

**San Joaquin Valley Air Pollution Control District  
State Implementation Plan PM10 Modeling Protocol**

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## San Joaquin Valley State Implementation Plan PM10 Modeling Protocol

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## Introduction

The State Implementation Plan (SIP) PM10 Modeling Protocol (Protocol) consists of a series of elements required to provide a comprehensive analysis for the San Joaquin Valley PM10 SIP. Air quality modeling analyses described in the Protocol are performed to demonstrate that the proposed control strategy is sufficient to achieve compliance with the PM10 National Ambient Air Quality Standards (NAAQS) for protection of public health. The Protocol is a general document establishing the approach and data to be used in accordance with U. S. Environmental Protection Agency (EPA) Guidance. EPA has final approval authority for the Protocol, especially for any variations from standard guidance that are necessary for special circumstances that affect our selection of models and analysis approach. The District and the Air Resources Board (ARB) consult with EPA on the development and approval of the Protocol. The Protocol is utilized as the plan of approach, but is considered to be a working document subject to revision during the SIP development process in response to unexpected findings or technical issues.

### **SJVAPCD PM10 SIP Modeling Protocol Contents**

The Protocol provides a description of the selection of general approach, ambient monitoring, meteorological and other pertinent data available to support the analysis, analysis methods, identification of the models used, justification for model selection, assumptions involved in model application, and model input and output data to demonstrate attainment of the federal PM10 air quality standards. The Protocol provides for an analysis that evaluates the 24-hour and annual average non-attainment areas to test and demonstrate the ability of proposed controls to achieve attainment of the air quality standards.

It is a complex process to address attainment for the entire Valley for all monitored areas and seasons because the Valley is a large geographic area with emissions that vary extensively by location and season. Consequently, the Protocol proposes a comprehensive analysis by combining, correlating and reconciling results of a series of evaluations to establish by preponderance of results that the SIP adequately addresses all nonattainment areas. Evaluations to be utilized as described in the Protocol and attached work plans include:

- **Meteorological Evaluation** The District is performing meteorological analysis of time periods related to episode conditions and the entire CRPAQS monitoring period. This information will be reviewed by ARB and the District to evaluate the meteorological factors and influences related to PM10 episodes. The analysis also establishes the representativeness of transport and formation of PM observed in historical episodes. It is essential to evaluate episodes with this perspective to identify contributing sources and factors.

- **Receptor Modeling** Receptor modeling using the chemical mass balance model (version CMB 8) will be conducted for annual and episode conditions at sites that currently do not comply with the federal PM10 air quality standards. This method uses chemical analysis of collected air monitoring samples and information about the chemical composition of contributing sources to evaluate the link between observed conditions and emission sources. The District will use the results of the CMB analysis with a modified rollback approach to calculate the effect on design values of predicted aggregate adopted and proposed control measure reductions and other predicted emission trends to establish attainment at sites noncompliant with the standards. This method works well for analysis of directly emitted particles but is less certain in predicting the effect of reductions of secondary precursors (gases that form particles in the air that may not produce particles in amounts directly proportional to the amount of emissions). The Protocol proposes supplementing the receptor modeling to the extent possible with findings developed by regional modeling of secondary particulate formation rates typical to the Valley to take into account the potential nonlinear secondary particle formation.
- **Regional Modeling** Regional modeling of secondary particulates will be conducted by ARB using a version of the Urban Airshed Model modified to address aerosol chemistry (UAM-Aero) to learn as much as possible from the IMS-95 dataset (an early component of CRPAQS) by evaluating a monitored event of nitrate particulate formation. Additional analysis of the dataset with modeling techniques under development for CRPAQS will be used for comparison to the UAM-Aero results. Results will improve understanding of particle formation rates and the ratios of precursors to particle formation, particularly for nitrate particulates. Results will be used in conjunction with receptor modeling to enhance the accuracy and reliability of predicted effects of emission trends and adopted and proposed control measure reductions of secondary precursors.
- **Statistical Analysis** Evaluation using a variety of accepted statistical methods will be conducted with available air monitoring data and other data identified as related to high concentrations of particulates. The process will evaluate the factors related to known and observed episodes and identify other combinations, patterns and factors not captured by monitoring that are potentially capable of causing PM10 episodes. Results of this process can be used in conjunction with the meteorological analysis to determine whether monitoring has captured events that represent the most severe likely combination of factors associated with PM10 episodes.

Combining the results of the meteorological and statistical analysis allows evaluation of whether the monitoring data and design value represent the likely worst case value, which would be a more stringent design value than is required, or whether the monitoring data may represent something less than the fourth highest likely value, which may not be sufficiently protective. Monitoring is conducted on a one-in-six day basis in accordance with EPA guidelines. In some locations during air quality studies

the sampling has been increased to provide a one-in-three day schedule. Since monitoring does not provide a daily record, review of the comprehensiveness of the monitoring data is appropriate.

Evaluation of the representativeness and comprehensiveness of monitored exceedances will be performed by examining the relative severity of factors associated with monitored events in comparison to factors that could have produced events on days that were not monitored. By evaluating factors associated with both monitored and unmonitored days, results of the meteorological evaluation and statistical analysis process provide evaluation of sufficiency of the control program to provide attainment of the annual and 24-hour standard in all cases. If days with combinations of PM10 related factors having a potential to produce high levels of PM10 are well represented by monitoring; then, addressing the observed exceedances would be established as sufficient for the entire Valley. If some of the observed meteorological and statistical patterns with combinations of factors associated with high levels of particulates are not well represented by monitoring observations, supplemental evaluation may be required to with available data to determine the likelihood and frequency of occurrence of such events. Since the PM10 concentration of an unmonitored event cannot be reliably determined, effectiveness of the control program to address applicable contributing sources to a potential episode must be evaluated. Results establish sufficiency of the control program to provide attainment of the annual and 24-hour standard for all predictable conditions.

### **Protocol Elements and Attachments**

Descriptions or work plans for each element of the Protocol analysis are attached to support the main Protocol document. Additional attachments will be provided with the Protocol to identify continuing research efforts that are expected to provide results that clarify current uncertainties. The California Regional PM10/PM2.5 Air Quality Study (CRPAQS) "Objectives and Approaches" and "Modeling Work Plan" identify the investigative and modeling efforts planned for the next several years to utilize data collected during the CRPAQS field studies. Guidance for control plan modification may be obtained from the results as they become available.

### **Determination of Attainment**

The program of analysis specified in the Protocol will provide a complete attainment demonstration by assessment of all exceedances to the PM10 annual and 24-hour standards that have been detected by the monitoring network and established as causing an area to be classified as nonattainment. Although the best available data will be utilized, uncertainties and limitations of the data affect results of analyses and may produce confirming and contradictory indications that must be reconciled by knowledgeable evaluation to establish reliable conclusions. Procedures for analysis have been selected to establish objective and reliable conclusions that have the highest

confidence that can be established from the best available data. The SIP control plan will establish an attainment demonstration by successfully addressing all identifiable exceedances in the nonattainment area.

## **San Joaquin Valley State Implementation Plan PM10 Modeling Protocol**

The PM10 Modeling Protocol (Protocol) outlines the plans of the California Air Resources Board (ARB) and the San Joaquin Valley Unified Air Pollution Control District (SJVAPCD) to develop analysis and modeling evaluation of San Joaquin Valley PM10 to support development of control plans to achieve compliance of the federal annual and 24-hour PM10 standards in accordance with EPA guidance for the State Implementation Plan (SIP). The Protocol is utilized as the plan of approach, but is considered to be a working document subject to revision during the SIP development process in response to unexpected findings or technical issues. The Protocol outlines the procedures and technical considerations involved in the modeling analysis for the SIP for submission to EPA Region IX for review and comment. The ARB, District and Valley transportation planning agencies are jointly preparing data analyses, emissions inventories and modeling analyses to address modeling requirements for the SIP. Modeling will be conducted with jointly developed input files and mutually accepted modeling assumptions.

### **Goal of the Protocol**

The goal of the Protocol is to determine an effective program of emission control, establishing the amount and types of emission reduction that must be implemented to achieve compliance with the federal annual and 24-hour PM10 National Ambient Air Quality Standards (NAAQS). "Under the Clean Air Act, many areas are required to submit modeled attainment demonstrations to show that proposed reductions in emissions will be sufficient to attain the applicable NAAQS." (PM10 Guideline Document, EPA-452/R-93-008, April 1993).

### **Regulatory Requirements for Contents of the SIP Protocol**

As required by Section 6.1 of the PM10 Guideline Document "Air quality modeling analyses are performed to demonstrate that a proposed control strategy provides for attainment and maintenance of the NAAQS (40 CFR 51.112a) and ...(40 CFR 51.1661). SIP submittals must include a description of how the modeling analysis was conducted by providing information on the models used; the justification of model selection; the modes of models used; assumptions involved in model application; the meteorological data; ambient monitoring data used; the justification of off-site data, if used; the model input data; the model output data." The Protocol contains the required elements, presenting data discussions first because the analysis of the data guides model selection and application. The Protocol also discusses how the results of the modeling will be processed to develop reliable findings and how the results will be utilized to

determine the effectiveness of proposed additional controls to achieve attainment of the federal annual and 24-hour PM10 standards.

The Protocol provides all of the required elements for an analysis that evaluates the 24-hour and annual average non-attainment areas to test and demonstrate the ability of proposed controls to achieve attainment of the air quality standards. Because the Valley is a large geographic area with emissions that vary extensively by location and season, the Protocol proposes a comprehensive analysis by combining, correlating and reconciling results of a series of evaluations to establish by preponderance of results that the SIP adequately addresses all nonattainment areas. The Protocol proposes a series of evaluation elements that include: meteorological evaluation of the influence of factors affecting PM10 concentrations, statistical analysis of representativeness and comprehensiveness of episodes evaluated, receptor modeling to establish the contributions of major source types and predicted control effects, and regional modeling to enhance predictions of secondary particulates.

The following discussion provides the basis and justification for development of the approach. Descriptions or work plans for each element of the Protocol analysis are attached to support the main Protocol document. Additional attachments will be provided with the Protocol to identify continuing research efforts that are expected to provide results that clarify current uncertainties.

## **Data: Meteorological**

Collecting meteorological data is as important as obtaining reliable pollutant data to predict PM10 formation, concentration and response to change. Meteorological data is used with pollutant data to improve day-to-day meteorological and air quality forecasting, characterize the nature and extent of pollutant problems, and prepare air quality trend analyses. Evaluation of air quality model performance relies on meteorological as well as pollutant data to support modeling processes to make long-term control strategy assessments and decisions as part of the continuing air quality management process of SIP planning

Meteorology and climate play important roles in determining the levels of air pollution in the Valley. Some meteorological patterns cause higher levels of air pollution by preventing the dispersion of pollutants. Pertinent meteorological parameters include wind speed and direction, ambient atmospheric temperature and inversion layers (i.e., layers where the air temperature increases with height), and precipitation. Substantial temporal and spatial variations in PM10 speciation profiles occur in the District in part because the types and quantities of source emissions are different in each major city and county, but meteorological factors also affect PM10 levels, affecting emissions, secondary particle formation and dispersion. Meteorology should not be considered as merely an input in the modeling, but rather as a key parameter to understanding and predicting PM10 formation and concentrations.

The Protocol includes evaluation elements distinct from data selection for modeling. The evaluation and interpretation of meteorological influences is essential to reliable control strategy and trend evaluations.

- **Meteorological Evaluation** The District is performing meteorological analysis of time periods related to episode conditions and the entire CRPAQS monitoring period. This information will be reviewed by ARB and the District to evaluate the meteorological factors and influences related to PM10 episodes. The analysis also establishes the representativeness of transport and formation of PM observed in historical episodes. It is essential to evaluate episodes with this perspective to identify contributing sources and factors.

Meteorological evaluation also assesses whether monitoring captured the peak values. Monitoring is conducted on a one-in-six day basis in accordance with EPA guidelines. In some locations during air quality studies the sampling has been increased to provide a one-in-three day schedule. Since monitoring does not provide a daily record it may not detect the maximum value. Evaluation of meteorological factors on days that were not monitored will be compared to historical monitored days to evaluate the representativeness and comprehensiveness of monitored exceedances by examining the relative severity of the collective associated factors. The control program will need to consider more severe conditions identified by meteorological analysis that were not captured by monitoring. The design of the control plan will be sufficient to provide attainment without additional analysis if monitoring captures the most severe days.

- **Statistical Analysis** Evaluation using a variety of accepted statistical methods will be conducted with available air monitoring data and other data identified as related to high concentrations of particulates. The process will evaluate the factors related to known and observed episodes and identify other combinations, patterns and factors not captured by monitoring that are potentially capable of causing PM10 episodes. The representativeness and comprehensiveness of monitored exceedances can be evaluated by comparing the severity of observed events to predicted constructs. Results of this process provide evaluation of: sufficiency of available data to establish reliable conclusions, identification of potential event types that require supplemental evaluation to determine control program sufficiency, and reasonableness of results of other methods. Results also provide verification of the completeness of the meteorological assessment to establish sufficiency of the control program to provide attainment of the annual and 24-hour standard for all predictable conditions.

### **Justification for Meteorological Evaluations**

Justification for including the meteorological evaluation elements as well as using appropriate meteorological data for modeling derives from prior analysis of meteorological influences on PM10 concentrations conducted for development of daily

forecasting of air quality and prior SIP development efforts. The chemical mechanisms involved in secondary particle formation and inversion patterns affecting retention and build up of PM10 concentrations must be effectively interpreted to support trend evaluation, atmospheric modeling, receptor modeling and consequent control strategy evaluations and decisions.

Extensive seasonal variation has been established for sources contributing to PM10 concentrations and atmospheric processes contributing to particle formation and retention. Analysis of filters reveals that different meteorological conditions and sources contribute to exceedances in the fall versus the winter. Colder, frequently stagnant conditions occurring in December and January favor formation of ammonium nitrate. Secondary PM10 species, such as ammonium nitrate, ammonium sulfate, and organic particles are formed through chemical interactions from directly emitted SO<sub>x</sub>, NO<sub>x</sub>, VOC and ammonia. Particulate sulfate and nitrate can form via both gas and aqueous phase pathways. In the aqueous phase, which is the main pathway during winter fog and cloud conditions, secondary ammonium nitrate and ammonium sulfate form when nitric acid and SO<sub>2</sub> dissolve in water droplets and then react with dissolved ammonia. Since the sulfate and nitrate ions compete with each other for the available ammonia, SO<sub>x</sub>, NO<sub>x</sub>, and ammonia must be treated as a coupled system in order to adequately understand the interactions and subsequent formation of nitrate and sulfate particles.

The period of October through January generally includes the most frequent and severe exceedances of the federal 24-hour PM10 standard. PM10 concentrations are generally low from April through June. Average concentrations and the frequency of exceedance of the federal 24-hour standards generally increase from August through October, remain high from October through January, and then fall off through February and March. During the October to January period the PM10 concentrations undergo a shift from dominance by primary particles to dominance by secondary particles. Secondary particles are a major fraction in colder, wetter periods, but are generally less important before mid-November. Prior source apportionment receptor modeling has identified the major contributors at all sites as primary geological material during the summer and fall, and secondary ammonium nitrate during the winter. Other contributions that were considered significant at one or more sites on one or more occasions included motor vehicle exhaust, field and fireplace vegetative burning, construction, secondary formation of ammonium sulfate, secondary formation of organic particulates from anthropogenic and biogenic VOC emissions, oil combustion and marine aerosols in some portions of the Valley.

Meteorological data are used to assess the potential for air pollution to accumulate in certain locations. Weather factors that may restrict horizontal and vertical air movement of air masses are important factors in air quality. Vertical movement of air disperses pollutants vertically while horizontal movement spreads the pollutants over a wider geographic area.

## **Inversion Layers**

Inversion layers exist when the air temperature increases with elevation above the ground. The strength, altitude of, and duration of inversions determine the amount of vertical atmospheric mixing which occurs, which subsequently contributes to PM10 concentrations in the District. Temperature inversions occur in a stable atmosphere of warm air over cooler air hindering the upward dispersion of pollutants. Mixing ceases at the base of the inversion, which is also known as the mixing height. The Valley experiences two common types of inversions; radiation inversions and subsidence inversions.

Nocturnal cooling of an air layer near the Valley surface causes radiation inversions. It extends upward several hundred feet and occurs during the evening and early morning hours. During a radiation inversion, little vertical mixing occurs near the surface. The inversion dissipates when solar radiation warms the ground, which in turn heats the lower layers of the atmosphere. This heating causes the surface-based inversion to weaken, and finally dissipate, which allows vertical mixing through a greater depth in the atmosphere. Inversions are more persistent (stable) during the winter months, when inversions occur from 50 to 1,000 feet above the Valley floor. Studies in the southern part of the Valley indicate more frequent and persistent early morning radiation inversions than in the northern part of the Valley due to the lack of marine air intrusion.

Subsidence inversions are caused by downward vertical motion in the atmosphere. This is common when the semi-permanent Pacific High pressure system is located off the west coast. As air descends, it warms due to compression, and as a result becomes warmer than the air beneath it. Daytime temperature inversions during the summer are usually encountered 2,000 to 2,500 feet above the Valley floor. During the summer months, the Pacific High also protects the Valley Air Basin from weather fronts, which could otherwise bring cleansing rains and help reduce PM10 concentrations.

## **Horizontal Mixing and Dispersion**

In addition to vertical mixing, horizontal mixing, or transport, is also important in the dispersal of air pollutants. The greater the velocity of wind in the mixing layer, the greater the amount of mixing (dispersion) and transport of pollutants. Analysis of wind flow shows that during the winter months, the mean flow is through the Valley from the southeast. By mid-spring, coastal breezes enter the Valley from the northwest, which reverses the airflow pattern. By summer, the northwest to southeast airflow is at its strongest point. During the spring and summer, average wind speeds reach 6-10 mph. The frequency of very light winds (0-3 mph) does not exceed 23 percent of all spring and summer wind speeds. In the fall and winter, average wind speeds range between 5-9 mph; however, very light winds occur from 20 to 40 percent of the time.

PM10 originating from or going to other air basins, referred to as pollutant transport, has not been definitively quantified. PM10 readings in the SJVAB are most severe during

the fall and winter periods when wind speed and direction are not conducive to interregional transport. Monitoring and speciation techniques currently available are not able to identify the origin of PM10 sources with sufficient detail to indicate if the SJVAB is experiencing transport from outside the air basin or contributing transport of PM10 to other air basins. Transport of some PM10 precursors has been studied as part of ozone transport evaluation, identifying transport of ozone and ozone precursors from and to other air basins surrounding the SJVAB. The transport of ozone was documented during the summer when the highest ozone readings are more likely to occur. This transport includes precursors of ozone and PM10; however, the amount of PM10 that could be generated in the SJVAB or other air basins from such transport has not been quantified. Pollution from areas outside of the Valley may or may not contribute to high PM10 levels within the Valley.

### **Wind Speed and Direction**

Wind speed and direction play an important role in dispersion and transport of air pollutants. Wind at the surface and aloft can disperse pollution by vertical mixing and by transporting it to other locations. Wind speed and direction data indicate that during the summer the light and variable winds usually result from an influx of air from the Pacific Ocean through the Bay Area delta region, entering the north end of the Valley. The wind generally flows in a south-southeasterly direction through the Valley, through the Tehachapi Pass, and into the Southeast Desert Air Basin portion of Kern County.

During the winter, wind speed and direction data indicate that wind occasionally varies from the south-southeasterly direction, and originates from the south end of the Valley, flowing in a north-northwesterly direction. Also during the winter months, the Valley experiences light, variable winds of less than 10 mph. Low wind speeds, combined with low lying inversion layers in the winter, create a climate conducive to the formation of high PM10 concentrations.

PM10 geologic dust emissions in the Air Basin do not follow the conventional assumption that wind erosion is the dominant factor. Average wind velocity is the lowest in the nation for an area this large. Winds normally exceed erosive velocity levels at a site for only 30 to 50 days per year and sometimes less. Sites along the southeastern edge of the Air Basin have a significantly lower number of erosive wind days than the western edge due to the mountain ranges, which act as wind barriers adjacent to these areas. Over 75% of the winds with enough velocity to cause erosion occur in the spring and summer seasons in the Air Basin when PM10 levels in the ambient air are among the lowest. This suggests that these winds are effective in dispersing PM10 concentrations and/or transporting PM10 out of the Air Basin. Other factors such as soil type and soil moisture content prevent these winds from entraining a large amount of PM10 during this period. Erosive winds are defined as having a velocity of 13 mph at a height of one foot above the ground or eighteen miles per hour at a height of approximately thirty-three feet above the ground; these two wind speeds are considered equivalent. Erosive wind speeds can be much lower for some soil

conditions (NRCS Field Office Technical Guidelines and National Agronomy Manual, Second Edition, Part 502, Wind Erosion, US Department of Agriculture, Soil Conservation Service, March 1988).

**Table 1**

**SJVAPCD Meteorological Monitoring**

Note: A = Arithmetic Average, R = Resultant

Station Name	Wind Speed	Wind Direction	Outdoor Temperature	Relative Humidity	Barometric Pressure	Solar Radiation
Arvin	R	R	X	X	X	X
Bakersfield-California	R	R	X	X		X
Bakersfield-Golden St	A, R	A, R	X	X	X	X
Clovis-Villa	A, R	A, R	X	X	X	X
Corcoran-Patterson	A, R	A, R	X		X	
Edison-Johnson	R	R	X			
Fresno-First Street	R	R	X			
Fresno-Sky Park	A, R	A, R	X			
Madera-Pump Yard	A, R	A, R	X	X	X	X
Maricopa-Stanislaus	A, R	A, R	X			
Merced-Coffee	A, R	A, R	X			
Modesto-14th Street	R	R	X			
Oildale-Manor	R	R	X			
Parlier	A, R	A, R	X	X	X	X
Shafter-Walker Street	A, R	A, R	X	X	X	X
Stockton-Hazelton	R	R	X	X		
Stockton-Mariposa	R	R	X	X		
Tracy-Patterson Pass	A, R	A, R	X			
Turlock-Minaret	A, R	A, R				
Visalia-Church	R	R	X			
Visalia-Airport	A, R	A, R	X	X	X	X

## **Temperature**

The San Joaquin Valley floor is characterized by warm to hot, dry summers and cooler winters. The average mean temperature over a 30-year period is 65°F. High daily temperature readings in summer average 95°F in the Valley. The Valley also experiences mild winters; the winter average daily low temperature is 45°F. Over the last 30 years, the Valley averaged 106 days per year 90°F or hotter, and 40 days a year 100°F or hotter. The daily summer temperature variation can exceed 30°F. The Valley has an "inland Mediterranean" climate averaging over 260 sunny days per year.

