the contingency measures in CAA Section 172(c)(9) for failure to attain or make progress to attainment are suspended for an area that has attained the standard.	Section 2.4.2
Subsequent plan revisions [Section 175A(b)]	A subsequent plan is required 8 years after the re-designation and will provide for maintenance of the NAAQS for 10 more years after expiration of the first 10-year maintenance period.	Section 2.5
Nonattainment requirements applicable pending plan approval [Section 175A(c)]	The Nonattainment requirements applicable to the Sacramento $PM_{2.5}$ Area will continue in force until EPA takes formal action re-designating the region to attainment for the $PM_{2.5}$ NAAQS.	
Contingency Measures Section 175A(d)	This plan identifies indicators, specific procedures/steps to determine if the contingency plan should be activated, and corrective actions to return the area to attainment after re-designation to attainment.	Chapter 8
General Conformity [Section 176(c)(1)]	This Plan documents criteria for projects subject to General Conformity Rule.	Chapter 10
Transportation Conformity [Sections 176(c)(2)-176(c)(3)]	The districts worked with SACOG through interagency consultation to review proposed Motor Vehicles Emissions Budgets, and receive comments from EPA, CARB, other regional agencies, and the public. This plan contains the MVEB.	Sections 9.2 & 9.4.
Monitoring Network [Sections 110(a)(2)(B) & 319, 40 CFR Part 58, and 40 CFR 50 Appendixes L & N	CARB and air districts in the Sacramento Region will continue the operation and maintenance of the air monitoring network.	Section 7.6

11.7 References

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12 Summary and Conclusions

12.1 $PM_{2.5}$ Nonattainment Designation

The Sacramento Federal $PM_{2.5}$ Nonattainment Area, encompassing Sacramento County, southwestern Placer County, western El Dorado County, northeastern Solano County, and eastern Yolo County, was designated nonattainment for the 2006 24-hour $PM_{2.5}$ standard on December 14, 2009. The 24-hour standard is 35µg/m^3, based on a 3-year average of the 98th percentile of 24-hour $PM_{2.5}$ concentrations. Three monitors in the Sacramento area, Del Paso Manor, T Street, and the Health Department, recorded violations based on 2006-2008 24-hour data. The attainment deadline is December 2014; the standard was attained three years before the deadline in 2011.

12.2 $PM_{2.5}$ Monitoring Network and Air Quality Data

Chapter 3 provides a detailed discussion of the regional monitoring network and the air quality data it collects. $PM_{2.5}$ is a mixture of solid and liquid particles in the ambient air with a diameter of 2.5 microns or less. Particles of this size are responsible for adverse health effects because of their ability to bypass the body's natural defenses and reach the lower respiratory tract. The United States Environmental Protection Agency (EPA) strengthened the 24-hour $PM_{2.5}$ National Ambient Air Quality Standard (NAAQS) from 65µg/m^3 to 35µg/m^3 in December 2006.

EPA designated the Sacramento region nonattainment for the 2006 24-hour $PM_{2.5}$ standard in 2009. The Sacramento region attained this standard by the end of 2011 with a design value (average annual 98th percentile $PM_{2.5}$ concentration for three consecutive years) of 35µg/m^3 and continued to attain in 2012 with a design value of 31µg/m^3. Chapter 3 includes a $PM_{2.5}$ seasonality analysis. The analysis showed that winter time conditions (e.g., atmospheric stability, low wind dispersion, and colder temperatures) were more conducive to higher $PM_{2.5}$ concentrations. Winter weather conditions are favorable to direct $PM_{2.5}$ pollutant buildup and increased secondary formation of particulates.

12.3 Emissions Inventory

Chapter 4 presents an updated emissions inventory of $PM_{2.5}$ and its precursor emissions. An emissions inventory is an accounting of the amount of air pollutants discharged into the atmosphere of a geographic area during a given time period. The submittal of attainment year (2011), interim year (2017) and final year (2024) emissions inventories of directly emitted $PM_{2.5}$ and its precursors (pursuant to 40 CFR part 51 subpart A) is required for the $PM_{2.5}$ maintenance plan.

This maintenance plan includes an emissions inventory for total directly emitted $PM_{2.5}$, and its precursors, sulfur dioxide (SO_2), NO_X, volatile organic compound (VOC), and ammonia (NH_3). The emissions inventory shows that residential combustion from fireplaces and woodstoves is the main contributor to the directly emitted $PM_{2.5}$ inventory at 52%. It also shows that mobile sources dominate the $PM_{2.5}$ precursor inventory at 54% (all precursor emissions combined).