## **Precipitation**

Precipitation in the Air Basin is confined primarily to the winter months with some occurring in late fall and early spring. Nearly 90% of the annual precipitation in the Valley falls between the months of November through April. Average annual rainfall for the entire Valley is about 10 inches on the Valley floor. There are north-south and east-west regional differences, with higher rainfall occurring in the northern and eastern parts of the Valley. Historical evaluations have correlated increased annual rainfall to decreased PM10 concentrations.

## **Air Basin Topography**

Air pollution within the SJVAB is intensified by topographical and meteorological conditions, which hinder the movement of air, thereby reducing the dispersion and dilution of emissions. The surrounding mountain ranges block dispersion, minimizing wind flows into and out of the basin. Meteorological conditions contributing to poor air quality also includes transport of pollutants into the SJVAB from upwind sources.

The San Joaquin Valley is a major geographic, population, and agricultural subregion of California. The District, and the corresponding air basin, includes the counties of San Joaquin, Stanislaus, Merced, Madera, Fresno, Kings, Tulare, and the Valley portion of Kern County. Comprising nearly 25,000 square miles, it represents approximately 16% of the geographic area of California. The Valley has a population of over 3 million people, with major urban centers in Bakersfield, Fresno, Modesto and Stockton.

The SJVAB consists of a continuous inter-mountain valley approximately 250 miles long and averaging 80 miles wide. On the western edge is the Coast Mountain range, with peaks reaching 5,020 feet, and on the east side of the Valley is the Sierra Nevada range with some peaks exceeding 14,000 feet. The Tehachapi Mountains form the southern boundary of the Valley. This mountain range includes peaks over 6,000 feet, and contains mountain passes to the Los Angeles basin and the Mojave Desert.

## **General Weather Types and Seasons**

Additional description of the general patterns and influences affecting the SJVAB is provided from excerpts from "Climate of the San Joaquin Valley Air Basin," C. D. Unger, State of California Air Resources Board, December 1974.

The climate of the San Joaquin Valley is characterized by hot, dry summers and cool, rainy winters. The most significant single control of the weather pattern is the semi-permanent subtropical high-pressure belt, often referred to as the "Pacific High". It is located off the west coast of North America and is a cell in which air descends almost continuously. The descending air is compressed, thereby raising its temperature and lowering the relative humidity. Major storms and region-wide precipitation are not typical when this pressure cell is dominant. This belt of high pressure migrates north and south seasonally. The SJVAB is under its influence almost continuously during summer months. In winter, the influence of the Pacific High is intermittent, giving rise to alternate periods of stormy, unsettled weather and periods of stable, rainless conditions. Annual rainfall totals vary from north to south, with northern counties experiencing as much as eleven inches of rainfall and southern counties experiencing as little as four inches per year. Air pollutants are generally transported from the north to the south and in a reverse flow in the winter due to these influences. Strong temperature inversions occur throughout the Valley in the summer, fall and winter. According to air quality monitoring data, exceedances of the federal 24-hour PM10 standard are generally seasonal, occurring usually during fall and winter months.

### **Summer**

During summer months the Pacific High pressure cell is positioned over the ocean to the west, off the northern California coast. The clockwise flow of air around the high results in persistent northwest winds over most offshore areas and enhances northwesterly flow through the interior valleys of California. The orientation of this trough and the pressure gradient between coastal and inland stations determines the variability in the summer weather pattern. Strong onshore pressure gradients occur with deep penetration of marine air through the Carquinez Strait into the Central Valley. Cooler temperatures and stronger northwest-to-southeast winds result from this pressure distribution.

Summertime relative humidity is quite low on the Valley floor, thereby causing large diurnal temperature variations. Daytime temperatures often exceed 100°F, and nighttime temperatures can often drop into the upper 50's. Daytime temperatures are generally warmer in the southern than in the northern end of the Valley because of the persistent influx of marine air under the influence of the thermal trough. Air over Bakersfield in the southern portion of the basin comes in through the Carquinez Strait where it was originally about 65°F, but is warmed in its journey down the Valley, reaching Bakersfield with an average maximum air temperature of 98°F at the surface.

When the pressure differential between the coast and the interior is weak, stagnant conditions result and dispersion is relatively poor. This may occur when a high-pressure cell aloft is located to the east of the Valley during the summer, thereby offsetting the westerly wind component. The thermal trough is weaker on days when Valley surface heating is minimal which also brings about poor ventilation conditions.

On a few days each summer, tropical air will be advected into the area at mid and high levels and may result in thunderstorms. The thunderstorms are most prevalent over the mountains east of the Valley floor; occasionally a vigorous thunderstorm occurs over the floor of the Valley, preceded by gusty winds and blowing dust.

## **Fall**

During the transition season of autumn, the storm belt and zone of strong Westerlies shifts southward through California, and passing frontal systems may produce showers and rain. With the approach of winter, the subtropical high shrinks and frontal passages become more vigorous. The advent of a high-pressure ridge over the area causes the formation of morning fog. As the intensity of solar radiation steadily diminishes through the fall months, daytime surface temperatures in the Valley decrease. This brings about a weakening in the thermal trough in the Valley, and the influx of marine air becomes negligible. Significant air stagnation occurs under these conditions.

## **Winter**

As the Pacific High shifts southward, it diminishes in strength, allowing storms, which develop in the Gulf of Alaska to penetrate further south. This can bring clouds and rain into the San Joaquin Valley. Occasionally, these storms will stall and deepen off the coast, and rainy weather will continue for several days. In between these periods, warm ridges may influence the Valley and there is a buildup of pressure through the interior of California. Mild, bright, sunny weather usually accompanies these synoptic types.

Another high-pressure cell that affects the San Joaquin Valley is the Great Basin High, which develops during the winter months in the area east of the Sierra Nevada. When this high is very strong, the descending winds will scour out the Valley, and dry, bright winter days result. When the high is weaker, a layer of cool, damp air is trapped in the basin and may last for a week or longer. Climatic records for Bakersfield show that heavy fog occurs on the average of 20 days each winter, with December and January having the most frequent fog. The top of the low stratus and fog is usually below 3,000 feet; therefore, higher elevations are usually clear under these conditions. Ventilation conditions below the inversion base are usually poor.

Many of the frontal systems, which pass through the San Joaquin Valley, are considerably weakened by the time they have reached this latitude. During the period when a weak, slow-moving frontal system is approaching the Valley, surface winds and

vertical mixing may be light. This often results in stagnant conditions, which may persist, from 12 to 48 hours in advance of the front.

The Southern San Joaquin Valley is generally in the rain shadow of the Tehachapi and the Coast Ranges to the south and west. For this reason, the southern Valley depends on cold, unstable, northwesterly flow for its precipitation, which produces showers following frontal passages. The northwesterly flow up the Valley is almost unobstructed by terrain barriers. The prefrontal southerly winds result in relatively little precipitation in the extreme southern end of the Valley. Winter temperatures in the San Joaquin Valley are generally mild. Temperatures will drop below freezing occasionally, but throughout the Valley, winter daytime highs are around 55°F, with lows around 35°F. Despite the latitudinal extent of the Valley, the variation of temperature in winter is small. The average January temperature is about 44°F, with little difference between the northern and southern portions of the Valley. Surface temperatures are dependent on elevation, with colder temperatures on the mountain ridges both east and west of the Valley floor.

## **Spring**

This is a transitional period in the San Joaquin Valley Air Basin. Cold pools of Gulf of Alaska air frequently move across the region, bringing instability and associated showery weather. In addition, the increased surface heating induces further instability. Frontal passages become steadily weaker and less frequent as summer approaches. Occasionally, in late spring, when Valley surface temperatures near the 90°F mark, vigorous updrafts along the Sierra range trigger the development of intense thunderstorms in the mountains in the afternoon and evening. Surface winds assume more of an up-valley component as the temperatures become warmer.

On infrequent occasions, a high-pressure system will stagnate over the Pacific Northwest, resulting in strong northerly winds, which may persist for several days. These are dry, desiccating winds that may cause severe crop damage, but bring generally favorable ventilation.

## Data: Ambient Monitoring

To quantify our understanding of the PM problem in the Valley, we propose to carry out the following analysis plan using the most recent years of data:

- Determine to the extent possible the duration of PM10 episodes using continuous data from BAMs, TEOMs, and nephelometers; examine whether 24-hour exceedances represent multi-day episodes.
- Determine the chemical speciation from ambient air samples collected with dichot and SSI samplers; conduct analysis and compare ambient speciation changes. Examine average concentrations and compare to peak values, and determine difference and trends among sites.
- Determine land use characteristics for design value(s) monitoring stations using digitized land use information; relate emission sources to ambient air speciation data derived from monitoring.

Data collected at locations other than District and ARB operated NAMS/SLAMS continuously operated sites (referred to as off site data) will be used to support analysis. Supplementary data will also be used from extra monitoring equipment at continuously operated sites or off site temporary monitoring. The supplemental monitoring includes additional instruments that comply with federal reference methods (FRM), devices that provide additional readings but may not be FRM equivalent and additional equipment that measures other atmospheric parameters to support evaluation and modeling. Data from equipment or sites which do not meet SLAMS criteria will not be used to demonstrate attainment or compute the design value; however, data from additional monitoring devices and sites will be used to analyze the sources and components of ambient PM10 samples and assess regional and local variations. This data will be used to analyze episodes of high ambient PM10 and determine effective controls to achieve and maintain attainment of the PM10 NAAQS. While not required to meet SLAMS requirements, collection of data is required to meet provisions in CFR Title 40, Chapter C, Part 58.14(b).

The federal Clean Air Act set the health-based National Ambient Air Quality Standards (NAAQS) specifying maximum acceptable levels of pollutants and authorized the EPA to revise and enforce the standards. Primary NAAQS protect public health with an adequate margin of safety, and secondary NAAQS are established to protect public welfare (i.e. soil, crops, vegetation, animals, visibility, building materials, etc.) from known or anticipated harmful effects. The levels for the primary and secondary NAAQS are the same for PM10. The current federal standards for PM10 are 50  $\mu\text{g}/\text{m}^3$  for an annual arithmetic mean averaged at each site over a three year period, and 150  $\mu\text{g}/\text{m}^3$  for a maximum 24-hour concentration not to be exceeded more than three times in

three years as determined by calculating the expected number of exceedances when monitoring at less than daily frequency.

Particulate Matter is any material, except pure water, that exists in the solid or liquid state in the atmosphere. The size of PM can vary from coarse wind blown dust particles to fine particle combustion products. PM10 comprises particles with an aerodynamic diameter less than or equal to a nominal 10 microns. Their small size allows them to make their way to the air sacs deep within the lungs where they may be deposited and result in adverse health effects. PM10 also causes visibility reduction.

The District exceeds both the federal annual and 24-hour PM10 standards for ambient air quality. According to air quality monitoring data, exceedances of the 24-hour standard are generally seasonal and occur during fall and winter months. There are marked differences in the speciation profiles of ambient air quality at monitored locations in the District. These variations occur in part because the types and quantities of source emissions are different in each major city and county, but meteorological factors also affect PM10 levels, affecting emissions, secondary particle formation and dispersion. Peak data statistics are not directly used to determine attainment status of the federal 24-hour PM10 standard. Peak values are used to determine design values, which are important in determining the reductions needed to reach attainment.

## **Monitoring Network**

The EPA requires that the state and the District measure the ambient levels of air pollution to determine compliance with the NAAQS. The District and the state operate the ambient monitoring network in order to comply with this mandate. The ARB and the District currently operate fifteen sites throughout the SJVAB. In addition, the agencies operate numerous co-located monitors to measure the precision and accuracy of data collected from the monitoring sites.

Air quality monitoring for PM10 is performed at State and Local Air Monitoring Stations (SLAMS) within the District, including National Air Monitoring Stations (NAMS) and Photochemical Assessment Monitoring Stations (PAMS). The EPA uses data from NAMS sites to develop national air quality trends.

Federal regulations require SLAMS networks to meet four basic monitoring objectives:

- Monitoring the highest concentration of a pollutant
- Monitoring representative concentrations in areas of high population density
- Monitoring the impact of major pollutant sources, and
- Monitoring pollutant background concentrations.

The physical location of an air monitoring station must achieve a spatial scale of representativeness that is consistent with the monitoring objective. Spatial scales of representativeness are categories of sampling exposure. The spatial scale for each site

results from the physical location of the site with respect to the pollutant sources and the population or area that is to be represented by the monitoring site. The categories are classified by the size of the area surrounding the monitoring site which experiences uniform pollutant concentrations.

The categories of spatial scale are:

*Microscale* - An area of uniform pollutant concentrations with a radius ranging from several meters up to 100 meters.

*Middle Scale* - Uniform pollutant concentrations in an area with a radius of approximately 100 meters to 0.5 kilometers.

*Neighborhood Scale* - Uniform pollutant concentrations in an area with a radius of approximately 0.5 to 4.0 kilometers.

*Urban Scale* - Citywide pollutant concentrations in an area with a radius ranging from 4 to 50 kilometers.

*Regional Scale* - Uniform pollutant concentrations that would be characteristic of a very large (for example, rural) area that has a radius from tens to hundreds of kilometers.

The middle, neighborhood, and urban scales typically are used for meeting the objective of monitoring in high-density populated areas. A monitoring objective for source impact could require micro, middle, or neighborhood scales. Neighborhood and regional scales are appropriate for monitoring background concentration levels. The relevant spatial scale for each site is determined from the physical location of the site with respect to the pollutant sources and the population or area represented by the monitoring site.

Monitoring for PM10 and finer particulate matter is focused primarily on monitoring representative population exposure concentrations. Thirteen of the fifteen current PM10 monitoring stations are at the neighborhood scale. The Bakersfield-California and Oildale-Manor stations are designed for middle scale.

Currently there are 15 PM10 Selective Size Inlet (SSI) stations located throughout the San Joaquin Valley. The District currently operates twelve (including collocated) PM10 monitors at 9 sites, the rest are operated by the ARB. The understanding of particulate episodes and sources is enhanced by review of PM2.5 monitoring data. There are 11 PM2.5 Federal Reference Method (FRM) samplers. The District operates five of the PM2.5 FRM samplers.

According to Title 40, Code of Federal Regulations, Part 58, Appendix D, section 3.7, the District is required to operate a minimum of three PM10 NAMS in the Stockton, Fresno, and Bakersfield urbanized areas and a minimum of one in the Modesto urbanized area based on 2000 census population figures and because the District is

characterized by high concentrations of PM10. Modesto 14th Street is currently classified as a SLAMS PM10 sampler but can be re-designated as a NAMS PM10 sampler so that the NAMS regulations will be satisfied for Modesto. Fresno-First Street, Clovis-Villa and Fresno-Drummond are classified as NAMS PM10 samplers, so that the requirement of three NAMS PM10 samplers in the Fresno area is satisfied.

Stockton currently has NAMS PM10 samplers at Stockton-Hazelton and at Stockton-Wagner/Holt. There are no other existing PM10 samplers in the Stockton area. The other existing stations in the area are not suitable for a NAMS PM10 sampler. Consequently, a new PM10 sampling site is being sought in the Stockton area for another NAMS PM10 sampler. The District has selected the intersection of Interstate 5 and March Lane for this site because this intersection has the highest traffic counts in the Stockton area and is near the industrial area of Stockton. This sampler will be a middle scale and high concentration PM10 sampler.

Bakersfield is required to have a minimum of three NAMS PM10 samplers, but currently has no PM10 samplers designated as NAMS. The District suggests that the PM10 sampler at Bakersfield-Golden State be designated a NAMS PM10 monitor because this station is near the downwind edge of the central business district and samples high particulate concentrations. The District also suggests that the Bakersfield-California station be reclassified as a NAMS PM10 sampler. Also if the ARB SLAMS PM10 sampler at Oildale-Manor were to be reclassified as a NAMS PM10 sampler, then the Bakersfield area would be in compliance with PM10 NAMS requirements.

### **Particulate Matter Sampling Frequency**

EPA requires that ongoing analysis of PM10 data from throughout the network be conducted to determine if the monitoring schedule meets the minimum sampling frequency requirements of Title 40, Code of Federal Regulations, Part 58.13. All PM10 monitoring in the San Joaquin Valley was conducted on the sixth-day minimum schedule required by EPA and the ARB. PM2.5 scheduling varied according to season. Sampling frequency for April-September was every six days and rose to every third day for the months of October-March.

During California Regional PM10/PM2.5 Air Quality Study (CRPAQS) field studies, selected sites had additional collocated monitoring to establish a one-in-three day sampling schedule. CRPAQS also provides a period with additional PM2.5 monitoring. During intensive episodes forecasted during CRPAQS additional continuous and filter based measurements were also collected. The Study is intended to provide products to support the development of effective PM10 and PM2.5 attainment plans for Central California. It is uniquely positioned to produce needed data within the implementation schedule specified for the new PM standards. The information developed will allow apportionment of high PM10 and PM2.5 concentrations to contributing sources.

## **Particulate Matter Speciation from Filter Samples**

The Selective Size Inlet (SSI) high-volume PM10 sampler is designated as Federal Reference Methods (FRMs). The District does not accept the Tapered Element Oscillating Microbalance (TEOM) and the Beta Attenuation Monitor (BAM) as equivalent for measurements in the San Joaquin Valley. Due to the extensive contribution of nitrate particulates in many events and considerable disagreement with observed sample masses, the District is not prepared to utilize the data from TEOM and BAM samplers as equivalent at this time. The District and ARB do not use BAM and TEOM data to determine attainment of the standard. The data from TEOMs and BAMs are used only as a relative indicator of hourly PM10 concentration, and to give an indication of levels on days when FRMs are not operating. The data from these instruments are also used for agricultural burning decisions and Air Quality Index (AQI) forecasting. Speciated particulate data can be obtained from both the exposed SSI and dichotomous (dichot) sampler filters. The SSI filters are made of quartz fibers and can be speciated to determine ammonium, chloride, nitrate, sulfate, and potassium concentrations, as well as total and organic carbon. The dichot filters are made of Teflon and are used to determine concentrations of elemental species. For a complete particulate speciation, both SSI and dichot filters must be analyzed. Dichot sampling was discontinued due to resource constraints, replacement by, overlap with and imperfect correlation to FRM sampling. Dichot sampling was discontinued in 2000, except for the Fresno-First site. The termination of dichot sampling unfortunately decreases available sample media for full speciation.

## **Real-time Particulate Matter Monitoring**

The District and the ARB are concerned about the lack of real-time Particulate Matter data in the San Joaquin Valley, particularly since the District is classified as serious non-attainment of the federal PM standards. In an effort to gather real-time hourly data, ARB is currently operating continuous PM10 monitors at Fresno-First and Stockton-Hazelton. ARB collects daily PM2.5 data at Fresno-First and Bakersfield-California.

BAM PM2.5 monitors are located at Bakersfield-California, Fresno-first, Modesto-14<sup>th</sup> Street, and Visalia-Church. The District has TEOM PM10 monitors at Clovis-Villa and Corcoran-Patterson. Also, since April 2002 the Corcoran-Patterson site is gathering real-time PM10 and PM2.5 data from Beta Attenuation Monitors (BAM). The data gathered by these units is being used to document diurnal variations in Particulate matter concentrations and document PM10 concentrations for Air Quality Index (AQI) reporting and forecasting. As previously discussed, the BAM and TEOM data will not be used to determine attainment of the Particulate Matter standards.

## **Variations in Ambient Data**

Ambient air quality samples suggest different causes of elevated PM10 levels. Particulate types include: directly emitted particulates and secondarily formed particulates such as ammonium nitrates and sulfates. Ambient monitoring samples are analyzed to determine the chemical make-up of the PM10 collected on the filter. Two different types of spatial distributions of PM10 and two different periods of the year are identified significant.

The first type of episode is of a local or sub-regional nature. These events generally consist of primary PM10 and occur in the fall. The second type of episode distribution is of a regional nature. Air monitoring data indicates that when meteorological conditions produce little or no air movement, secondary particulate levels (largely ammonium nitrate) are elevated in the entire Valley.

The first of the two periods of the year is during the months of October, November, and December. The PM10 during this period is dominated by primary particulates. One species of primary particulates (primary geologic) comprises the highest portion (at least two thirds) of the samples taken during this period. Primary geologic is simply dust generated from dirt that is under ten microns in size. Sources contributing to elevated geologic dust include paved and unpaved roads, construction activities, and agricultural operations. Seasonal transition date can be mid November to mid December. Nitrates start increasing in mid November, geologic materials do not decline until there is significant rainfall, which can occur anytime from mid November to mid December.

The second elevated PM10 period of the year begins mid November to mid December and extends through February. The samples during this period are dominated by secondary particulates (often 70 percent or more of the material found on a filter). Secondary particulates are particles that are the end products of many chemical reactions that occur in the atmosphere. Precursors, the chemicals that are involved in the chemical reactions, are NO<sub>x</sub>, VOC, SO<sub>x</sub> and ammonia.

Meteorological conditions have a direct influence on these two periods. Generally, during the first period, rain has not occurred and it is characterized by low wind speeds and stagnant air. The second period is characterized by extended periods of stagnant air interspersed with cold, damp, foggy conditions conducive to the formation of particulate nitrate in amounts that are frequently the dominant component of PM10. Both periods commonly experience stagnant conditions. During a stagnant period, primary geologic or secondary particulates accumulate, resulting in concentrations, which eventually exceed the PM10 standard.

A third type of exceedance can also occur in the Valley. This type of exceedance is caused by high winds that lift dust into the air. Although these do not occur often, they can occur once every few years at any time during the year. District monitors have not detected elevated levels of concern from this type of event in recent years.

## **Diurnal Variations**

Traditional monitors require someone to physically visit a site and change the filters. This requirement influences the District's sampling frequency of a one-in-six day monitoring schedule. During one special study as part of the California Regional PM10/PM2.5 Air Quality Study, Integrated Monitoring Study-1995 (IMS95), special monitors were run on a daily basis for approximately one month with the filters being changed every three hours. This sampling process provides data that can be analyzed to provide information about the variability of PM10 throughout the day. New technologies are being developed to allow data to be collected in real time.

IMS95 data showed that in urban areas, the greatest concentrations of PM10 during December and January are measured in the evening hours after most people arrive home from work. This data suggest that PM10 could be emitted and forming at increased rates during the evening hours (6:00 PM through midnight). Other findings from CRPAQS have already been incorporated in our discussions of our understanding of seasons, episode development and patterns.

## **Transport**

PM10 originating from or going to other air basins, referred to as pollutant transport, has not been definitively quantified. PM10 readings in the SJVAB are most severe during the fall and winter periods when wind speed and direction are not conducive to interregional transport. Monitoring and speciation techniques currently available are not able to identify the origin of PM10 sources with sufficient detail to indicate if the SJVAB is experiencing transport from outside the air basin or contributing transport of PM10 to other air basins. Transport of some PM10 precursors has been studied as part of ozone transport evaluation, identifying transport of ozone and ozone precursors from and to other air basins surrounding the SJVAB. The transport of ozone was documented during the summer when the highest ozone readings are more likely to occur. This transport includes precursors of ozone and PM10; however, the amount of PM10 that could be generated in the SJVAB or other air basins from such transport has not been quantified. Pollution from areas outside of the Valley may or may not contribute to high PM10 levels within the Valley.

## **Trend Analysis**

The San Joaquin Valley Air Basin has followed the national trend of declining PM10 levels since the 1980s, with relatively stable values over the last few years. The national long term trend of declining PM10 values and the unusual nature of recent meteorological influences of El Niño and La Niña affect District PM10 trends. The SJVAB also experiences periods of long-term drought that would be expected to increase the geologic component of PM10 by decreasing soil moisture and increasing

the emission factors for sources that generate fugitive PM10 emissions. Complex meteorological phenomena make it challenging, if not impossible, to differentiate between improvements made in ambient air quality due to regulatory actions and voluntary emission reduction projects, and those improvements due to unusual meteorological effects.

**Table 2**  
**Trend Data: PM10 24-Hour Maximum**  
**Micrograms/m<sup>3</sup>**

Station Name	1995	1996	1997	1998	1999	2000	2001
<b>Bakersfield-California</b>	130	153	137	148	143	140	190
<b>Bakersfield-Golden State</b>	132	153	124	159	183	145	205
<b>Clovis-Villa</b>	120	108	103	113	151	114	155
<b>Corcoran-Patterson</b>	---	141	199	128	174	128	165
<b>Fresno-Drummond</b>	126	121	121	132	162	138	186
<b>Fresno-First Street</b>	122	144	124	141	154	138	193
<b>Hanford-Irwin</b>	185	120	143	146	143	119	185
<b>Merced-2334 M Street</b>	---	---	---	---	134	104	113
<b>Modesto-I Street</b>	115	133	119	61	---	---	---
<b>Modesto-14<sup>Th</sup> Street</b>	---	74	---	125	132	112	158
<b>Oildale-Manor</b>	195	138	125	103	156	122	158
<b>Stockton-Hazelton</b>	109	127	98	106	150	91	140
<b>Stockton-Wagner/Holt</b>	---	117	130	99	118	104	119
<b>Taft-College</b>	93	94	78	84	101	99	128
<b>Turlock-Minaret</b>	120	122	111	108	157	104	148
<b>Visalia-Church Street</b>	128	115	96	160	152	130	143

Notes: PM10 Federal 24-Hour Standard is 150 micrograms/m<sup>3</sup>

**Table 3**

**PM10 Monitoring Stations in the SJVAPCD**

Site Name	AIRS Site Code	Method Code	Sampling Interval/Frequency	Scale	Monitoring Objective	Type	Agency
Bakersfield-California	06 029 0014	063	24 Hour/6-day	Middle	Representative Conc.	SLAMS	ARB
Bakersfield-Golden St	06 029 0010	063	24 Hour/6-day	Neighborhood	High Concentration	SLAMS	SJVAPCD
Clovis-Villa	06 019 5001	063	24 Hour/6-day	Neighborhood	Representative Conc.	NAMS	SJVAPCD
Corcoran-Patterson	06 031 0004	063	24 Hour/6-day	Neighborhood	High Concentration	SLAMS	SJVAPCD
Fresno-Drummond	06 019 0007	063	24 Hour/6-day	Neighborhood	Representative Conc.	NAMS	SJVAPCD
Fresno-First Street	06 019 0008	063	24 Hour/6-day	Neighborhood	High Concentration	NAMS	ARB
Hanford-Irwin	06 031 1004	063	24 Hour/6-day	Neighborhood	Representative Conc.	SLAMS	SJVAPCD
Merced-2334 M Street	06 047 2510	063	24 Hour/6-day	Neighborhood	Representative Conc.	SLAMS	SJVAPCD
Modesto-14 <sup>th</sup> Street	06 099 0005	063	24 Hour/6-day	Neighborhood	Representative Conc.	SLAMS	ARB
Oildale-Manor	06 029 0232	063	24 Hour/6-day	Middle	Source Impact	SLAMS	ARB
Stockton-Hazelton	06 077 1002	063	24 Hour/6-day	Neighborhood	High Concentration	NAMS	ARB
Stockton-Wagner/Holt	06 077 3010	063	24 Hour/6-day	Neighborhood	Representative Conc.	NAMS	SJVAPCD
Taft College	06 029 2004	063	24 Hour/6-day	Neighborhood	Representative Conc.	SLAMS	SJVAPCD
Turlock-Minaret	06 099 0006	063	24 Hour/6-day	Neighborhood	Representative Conc.	SLAMS	SJVAPCD
Visalia-Church	06 107 2002	063	24 Hour/6-day	Neighborhood	Representative Conc.	SLAMS	ARB

**Table 4**

**PM2.5 Monitoring Stations in the SJVAPCD**

Site Name	AIRS Site Code	Sampling Interval/Frequency	Scale	Monitoring Objective	Type	Agency
Bakersfield-California	06 029 0014	24 Hour/Daily	Neighborhood	Representative Conc.	SLAMS	ARB
Bakersfield-Golden St	06 029 0010	24 Hour/X	Neighborhood	Representative Conc.	SLAMS	SJVAPCD
Bakersfield-Planz	06 029 0016	24 Hour / 3 <sup>rd</sup> day	Neighborhood	Representative Conc.	SLAMS	ARB
Clovis-Villa	06 019 5001	24 Hour/X	Neighborhood	Representative Conc.	SLAMS	SJVAPCD
Corcoran-Patterson	06 031 0004	24 Hour/X	Neighborhood	Representative Conc.	SLAMS	SJVAPCD
Fresno-First Street	06 019 0008	24 Hour/Daily	Neighborhood	Representative Conc.	NAMS	ARB
Fresno-Hamilton/Winery	06 029 5025	24 Hour/X	Neighborhood	Representative Conc.	SLAMS	SJVAPCD
Merced-2334 M Street	06 047 2510	24 Hour/X	Neighborhood	Representative Conc.	SLAMS	SJVAPCD
Modesto-14 <sup>th</sup> Street	06 099 0005	24 Hour/ 3 <sup>rd</sup> day	Neighborhood	Representative Conc.	SLAMS	ARB
Stockton-Hazelton	06 077 1002	24 Hour/ 3 <sup>rd</sup> day	Neighborhood	Representative Conc.	SLAMS	ARB
Visalia-Church	06 107 2002	24 Hour/ 3 <sup>rd</sup> day	Neighborhood	Representative Conc.	SLAMS	ARB

X=Sampling frequency for Apr-Sep is every six days and increases to three for the months of Oct-Mar.

**Table 5**

**SJVAPCD 1999-2001  
 Days Exceeding the 24-Hour PM10 NAAQS**

Data from 1999-2001 is used to establish design values for the SIP

<b>Date</b>	<b>Monitoring site</b>	<b>Concentration (<math>\mu\text{g}/\text{m}^3</math>)</b>
January 12, 1999	Oildale	156
October 21, 1999	Fresno—East Drummond	162
	Corcoran	174
	Turlock	157
November 14, 1999	Bakersfield—Golden State Hwy	183
December 17, 1999	Corcoran	174
January 1, 2001	Fresno—East Drummond	186
	Fresno—First Street	193
	Fresno—Clovis	155
	Bakersfield—Golden State Hwy	205
	Bakersfield—California Ave	186
	Oildale	158
January 4, 2001	Bakersfield—California Ave	190
January 7, 2001	Bakersfield—Golden State Hwy	174
	Bakersfield—California Ave	159
	Corcoran	165
	Hanford	185
	Modesto 14 <sup>th</sup> Street	158
November 9, 2001	Hanford	155

## Expected Exceedances

According to the Code of Federal Regulations (CFR), Appendix K to Part 50, attainment of the federal 24-hour PM10 standard is reached when the “expected number of exceedances per year at each site is less than or equal to one” when averaged over three or more years. This calculation is intended to compensate for the possibility of missing the measurement of one or more exceedances of the standard when sampling is not performed on a daily basis.

**Table 6**

<b>Federal PM10 24 Hour Standard Expected Exceedance Days</b>			
<u>Site</u>	Last year of data	Expected Number of Exceedance Days (3-year average)	Attainment Status
<i>Bakersfield-5558 CA</i>	<i>2001</i>	<i>3.0</i>	<i>nonattainment</i>
<i>Bakersfield-Gold</i>	<i>2001</i>	<i>6.0</i>	<i>nonattainment</i>
<i>Clovis</i>	<i>2001</i>	<i>2.0</i>	<i>nonattainment</i>
<i>Corcoran-Patterson</i>	<i>2001</i>	<i>4.6</i>	<i>nonattainment</i>
<i>Fresno-Drummond</i>	<i>2001</i>	<i>4.8</i>	<i>nonattainment</i>
<i>Fresno-First</i>	<i>2001</i>	<i>2.0</i>	<i>nonattainment</i>
<i>Hanford-Irwin St</i>	<i>2001</i>	<i>4.2</i>	<i>nonattainment</i>
Merced-M	2001	0.0	attainment
<i>Modesto-14th St</i>	<i>2001</i>	<i>0.9</i>	<i>attainment</i>
<i>Oildale</i>	<i>2001</i>	<i>3.1</i>	<i>nonattainment</i>
Stockton-Hazelton	2001	0.0	attainment
Stockton-WH	2001	0.0	attainment
Taft	2001	0.0	attainment
<i>Turlock</i>	<i>2001</i>	<i>3.8</i>	<i>nonattainment</i>
Visalia	2001	0.0	attainment
<b><u>Combined Sites</u></b>			
<i>Bakersfield</i>	<i>2001</i>	<i>2.9</i>	<i>nonattainment</i>
<i>Corcoran</i>	<i>2001</i>	<i>4.3</i>	<i>nonattainment</i>
<i>Hanford</i>	<i>2001</i>	<i>4.5</i>	<i>nonattainment</i>
<i>Modesto</i>	<i>2001</i>	<i>0.9</i>	<i>attainment</i>
Note: Italicized type represents sites that have data modified by use of one or more of the following: collocated monitors, Stratified sampling schedule, and/or substitution policy.			

**Table 7**

**PM10 Annual Arithmetic Average  
 Micrograms/m<sup>3</sup>**

Station Name	1995	1996	1997	1998	1999	2000	2001
Bakersfield-California	49.7	43.2	41.6	37.7	47.6	45.3	47.1
Bakersfield-Golden State	58.0	54.1	46.5	47	59.3	53.6	57.1
Clovis-Villa	39.9	35.7	39.0	32.7	46.6	39.4	40.6
Corcoran-Patterson	----	52.0	48.1	36.0	52.2	46.9	44.4
Fresno-Drummond	49.0	39.3	46.7	38.6	53.1	45.9	49.4
Fresno-First Street	46.0	37.4	42.6	33.2	44.6	40.5	38.3
Hanford-Irwin	53.8	40.9	46.2	38.3	53.4	46.6	45.8
Merced-2334 M Street	---	---	---	---	49.3	34.9	36.6
Modesto-I Street	37.8	28.9	39.1	40.7	39.4	34.1	33.3
Modesto-14 <sup>th</sup> Street	---	25.6	26.5	25.8	31.5	26.5	24.1
Oildale-Manor	46.6	36.1	39.6	36.5	48.4	40.7	46.0
Stockton-Hazelton	28.6	27.4	29.7	29.1	36.4	30.8	34.4
Stockton-Wagner/Holt	----	29.2	26.1	25.7	33.9	29.3	29.2
Taft-College	38.5	34.4	30.9	29.0	34.3	34.1	37.0
Turlock-Minaret	41.6	32.0	37.1	30.9	45.9	33.9	36.9
Visalia-Church Street	53.6	44.8	41.5	39.8	54.9	52.7	51.5

Note: This data is from the ARB public information web site and was prepared using simplified techniques that result in minor variations from averages prepared with federal procedures. PM10 Federal Annual Arithmetic Average Standard is 50 micrograms/m<sup>3</sup>

**Table 8**

<b>Federal PM10 Annual Standard Attainment Status</b>				
<b><u>Site</u></b>	<b>Last year of data 3-year Average</b>		<b>Attainment</b>	
Bakersfield-5558 CA	2001	46		yes
<b>Bakersfield-Gold</b>	<b>2001</b>	<b>55</b>		<b>no</b>
Clovis	2001	43		yes
Corcoran-Patterson	2001	49		yes
Fresno-Drummond	2001	50		yes
Fresno-First	2001	42		yes
<b>Hanford-Irwin St</b>	<b>2001</b>	<b>51</b>		<b>no</b>
Merced-M	2001	40		yes
Modesto-14th St	2001	37		yes
Oildale	2001	46		yes
Stockton-Hazelton	2001	35		yes
Stockton-WH	2001	33		yes
Taft	2001	37		yes
Turlock	2001	40		yes
<b>Visalia</b>	<b>2001</b>	<b>54</b>		<b>no</b>
<b><u>Combined Sites</u></b>				
<b>Bakersfield</b>	<b>2001</b>	48		yes
<b>Corcoran</b>	<b>2001</b>	49		yes
<b>Hanford</b>	<b>2001</b>	<b>53</b>		<b>no</b>
Modesto	2001	37		yes

### Statistical Analysis

Evaluation using a variety of accepted statistical methods will be conducted with air monitoring data and other data identified as related to high concentrations of particulates. The evaluation will examine the factors related to known and observed episodes and assess the representativeness and comprehensiveness of monitored exceedances. Evaluation of components of the mass on PM10 and PM2.5 filters is being conducted to establish an analysis of episode sources to compare and contrast to receptor modeling with the Chemical Mass Balance (CMB) model. Results of this analysis provide evaluation of: sufficiency of available data to establish reliable conclusions, identification of potential event types that require supplemental evaluation to determine control program sufficiency, and reasonableness of results of other methods. Most of this analysis is being conducted by ARB with additional evaluation of geologic components through a contract with Countess Environmental.

Countess Environmental has accepted a contract to develop further understanding of the impact of fugitive geological dust on ambient PM10 concentrations in the SJV Air Basin by quantifying the temporal and spatial variations in ambient fugitive geological dust concentrations, the variability in the chemical composition of fugitive geological dust, and the variation in the coarse to fine size fractions of fugitive geological dust. This project will utilize recent ambient PM10 monitoring mass and element concentrations data from the CRPAQS monitoring network to address the impact of fugitive geological dust on ambient PM10 concentrations in the SJV Air Basin.

Implementing control measures for fugitive dust emissions of geological origin has been identified as an essential element to attain both the 24-hour and annual NAAQS PM10 standards. This is especially true for the Corcoran, Hanford, and Oildale sites where the contributions from geological sources are highest in the fall, and range between 52% and 72% for the 24-hour PM10 design values for these three sites (SJVAPCD, 2001). Since geological driven events tend to be localized, PM10 exceedances have generally occurred more frequently and in higher concentrations in urban areas than in non-urban areas due to anthropogenic activities that result in mechanical entrainment of fugitive geological dust. Stagnation events where the wind speeds are insufficient to disperse high PM10 concentrations also contribute to PM10 exceedances. Although windblown dust events are not typical within the Air Basin, they have occurred and have contributed to high PM10 concentrations.

The 2000 PM10 emissions inventory for the SJV Air Basin indicates that approximately 75% of the daily 481 tons per day of PM10 (on an annual basis) are due to open area fugitive geological dust sources. Anthropogenic sources (paved and unpaved road dust, farming operations, and construction/demolition) account for approximately 86% of the fugitive geological dust PM10 emissions, and wind erosion of exposed surfaces of geological material accounts for the balance as represented in the emissions inventory. However, these fugitive geological dust emissions estimates overstate the impact of these emissions on downwind ambient PM10 concentrations by a factor of two to four since the models used to predict the ambient PM10 concentrations do not account for aerosol loss mechanisms such as deposition and impaction

The Countess Environmental project will analyze:

- All the available PM10 Minivol mass and element data (i.e., sampler code: g) from PM10 Minivols operated during the period 12/01/99 through 1/31/01 with a sampling schedule of one 24-hour sample every third day at the following seven sites throughout the SJV Air Basin: Bakersfield, Corcoran, Fresno, Hanford, Modesto, Oildale, and Visalia.
- PM10 Minivol and PM2.5 Minivol mass and element data available from the four sites with collocated PM10 and PM2.5 Minivols (Corcoran, Modesto, Oildale, and Visalia) in order to calculate the PM10/PM2.5 and CM/PM2.5 ratios of ambient concentrations of fugitive geological dust, where CM is the coarse mass concentration between 2.5 and 10 microns.

The Countess Environmental project will emphasize evaluation of:

- Temporal, spatial and chemical variations in fugitive geological dust concentrations as indicators of different fugitive geological dust sources and different source strengths; and
- Variations in the ratio of coarse to fine size fractions of fugitive geological dust as indicators of the age of the resuspended dust as well as indicators of different fugitive geological dust sources.

Anticipated tangible benefits of the project include:

- Quantification of the contribution of fugitive geological dust to ambient PM10 concentrations within the San Joaquin Valley;
- Characterization of the temporal variation and spatial variation of ambient fugitive dust concentrations within the Valley;
- Characterization of the variation in chemical composition of the ambient fugitive dust concentrations within the Valley;
- Characterization of the zone of influence for sources of road dust and agricultural dust in the Corcoran/Hanford area during the Fall; and
- Characterization of the variation in the ratio of the coarse to fine fugitive dust aerosol size fractions. This ratio may serve as an important tool to provide estimates of the age of the fugitive dust, and/or to distinguish between different source categories contributing to the ambient fugitive dust in the Valley.

## Data: Design Value Determinations

PM10 concentrations in the San Joaquin Valley vary between sites and seasons with regard to sample speciation and contributions from specific source types. For this reason, use of a single design value for the entire San Joaquin Valley is not appropriate. As indicated by applicable EPA guidance the design concentration is the ambient PM10 level for a particular site that must be reduced to the level of the NAAQS. The PM10 annual and 24-hour NAAQS require two separate design concentrations, one for each standard per site. The annual design concentration is the expected annual arithmetic mean. The uncertainty in the design concentration estimate is reduced to the extent that sufficient, representative meteorological and monitoring data are available. At least three years of representative air quality measurements are considered in determining 24-hour design concentrations. The ambient PM10 data collected by hi-volume sampler with a size selective inlet (SSI) is used as the PM10 mass for record. The highest concentrations observed with an SSI sampler on a one-in-six day sampling schedule from the most recent years of data collection provide the design values for each NAAQS site in the Valley.

**Table 9**

<b>Federal 24-Hour PM10 Design Values</b>				
<b>Site Name</b>	<b>Design Value</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>
Bakersfield, California Ave.	<b>190</b>	143	140	<b>190</b>
Bakersfield-Golden #2	<b>205</b>	183	145	<b>205</b>
Clovis	<b>155</b>	151	114	<b>155</b>
Corcoran, Patterson Ave.	<b>174</b>	<b>174</b>	128	165
Fresno-Drummond	<b>186</b>	162	130	<b>186</b>
Fresno-First	<b>193</b>	154	138	<b>193</b>
Hanford, Irwin St	<b>185</b>	143	119	<b>185</b>
Merced-M Street	134	<b>134</b>	104	113
Modesto, 14th Street	<b>158</b>	132	112	<b>158</b>
Oildale, 3311 Manor St	<b>158</b>	156	122	<b>158</b>
Stockton, Hazelton-Hd	150	<b>150</b>	91	140
Stockton, Wagner-Holt	119	118	104	<b>119</b>
Taft, College	128	101	99	<b>128</b>
Turlock, 900 Minaret Street	<b>157</b>	<b>157</b>	104	148
Visalia, Church Street	152	<b>152</b>	130	143

Design Value Column – bold indicates value exceeds standard

Year Columns - bold indicates observed value that set the Design Value

The first of four options allowed by federal guidance was used to calculate the design values for the 24-hour standard. The method used is the highest measured value in the three years under consideration. Other allowed methods either are not supportable by the number of data points collected or produce an artificial value not based on an actual observation that is higher than the observed values.

Only eight of the 15 sites had complete data sets for establishing the annual design value. These sites are: Bakersfield-CA, Clovis, Corcoran, Fresno-First, Modesto-14<sup>th</sup> Street, Oildale, Stockton-Hazelton, and Visalia. Calculating the design value is simple for sites with a complete data set. The procedures are found in 40 CFR Part 50, Appendix K.