The forecasted emission inventory shows that between 2011 and 2024, $PM_{2.5}$ precursors steadily decline about 21% primarily due to the phase-in of cleaner vehicles and equipment subject to steadily tightening emission standards. The forecast also shows directly emitted $PM_{2.5}$

increase by less than 1%. Emission reduction benefits from SMAQMD Rule 421, Mandatory Episodic Curtailment of Wood and Other Solid Fuel Burning, on the directly emitted $PM_{2.5}$ inventory are not well represented in a winter average inventory. During a poor air quality day, Rule 421 is expected to reduce an additional 5 tons per day of Sacramento Federal Nonattainment Area (SFNA) $PM_{2.5}$ emissions in 2024 or an additional reduction of 20% in the 2024 SFNA directly emitted $PM_{2.5}$ inventory. Thus, the emission inventory trends demonstrate that the region will continue to attain the 24-hour $PM_{2.5}$ NAAQS through 2024 by showing that the combined total future emissions of directly emitted $PM_{2.5}$ plus its precursors for SFNA-$PM_{2.5}$ remain below the attainment year emissions level.

12.4 Meteorological Analysis

The EPA guidance states that "… attainment due to *unusually favorable meteorology* would not qualify as an air quality improvement due to permanent and enforceable emissions reductions." (Calcagni, 1992) The meteorological analysis presented in Chapter 5 addresses the likelihood that "unusually favorable meteorological conditions" caused the region to attain the 2006 NAAQS for $PM_{2.5}$. Chapter 5 presents three independent analyses that evaluate the meteorological impacts on ambient $PM_{2.5}$ concentrations: one prepared by the California Air Resources Board (CARB), one prepared by Sonoma Technology Inc., and one prepared by the Sacramento Metropolitan Air Quality Management District. These analyses applied different statistical methods to answer the question: Is Sacramento's attainment due to "*unusually favorable meteorology?*"

CARB and STI used a statistical technique, referred to as Classification and Regression Tree (CART) analysis, to help support the Sacramento Region's attainment and maintenance demonstration of the 24-hour $PM_{2.5}$ standard. CART is a non-parametric technique that produces a classification tree if the dependent (target) variable is categorical or a regression tree if the dependent variable is numeric. In this analysis of $PM_{2.5}$ and meteorology, the final CART tree explains daily $PM_{2.5}$ in terms of the meteorological variables (parameters) used to make the splits, such as surface temperature, surface wind speed, relative humidity, etc.

CARB and STI applied the CART technique to evaluate the trends of $PM_{2.5}$ annual averages and number of exceedance days. CARB and STI's findings indicate that the actual observed and meteorologically adjusted $PM_{2.5}$ trends decline. The results demonstrate that the $PM_{2.5}$ concentrations were declining because of emission reductions and not meteorology.

In the second analysis, SMAQMD examined the relationship between $PM_{2.5}$ concentrations and meteorology in the region, statistically comparing each attainment year with the 10-year average for several meteorological parameters. The meteorological parameters analyzed were surface temperature, temperature inversion, surface wind speed and direction, 500mb height, dew point temperature, and rainfall. The results suggest that warm surface temperature, strong vertical mixing (temperature inversion), strong surface wind speed, low 500mb height, and rainfall are conducive to low ambient $PM_{2.5}$ concentrations, which is consistent with scientific studies of the region.

The statistical analysis found that despite some variability of meteorological conditions during the past decade, the conditions could not be considered as "unusually favorable" for low ambient $PM_{2.5}$ concentrations. Among SMAQMD's findings is that surface temperature and winter rainfall in 2010 are the only two meteorological parameters that favored low ambient $PM_{2.5}$ concentrations. It is not reasonable to conclude that unusually favorable meteorological conditions were present during the attainment years when only two favorable conditions were present for one of the three attainment years.

In the third analysis, STI used their forecasting conceptual model to assess whether daily meteorological conditions were usually favorable for low ambient $PM_{2.5}$ concentrations. The analysis showed considerable variability in the number of predicted exceedances from year to year over the 2002-2012 period, with the most predicted exceedances occurring in 2011, the second most in 2009, and the fewest number of exceedances in 2010. While this analysis indicates that meteorological conditions in 2010 were favorable for lower $PM_{2.5}$ concentrations, meteorological conditions were unfavorable for low $PM_{2.5}$ concentrations in 2009 and were very unfavorable for low $PM_{2.5}$ concentration in 2011. Therefore, this analysis demonstrates that meteorological conditions during the 2009-2011 attainment period as a whole were not unusually favorable for low ambient $PM_{2.5}$ concentrations.