- Determine that you have a complete data set (75% or greater data capture during each calendar quarter)
- Truncate all decimals
- Average each quarter
- Average the four quarters together for an annual average
- Average the three annual averages together to determine the design value

**Table 10**

Federal Annual Average PM10 Design Values		
Site Name	Design Value Calculated by SJVAPCD	Design Value Reported in EPA Notice
Bakersfield, California Ave.	48	
Bakersfield-Golden #2	<b>57</b>	<b>55</b>
Clovis	43	
Corcoran, Patterson Ave.	49	
Fresno-Drummond	50	<b>47-53</b>
Fresno-First	42	
Hanford, Irwin St	<b>53</b>	<b>51</b>
Merced-M Street	40	
Modesto, 14th Street	37	
Oildale, 3311 Manor St	46	
Stockton, Hazelton-HD	35	
Stockton, Wagner-Holt	30	
Taft, College	36	
Turlock, 900 Minaret Street	39	
Visalia, Church Street	<b>54</b>	<b>54</b>

Design Value – bold indicates value exceeds standard

If non-scheduled monitoring was done in a quarter, such as at Visalia, then additional calculations are necessary.

Four of the seven sites with missing data (Merced, Stockton-Wagner Holt, Taft, and Turlock) have very low PM10 levels that will clearly be in compliance with the standard using any calculation method. At Merced, Stockton-Wagner Holt, and Taft; the data incompleteness was patched according to approved EPA methodology. The data (for the quarter of the year with missing or incomplete data) was replaced by determining the highest quarterly average for that quarter of the year from other years of data and substituting that maximum quarter value for the missing quarter or incomplete quarter.

Due to the importance of establishing a correct design value for non-attainment sites, the other three sites required special calculations to establish realistic substitution values for missing data. For example: the Bakersfield-Golden #2 site is nonattainment of the annual standard. The third quarter of 2001 is incomplete with only 7 of 15 samples collected. To establish nonattainment, the approved procedure is to substitute one-half of the minimum detection limit ( $2.5 \mu\text{g}/\text{m}^3$ ) for each of the seven missing samples, then follow the averaging procedures. The result of  $55 \mu\text{g}/\text{m}^3$  clearly demonstrates that the site is nonattainment; however, it is not a realistic design value because it underestimates the values that would have been collected. The design value was calculated by substituting the highest third quarter average of the two complete third quarters ( $59.40 \mu\text{g}/\text{m}^3$ ). This produces a design value of  $57 \mu\text{g}/\text{m}^3$ .

### **Evaluation of Design Values**

As deemed necessary from evaluation of data, design values will be defined for each season or site in the Valley for which substantially different combinations of sources are shown to be contributing to the PM10 mass if these differences require substantially different attainment demonstrations.

Analysis of the episodes involves review meteorological analysis of the event and filter analysis of chemical components measured during the episode, or similar episodes if species data are not available for the episodes of interest. Results of meteorological and component analysis will be synthesized to establish similarities and differences of episodes and seasons. This information helps in assessing what reductions in emissions are needed and will be effective for the different sites and types of episodes.

## **Data: Off-Site Use Justification**

Data additional to the NAMS and SLAMS monitoring data have been utilized to enhance understanding of PM-10 sources and characteristic patterns. This information was used to assist in the development of effective control strategies for the SIP but does not qualify for use to establish design values or demonstrate attainment. Data from equipment or sites that do not meet SLAMS criteria is considered as supplementary data to be used to analyze the sources and components of ambient PM-10 samples and to analyze episodes of high ambient PM-10 to increase the understanding of significant factors and determine effectiveness of control strategies to achieve and maintain attainment of the PM-10 NAAQS.

Evaluation using a variety of accepted statistical methods will be conducted with air monitoring data and other data identified as related to high concentrations of particulates. Supplemental field program sample collection at District sites and other temporary monitoring locations will be included. The evaluation will examine the factors related to known and observed episodes and assess the representativeness and comprehensiveness of monitored exceedances. Evaluation of components of the mass on PM10 and PM2.5 filters is being conducted to establish an analysis of episode sources to compare and contrast to receptor modeling with the Chemical Mass Balance (CMB) model. Results of this analysis provide evaluation of: sufficiency of available data to establish reliable conclusions, identification of potential event types that require supplemental evaluation to determine control program sufficiency, and reasonableness of results of other methods.

As part of the California Regional PM10/PM2.5 Air Quality Study, an integrated field monitoring study (IMS) was conducted during the winter of 1995. The objectives of the IMS are to: 1) support the objectives of several planning studies comprising the core of the IMS, 2) develop a refined conceptual model of winter-like exceedances, and 3) provide a database for preliminary modeling and data analysis. Daily PM10 and PM2.5 monitoring with three-hour resolution were conducted at four core air quality sites located in the region between Fresno and Bakersfield. Samples were analyzed for mass, ions, elemental and organic carbon, and elemental constituents. These data were supplemented with collection of fog measurements, surface and aloft meteorological data, measurement of gaseous precursors, and saturation sampling. CRPAQS collected extensive data during the period of December 1999 to February 2001. This data is still being quality assured and entered into a common database. Analysis and modeling of the main CRPAQS database will occur over at least the next two years. CRPAQS data is used to better understand the PM10 problem in the Valley and identify methods to reduce PM10 concentrations.

## **California Regional PM10/PM2.5 Air Quality Study**

The California Regional PM10/PM2.5 Air Quality Study is a comprehensive public/private sector collaborative program whose goals are to provide an improved understanding of particulate matter and visibility in central California and to provide decision-makers with the tools needed to identify equitable and efficient control methods. The study is intended to evaluate both the national and State air quality standards for particulate matter smaller than 10 microns in diameter (PM10) and the new national standards for particulate matter smaller than 2.5 microns (PM2.5), which are consistently exceeded in central California. This adverse air quality compromises the health of the more than 10 million people living in the region, reduces visibility, affects crop yields, causes materials damage, and adversely impacts quality of life.

The information developed by the study will allow apportionment of high PM10 and PM2.5 concentrations to contributing sources, thereby avoiding burdens on the regulated community from excess or ineffective control requirements. Implementation of the control plans that are improved by analysis of study data will result in significant improvements in visibility, and the health and well being of the citizens of central California.

The study has involved extensive planning and preparatory research. Early projects included literature review of previous studies, development of conceptual models for episode behavior, a multi-year assessment of agricultural practice contributions to particulate emissions, a preliminary field monitoring program known as the 1995 Integrated Monitoring Study (IMS95) that evaluated our conceptual understanding of particulate episodes and evaluated monitoring equipment and data collection needs, analysis and modeling of historical and IMS95 data to improve our understanding through analysis of collected data, and emission inventory development and improvements.

Based upon extensive analysis of data from the 1995 Integrated Monitoring Study and the improved understanding gained from this and other early elements, a major field program was designed and undertaken to address fall and winter particulate matter episodic conditions as well as annual average particulate matter assessment. Input to the design of the field program was solicited from regulatory agencies, data analysts and modelers, and the research/contracting community. The objective of the field program, as with the earlier efforts, was to obtain a documented data set, with appropriate data qualification statements, suitable for characterizing the nature and causes of particulate concentrations and visibility impairment in central California by supporting modeling and data analysis activities.

The field program commenced in December of 1999 and continued through February of 2001. The monitoring consisted of 14 months of data collection throughout the San Joaquin Valley (SJV) and surrounding regions, as well as intensive, shorter-term monitoring during fall and winter-like episodic conditions when PM10 and PM2.5

concentrations are highest. The program established an array of monitoring throughout the period, enhanced during summer months along with a companion ozone study (Central California Ozone Study) and considerably expanded during the fall and winter with intensive data gathering and monitoring operations.

Air quality sampling locations for the annual monitoring program built upon and took advantage of, the extensive existing PM10 network, as well as the new PM2.5 monitoring networks established by the Air Resources Board and local air pollution control districts. More than 70 PM10 sites and 50 PM2.5 sites comprised this backbone network. Study enhancements to these networks included full scale “anchor” monitoring sites measuring gaseous and aerosol species, through both filter-based and continuous species specific methods. In addition, “satellite” monitoring sites measured aerosol species using portable PM monitors and nephelometers. Surface and aloft meteorological measurements were collected utilizing a network of surface meteorological sites, radar profilers, and sodars. A special 100-meter tower collected data at several elevations on meteorological and air quality parameters.

The fall episodic program took place in October and November of 2000 in the central portion of the San Joaquin Valley. This monitoring window corresponds to periods of historically high PM10 concentrations that are dominated by geological material. Specific issues addressed in the fall monitoring program included identification of the sources of geological material, determination of the zone of influence of these sources, and development of improved data on dust suspension and deposition. The fall measurement program included neighborhood scale saturation monitoring and measurement of organic species and particle morphology.

The winter episodic field study took place during December 2000 through February 2001. PM2.5 concentrations have been historically highest during the winter months, with secondary ammonium nitrate and carbonaceous material the dominant constituents. Specific issues addressed in the winter monitoring program included identification of the sources of carbonaceous material, determination of the limiting precursors for secondary PM species, surface and aloft transport and mixing mechanisms under low wind speed conditions, and the zone of influence of both primary and secondary sources of PM. The winter measurement program included an expanded set of anchor sites, and an enhanced upper-air monitoring network. On days forecasted to have the highest PM concentrations, additional special measurements were collected including organic species tracers, fog chemistry, time-of-flight mass spectrometry, and measurement of wet deposition. Special emphasis was placed on collection of continuous and species-specific particulate measurements to support both receptor and grid-based modeling approaches. Methods for collecting information on air quality aloft included use of the 100-meter tower, an elevated site in the Sierra Nevada mountains, and a remotely piloted blimp, which has been specially designed to fly under low visibility, stagnant conditions.

Episode specific and enhanced emission inventory estimation data was also collected. Several projects were targeted at collecting improved information for transportation

sources, including development of updated chemical speciation profiles, and vehicle traffic counts. Other emissions projects include development of a GIS-based ammonia inventory, and collection of day-specific emissions. A comprehensive emissions inventory for the region is being developed to complement the field measurements.

Analysis and modeling of the data collected during the field program will be carried out over the next few years. Processing the data into a centralized database and quality assurance evaluation of the data is already in progress. Data analysis contracts have already been initiated and early modeling efforts are in progress.

## Model: Selection Justification

While there are several techniques available to model the direct emission, secondary formation and dispersion of particulate matter, it is important to select a methodology that is appropriate for the San Joaquin Valley (SJV) and considers and compensates for the strengths and weaknesses of available approaches. Data requirements and availability for emissions, meteorology, and air quality as well as the validity of the representation for 24-hour and annual average PM10 concentrations must be considered in applying the appropriate approaches. Based upon availability of emission estimates, meteorology, and air quality data in the Valley, there are three fundamental methods that are available and appropriate to some extent to evaluate current and future emissions for the SIP: receptor speciated-rollback, receptor chemical mass balance and regional grid-based dispersion modeling with episode specific chemistry, photochemistry, aerosol chemistry and meteorology.

If a single source is contributing to PM10 NAAQS violations with a significant coarse fraction and identification and emission strength of that source is known, then dispersion model, such as AEROMOD, can be used to evaluate control strategies for that source. The method can be extended to include a few major well-defined sources, but Chemical Mass Balance (CMB) modeling and wind trajectory analysis to define the probable area of contributing sources to determine the available emission source types is more informative as the number of sources increases and source strengths decrease and is therefore more appropriate to model the coarse fraction of PM10. Multiple sources with low to medium source strengths are the predominant cause of PM10 NAAQS violations in the Valley. The grid-based photochemical methods, albeit being more mathematically rigorous than CMB, are not suitable for the coarse fraction because the commonly used grid spacing (approximately 4-5 km) is too large compared to mean fall-off distances (typically less than 1 km) for larger particles. However, CMB uses linear assumptions for all portions of particulate matter; which may not provide an assessment for secondary fine particles that can be relied upon for use in evaluating control measures and future year projections. Although the CMB model can determine the total amount of a secondary aerosol species, it cannot estimate specific source contributions to secondary aerosols. Photochemical modeling incorporating aerosol chemistry to determine appropriate formation ratios and relationships should be used to assess modeling of the secondary fraction.

Speciated-rollback modeling assumes that changes in ambient air concentrations are directly proportional to changes in PM10 and precursor emissions. To apply this method baseline and future years must be established and emission estimates generated for various precursor gases (reactive organic gases (ROG), SO<sub>x</sub>, and NO<sub>x</sub>) and directly emitted particulate matter (soil related components, mineral dust, primary organic carbon, elemental carbon) for each episode and area to be evaluated. The inventory is developed for the region over which emissions will affect the local air quality. This requires an evaluation of the area of influence of local sources for each

episode and determination of regional contributions to the observed concentrations. The difficulty of establishing this level of data and analysis for each episode and the dominant contribution of area sources cause this approach to be inferior to CMB for our specific case and recommend against its use for the SIP process for the SJVAB. However, aspects of the speciated rollback process can be used to enhance receptor modeling. For example, the effort to establish reasonable zones of influence for local sources can be used to enhance profile selection in receptor modeling.

Receptor chemical mass balance (CMB) modeling is an emission source reconciliation approach that relates ambient air quality measurements with emission sources that contribute to the air quality of a region. CMB modeling requires chemically speciated ambient data and emission source profiles. This data is available through dichotomous sampler operation (which has been discontinued) and CRPAQS field programs. Some of the chemical speciation data is collected using methods, samplers and chemical analysis supplemental to NAAQS monitoring. Although CMB modeling cannot identify the sources contributing to secondary particulate matter formation, the method can provide insight into the major contributors to primary PM10 as well as a bounding estimate of total secondary contributions. It is important that the CMB model use current information on source profiles because changes in fuels and control technology may make older data inappropriate. Evaluation of source profile selection including temporal and spatial evaluation of available emission sources improves expected accuracy of the method. Once the relationship between emissions and concentration is established, response to control projections and trends can be estimated using projections of future emissions to provide an equivalent projection of future concentration with a technique referred to as rollback analysis. This technique assumes linear chemistry and assumes predominance by local emissions; an assumption that may not be appropriate for secondary particulate formation which is not believed to be linear in chemistry and is known to typically have larger source zones of influence. It is therefore desirable to supplement this approach with improved assessment of aerosol chemistry involved in formation of secondary particulates.

Regional grid-based dispersion modeling with chemistry, photochemistry and aerosol chemistry is the most sophisticated and comprehensive approach. Regional grid-based models are theoretically the best type of model for SIP applications. These models have a fundamental advantage over speciated-rollback and CMB modeling because of their ability to simulate the integrated effects of emissions, meteorology, and air quality in time and three-dimensional space over large spatial areas. Grid models furthermore undergo a model performance evaluation by comparing model estimates of historical concentrations with observational data. This allows an assessment of the model's reliability to estimate ambient air concentrations. However, grid-based models require extensive input data for emissions, meteorology, and air quality for each episode to be evaluated. For each episode this requires generation of an hourly-gridded-emission inventory as well as three-dimensional meteorological data, such as winds and temperatures, and hourly boundary conditions. Three-dimensional databases are not available for the episodes; however, CRPAQS provides an extensive database for 1995 (IMS-95) that can be used to assess secondary formation ratios. A more extensive

dataset collected from 1999 to 2001 is not yet ready for similar analysis. Rather than modeling each episode's chemistry, evaluation of IMS-95 data can provide a reasonable assessment of secondary formation chemistry, providing a first order estimate of response ratios. This information can be used to address the weakest area of the CMB modeling approach.

## **EPA Guidance on Selection of Modeling Technique**

Provisions of EPA guidance allow reliance on receptor modeling when it is determined to be the most suitable approach. "The chemical mass balance (CMB) model is considered to be the most advanced of the available receptor models and its use is the most acceptable for attainment demonstration purposes." "Under certain conditions, there may be no recommended dispersion model, or the recommended model may not be applicable. For example, if area sources are the dominant contributors to ambient PM10 concentration, an attainment demonstration might be based on rollback of the apportionment derived from two reconciled receptor models. In such instances, the modeling approach must be approved by the appropriate Regional Office on a case-by-case basis." (EPA Guideline Document, pp 6-8, 1993). Previous efforts with receptor modeling identified 55 to 64 percent contribution in urban areas from "area" sources. Contributions from receptor modeling, attributed majority contribution from "soil," construction, and vegetative burning. This circumstance for the SJV supports selection of CMB modeling as the appropriate modeling technique in accordance with the recommendations of EPA guidance.

United States Environmental Protection Agency (U.S. EPA) PM10 SIP development guidelines call for an attainment demonstration of the national ambient air quality standards (NAAQS) by means of either a dispersion model or other procedure which is shown to be adequate and appropriate.<sup>1</sup> While dispersion modeling potentially provides a means to address the above questions and thereby demonstrate attainment, there are a number of limitations to its applicability in the unique San Joaquin Valley situation. These limitations include the adequacy of representing particulate matter deposition and persistence of fugitive dust, the capabilities of the model under stagnant conditions, and the accuracy of determining the absolute magnitude of fugitive dust emissions, especially under episodic conditions. EPA guidance discussing the normal use of dispersion models does not fit well with the assessment requested.<sup>2</sup>

U.S. EPA guidance recognizes that dispersion models are more reliable for estimating longer time-averaged concentration (e.g. annual average) than for estimating short-term concentrations such as 24-hour standard.<sup>3</sup> Prior analysis has determined that the 24-hour PM10 standard is the more restrictive standard for the San Joaquin Valley. The importance of this finding is that it further limits the technical applicability of dispersion modeling for use in the analysis for the PM10 SIP. The finding that the 24-hour PM10 standard is predominant will be rechecked with more recent data as a part of the PM10 SIP development.

Based upon EPA guidance for employment of dispersion modeling, evaluation of the predominant standard, and evaluation of the adequacy and accuracy of supporting information, the San Joaquin Valley Unified Air Pollution Control District (District) and the Air Resources Board (ARB) have concluded that dispersion modeling is not the most appropriate tool for demonstrating attainment of the PM10 standards in the San Joaquin Valley. U.S. EPA staff has acknowledged the limitations of dispersion modeling and has indicated their openness to a technically sound alternative to a dispersion modeling based attainment demonstration.

### **Proposed SIP Modeling Approach**

The Protocol proposes using receptor CMB modeling, supported and enhanced by regional aerosol modeling to evaluate secondary formation ratios, with profile selection for CMB modeling enhanced by assessment of local temporal and spatial emissions. The complementary suite of modeling methods we propose to employ for this is based on relying on CMB to analyze the episode specific primary fraction of PM10 and regional modeling with aerosol chemistry to provide general formation ratios for secondary particulates. CMB modeling will identify emission source contributors by chemical species, which will be used with rollback modeling to estimate reductions of emissions and emission controls needed to attain ambient standards. Rollback projection to forecast future concentrations will rely on CMB episode evaluation for primary particles and episode application of IMS-95 formation rate dynamics for the secondary fraction.

As previously referenced, EPA guidance allows for the attainment demonstration to be derived from two reconciled receptor models. The CMB receptor model, with modifications described in the preceding paragraph, provides the primary receptor model analysis. Reconciliation with alternative receptor evaluation will be accomplished by compilation of independent analyses produced from a series of elements of receptor analysis that have been previously identified and discussed within the Protocol. To reconcile with CMB receptor results, source receptor relationships will be alternatively evaluated by combining the results and findings of:

- Filter component statistical analysis performed by ARB and Countess Engineering to establish factor analysis, predominant components and variations as discussed in the Data section of the Protocol
- Meteorological analyses as discussed in the Meteorology section of this Protocol to establish source areas, episode dynamics and expected primary and secondary source contributions
- Results of the Protocol attachment "SJV Statistical Models Application 1988 to 2001" to identify predominant or predictive patterns of particulate levels and source contributions through statistical evaluation.

### **Technical Justification for Regional Modeling Approach**

Secondary particulate matter is formed in the atmosphere from gaseous precursors. It is well established through the vast experience of ozone modeling that atmospheric chemistry of secondary particulates may be non-linear and the concentrations of nitric acid (HNO<sub>3</sub>) and ammonium nitrate (NH<sub>4</sub>NO<sub>3</sub>), may not be linearly proportional to the concentrations of either NO<sub>x</sub> or VOC. Therefore, an essential component of developing emissions control strategies involves gas and particle phase photochemical modeling.

## References:

Specifically cited guidance:

<sup>1</sup> 51.112 of 40 CFR Demonstration of adequacy. As also cited by PM10 SIP Development Guideline, EPA-450/2-86-001, June 1987, section 4.1 “Section 51.12 of 40 CFR requires that the adequacy of a control strategy for attainment and maintenance of NAAQS be demonstrated by means of a dispersion model or other appropriate procedure which is shown to be adequate and appropriate for this purpose.”

<sup>2</sup> Based upon review of several guidance documents. Applicable citations include:  
Appendix W 40 CFR Part 51, sections 3.2, 7.2.2, 7.2.2d, 8.2.10, 11.1.b, 11.2.2.b approval for use of alternative models, guidance on PM modeling, limits of dispersion models, stagnation concerns, cases dispersion modeling is not acceptable, areas dominated by nontraditional sources;

PM-10 SIP Development Guideline, Supplement, June 1988, page 9 and 10 discusses treating area sources as background in dispersion modeling;

PM10 SIP Development Guideline, EPA-450/2-86-001, June 1987, page 4-10 dispersion modeling less reliable for 24 hour standard;

Example Modeling to Illustrate SIP Development for the PM10 NAAQS, EPA-450/4-87-012, May 1987, page 10 through 19 especially section 2.3.1 and section 6.4.1 small sources are added to area sources and assumed to not dominate local air quality, dispersion modeling assumes point sources to be the primary cause of Nonattainment;

Protocol for Reconciling Differences Among Receptor and Dispersion Models, EPA-450/4-87-008, March 1987, page 2 and 7, CMB is better for categories, DM for known individual sources, grouped to mimic and compare to CMB; and

EPA PM-10 Guideline Document and Appendix A & B, EPA-452/R-93-008, April 1993, especially sections 6.3, 6.5.3, and 6.7.5 predominant area sources call for rollback on receptor modeling, area sources for dispersion modeling to be based on average annual emissions – not a method intended to identify area source hot spots, reference to inappropriateness of dispersion modeling for nontraditional source in GAQM.

<sup>3</sup> PM10 SIP Development Guideline, EPA-450/2-86-001, June 1987, section 4.3.2 page 4-10. “Dispersion models are more reliable for estimating longer time-averaged concentrations (e.g., annual average) than for estimating short-term concentrations (e.g., 24-hour) at specific locations.<sup>11</sup>” Reference 11 cited by this passage is Rhoads, R. G., “Accuracy of Air Quality Models,” Memorandum to Air and Hazardous Division

Directors, U. S. Environmental Protection Agency, Research Triangle Park, NC, July 22, 1981.

List of applicable guidance reviewed:

40 CFR Appendix V 2.2 e. (7-1-92 edition, currently in force)

40 CFR Appendix W (7-1-99 edition, currently in force although newer editions are under review)

EPA PM-10 Guideline Document and Appendix A & B, EPA-452/R-93-008, April 1993

PM-10 Serious Area SIP guidance: Final Staff Work Product, September 24, 1993

EPA Receptor Model Technical Series, Volume III (1989 Revision), CMB7 User's Manual, EPA-450/4-90-004, January 1990

PM-10 SIP Development Guideline, Supplement, June 1988 (OAQPS - no number)

Response to Questions Regarding PM10 State Implementation Plan (SIP) Development, June 1988

Chemical Mass Balance Receptor Model diagnostics, EPA-450/4-88-005, April 1988

PM10 SIP Development Guideline, EPA-450/2-86-001, June 1987

Example Modeling to Illustrate SIP Development for the PM10 NAAQS, EPA-450/4-87-012, May 1987

Protocol for Applying and Validating the CMB Model, EPA-450/4-87-010, May 1987

Protocol for Reconciling Differences Among Receptor and Dispersion Models, EPA-450/4-87-008, March 1987

## **Model: Modes Used**

### **Receptor Modeling**

The EPA Chemical Mass Balance Model version 8.0 installed on a PC will be used for receptor modeling. Validation procedures for use of the model outlined in the EPA “Protocol for Applying and Validating the CMB Model” will be followed. The validation process includes the following steps:

1. Determine the general applicability of the CMB model to the application at hand.
2. Setup the model by identifying and assembling the source types, source profiles, and receptor concentrations needed for model input. Make a preliminary application of the model to these data.
3. Examine the model’s statistics and diagnostics to identify potential deviations from the model assumptions.
4. Evaluate problems that might result from problems with model input data.
5. Make model input changes which can be justified to resolve the identified problems and re-run the model.
6. Assess the stability of the model results and their consistency with the preliminary analyses.

### **Regional Modeling**

There are two available computational methods for representing secondary particulate matter formation based on internal and external mixture approximations.

Codes are available for the internal mixture approximation and ARB staff has experience using them. The internal mixture approximation represents particles of same diameter as having the same chemical composition regardless of the source. There is ample evidence to discredit this assumption, but computational efficiency for this approximation has made it a widely used method. UAM-Aero is a code based on this approximation that is readily available and has been used in previous PM10 SIP submittals. UAM-Aero will be applied to the IMS-95 database with improved emissions. The Models3/CMAQ code, also based on the internal mixture approximation, will be evaluated with a major modification to its aerosol modules in collaboration with University of California at Davis. The modifications and subsequent applications to IMS-95 may not be completed successfully and evaluated in time for submission due to the time limitation for completion of the SIP.

The external mixture approximation keeping track of particulate emissions from individual source types, overcoming the limitation of the internal mixture approximation. This gives the external mixture approximation the ability of direct source apportionment.

CIT-UCD, developed first at the California Institute of Technology and then improved at the University of California at Davis, is an external mixture approximation. This code has been applied successfully in the South Coast air basin of California. The code is being adapted to the San Joaquin Valley in collaboration with researchers at the University of California at Davis. This code is significantly more computationally intensive than those using the internal mixture approximation and we do not anticipate being able to use it routinely for this type of analysis.

If the emissions inventories for CRPAQS become available in time, we will also conduct photochemical box-model simulations to quantify the precursor limitations of  $\text{NH}_4\text{NO}_3$ .

**Regional Modeling Domain Structure:** The modeling domain does not cover the entire SJV. The available dataset from IMS-95 covers approximately 215 km east to west and 290 km north to south and extends from the Coastal Range to the crest of the Sierra Nevada and from the Tehachapi Mountains to Merced. The grid resolution used will be four-kilometer squares. The vertical grid structure will contain two layers below the mixing height and three above. The top of the domain will be placed at 2 km above ground level. There will be 54 grid cells east to west and 72 in the north to south directions.

**Choice of Chemical Mechanism:** Selecting a chemical mechanism that represents both  $\text{NO}_x$  and VOC chemistry in detail is important because  $\text{HNO}_3$  is a secondary product whose precursors are  $\text{NO}_x$  and VOC and  $\text{HNO}_3$  is one of the gaseous precursors to  $\text{NH}_4\text{NO}_3$ . Almost all chemical mechanisms available have robust  $\text{NO}_x$  chemistry but the sophistication of VOC chemistry varies widely. Of the mechanisms available to ARB, those generated at the State-wide Air Pollution Research Center (SAPRC) of University of Riverside have the best representation of VOC chemistry. There are at least three different versions of SAPRC mechanisms. ARB already has the 1990 version implemented in the air quality models. There two newer versions, 1997 and 1999, are available but it would take a considerable amount of effort to update the codes to these levels. It is worth noting that for CRPAQS modeling we will use the latest version of SAPRC mechanism available at that time.

## **Model: Analysis and Use Description**

PM10 concentrations in the San Joaquin Valley vary between sites and seasons with regard to sample speciation and contributions from specific source types. Achieving attainment requires an understanding of the seasonal variations as well as average contributions.

Analysis of PM-10 concentrations, chemical composition and meteorology has provided information of the temporal and spatial behavior of PM10 in the Valley. Results reveal three different situations that must be addressed:

- Sites with annual average concentrations above the 50  $\mu\text{gm}$  standard,
- Sites with 24-hour levels above 150  $\mu\text{gm}$  in the fall (October to mid-December, sometimes transitioning as early as mid November) with largest contribution from geologic sources, and
- Sites with 24-hour levels above 150  $\mu\text{gm}$  in the winter (mid-November to mid December through February) with largest contribution from secondary formation and fine particulate matter sources.

Both types of events with levels above 150  $\mu\text{gm}$  must be examined for attainment. If a site has episodes in both seasons, the potential difference in source contributions for the episodes does not allow a presumptive assumption that only the highest value needs to be examined. Evaluation is not required at sites with annual design values at or below 50  $\mu\text{gm}$  (rounded to the nearest microgram) and sites with 24-hour design values at or below 150  $\mu\text{gm}$  (rounded to the nearest ten microgram level). However, areas with design values in compliance with the standards do have emissions that contribute to the concentrations observed in locations that do not comply with the standards. Therefore, the contribution to regional levels from sites in compliance is considered for current and projected future years when evaluating the sites with concentrations above the standards.

Data requirements for emissions, meteorology, and air quality, as well as the validity of the representation for 24-hour and annual average PM-10 concentrations must be considered in applying the appropriate approach. Based upon availability of emissions estimates, meteorology, and air quality data in the Valley, the Protocol establishes an approach that combines the best information that can be developed at this time by technical and statistical analysis of meteorology and other parametric data, receptor modeling and regional modeling.

- **Receptor Modeling** Receptor modeling using the chemical mass balance model (version CMB 8) will be conducted for annual and episode conditions at sites that currently do not comply with the federal PM10 air quality standards. This method uses chemical analysis of collected air monitoring samples and information about the chemical composition of contributing sources to evaluate the link between observed conditions and emission sources. The District will use the results of the CMB analysis with a modified rollback approach to calculate the effect on design values of predicted aggregate adopted and proposed control measure reductions and other predicted emission trends to establish attainment at sites noncompliant with the standards. This method works well for analysis of directly emitted particles but is less certain in predicting the effect of reductions of secondary precursors (gases that form particles in the air that may not produce particles in amounts directly proportional to the amount of emissions). The Protocol proposes supplementing the receptor modeling to the extent possible with findings developed by regional modeling of secondary particulate formation rates typical to the Valley to take into account the potential nonlinear secondary particle formation.
- **Regional Modeling** Regional modeling of secondary particulates will be conducted by ARB using a version of the Urban Airshed Model modified to address aerosol chemistry (UAM-Aero) to learn as much as possible from the IMS-95 dataset (an early component of CRPAQS) by evaluating a monitored event of nitrate particulate formation. Additional analysis of the dataset with modeling techniques under development for CRPAQS will be used for comparison to the UAM-Aero results. Results will improve understanding and provide useful secondary particle formation rates and precursor ratios, particularly for nitrate particulates. Results will be used in conjunction with receptor modeling to enhance the accuracy and reliability of predicted effects of emission trends and adopted and proposed control measure reductions of secondary precursors.

EPA guidance cautions on the accuracy of CMB if the 24-hour concentration modeled has not been established as typical in concentration or contributing species and recommends that supporting analysis be performed of the representative nature of the episode and/or additional analysis of other 24-hour periods. "For violations of the 24-hour NAAQS, it is preferable to apply the CMB model on the days on which "exceedances" of the NAAQS were observed. In this case, one would analyze and compare all observations greater than the level of the NAAQS. In order to obtain representative results, a minimum of five samples (e.g., the five highest values) should be compared. If there are fewer than five observed "exceedances" of the NAAQS, the five highest values overall should be used so that the analysis is based upon a representative number of days. If a receptor model study was undertaken for a short time period, it must be shown that the period covered was generally representative of the types of source activity and meteorology which are associated with exceedances measured outside of the receptor model study." (Protocol for Reconciling Differences Among Receptor and Dispersion Models, p 5-6, EPA-450/4-87-008, March 1987). Analysis of the meteorology to determine if episodes are representative is discussed in the "Data: Meteorological" portion of the Protocol. The meteorological evaluation

described in this protocol provides representative analysis of episodes to meet receptor modeling guidance requirements.

### **Simulation of Observed Particulate Concentrations**

CMB receptor modeling is an analysis method used to link observed levels of particulates to the sources of emissions grouped into source categories. The CMB model links the speciated chemical composition of the filter sample at the site to emissions inventories that represent the emissions at the time of the 24-hour observation, or represent seasonal or annual average values as appropriate. Where emission information is lacking for a particular component (e.g., seasonally resolved mineral dust emissions) rollback can still be applied to other components.

The CMB technique evaluates the observed event and the results are specific to the date of the event. The 24-hour design value exceedance events are modeled with this method and the results are examined to establish a common analysis of the seasonal events. The seasonal analysis is supplemented by examination of chemical speciation at other times of year to develop a CMB evaluation of annual average PM-10 levels. CMB modeling of the monitoring data for the design value day, and a representative CMB analysis for the annual design value establish the base case situation at sites that need emissions reductions to achieve attainment.

Exceedances will be characterized and grouped by chemical speciation and source attribution based on conceptual models indicated by data evaluation and modeling analyses. This information will be used to help identify the contributing sources. For 24-hour exceedances where ammonium and nitrate ions are a significant fraction of the total particulate mass, particle speciation, gaseous concentration, meteorological, and emissions data will be analyzed to attempt to determine the limiting precursor. Results of the regional modeling may further clarify the spatial and temporal nature of this relationship.

Each of the exceedances of the 24-hour standard will be evaluated with receptor modeling to identify the relevant sources and the appropriate degree of control for each season and area. All sites with at least nitrate/sulfate and geological species data will be modeled with CMB8. Sites that do not have sufficient speciation data will be matched with an appropriate site/date that can be modeled based on representative meteorology and expected source contributions. CRPAQS CMB results will need to be scaled to the design value to provide assessment of modeled components of the design value. Since the design values for the 24 hour standard exceed the standard by greater percentages than the annual standard design values, it is expected that the controls necessary to attain the 24-hour standard will also attain the annual standard.

Evaluation of annual concentrations by receptor modeling to determine probable source contributions must include appropriate consideration of, and adjustments for, seasonal differences in sources and seasonal differences in atmospheric conditions that affect

particle origin, formation and atmospheric residence time. In addition to CMB modeling of episode days, monthly averages for the seven sites will be modeled to develop annual average contribution estimates. The relative merits of running the overall average, quarterly averages, monthly averages, or every day have been reviewed and the protocol reflects the determination that the monthly average approach is the best approach with available data.

### **Simulation of Future Particulate Concentrations**

From the CMB receptor modeling identification of emissions source contributions by chemical species, future source contributions will be estimated from baseline and projected inventories with rollback techniques to evaluate the effects of trends and proposed emissions reductions in future years. The design value concentrations are modeled at each site where concentrations were measured that exceeded the federal PM10 standards and where adequate data is available to support a valid analysis.

Rollback techniques assume a proportional relationship between source categories separable by CMB analysis and types of emissions and emission inventory estimates. Rollback projection can be applied based on either a regional (county or multi-county) emission inventory or a local emission inventory of sources located around a monitoring site to the extent that the meteorological analysis of the episode can determine an appropriate zone of influence for the local emissions and determine appropriate "background concentrations" for each chemical component. Attachment 3e "CMB Attainment Analysis Formulas Worksheet" contains default assumptions for regional and background concentrations that will be adjusted as appropriate based upon available information during the process of analysis.

The appropriate areal extent of sources to include in the inventory for rollback calculation will be estimated based upon back trajectories, atmospheric residence time, pollutant deposition rates, and emission distributions and activity data. Back trajectories will be calculated from two-dimensional wind fields constructed from available surface wind data. Atmospheric residence time for particles will be estimated based upon deposition rates for the source specific particle densities and size cuts. Potential sources within the area indicated by back trajectories will be examined in detail and included in the rollback calculation.

Baseline and projected future year seasonal and annual emissions inventories are compared with a rollback analysis that assumes linear relationships between emissions and concentrations. To improve rollback projection of future secondary particulate levels in correspondence to future emission levels, regional modeling of formation ratios with the indicated IMS95 dataset will be used to establish secondary particulate nonlinear relationships.

## **Utilization of Regional Modeling Reaction Rates with Chemical Mass Balance Results for Proportional Rollback Analysis**

The proposed approach is to use the conversion factors of precursors into secondary particulate matter in the control strategy design and proportional rollback phases of the attainment demonstration for episodes with large portions of secondary particulates in the observed mass. The proposed approach may not be the optimal and we may need to explore other possibilities as we gain more experience with the modeling process. During analysis of modeling results we must consider: applicability of the modeling emissions inventory to the design value, applicability of the modeling meteorological fields to the design value, and the zone of influence of a monitor with respect to PM and gaseous precursors. The proposed approach will be applied to particulate episodes, but must also be evaluated for its usefulness in making reasonable assessments of annual average design values.

Technical difficulties preclude an attainment demonstration for PM10 based entirely on grid-based photochemical modeling. The main difficulties include the inability of grid-based photochemical models to represent the dispersion of coarse particle falloff distances that are less than the grid spacing and field data with insufficient density of instrumentation and data collection to support such an analysis. Using smaller grid spacing and/or using a coupled grid and dispersion approach we can address the first difficulty, but only limited data sets with this level of information density are available. Similarly, the Chemical Mass Balance process has inherent difficulties evaluating components formed in nonlinear processes of atmospheric chemistry.

The results of Chemical Mass Balance (CMB) modeling can be used directly to project future concentrations from revised inventories and control scenarios in cases where atmospheric chemistry is not involved or is expected to be linearly proportional. Cases of PM10 episodes that are heavily dominated by primary emitted particles qualify for direct CMB analysis and rollback. These episodes are dominated by sources that emit carbon and soil based emissions from roads, agriculture, construction and related activities. If the contributions from other types of particulates including nitrate and sulfate particulates produced from atmospheric reactions are small, then using an assumption of linear chemistry is considered to be acceptable. The CMB method identifies the contributing sources and the proportional rollback method, using an assumption that observed concentrations are directly proportional to emissions, is used to predict future concentrations based on strategies for emissions control.

Episodes involving large quantities of secondary particulates need to be evaluated with an understanding of the atmospheric processes. Particle formation rates may vary due to influences of meteorology and precursor ratios. Temperature, relative humidity, photochemical energy flux, wind speed and atmospheric mixing affect the formation rates of secondary particulates. The balance of precursors and concentrations of ozone and carbon dioxide also influence particle formation. Evaluating the complexity of the relationships involved in particle formation provides information to determine whether an

assumption of linear response is acceptable or whether specific ratios and factors must be used to predict the secondary particle formation.

While the regional modeling is expected to provide improved projection of secondary particulates, it will not be used to model primary particulates. The CMB method is capable of handling these sources directly as a receptor technique linked to actual observations. The regional model would be burdened by limitations and uncertainties in available information for area source particulate emission rates, distributions and deposition rates for directly emitted large particles and would therefore not provide a superior estimate for use with rollback analysis. CMB does a better job representing the limited radii of influence for primary particles. The regional model evaluates gaseous precursors and fine particles that cannot be effectively considered by CMB.

Complex episodes with large quantities of secondary particulates formed from gaseous precursors (such as NO<sub>x</sub>, VOC, and NH<sub>3</sub>) should be evaluated with the best information available about atmospheric chemistry and formation rates. We do not have sufficient information to model the chemistry of each event with a regional photochemical model with aerosol chemistry. The proposed approach will use extensive data collected for a typical winter episode (IMS 95 project data) to establish formation rates and ratios for secondary particulates. This information will be used with results of the CMB process to modify the rollback projection of secondary particulates for episodes where the secondary particulates are a significant fraction of the total mass. The results of the regional modeling will identify the degree of variation from linear assumptions, which in turn will determine the minimum level at which the contribution of secondary particulates requires application of the derived formation rates for rollback projection.

Combining CMB with grid-based photochemical aerosol chemistry modeling analysis provides the best available construct to establish a reliable rollback analysis. In this approach, CMB will provide source apportionment for primary particles will only apportion secondary particles for cases where the linear assumption can be determined to provide a reasonable first order estimate. The grid-based photochemical model will provide the conversion factors of precursors into secondary particles that can be used to correct the proportional rollback analysis of secondary particulates. The conversion factors will be used for the analysis of control strategies projections.

### **Demonstration of Attainment**

Rollback calculations determine the amount of reductions needed from the major source categories as defined in the receptor modeling to achieve compliance with federal PM<sub>10</sub> standards at all monitoring sites. The results of this process predict future year 24-hour and annual PM<sub>10</sub> concentrations that would result from trends and current and proposed control programs. Attainment is demonstrated for each site that is projected to have future concentrations at or below the federal standards. The predicted PM<sub>10</sub> concentration may also be achieved by reductions equivalent to the difference between baseline and rollback inventories with different reductions in individual sources or source categories.

## Model: Application Assumptions

### Receptor Modeling Assumptions

Receptor-oriented air quality models for PM-10 infer source contributions by searching for patterns formed by the chemical elements present in the ambient samples. The CMB model consists of a set of linear equations that express the ambient concentrations of chemical species as the sum of products of source compositions and source contributions. The basic model equations represent the source receptor relationship. The effective variance weighting and the error propagation are all based on physical principals. The fundamental CMB model equations have been subjected to verification and evaluation using both real and simulated data as part of the Quail Roost II Conference (Stevens and Pace, 1984). Additional verification and evaluation efforts have been undertaken by several investigators, including, but not limited to: Watson et al. (1984), DeCesar and Cooper (1982), Dzubay et al. (1984), Gerlach et al. (1982), Currie et al. (1984), Watson and Robinson (1984), Javitz and Watson (1986), Watson and Chow (1986), Henry and Kim (1986). Detailed citations for these studies are available through the ARB or from "Protocol for Applying and Validating the CMB Model," EPA-450/4-87-010, 1987.

The fundamental assumptions of the CMB model are: 1) Compositions of source emissions are constant over the period of ambient and source sampling; 2) Chemical species do not react with each other; (i.e. they add linearly) 3) All sources with a potential for significantly contributing to the receptor have been identified and have had their emissions characterized; 4) The number of sources or source categories is less than the number of species; 5) The source compositions are linearly independent of each other; 6) Measurement uncertainties are random, uncorrelated, and normally distributed. Minor deviation from the assumptions does not invalidate the results. "Model evaluation studies based on synthetic data sets (Stevens and Pace, 1984; Javitz et al., 1988) show that modest departures from the above assumptions can be accepted within the context of actual applications." (Appendix A to Sonoma Technology, Inc. "PM-10 Air Quality Models for Application in the San Joaquin Valley PM-10 SIP," page 11, Cass, 1996).

CMB was designed to determine sources of primary PM-10 emissions from analysis of observed samples. The CMB model cannot estimate specific source contributions to secondary aerosols, but it can be used to determine the total amount of a secondary aerosol species such as ammonium nitrate or ammonium sulfate. The following conditions must be met for the CMB modeling to be applicable:

- A sufficient number of PM-10 receptor samples have been taken with accepted sampling methods to evaluate compliance with the federal annual and 24-hour PM-10 standard.

- These samples are amenable to and have been analyzed for a variety of chemical species. Minimal analyses include concentrations of aluminum, bromine, calcium, chlorides, copper, lead, manganese, nickel, potassium, silicon, titanium, vanadium, and zinc. Preferable additional analyses would include other elements such as arsenic, chromium, selenium, trace elements, cations, anions, elemental carbon and organic carbon.
- From the identified species, the potential source contributions can be identified and grouped into source categories of distinct chemical compositions. Additional source profiles are being collected from more recent special studies, as well as new work conducted as part of CRPAQS.
- From the identified species and source categories, compositions for the source categories are obtainable which represent the source profile as it is perceived at the receptor.
- The number of source types in a single application of the CMB must be fewer than the number of chemical species at the receptor measured at concentrations greater than the lower quantifiable limits. In other words, to model the source types, a sufficient number of chemical species must be collected in the sample that are measured in amounts greater than the minimum reliable detection limits for the analysis techniques used.

CMB modeling is well established as a good technique for the San Joaquin Valley and meets these requirements. "Chemical mass balance methods are known to be applicable to modeling long-term average air quality relationships for particulate matter in the San Joaquin Valley because a study of that kind has been conducted by Chow et al. (1992). Existing emissions inventories for the Valley provide a basis for identifying the most important sources that should be considered for inclusion in the model. Extensive libraries of source composition profiles exist based on source measurements made in the Valley (Houck et al., 1989) and elsewhere." (Appendix A to Sonoma Technology, Inc. "PM-10 Air Quality Models for Application in the San Joaquin Valley PM-10 SIP," Cass, 1996).