12.5 Control Measure Analysis

Chapter 6 analyzes local, state, and federal control measures adopted to help reduce $PM_{2.5}$ in the Sacramento region. Since 2008, the local air districts of the Sacramento $PM_{2.5}$ Nonattainment Area adopted 13 control measures that reduced $PM_{2.5}$ or its precursors. These control measures include rules for wood burning appliances, wood burning curtailment, industrial heaters and steam generators, and agricultural burning management. These control measures led to the emission reductions ensuring attainment and maintenance of the $PM_{2.5}$ standard. Table 12.1 summarizes the adopted control measures. Since the Sacramento region has already attained the NAAQS, no new control measures and Reasonably Available Control Measures (RACM) analysis are required.

Table 12.1 Summary of Local $PM_{2.5}$ Control Measures—Sacramento $PM_{2.5}$ Nonattainment Area

Rule Number	Rule	Air District	Adoption Date
417	Wood Burning Appliances	SMAQMD	10/26/2006
421	Mandatory Episodic Curtailment of Wood and Other Solid Fuel Burning	SMAQMD	10/25/2007
411	Boiler. Process Heaters, and Steam Generators	SMAQMD	08/23/2007
414	Water Heaters. Boilers, Process Heaters < 1,000,000 BTU/hr	SMAQMD	03/25/2010
233	Biomass Boilers	PCAPCD	12/10/2009
301	Non-Agricultural Burning Smoke Management	PCAPCD	02/09/2012
302	Agricultural Waste Burning Smoke Management	PCAPCD	02/09/2012
303	Prescribed Burning Smoke Management	PCAPCD	02/09/2012
304	Land Development Burning Smoke Management	PCAPCD	02/09/2012
305	Residential Allowable Burning	PCAPCD	02/09/2012
306	Open Burning of Non-Industrial Wood Waste at Designated Disposal Sites	PCAPCD	02/09/2012
2-37	Natural Gas-Fired Water Heaters and Small Boilers	YSAQMD	04/08/2009
2-40	Wood Burning Appliances	YSAQMD	05/13/2009
2-44	Central Furnaces	YSAQMD	05/13/2009

In addition to local control measures, CARB adopted control measures in its 2007 State Strategy that reduce $PM_{2.5}$ and its precursors from on-road and off-road vehicles. These are statewide programs with implementation dates between 2008 and 2018. Table 12.2 summarizes CARB's control measures for $PM_{2.5}$.

Table 12.2 Summary of State Control Measures

CARB Measures/Waiver	Date submitted to EPA	Implementation
Smog Check Improvements	10/28/2009	2008-2013
Cleaner In-Use Heavy-Duty Trucks	09/21/2011	2011-2015
Clean Up Existing Harbor Craft Waiver	12/13/2011	2009-2018
Cleaner In-Use Off-Road Equipment Waiver	08/12/2008	2009

Measures to reduce directly-emitted $PM_{2.5}$ and $PM_{2.5}$ precursors have been implemented by both the local air districts of the Sacramento Region, as well as State and federal agencies. These permanent and enforceable measures led to attainment in 2011 and will help the region maintain the standard for the next decade.

12.6 Maintenance Demonstration

Chapter 7 describes the basic requirements for a maintenance demonstration, provides a maintenance demonstration analysis, and discusses methods for implementing verification and tracking procedures. The Clean Air Act (CAA) Section 175A contains planning requirements pertaining to the general framework of a maintenance plan. These requirements include a demonstration that the NAAQS will be maintained for at least 10 years after re-designation is approved by EPA.

The maintenance demonstration primarily relies on the method described in EPA Guidance (Calcagni, 1992) showing that the projected total $PM_{2.5}$ and its precursor emissions in the horizon year are less than the attainment year inventory. The NO_X and VOC emissions are expected to decrease by 37 tpd and 12 tpd respectively between 2011 and 2024. The projected future emissions of directly emitted $PM_{2.5}$ and NH_3 show slight increases compared to attainment year levels. SO_2 emissions do not change.

Chemical Mass Balance modeling was applied to confirm that the future emission would not cause a violation of the standard. Modeling results show that the future ambient concentrations and design values are lower than the attainment year levels. Specifically, the design values are forecast to decrease from 2011 levels, from 35 $\mu g/m^3$ to 31 $\mu g/m^3$ in 2024 at DPM and from 33 $\mu g/m^3$ to 29 $\mu g/m^3$ at T St. The largest reduction comes from the forecasted change in NO_X emissions and the corresponding change in ambient ammonium nitrate concentrations (-38%).

In summary, the air districts in the nonattainment area will continue to operate an appropriate air quality monitoring network to verify attainment and track progress and take corrective action if needed, review the assumptions and data used to demonstrate maintenance, and commit to prepare a subsequent maintenance plan in 2022.