### **CMB Analysis with Linear Rollback**

CMB analysis with linear rollback can be applied to short and long term data. However, the lack of treatment of meteorology in the model affects seasonal and annual average modeling less than modeling of a 24-hour episode. If the meteorology and source activity of a specific exceedance day used for modeling is not representative of other exceedance days, the resulting analysis may not be generally representative. "If a receptor model study were undertaken for a short time period, it must be shown that the period covered was generally representative of the type of source activity and meteorology associated with exceedances observed in other receptor model studies."

(EPA Guideline Document, page 6-3, 1993). The Guideline further suggests that CMB modeling for episodic conditions can be performed with the caution that due to the variability of meteorological conditions, calculated emissions reductions should ensure that the 24-hour NAAQS will be met at all other sites/days.

In the rollback projection, ambient pollutant concentrations are linked to CMB receptor analysis of source contributions. “The CMB model is believed to be the most reliable model for determining the source contributions of primary particles, especially for fugitive dust sources, because it does not rely on emissions rate estimates or characterization of atmospheric transport... The principle limitations of the CMB model are that 1) it can only separate the source contributions of a small number of sources... and 2) it cannot estimate source contributions to secondary aerosol species.” (Sonoma Technology, Inc. “PM-10 Air Quality Models for Application in the San Joaquin Valley PM-10 SIP”, page 7-1, 1996). The output of the CMB receptor model will be used with linear rollback; utilizing the most accurate source identification available with a reliable technique for assessing control programs.

The future year source contributions, excess of regional background concentrations, are assumed to respond in a linear relationship to controls. This means the change in concentration is expected to be in direct proportion to changes in area-wide emissions. For an inert pollutant or source contribution, such as geologic material, the rollback projection is a valid predictor of future pollutant concentrations provided that the relative spatial and temporal emissions distribution is the same before and after emissions controls have been implemented. When the rollback projection is used to predict the effects of reductions in gaseous precursor emissions on secondary aerosol constituents, chemical transformation processes are assumed to be linear. Significant departures from linearity in the atmosphere could undermine the accuracy of results; however, “Despite the clearly nonlinear nature of the fundamental chemical transformation mechanisms, there is considerable evidence from nonlinear models and observations that the conversions are approximately linear for many of the practical emissions control situations studied to date.” (Sonoma Technology, Inc. “PM-10 Air Quality Models for Application in the San Joaquin Valley PM-10 SIP”, page 4-7, 1996).

### **Receptor and Regional Modeling General Assumptions**

Establishing modeling assumptions and background values requires discussion of particle size, formation, composition and chemistry in accordance with current scientific understanding of PM10. This information provides a basis for addressing issues such as natural background and regional and local contribution. Assumptions involved in model application are based on data analysis and an understanding of the physical and chemical properties, sources and behavior of PM10. Developing an understanding of the principle factors and influences of PM10 concentrations provides a greater degree of certainty that proposed control strategy reductions will have the desired and expected results and that a projection of attainment has the highest degree of reliability achievable with current information.

Particulate matter represents a broad class of chemically and physically diverse substances. In addition to characterizations by size, particles can be described by their formation mechanism or origin, chemical composition, physical properties, and in terms of what is measured by a particular sampling technique. To be able to prepare to conduct modeling the principal factors for input data must be established. To be able to interpret the model output, a clear understanding of the influences of the principal factors must also be established. The EPA document “Air Quality Criteria for Particulate Matter” contains an extensive analysis of PM10 scientific information.

**Factors Essential for Modeling Analysis:** A variety of diverse activities contribute significantly to particulate matter concentrations: fugitive dust including road dust, motor vehicles, and wood smoke are the major contributors to ambient PM10 samples; nitrates and organic carbon are the major secondary components. Other sources include fuel combustion (from vehicles, power generation, and industrial facilities), residential fireplaces, agricultural burning, atmospheric formation from gaseous precursors (largely produced from fuel combustion), wind blown dust, and construction and demolition activities. From these diverse sources come the mix of substances that comprise PM10.

In addition to evaluation of air monitoring data and baseline and projected emissions inventories, the properties, sources and behavior of PM10 must be clearly understood to perform modeling. Modeling cannot be conducted without an understanding of the spatial influence of emissions sources and sufficient information to estimate background PM10 levels. Apportionment of secondary PM10 is difficult because it requires consideration of atmospheric reaction processes and rates. Current scientific knowledge is used to select and evaluate modeling methods and results.

Factors essential for modeling analysis include:

- Origin of particles, sources and properties
- Chemistry and physics of atmospheric particles
- Atmospheric behavior, transport and fate of airborne particles
- Understanding of local episodes and annual concentrations
- Background concentrations to support modeling

**Origin of Particles, Sources and Properties:** The chemical complexity of airborne particles requires that the composition and sources of a large number of primary and secondary components be considered. Airborne PM10 is not a single pollutant, but a mixture of many subclasses of pollutants with each subclass containing many different chemical species. Atmospheric PM10 occurs naturally as fine and coarse particles that, in addition to falling into different size ranges, differ in formation mechanisms, chemical composition, sources, and exposure relationships. The indicator for particulate matter standard is PM10. However, PM2.5 particles are frequently referred to as fine, while

the difference between PM<sub>2.5</sub> and PM<sub>10</sub> (PM<sub>10</sub> -PM<sub>2.5</sub>), is referred to as the coarse fraction or coarse PM<sub>10</sub>. Fine and coarse particles generally have distinct sources and formation mechanisms; however, the size of particles formed in these processes can vary, overlapping the 2.5 $\mu$  size used to differentiate small and fine particulate matter.

There are fundamental differences in sources, formation mechanisms, and chemical composition, as well as the difference in particle size. The differences in sources and characteristics must be considered in the modeling process to determine effective control strategies. Fine and coarse particles have distinctly different sources, both natural and anthropogenic and have different physical and chemical properties. Therefore different control strategies may be needed to address fine and coarse particle control. Because fine and coarse particles are derived from different sources, it is also necessary to quantify ambient levels of fine and coarse particles separately in order to plan effective control strategies. Fine and coarse particles should be considered as separate subclasses of pollutants.

Most of the coarse fraction particles are emitted directly as particles and result from mechanical disruption and abrasion of surfaces such as crushing, grinding, tire friction and evaporation of sprays, suspensions of dust from construction, agricultural operations, mining and wind erosion. Some combustion-generated particles such as fly ash are also found in the coarse fraction. Major components of coarse particles are aluminosilicates and other oxides of crustal elements (e.g., iron, calcium, etc.) in soil dust; fugitive dust from roads, industry, agriculture, construction and demolition; fly ash from combustion of oil and coal; and additional contributions from plant and animal material. Fungal spores, pollen, and plant and insect fragments are examples of natural bioaerosols also suspended as coarse particles.

Fine particulate matter is produced mainly by the condensation of gases in the high temperature environment of combustion chambers; the condensation of atmospheric precursor gases, some of which may undergo further reactions in particles; and the condensation of low vapor pressure photochemical reaction products. Major sources of these fine mode substances are fossil fuel combustion by electric utilities, industry and motor vehicles; vegetation burning; and the smelting or other processing of metals. Major components of fine particles are: sulfate, strong acid, ammonium, nitrate, organic compounds, trace elements (including metals), elemental carbon, and water.

Primary (directly emitted) fine particles are formed from condensation of high temperature vapors during combustion. Particles formed as a result of chemical reaction of gases in the atmosphere are termed secondary particles because the direct emissions from a source are a gas that is subsequently converted to form a particle. Fine particles, both directly emitted primary particles and secondary particles formed later in the atmosphere are usually formed from gases in three ways: (1) nucleation (gas molecules coming together to form a new particle), (2) condensation of gases onto existing particles, and (3) by liquid phase reactions. Gases may dissolve in a liquid, react with another dissolved gas, and when fog and cloud droplets evaporate, particulate matter remains, usually in the fine particle mode. Particles formed from

nucleation also coagulate to form relatively larger particles, although such particles normally do not grow into the coarse size range. Although directly emitted particles are found in the fine fraction, particles formed secondarily from gases dominate the fine fraction.

**Table 11**

**Comparison of Ambient Fine and Coarse Mode Particles**

	<b>Fine</b>	<b>Coarse</b>
Formed from:	Gases	Large solids/droplets
Formed by:	Chemical reaction Nucleation Condensation Coagulation Evaporation of fog and cloud droplets in which gases have dissolved and reacted	Mechanical disruption (crushing, grinding, abrasion of surfaces, etc.) Evaporation of sprays Suspension of dusts
Composed of:	Sulfate, SO <sub>4</sub> <sup>-</sup> Nitrate, NO <sub>3</sub> <sup>-</sup> Ammonium, NH <sub>4</sub> <sup>+</sup> Hydrogen ion, H <sup>+</sup> Elemental carbon, Organic compounds (e.g., PAHs, PNAs) Metals, (e.g., Pb, Cd, V, Ni, Cu, Zn, Mn, Fe) Particle-bound water	Resuspended dusts (Soil dust, street dust) Coal and oil fly ash Oxides of crustal elements, (Si, Al, Ti, Fe) CaCO <sub>3</sub> , NaCl, sea salt Pollen, mold, fungal spores Plant/animal fragments Tire wear debris
Solubility:	Largely soluble, hygroscopic and deliquescent	Largely insoluble and non-hygroscopic
Sources:	Combustion of coal, oil, gasoline, diesel, wood Atmospheric transformation products of NO <sub>x</sub> , SO <sub>2</sub> , and organic compounds including biogenic organic species, e.g., terpenes High temperature processes, smelters, steel mills, etc.	Resuspension of industrial dust and soil tracked onto roads and streets Suspension from disturbed soil, e.g., farming, mining, unpaved roads Biological sources Construction and demolition, coal and oil combustion, ocean spray
Atmospheric half-life:	Days to weeks	Minutes to hours
Travel distance:	100s to 1000s of km	<1 to 10s of km

Source: USEPA 1996 Criteria Document, page 3-145, adapted from Wilson and Suh (1996)

**Chemistry and Physics of Atmospheric Particles:** The major chemical constituents of PM10 are sulfates, nitrates, carbonaceous compounds (both elemental and organic carbon compounds), acids, ammonium ions, metal compounds, water, and crustal materials. The amounts of these components vary from place to place and over time. Fine and coarse particles generally have distinct chemical composition, solubility, and acidity. Fine particulate matter is composed of sulfates, acids, nitrates, elemental carbon, volatile organic carbon compounds, water and trace elements such as metals. Coarse fraction particulate matter is primarily crustal, consisting of silicon (Si), aluminum (Al), iron (Fe), and potassium (K). Biological material such as bacteria, pollen, and spores are also found in the coarse particulate matter.

**Coarse Particulate Matter:** Particles are designated as primary if they are emitted directly into the air as particles or as vapors which condense to form particles without chemical reaction. Examples of primary particles are elemental carbon chain agglomerates formed during combustion and chemical species such as lead, cadmium, selenium, or sulfuric acid which are volatile at combustion temperature but form particulate matter rapidly as the combustion gases cool. Coarse particles are normally primary since they are formed by mechanical rather than by chemical processes. An exception is the reaction of acid gases with carbonate (CO) containing particles in which the CO may be replaced by sulfate, nitrate, or chloride. Other exceptions are the reaction of nitric acid (HNO<sub>3</sub>) with sodium chloride (NaCl) to form sodium nitrate (NaNO<sub>3</sub>) and hydrogen chloride (HCl) gas and the reaction of sulfur dioxide (SO<sub>2</sub>) with wet NaCl to form sodium sulfate (Na<sub>2</sub>SO<sub>4</sub>) and HCl gas. Coarse particulate matter sources are primarily crustal, biological, or industrial in nature.

Crustal material, from soil or rock, primarily consists of compounds that contain Si, Al, Fe, Mg, and K. Small amounts of Fe and K are also found among fine-mode particles but come from different sources. In urban areas, much crustal material arises from soil which is tracked onto roads during wet periods and is suspended in the air by vehicular traffic. In rural areas, tilling, wind blowing over disturbed soil, or vehicles traveling on unpaved roads can generate coarse particles. Where farms have been treated with persistent pesticides or herbicides, these materials may also be present in suspended soil particles.

A variety of industrial operations including construction and demolition, open pit mining, grain handling, coal handling generate coarse particles. Coarse particulates may also be present from coal and oil combustion generation of fly ash, which is similar in chemical composition to soil and crustal material but can be differentiated by microscopic examination.

**Fine Particulate Matter:** In the ambient atmosphere, fine particulate matter is mainly composed of varying proportions of six major components: sulfates, acids, nitrates, elemental carbon, organic carbon, and trace elements such as metals. A variety of

transition metals and non-metals are volatilized during the combustion of fossil fuels, smelting of ores, and incineration of wastes and are emitted as fine particles or vapors that rapidly form fine particles. Varying amounts of water may also be present. Sulfates, nitrates, and some organic compounds are hygroscopic, that is, they absorb water and form solution droplets. A variety of atmospheric pollutant gases can dissolve in the water component of the particle. Some types of higher molecular weight organic compounds react with hydroxyl (OH) radicals, and olefinic compounds also react with ozone, to form oxygenated organic compounds that can condense onto existing particles. Chain agglomerates of very small elemental carbon (EC) particles are formed during combustion, such as in open-hearth fireplaces, wood stoves and diesel engines.

Several categories of organic carbon (OC) compounds are also often found in ambient air: primary anthropogenic - incomplete combustion forms hundreds of organic compounds with low enough vapor pressure to be present in the atmosphere as particles including polyaromatic hydrocarbons (PAHs); secondary anthropogenic - some organic compounds, including aromatics larger than benzene, cyclic olefins and diolefins, and other C7 (compounds with seven carbon atoms in the chain) or higher hydrocarbons react with O<sub>3</sub> or OH to form polar, oxygenated compounds with vapor pressures low enough to form particles; primary biogenic - viruses, some bacteria, and plant and/or animal cell fragments may be found in the fine mode; secondary biogenic - terpenes, C10 cyclic olefins released by plants, also react in the atmosphere to yield organic particulate matter.

Particles are designated as secondary if they form following a chemical reaction in the atmosphere which converts a gaseous precursor to a product which either has a low enough saturation vapor pressure to form a particle or reacts further to form a low saturation vapor pressure product. Fine particulate matter is derived from combustion material that has volatilized and then condensed to form primary particulate matter or from precursor gases reacting in the atmosphere to form secondary particulate matter. New fine particles are formed by the nucleation of gas phase species, and grow by coagulation (existing particles combining) or condensation (gases condensing on existing particles). Fine particles are composed of freshly generated particles, in an ultrafine or nuclei mode, and an accumulation mode, so called because particles grow into and remain in that mode.

SO<sub>2</sub>, NO<sub>x</sub>, and certain volatile organic compounds are major precursors of fine secondary particulate matter. SO<sub>2</sub> and nitrogen dioxide (NO<sub>2</sub>) react with hydroxy radical (OH) during the daytime to form sulfuric acid (H<sub>2</sub>SO<sub>4</sub>) and nitric acid (HNO<sub>3</sub>). Both VOC and NO<sub>x</sub> are important in the formation of free radicals that contribute to the formation of nitric acid (HNO<sub>3</sub>).

NO<sub>x</sub> is formed during combustion or any high temperature process involving air. The NO is converted to NO<sub>2</sub> by ozone (O<sub>3</sub>) or other atmospheric oxidants. During the daytime, NO<sub>2</sub> reacts with the hydroxyl radical (OH) to form HNO<sub>3</sub>. During the nighttime NO<sub>2</sub> reacts with O<sub>3</sub> and forms HNO<sub>3</sub> through a sequence of reactions involving the nitrate radical (NO<sub>3</sub>). Ammonia (NH<sub>3</sub>) reacts preferentially with H<sub>2</sub>SO<sub>4</sub>, but if sufficient

$\text{NH}_3$  is available, particulate ammonium nitrate ( $\text{NH}_4\text{NO}_3$ ) will form. An example of this process is the conversion of  $\text{NO}_2$  to  $\text{HNO}_3$  that may react further with  $\text{NH}_3$  to form particulate ammonium nitrate ( $\text{NH}_4\text{NO}_3$ ).

$\text{SO}_2$ , mainly from combustion of fossil fuel, is oxidized in the atmosphere to form  $\text{H}_2\text{SO}_4$  particles that nucleate or condense on existing particles. The  $\text{H}_2\text{SO}_4$  may be partially or completely neutralized by reaction with  $\text{NH}_3$ . Since the particles usually contain water, the actual species present are  $\text{H}^+$ ,  $\text{HSO}_3^-$ ,  $\text{SO}_3^{2-}$ , and  $\text{NH}_4^+$ , in varying proportions depending on the amount of  $\text{NH}_3$  available to neutralize the  $\text{H}_2\text{SO}_4$ . Strong acidity of particles is due to free  $\text{H}^+$  or  $\text{H}^+$  available from  $\text{HSO}_3^-$  or  $\text{H}_2\text{SO}_4$ .  $\text{SO}_2$  also dissolves in cloud and fog droplets where it may react with dissolved  $\text{O}_3$ ,  $\text{H}_2\text{O}_2$ , or, if catalyzed by certain metals, with  $\text{O}_2$ , yielding sulfuric acid or sulfates, that lead to particulate matter when the droplet evaporates.

**Atmospheric Behavior, Transport and Fate of Airborne Particles:** Fine and coarse particles typically exhibit different behavior in the atmosphere. Larger particles generally deposit more rapidly than small particles; as a result, coarse particles will be less uniform in concentration across an urban area than fine particles. Aerosol effects on visibility and climate, through light scattering and changes in cloud microphysics, primarily arise from fine particles.

Coarse particles tend to be less evenly dispersed around urban areas and exhibit more localized elevated concentrations near sources, remaining in the atmosphere minutes to hours, traveling kilometers to tens of kilometers. Coarse particles tend to rapidly fall out of the air and have atmospheric lifetimes of only minutes to hours depending on their size and other factors. Their impact is typically limited by fallout to the proximate area downwind of their emission point. Coarse particles are not readily transported across urban or broader area, because they are generally too large to follow air streams and they tend to be easily removed by impaction on surfaces.

Fine particles tend to be more uniformly dispersed than coarse fraction particles across urban or large geographic areas because fine particles remain suspended for much longer times and travel much farther than coarse fraction particles. Fine particles typically remain in the atmosphere on the order of days to weeks traveling as much as hundreds to thousands of kilometers. Secondary fine particles are formed by atmospheric transformation of gases to particles. Atmospheric transformation can take place locally during stagnations or during transport over long distances. Fine particles have very low dry deposition velocities, which contribute to their uniformity throughout the air mass.

**Atmospheric Behavior of Coarse and Fine Particles:** Coarse particles normally have short lifetimes (minutes to hours) and only travel short distances (less than tens of kilometers). Therefore, coarse particles tend to be unevenly distributed across urban areas and tend to have more localized effects than fine particles. Coarse particles are

removed mainly by gravitational settling and inertial impaction. Coarse particles are large enough so that the force of gravity exceeds the buoyancy forces of the air. Large particles tend to rapidly fall out of the air; the atmospheric half-life of coarse particles depends on their size, but is usually only minutes to hours. Coarse particles are too large to follow air streams and are easily removed by impaction on surfaces. However, vigorous mixing and convection, such as occurs during dust storms, can lead to longer lifetimes for the smaller size range of coarse particles.

Fine particles are small enough that the random forces from collisions with gas molecules largely overcome gravitational forces. Fine particles tend to follow air streams and are typically not removed by impaction. As a result, they are not easily traced back to their individual sources. Fine particles formed from accumulation processes are significantly larger than gas molecules and their diffusion velocity is low. These particles have very long half-lives in the atmosphere, travel long distances, and tend to be more uniformly distributed over large geographic areas than coarse-mode particles. Removal by dry deposition is inefficient since they do not readily diffuse through the boundary layer of still air next to surfaces. The atmospheric half-life of fine accumulation particles with respect to dry deposition is on the order of weeks; however, removal occurs when the particles absorb water, grow into cloud droplets, grow further to raindrops, and fall out as rain. This process reduces the typical atmospheric half-life to a few days. Ultrafine or nuclei-mode particles, formed by nucleation of low saturation vapor pressure substances, tend to exist as disaggregated individual particles for very short periods of time (less than minutes) in the ambient atmosphere and tend to age rapidly into larger accumulation particles that may be dispersed more widely over long distances.

**Background Concentrations to Support Modeling:** Background concentrations are an input for the specified rollback modeling. Background estimates for each identifiable chemical species in the fine and coarse fraction will be determined based upon available data. The appropriate definition of background for speciated-rollback is the air quality concentrations at the influx boundaries for the sites to be modeled. Existing SJV monitoring sites are intended to represent concentrations in populated areas-thus none provide an ideal background site for modeling to minimizing influences from anthropogenic sources. However, some sites may provide reasonable estimates of "background" under certain conditions. Consideration will be given to values from air monitoring stations that are closest to the influx boundaries for the sites in the Valley and CRPAQS non-urban sites.

Natural sources contribute to both fine and coarse particles in the atmosphere. For modeling purposes, background particulate matter includes the distribution of particulate matter from natural sources as well as anthropogenic emissions of particulate matter and precursor emissions of VOCs, NO<sub>x</sub>, and SO<sub>x</sub> from areas outside of the SJVAB. To discriminate the portion of the measured PM<sub>10</sub> affected by control strategies, emissions from outside of the SJVAB must be treated as background. If these emissions are not treated as background during the modeling process and are attributed to local

emissions, control effects would be overestimated in the modeling process. This definition of background is different than would be used for health assessment studies, where background is limited to natural sources and all anthropogenic emissions are evaluated for their cumulative health impact.

Background levels of particulate matter vary by geographic location and season. The natural component of the background arises from physical processes of the atmosphere that entrain fine particles of crustal material (i.e., soil) as well as emissions of organic particles resulting from natural combustion sources such as wildfires. In addition, certain vegetation can emit fine organic aerosols as well as their precursors. The exact magnitude of the natural portion of particulate matter for a given geographic location cannot be precisely determined because they are difficult to separate from the long range transport of anthropogenic particles or precursors. Only broad estimates for longer averaging times can be developed at this time. Regional annual average natural background levels are estimated as 4 - 8  $\mu\text{g}/\text{m}^3$  PM10 and 1-4  $\mu\text{g}/\text{m}^3$  PM2.5 for the western US. Annual average PM10 concentrations in national parks, wilderness areas, and national monuments in the western United States range from 5 to 10  $\mu\text{g}/\text{m}^3$  based on data from Interagency Monitoring of Protected Visual Environments (IMPROVE). Valley annual average background concentrations, which include anthropogenic emissions from outside the region, range from 10 to 20  $\mu\text{g}/\text{m}^3$  and vary from site to site within the Valley.

The range of background concentrations can be higher on an episodic basis. Specific natural events such as wildfires, volcanic eruptions, and dust storms can lead to very high levels of particulate matter. Disregarding such large and unique events, an estimate of range of "typical" background on a daily basis can be obtained from reviewing various multi-year data as well as special field studies. Background geogenic and biogenic emissions sources include: wind blown dust from erosion and reentrainment; sea salt; particles formed from the oxidation of sulfur compounds emitted from oceans and wetlands; the oxidation of NO<sub>x</sub> from natural forest fires and lightning; and the oxidation of hydrocarbons emitted by vegetation.

**Natural Background Emissions: Bioaerosols:** As part of establishing background concentrations, the mass contributed by living organic matter and biogenic emissions must also be considered.

Ambient bioaerosols include fungal spores, pollen, bacteria, viruses, endotoxin, and animal and plant debris. Bacteria, viruses and endotoxin are mainly found attached to aerosol particles, while entities in the other categories are found as separate particles. Data for characterizing ambient concentrations and size distributions of bioaerosols are sparse. Based on climatic factors, the overall Valley contribution of bioaerosols to total PM10 particulate mass may be on the order of five to ten percent. Levels as low as five to ten percent and as high as 30 percent have been measured; however, data is not available to establish levels typical for California. This level of contribution to PM10

mass does not include the cytoplasmic content of spores and pollen often found to be adhered to particles emitted by motor vehicles and particles of crustal origin.

Fungal spores range in size from 1.5  $\mu\text{m}$  to over 100  $\mu\text{m}$ , although most are 2 to 4  $\mu\text{m}$  in size. They form the largest and most consistently present component of biological aerosols in ambient air. Levels vary seasonally, usually being lowest when and where snow is on the ground. Fungal spores often reach levels of 1,000 to 10,000 spores/ $\text{m}^3$  during the summer months (Lacey and Dutkiewicz, 1994; Madelin, 1994) and may be as high as 100,000/ $\text{m}^3$  near some anthropogenic sources (agriculture activities, compost, etc.).

Bacterial aerosol counts may range as high as 30,000 bacteria/ $\text{m}^3$  downwind of sewage treatment facilities, composting areas, waterfalls from polluted rivers, or certain agricultural activities. Typical levels in urban areas range from several hundred to several thousand bacteria/ $\text{m}^3$  (Lighthart and Mohr, 1994). Levels of bioaerosols (fungi and bacteria) are generally higher in urban than in rural areas (Lighthart and Stetzenbach, 1994).

Gaseous hydrocarbon emissions from plants also form secondary particulates. These particles are not identified as bioaerosols and cannot be distinguished from secondary particles from anthropogenic activities with information available at this time.

### **Utilization of Application Assumptions**

Particle dynamics, physics, atmospheric behavior and fate establish background and regional contribution estimates. These estimates are assumptions considered in rollback calculations to prevent overstating the probable effect of controls. If such assumptions were not utilized, the analysis would link all of the observed particulate to local quantified sources. This would overstate the predicted effectiveness of controls. The assumptions for background and regional components should not be set to the lowest possible level, which would overstate control effectiveness and potentially lead to a failure to attain or to the highest possible contribution, which would underestimate control effectiveness and require implementation of excessive control measures.

Based upon review of the preceding information, default estimates of regional and background contributions have been established in Attachment 3e "CMB Attainment Analysis Formulas Worksheet." The default assumptions will be adjusted as appropriate based upon available information during the process of analysis for seasonal or episodic differences. For example, episodes with higher wind speeds would be assumed to have more regional component than short-term stagnation events. Multi-day stagnation events may have an accumulation of regional components. Other seasonal and meteorological factors or episode evaluation parameters may indicate an adjustment to background assumptions is warranted. However, assumptions are inherently an estimate of contributions that were not, or could not be, directly measured and are therefore approximations that may need to be revised by future improvements to the state of knowledge.

## **Model: Input Data**

### **Emissions Estimates to Support Modeling**

According to EPA PM10 Emission Inventory Requirements, EPA-454/R-94-033, the Attainment Demonstration SIP modeling must demonstrate that attainment will be achieved for both the annual and 24-hour NAAQS, and must demonstrate that allowable emissions have been determined for primary and secondary particulate matter. "States will have to model short-term (daily) and long-term (annual) air quality for PM10 to assure that both standards will be protected, even if air quality measurements show exceedances for only one time period. In dual season situations (e.g., summer wind blown dust and winter wood burning), an emission inventory should be done for each season separately, and the results combined for the analysis of the annual standard." "Enforceable emissions limits must be sufficient to protect both the short term (24-hour) and annual NAAQS for PM10. The SIP emission limits should be based on the NAAQS (annual or 24-hour) which results in the most stringent control requirements. Specific control measures designed to achieve the required emission limitation must then be implemented in the SIP."

The District and ARB maintain annual emission inventories of permitted emissions and estimations of mobile source, area source and naturally occurring emissions. To achieve the greatest possible reliability and accuracy of evaluations and predictions, the emission inventories must be adjusted for modeling to examine specific episodes and seasons for current and future years. The modeling inventory is used as a tool to evaluate control measures, the impact of rulemaking, receptor modeling reconciliation, and projection to future years.

Emissions inventories must be examined and modified for correlation and analysis of observed exceedances. Similar adjustments must be made to prepare modeling inventories representative of different seasons. The emissions will be grouped as required for CMB analysis and rollback projection.

The emission inventories for modeling must also be prepared to address the appropriate spatial scale with an understanding of the appropriate area identified as influencing the ambient concentration at the monitor. This may require an emission inventory for a larger geographic area for fine fraction components as well as a local inventory for the coarse fraction. The coarse fraction domain of the local inventory will be estimated using backward trajectories derived from using surface meteorological data and a two-dimensional wind model.

The emissions inventories prepared to correlate with observed design values are called baseline inventories. Projections of future year conditions without additional controls are referred to as future year inventories and the projection with controls to achieve attainment are referred to as attainment inventories.

## Receptor Modeling Source Profiles

Source profiles will be derived from the EPA source library, local geological and burning profiles collected during the 1988-89 Valley Air Quality Study, and recent motor vehicle profiles developed in Phoenix and Los Angeles. ARB is working with DRI to obtain newer wood burning, motor vehicle, and meat cooking source profiles. These will also be supplemented by soil profiles collected by U. C. Davis as part of their agricultural emission factor work for Technical Support Study 12.

Selection of appropriate source profiles to be used at each site will be based on trial CMB runs using selected samples from each site. The performance measures, as outlined in Section 5.0, will be used to determine the adequacy of each profile. Profiles appropriate to regional and site-specific activities, as well as the season of the year will be considered. Composite profiles may be generated to reflect the contribution of sources that cannot be distinguished individually, such as paved versus unpaved roads.

## Receptor Modeling Chemical Species

The chemical species to be used in the CMB analysis are listed below. If the presence or absence of a specific species causes a large difference in source contribution estimates, the species will be retained if all performance measures are within target ranges. If the performance measures are not within target ranges, the species will be evaluated for possible errors and may be removed from the input file. Additional species and carbon fraction profiles will be added as they become available. This may include additional trace elements measured in newer source profiles, as well as elemental and organic carbon fractions.

<b>Abbreviation</b>	<b>Name</b>	<b>Abbreviation</b>	<b>Name</b>
TMAC	PM <sub>10</sub> Mass	MNXC	Manganese
N3IC	Nitrate	FEXC	Iron
S4IC	Sulfate	NIXC	Nickel
N4TC	Ammonium	CUXC	Copper
ALXC	Aluminum	ZNXC	Zinc
SIXC	Silicon	BRXC	Bromium
CLXC	Chlorine	PBXC	Lead
KPXC	Potassium	PHXC	Phosphorus
CAXC	Calcium	ECTC	Elemental Carbon
TIXC	Titanium	OCTC	Organic Carbon
VAXC	Vanadium	TCTC	Total Carbon
CRXC	Chromium		

## Receptor Modeling Ambient Data

Attachment 1 summarizes the routine and CRPAQS measurements that are applicable to CMB source apportionment. All PM<sub>10</sub> 24-hour exceedances in the San Joaquin Valley from 1997 to 2000 based on the routine ARB/District monitoring network are listed in detail in Attachment 2. All sites with at least nitrate/sulfate and geological species data will be modeled with CMB8. Sites that do not have sufficient speciation data will be matched with an appropriate site/date that can be modeled based on representative meteorology and expected source contributions.

**Routine Data:** PM<sub>10</sub> chemical composition data collected from the routine monitoring network between January 1, 1997 and December 31, 2001 will be used in the CMB8 analysis. The specific sites and dates are indicated in Attachment 3. CMB8 modeling will be performed for days leading up to exceedances for multiple sites in the region to examine spatial and temporal variability in source contributions.

### CRPAQS Data:

Annual Measurements: Data will be available for 71 days from December 1, 1999 to February 3, 2001 at the seven sites shown below. All sites collected 24-hour PM<sub>10</sub> mass data. Sites and dates that correspond to PM<sub>10</sub> exceedance periods identified above will be modeled. Additional days that correspond to high geological contributions in the fall will also be modeled. These sites/dates for CMB modeling are listed in Attachment 4. In addition to CMB modeling of episode days, monthly averages for the seven sites will be modeled to develop annual average contribution estimates.

Site ID	Site Name
BGS	Bakersfield-Golden
COP	Corcoran-Patterson
FSD	Fresno-Drummond
HAN	Hanford-Irwin
M14	Modesto-14th
OLD	Oildale-Manor
VCS	Visalia-Church

Winter Intensive Field Study: Data are available for 15 forecast episode days from December 15, 2000 through February 3, 2001, including the January 1 through January 7, 2001 exceedance period. All sites collected diurnal PM<sub>2.5</sub> data. Focus will be on CMB8 modeling of PM<sub>10</sub> exceedance days. PM<sub>2.5</sub> data at satellite sites are also available to supplement this dataset.

### CRPAQS Winter Anchor Sites

Site ID	Site Name
ANGI	Angiola
BAC	Bakersfield-California
BTI	<i>Bethel Island – not within SJV air basin</i>
FSF	Fresno-First
SNFH	Sierra Foothill

Fall Intensive Field Study: Available data covers the period of October 9, 2000 through November 14, 2000. Approximately 20 of these days have speciation data available for modeling (October 9, 14-24; November 2-9). All sites collected 24-hour PM<sub>10</sub> mass data. The sites consisted of a temporary anchor site at Corcoran- Patterson and 25 satellite sites within and surrounding the city. Sites with possible speciated data for CMB modeling are:

### CRPAQS Fall Anchor Site

Site ID	Site Name
COP	Corcoran – Patterson

### CRPAQS Fall Satellite Sites

Site ID	Site Name
CO5	Corcoran Railroad Shoulder
DAIP	Dairy – paved road
DAIU	Dairy – unpaved road
GRA	Grain Elevator
GRAS	Grain Elevator – South
H43	Highway 43
HAN	Hanford – Irwin
ORE	Oregon St
SFE	Santa Fe Street
YOD	Yoder Street

## Regional Modeling

**Emissions Modeling Methodology:** A spatially, temporally, and chemically resolved emissions inventory for the January 4-6, 1996 episode was developed for CO, NO<sub>x</sub>, SO<sub>2</sub>, NH<sub>3</sub>, PM<sub>10</sub>, and total organic gases (TOG) for area-, motor vehicle-, and point sources. Day-specific emissions input data for use in generating this modeling inventory were not collected during the IMS-95 study period. The preparation of emissions inventories for this study using the EMS-95 emissions processing system (Version 2.01) is described in detail elsewhere (Hughes *et al.*, 1998).

Ammonia Emissions: A special ammonia inventory improvement project was undertaken via a CRPAQS contract with Environ. Although this project will not provide

gridded hourly ammonia estimates for specific emissions categories, as expected, it will provide gridded, hourly estimates for combined categories of point, area, and mobile source emissions as well for fertilizer application, soils, domestic sources, and residential wood combustion.

Mobile Sources: Initially, gridded mobile source emissions for each episode day-of-week were estimated by spatially and temporally distributing EMFAC 2001, version 2.08, CO, NO<sub>x</sub>, SO<sub>2</sub>, PM<sub>10</sub>, and TOG emissions using hourly, grid cell ratios that were developed from SARMAP mobile source emissions. An effort to update mobile source emissions using DTIM and region-specific roadway networks is under way.

Areawide and Stationary Sources: Temporal inputs and emission estimates for CO, NO<sub>x</sub>, SO<sub>2</sub>, PM<sub>10</sub>, and TOG area and point sources were extracted from the California Emissions Inventory Development and Reporting System (CEIDARS). Area sources from the 1999 base year CEIDARS inventory was backcasted using the California Emissions Forecasting System (CEFS) and historical 1996 point source data were retained (ARB data reference RF#820). EMS-95 was used to process these average-day emissions estimates into gridded, hourly estimates for the January 4-6 time period. Spatial surrogates developed under a CRPAQS contract with Sonoma Technology were used to spatially distribute all area source emissions.

Biogenic Emissions: Biogenic emissions are assumed to be negligible due to low leaf biomass, low solar insolation, and low ambient temperatures during wintertime.

Chemical Speciation and Particle Size Distribution: A combination of ARB and UCD chemical speciation and particle size profiles for gaseous and particulate matter emissions were used.

**Initial and Boundary Conditions:** The boundary conditions used for gaseous and PM during this simulation are time and space dependent. They were obtained by interpolating all available observations for a given pollutant over the modeling domain and then extracting the concentrations for appropriate boundary cells. The initial conditions used for 0000 hours on the spin up day of January 03, 1996 were from the interpolated concentration field for that hour.

**Meteorological Modeling Methodology:** The meteorological input parameters to the UAM-Aero model are three-dimensional wind fields, temperature, relative humidity, and surface fields of fog. The model also requires the mixing height and solar irradiance for each grid cell for each hour. The meteorological measurements were conducted at several surface sites and six upper air sites. The six upper air stations were located at El Nido (ELN), Fresno (FEI), Mouth of the Kings River (MKR), Corcoran (COR), Bakersfield (BFK), and Mettler (MTL). Radar wind profilers with radio acoustic sounding systems were operated at ELN, MKR, COR, and MTL sites. Raiwansonde launches

were conducted at FEI and BFK every four hours. All these sites measured wind vectors, temperature, and relative humidity.

Interpolated surface meteorological fields with hourly time resolution were constructed over a grid system of 4-km by 4-km cells that covers the study area using the procedures developed by Harley *et al.* (1993) and the interpolation scheme described by Goodin *et al.* (1979). Three dimensional meteorology fields (wind, temperature, humidity) were created using five vertical layers spanning 1000 vertical meters in the atmosphere. Both surface and three-dimensional meteorological fields were visualized after creation to identify obvious outliers and/or interpolation problems.

Wind Fields: The 3-D wind fields were generated using a diagnostic wind model. First, the model was exercised to generate 2-D fields for each hour using the wind data available from 45 surface meteorological stations in the IMS-95 domain. California Air Resources Board, the California Irrigation Management Information System, and the National Climatic Data Center made these measurements. These 2-D fields were then interpolated in the vertical dimension using the wind data available from the six upper-air meteorological sites. Three dimensional wind fields were smoothed after interpolation using a 5-point averaging operator. Vertical velocity in each grid cell was specified such that wind-field divergence equals zero.

Temperature, Relative Humidity: The surface temperature and relative humidity (RH) data were available at the 74 surface meteorology stations. They were first interpolated to produce the 2D fields. These 2-D fields were then interpolated in the vertical dimension using the data available from six upper-air meteorology sites.

Fog Fields: The determination of clear, hazy, or foggy conditions were based on RH, despite its unreliability, since actual fog observations were very limited. An attempt was made to compare the resulting fog fields with those derived from satellite pictures. However, due to the poor resolution of the satellite pictures and the limited availability of them only for two hours per day, the comparison was inconclusive.

Mixing Heights: The mixing height was determined for each upper air station by examining the available vertical temperature profiles. The estimated mixing heights for were then used to interpolate mixing heights for the entire domain.

Solar Radiation: Total solar radiation and ultraviolet solar radiation were available for 28 measurement sites and they were interpolated over the modeling domain.

## **Model: Output Data**

### **Receptor Modeling**

Outputs from the CMB 8 model follow standard formats. The primary output of interest is the source contribution estimate (SCE) for each episode and source category. Other outputs provide performance statistics discussed in the next section of the Protocol Model: Analysis of Results.

### **Regional Modeling**

Regional modeling will output gridded projections of secondary particulate matter. Additionally, time series analysis of grid cells of interest will also be possible. Other parameters may also be plotted in grid or time series for evaluation. Valid results of interest will be included in final modeling documentation.

The model evaluates ammonium nitrate ( $\text{NH}_4\text{NO}_3$ ) formed from the gaseous precursors ammonia and nitric acid ( $\text{HNO}_3$ ). Ammonia is mainly emitted into the atmosphere from various sources.  $\text{HNO}_3$  is a secondary gaseous product of the reactions between oxides of nitrogen ( $\text{NO}_x$ ) and volatile organic compounds (VOC) in the presence of sunlight. The regional model will also simulate the formation of secondary organic aerosols (SOA) and ammonium sulfate ( $(\text{NH}_4)_2\text{SO}_4$ ). The representation of SOA in the modeling tools currently available is not very robust; therefore, a proportional rollback approach will be used for the photochemical modeling of SOA. The representation of  $(\text{NH}_4)_2\text{SO}_4$  is robust but only minor amounts ( $\sim 5 \mu\text{g}/\text{m}^3$ ) of that pollutant is present in the San Joaquin Valley in observed episodes.

## Model: Analysis of Results

### Receptor Modeling

Model output and performance measures will be analyzed both individually and in aggregate to determine the applicability of the source profiles. Preliminary sets of source profiles will consist of at least one source profile from each source category. Final profile selection will result from interactive application of the CMB with evaluation of the performance measures listed in Section 5.0. Analysis will be repeated by eliminating source profiles that give negative estimates or those with standard errors that exceed the estimates.

Calculated contributions will be compared to measured ambient concentrations. Reasonable agreement between calculated contributions and measured ambient concentrations would indicate that all major source categories were included in the calculations, ambient and source profile measurements were fairly accurate, and source profiles were reasonably representative of actual emissions. Sensitivity matrices will be constructed to determine the source profiles with the most influence on species apportionment. Final analysis will include comparison to regional activities and current emission inventories, and will be done in conjunction with meteorological and climatological analysis.

Analysis of model output of days leading up to an exceedance, or from other sites in the area, will be also conducted. Information from these model runs will aid in determining if exceedance occurred from a general buildup of PM, or whether key emission sources in the region, or unique sources in the area of the monitoring site, were responsible.

The CMB8 model provides a statistical diagnostic evaluation of correspondence of the CMB source identification to the observed sample. The basic statistical performance evaluations include  $R^2$  -  $R^2$  error analysis,  $\chi^2$  -  $\chi^2$  distribution, and Pmass - percent of mass accounted for by the sum of masses attributed to identified sources. The following performance measures will be used to assess the adequacy of the CMB model runs:

Source Contribution Estimate (SCE) This is the contribution of each source type to the PM mass. Each SCE should be greater than its standard error.

Standard Error (STDERR) This is an indicator of the uncertainty of each SCE. The STDERR should be much less than the SCE.

T-Statistic (TSTAT) This is the ratio of the SCE to the STDERR. A value greater than 2.0 indicates the precision of the SCE is high and that the source is a significant contributor.

R-Square (R SQUARE) This measures the variance in the sample concentrations, which is explained by the model calculated species concentrations. A value less than 0.8 indicates that the selected sources do not account for the variance in the sample.

Chi Square (CHI SQUARE) This is a measure of goodness of fit, which is inversely proportional to the squares of the uncertainties in the source profiles and the receptor data. A CHI SQUARE greater than 4.0 indicates that one of the calculated species concentrations differs from the measured value by several uncertainty intervals.

Percent of Mass Accounted For (PERCENT MASS) This is the ratio of the sum of the SCEs to the measured mass of the sample. PERCENT MASS should be within 80% to 120%.

Uncertainty/Similarity Clusters (U/S CLUSTERS) This is an indicator of groups of source profiles which are either collinear or which have very high uncertainties.

Sum of Combined Sources (SUM OF CLUSTER SOURCES) This represents the sum of the SCEs in the U/S CLUSTER with the standard error of the sum. When the standard error is low, it suggests that a composite profile can be created to represent the cluster.

Ratio of Residual to its Standard Error (RATIO R/U) This indicates the difference between the calculated and measured species concentration (residual) divided by the uncertainty of the residual. An R/U value greater than +/- 2.0 indicates that one or more source profiles are contributing too much or too little to the species concentration.

Ratio of Calculated to Measured Species (RATIO C/M) This is the ratio of the calculated species concentration to the measured species concentration along with the standard error of the ratio. The ratio should be near 1.0.

## **Regional Modeling**

Once the base-case simulation is performed, the estimated emissions, meteorology, and air quality need to be compared with observations to assure that the modeling system (emissions, meteorology, and air quality) is a satisfactory representation of the episode modeled. Only with such an assurance one can use the modeling system to evaluate control strategies.