12.7 Maintenance Contingency Plan

The contingency plan proposed in Chapter 8 tracks progress and ensures prompt correction of any violations of the $PM_{2.5}$ NAAQS that occur after re-designation and maintains the standard. The Sacramento region will continue to operate a $PM_{2.5}$ monitoring network that meets federal requirements. The plan identifies specific indicators and procedures to determine if the contingency plan should be activated to ensure continued attainment. The air districts will first evaluate a violation to verify one has occurred. If a violation has been verified, the air districts will evaluate the level of emission reductions needed to maintain the standard. Next, the air districts will determine if adopted rules that have not yet been implemented will provide the necessary reductions. The air districts would further evaluate applicable RACM if the adopted rules cannot provide sufficient emission reductions.

12.8 Transportation Conformity Budgets

Chapter 9 introduces the proposed on-road motor vehicle emissions budgets (MVEBs). Under the Federal 1990 Clean Air Act Amendments, federal transportation plans or projects should not interfere with any state air quality implementation plans (SIPs). The quantification and comparison of MVEBs is the method for determining conformity between transportation and air quality plans. Currently, the Sacramento region has no established $PM_{2.5}$ MVEBs. The Sacramento Area Council of Governments (SACOG) and the Metropolitan Transportation Commission (MTC) are currently using the “Build/No Build” test to determine $PM_{2.5}$ SIP conformity for the region’s transportation plans and programs. To reflect updated motor vehicle emission forecasts, this maintenance plan includes the proposed transportation conformity budgets for 2017 and 2024.

Table 12-1 lists the proposed transportation conformity budgets for 2017 and 2024. The proposed budgets incorporate the most recent on-road motor vehicle inventory factors from the EMFAC2011 emissions model, updated travel activity data, and latest control strategies. The MVEBs incorporate a "safety margin," which includes an additional 1.88 tons per day of NO_X and 0.09 tons per day of direct $PM_{2.5}$ in 2017 and 2.10 tons per day of NO_X and 2.02 tons per day of direct $PM_{2.5}$ in 2024.

The additional increase in NO_X and $PM_{2.5}$ emissions are accounted for in the maintenance demonstration emission forecasts and the maintenance demonstration analysis.

Table 12.3 Proposed Motor Vehicle Emissions Budgets for Maintenance of $PM_{2.5}$ NAAQS (Tons/Day)

2017		2024	
NO_X	$PM_{2.5}$	NO_X	$PM_{2.5}$
39	2	25	3

If the proposed MVEBs are determined to be adequate for transportation conformity purposes, and are approved by EPA, future transportation plans will need to limit on-road emissions to these levels. SACOG and MTC must ensure that the aggregate transportation emissions do not exceed the approved MVEBs in any future transportation plan amendments or updates.

12.9 Re-designation Request

Chapter 11 documents that all requirements for redesignation to attainment of the 24-hour $PM_{2.5}$ standard have been addressed, including a demonstration that future transportation planning actions meet transportation conformity requirements. In this chapter the air districts in the Sacramento region are requesting that EPA redesignate the Sacramento region to attainment for the 2006 24-hour $PM_{2.5}$ NAAQS. The Sacramento region has met the following criteria, which will allow the EPA Administrator to promulgate redesignation as outlined in the Federal CAA Section 107(d)(3)(E):

- Attained the 24-hour $PM_{2.5}$ NAAQS by December 31, 2011.
- Fully approved $PM_{2.5}$ SIP for the area: submittal contained in this plan.
- Improvement in air quality is due to permanent and enforceable reductions: control measures have reduced overall emissions despite increasing population and VMT, and not due to temporary emission reductions or unusually favorable meteorology.
- Fully approved $PM_{2.5}$ maintenance plan for the area: submittal contained in this plan.
- Met CAA Section 110 and Part D requirements: contingent on the approval of this implementation and maintenance plan, and motor vehicle emissions budgets.

12.10 Overall Conclusions

Local and State programs and control measures provided permanent and enforceable measures that successfully led the Sacramento region to attainment of the 2006 24-hour $PM_{2.5}$ NAAQS by the end of 2011. The Sacramento region continued to attain in 2012. The meteorological analysis showed that attainment was not due to unusually favorable weather conditions. The Plan also demonstrates that attainment was not due to temporary emissions reductions. This Plan contains a Maintenance Plan that meets federal requirements. Continued attainment of the $PM_{2.5}$ standard is demonstrated throughout the 10-year maintenance period, 2014-2024, to ensure conformity with the maintenance plan. The Plan establishes MVEBs and contains information that shows the Sacramento region has a fully approvable SIP. Therefore, the Sacramento Federal $PM_{2.5}$ nonattainment area is requesting that EPA re-designate the region ‘attainment’ for the 2006 24 hour $PM_{2.5}$ NAAQS.