The rigorous comparison of model estimates with observations is termed model performance evaluation. These comparisons, in principle, should be done for emission, meteorology, and air quality estimates. However, there are difficulties in evaluating the performance of the emissions model, especially when measurements appropriate for that purpose is not made. That was the case in IMS-95. Thus, the emission model evaluation would be limited to quality assurance testing. Similar difficulties arise in

evaluating the diagnostic meteorology field as well. Here, all the observations were used in constructing the meteorology fields, and thus, no independent observations are left for comparison. Therefore, meteorology model evaluation would also be limited to quality assurance testing.

It is possible, however, to conduct a rigorous evaluation of the air quality model performance despite the fact that some observations were used for initial and boundary conditions. The statistical metrics used for the comparison of estimates with observations are given in Appendix A. For gaseous pollutants the comparison is straightforward. But, for particulate matter that has several components, the comparison will be done for the total mass as well as for the mass of individual components.

Unlike for ozone, there are no performance standards for particulate matter modeling. Thus, the acceptability of models estimates will be determined through a consensual process that involves US-EPA, ARB, and the San Joaquin Valley APCD.

## Statistical Measures for Regional Modeling Performance Analysis

### Peak Estimation Accuracy:

Paired Peak Estimation Where,  $C_o(x,t)$  is the peak concentration observed at location  $x$  at time  $t$  and  $C_e(x,t)$  is the model estimated concentration at the same location at the same time. Then  $A_{ts}$ , is a measure of the extent to which the observed and estimated peaks are paired in space and time.

**Equation A1: Paired Peak Estimation**

$$A_{ts} = \frac{(c_e(x,t) - c_o(x,t))}{c_o(x,t)} \times 100\%$$

Temporally Paired Peak Estimation: In the above expression if we relax the requirement that the modeled estimate should be in the same grid cell as the observation, we measure the models ability to reproduce the observed peak at the correct hour in the vicinity of the observed peak (e.g. 25 km radius).

Spatially Paired Peak Estimation: In equation (A1), if we relax the requirement that the model estimate should be at the same time as the peak observation, we measure the model's ability to reproduce the observed peak at the correct location at a reasonably close hour (e.g. within 3 hours).

Unpaired Peak Estimation: In equation (A1), if we relax the requirement that model estimate should be at the same location and hour as the observation, we measure the

model's ability to reproduce the peak in the vicinity (say, 25 km radius) of the monitor at a reasonably close hour (e.g. within 3 hours).

**Bias:**

**Equation A2:** Mean Bias Error where N is the number of valid hourly observation-estimation pairs drawn from all valid monitoring data on the simulation day of interest.

$$MBE = \frac{1}{N} \sum_{i=1}^N (c_e(x_i, t) - c_o(x_i, t))$$

**Equation A3:** Mean Normalized Bias Error similar to equation (A-2) but normalized with respect to the observation.

$$MNBE = \frac{1}{N} \sum_{i=1}^N \frac{(c_e(x_i, t) - c_o(x_i, t))}{c_o(x_i, t)} \times 100\%$$

**Error:**

**Equation A4:** Mean Gross Error where, N is the number of valid hourly observation-estimation pairs drawn from all valid monitoring data on the simulation day of interest. Summing the absolute values of the difference prevents cancellation of errors.

$$MAGE = \frac{1}{N} \sum_{i=1}^N |(c_e(x_i, t) - c_o(x_i, t))|$$

**Equation A5:** Mean Normalized Gross Error, similar to equation (A-4) but normalized with respect to the observation.

$$MNBE = \frac{1}{N} \sum_{i=1}^N \frac{|(c_e(x_i, t) - c_o(x_i, t))|}{c_o(x_i, t)} \times 100\%$$

## Variance

**Equation A6:** Variance is measure of spread of data. If the variance is low, then the difference between observations and estimation is small and vice versa.

$$\sigma^2 = \frac{1}{N} \sum_{i=1}^N |c_e(x_i, t) - c_o(x_i, t)|^2$$

## **Determining Attainment for All Cases**

The program of analysis specified in the Protocol will provide a complete attainment demonstration by assessment of all exceedances to the PM10 annual and 24-hour standards that have been detected by the monitoring network and established as causing an area to be classified as nonattainment. The demonstration will show that the proposed emission control program will successfully lower PM10 emissions to the extent that exceedances of the federal PM10 standards are eliminated and that such conditions will be achieved at the earliest practical date consistent with the requirements of the Clean Air Act. The Protocol addresses winter type episodes predominated by secondary particulate formation in urban areas and the monitored exceedances of fall episodes predominated by emissions identified as having a geologic material signature composed of material found in Valley soil.

Winter 24-hour exceedances are identified as being predominated by urban emissions. The largest urban communities experience the highest winter PM10 levels and these cities are monitored in accordance with federal requirements. Providing attainment in those communities by controls that are imposed throughout all other urban areas in a uniform manner and appropriately consider and address regional contributions to the observed episode(s) is considered adequate to establish sufficiency of the control program for winter-type episodes for all urban areas. Similarly, urban monitoring and control programs for attainment also address annual exceedances dominated by winter PM10 levels.

Fall and other seasons experience events dominated by material found in Valley soil that becomes entrained in the atmosphere due to a variety of urban and rural activities. While most of the observed exceedances dominated by material found in Valley soil in the Valley have been observed in the fall, it is also possible to have events related to high winds or unusual activities. Providing attainment for observed episodes in monitored communities by controls that are imposed throughout all other urban areas in a uniform manner and appropriately consider and address regional contributions to the observed episode(s) is considered adequate to establish sufficiency of the control program for observed fall type episodes for all urban areas. Similarly, urban monitoring and control programs for attainment also address annual exceedances dominated by fall PM10 levels.

Analyses will include the examination of historical monitoring data, evaluation of source zone of influence, demonstration of spatial representativeness of monitored episodes and assessment of control strategy impact via rollback analysis (chemical mass balance modeling with speciated rollback and enhanced analysis of secondary particulates for appropriate episodes).

Examining historical data provides context for design value observations and an assessment of whether the design values are consistent with previous experience.

Evaluation of source zone of influence is necessary for prediction of effects of control strategies with receptor and rollback techniques. Evaluation of the spatial representativeness of monitored episodes is important to determine which episodes are dominated by local sources and which have significant contributions from larger portions of the region.

Combining the results of all of these analyses with the meteorological and statistical analysis allows evaluation of whether the monitoring data and design values represent the likely worst case value, which would be a more stringent design value than is required, or whether the monitoring data may represent something less than the fourth highest likely value, which may not be sufficiently protective. This review is important to determine that the control program is sufficient to achieve attainment of the annual and 24-hour standard and is not excessive in its requirements. If design values are determined to be representative and well represented by monitoring; then, addressing the observed exceedances would be established as sufficient for the entire Valley. If design values are not well represented by monitoring observations, evaluation with available data is required to determine the likelihood and frequency of occurrence of such events and the effectiveness of the control program to address applicable contributing sources. Results establish sufficiency of the control program to provide attainment of the annual and 24-hour standard for all identifiable exceedance conditions.

Procedures for analysis have been selected to establish objective and reliable conclusions that have the highest confidence that can be established to establish the SIP as comprehensive and sufficient for the entire Valley in all cases. Although the best available data will be utilized, uncertainties and limitations of the data affect results of analyses and may produce confirming and contradictory indications that must be reconciled by knowledgeable evaluation to establish reliable conclusions. The SIP control plan will establish an attainment demonstration of the PM10 annual and 24-hour standards by successfully addressing all identifiable exceedances that classify the District as nonattainment.

## **Attachments**

The following documents are attached and incorporated as elements of the Protocol, providing more detailed discussions of the analysis and modeling process:

- Meteorological Analysis for the San Joaquin Valley PM-10 SIP
- SJV Statistical Models Application 1988 to 2001
- Countess Analysis
- CMB Workplan
- CMB Attachment 1
- CMB Attachments 2-4
- CMB Attachment 5
- CMB Attainment Analysis Formulas Worksheet
- UAM SJV PM10 ADP Workplan

## **Appendices**

Future improvements to the understanding of PM10 episodes and modeling capabilities are expected from completion of the data analysis and modeling portions of the California Regional PM10/PM2.5 Air Quality Study (CRPAQS) project. The technical issues that will be addressed in the future are discussed in the attached documents “CRPAQS Objectives and Approaches” and “CRPAQS Modeling Plan.” The final results of this project are not yet complete and therefore cannot be incorporated at this time. However, early portions of the study have produced data, analysis and documents that have been used to supplement the regulatory monitoring network and interpretation of the data recorded from all sites.

*-end-*

*SJV PM10 SIP Protocol.doc*

# **Meteorological Analysis for the San Joaquin Valley PM-10 SIP**

## **Purpose**

The San Joaquin Valley APCD (the District) and the California Air Resources Board (ARB) are utilizing Particulate Material (PM) measurements and meteorological parameters to determine what role the meteorology plays in the transport and circulation of pollutants that result in high PM10 concentrations across the San Joaquin Valley. This evaluation is essential, providing the linkage between environmental conditions and observed particle concentrations. Establishing causal and contributing relationships is essential to understanding the events and determining effective actions to improve air quality.

## **Procedures**

Surface wind flow and direction are analyzed to determine flow patterns that aid in dispersion and transport of particulates. Consistent wind direction measurements from several different monitoring sites with velocities of more than three or four meters per second are an indication that organized flow may exist which disperses pollutants. In organized flow conditions upwind areas may possibly affect the PM10 concentrations by dispersion and transport of emissions to the downwind area. Wind directions that appear to be random with speeds of less than two to three meters per second may indicate a stagnant or disorganized flow that does not disperse pollutants. Stagnant conditions may allow a buildup of emissions to dominate the air quality. This can occur as either a buildup of local primary particulates or regional secondary particulates. The buildup of particulate concentrations is increased by duration of the stagnant period and decreased by any periods of organized flow or rainfall.

Precipitation measurements are also analyzed as an indicator of the vigorous trough passages, which provide enough vertical mixing to produce rainfall. The strength of the frontal system and trough is a good indicator of how much PM dispersion occurs.

Solar intensity measurements (amount of sunlight reaching the surface levels of the atmosphere) are analyzed to determine if particulate material aloft or at the surface lowers the solar radiation input, which establishes the equilibrium between photochemical reactions and particulate matter formation. Atmospheric chemistry reactions change from a more photochemistry-ozone forming regime to a more particulate regime if the solar intensity is dropped to below normal levels.

Much of the focus of analysis will be on exceedance episodes; however it is also possible to determine what type of meteorology facilitates good dispersion that leads to "clean" days.

## **Previous and Current Findings of Meteorological Analysis**

Previously an analysis was conducted to examine the relationship of historical 850 MB temperatures and PM measurements. The evaluation "Meteorological Data Analysis and Trajectory Modeling of PM10 Episodes during 1993 to 1995 for the San Joaquin Valley State Implementation Plan" determined that an episode was possible in the San Joaquin Valley when 850 MB temperatures in the fall were above +15<sup>0</sup> C and +10<sup>0</sup>C during the winter (late November or December to February). A stronger indication for a PM episode to occur is when 850 MB temperatures were above +18<sup>0</sup>C in the fall and above +14<sup>0</sup>C in the winter. A height of 5,760 meters in the San Joaquin Valley is sufficient to suspect an episode, and that a height of 5,820 meters or more in the Valley made an episode occurrence a likelihood. It was also determined that the 500 MB height is also important in that it is directly correlated to the temperature of the entire column of air

Continuing efforts by ARB and the District have analyzed several synoptic and surface meteorological parameters in order to understand the behavior of particulate matter and how it is transported and dispersed. These synoptic and surface meteorological parameters include: an 850 MB stability parameter (850 MB temperature minus minimum temperature), 500 MB heights, surface wind speed and direction, precipitation, surface temperature and relative humidity, solar intensity measurements, and visibility. Each one of these parameters plays a major role in the formation, transport, and dispersion of particulate material within the boundary layer of the San Joaquin Valley.

The 850 MB temperature stability parameter was utilized because 850 MB temperature (approximately 5,000 feet) minus the minimum surface temperature is a good indicator of the inversion strength, the mixing layer depth, and whether air is being warmed from a synoptic subsidence inversion aloft. This inversion is commonplace when a ridge builds along the West Coast of California, providing general adiabatic warming of subsiding air over the region.

During periods of high pressure aloft, flows at the surface are usually light and accompanied by low mixing depths. The 500 MB height is important in that it is directly correlated to the temperature of the entire column of air and along with the placement of the mean ridge and trough patterns is indicative of PM amounts and trends.

## **Continuing Analysis Elements for the Modeling Protocol**

The District and ARB are continuing to evaluate meteorological data relationships to PM10 through additional efforts including synoptic evaluations of episode and CRPAQS data and ARB statistical evaluation of meteorological patterns.

**New Review of CRPAQS and Historical Data:** Both the District and ARB will examine observed exceedances in the past and perform an analysis based on historical meteorological analysis and statistical models. In order to better understand the nature of PM10 formation, build up, and dispersion; an extensive network of particulate and weather monitors were utilized during the California Regional PM10/PM2.5 Air Quality Study (CRPAQS). The CRPAQS data provides a more extensive set of measurements collected in field studies (selected measurement periods 1995-2001) to improve the understanding that will be developed from analysis of historical data.

**District Analysis:** The District will conduct meteorological analysis to determine episode strength and periodicity of PM. The meteorological analysis will involve: examining synoptic (weather) charts and local weather phenomena during exceedance and non-exceedance events, conducting a historical analysis of the meteorological parameters and PM over several years and investigating the relationships between the 850 MB stability parameter and PM2.5 data. After examining the relationship between the 850 MB stability parameter and PM2.5 data, it will be determined whether or not it is reasonable (i.e., statistically valid) to use the 850 MB parameter (or some combination of meteorological variables) as a surrogate for historical PM2.5 data.

**ARB Meteorological Analysis:** ARB will conduct an analysis on past PM10 episodes between 1997 and 2001. The meteorological analysis will involve: using surface maps, infrared satellite imagery, and 850, 500, and 300 MB upper air charts. This analysis will provide a general overview of the meteorological conditions occurring during major PM10 episode days from 1997 and 2001 and can be used as guidance for identifying future PM10 episodes.

**ARB Statistical Analysis:** ARB is also analyzing meteorological factors through statistical methods to identify any relationships that have not been previously identified. This element is included in the protocol as a separate work plan "Application of Statistical Models for Analysis of High PM10 and PM2.5 Concentrations in the San Joaquin Valley During 1988 to 2001."

Results of these analyses guide the interpretation of episode factors by providing linkage between environmental conditions, observed particle concentrations, causal and contributing relationships. The relationships established for environmental conditions and particulate concentrations can be used to forecast the particulate levels likely to occur from trend and control program estimates of future emissions.

# **Application of Statistical Models Analysis of High PM10 and PM2.5 Concentrations in the San Joaquin Valley During 1988 to 2001**

## **Purposes of Analysis:**

1. Determine frequency of occurrence of Watson's conceptual models and add new variations if found.
2. Examine representativeness of episodes – present episodes (1997 – 2001) versus those in the lower to mid 1990's,
3. Categorize meteorological regimes and episodes for supporting CMB model runs, and
4. Determine seasonal differences in the influence of meteorological independent variables.

**Intent:** To support the San Joaquin Valley 2002 SIP for PM10

**Scope:** Analyzing the impact of meteorological data on high PM10 and PM2.5 concentrations in the SJV from 1992 to 2001. If time permits, look at the period of 1988 to 1991, during the drought period when they were many PM10 exceedances. Possibly include impact of meteorology on PM10 species such as nitrates, sulfates, and elemental and organic carbon. Look at the representativeness of 1997 to present episodes, comprising those episodes that need to be analyzed for this SIP, to those that occurred from 1992 to 1996 (where we did some data analysis for the 1997 SIP revision but did not perform a CART analysis).

**Candidate Modeling Techniques:** Simple scatter plots in SAS, single or multiple linear regression in SAS for project QA and initial analysis and then CART 3.6. Possibly use a factor analysis to corroborate the CART analyses (if time and resources permit).

**Candidate dependent variable:** PM10 and PM2.5 mass plus remotely possibly constituents – 24-hour or hourly data only (not enough time left in the schedule to consider shorter times such as 5 minutes, etc.) Look at % of PM10 that is PM2.5 that is a good predictor of “fall” versus “winter” type episodes.

**Candidate independent meteorological variables:**

**Upper air data:** 850 mb Temp-Minimum, 500 mb heights. All items were recorded once daily from 1992 to 2001. Extent of coverage: Oakland Ca. and possibly Vandenberg AFB, CA.

**Surface data:** wind speed, wind direction, precipitation (simple amount during day or, preferably, parameterized for amount and duration of effects), temperature, fog or visibility, relative humidity, a photochemical signature term such as O3-NO from District data, length of day or an hourly solar index. Extent of coverage: all district and ARB data for the SJV, data for about 5 stations from the District, the remainder from AIRS. CIMIS data for precipitation coverage for the Valley (about 25 stations throughout the valley, especially east and west side, may reduce analysis to about 10 key representative sites. About 10 sites from NWS that monitor many parameters including RH, temperature, winds, precipitation, visibility (in range downwind), cloud cover and type, etc.

**Candidate Analysis Techniques:**

Segregate data into significant “years,” in this case 1992 to 1997 which represent wetter than normal years and 1998 to 2001 which were drier than normal. Furthermore, segregate the data into seasons; fall, winter, summer, and spring and do a pattern analysis by month. Also, subdividing valley into three regions – north, central, and south. Look at CART for possible application, review existing studies including IMS95 and CRPAQS, review conceptual models by Watson, and review the District PM forecasting equation.

**Deadline for Project Completion:** No later than September 30, 2002

**Personnel:** Rich Hackney as Project Leader and Jeff Austin as Project Consultant for Statistics.

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# Quantifying the Contribution of Fugitive Geological Dust to Ambient PM10 Levels in the San Joaquin Valley

Proposal submitted to:

San Joaquin Valley Unified APCD

July 30, 2002

**Exhibit A**

## 1.0 INTRODUCTION

As a result of the San Joaquin Valley (SJV) Planning Area being classified by EPA as a “serious” PM10 nonattainment area, the SJVUAPCD (District) and CARB submitted a serious PM10 Attainment Demonstration Plan to EPA in 1997. This plan was subsequently withdrawn by CARB in early 2002 prior to action on the plan by EPA, leaving the state in the position of having to prepare a revised attainment plan to avoid federal sanctions. The 1997 PM10 attainment plan recognized the importance of implementing control measures for fugitive dust emissions of geological origin to attain both the 24-hour and annual NAAQS PM10 standards. This is especially true for the Corcoran, Hanford, and Oildale sites where the contributions from geological sources are highest in the fall, and range between 52% and 72% for the 24-hour PM10 design values for these three sites (SJVUAPCD, 2001). Since geological driven events tend to be localized, PM10 exceedances have generally occurred more frequently and in higher concentrations in urban areas than in non-urban areas due to anthropogenic activities that result in mechanical entrainment of fugitive geological dust. Stagnation events where the wind speeds are insufficient to disperse high PM10 concentrations also contribute to PM10 exceedances. Although windblown dust events are not typical within the Air Basin, they have occurred and have contributed to high PM10 concentrations. The 2000 PM10 emissions inventory for the SJV Air Basin developed by CARB indicates that approximately 75% of the daily 481 tons per day of PM10 (on an annual basis) are due to open area fugitive geological dust sources. According to CARB, anthropogenic sources (paved and unpaved road dust, farming operations, and construction/demolition) account for approximately 86% of the fugitive geological dust PM10 emissions, and wind erosion of exposed surfaces of geological material accounts for the balance. However, these fugitive geological dust emissions estimates overstate the impact of these emissions on downwind ambient PM10 concentrations by a factor of two to four since the models used to predict the ambient PM10 concentrations do not account for aerosol loss mechanisms such as deposition and impaction (Countess et. al., 2000).

Countess Environmental (CE) is submitting this proposal to assist the District gain further understanding of the impact of fugitive geological dust on ambient PM10 concentrations in the SJV Air Basin with the knowledge that the District is on a “fast-track” schedule for developing a revised PM10 attainment plan. Dr. Richard Countess, a nationally recognized air quality consultant with many years of experience in conducting research studies including performing assessments of air quality data, will lead the data analysis efforts required for this project. Dr. Countess has been active in the study of fugitive geological dust for the past two decades. As a small business, CE offers the advantages of very competitive rates and the services of highly qualified individuals to ensure timely completion of high quality project deliverables. CE’s proposes to evaluate the contribution of fugitive geological dust to the ambient PM10 concentrations within the SJV Air Basin with a emphasis on the following issues:

- temporal, spatial and chemical variations in fugitive geological dust concentrations as indicators of different fugitive geological dust sources and different source strengths; and
- variations in the ratio of coarse to fine size fractions of fugitive geological dust as indicators of the age of the resuspended dust as well as indicators of different fugitive geological dust sources.

Anticipated tangible benefits of the project include:

- quantification of the contribution of fugitive geological dust to ambient PM10 concentrations within the San Joaquin Valley;

- characterization of the temporal variation and spatial variation of ambient fugitive dust concentrations within the Valley;
- characterization of the variation in chemical composition of the ambient fugitive dust concentrations within the Valley;
- characterization of the zone of influence for sources of road dust and agricultural dust in the Corcoran/Hanford area during the Fall; and
- characterization of the variation in the ratio of the coarse to fine fugitive dust aerosol size fractions. This ratio may serve as an important tool to provide estimates of the age of the fugitive dust, and/or to distinguish between different source categories contributing to the ambient fugitive dust in the Valley.

## 2.0 TECHNICAL APPROACH

This section discusses CE's proposed approach for quantifying the temporal and spatial variations in ambient fugitive geological dust concentrations, the variability in the chemical composition of fugitive geological dust, and the variation in the coarse to fine size fractions of fugitive geological dust. CE proposes to utilize recent ambient PM10 monitoring data (mass and element concentrations) from the CRPAQS monitoring network available from CARB to address the impact of fugitive geological dust on ambient PM10 concentrations in the SJV Air Basin. Many of the PM monitoring sites utilized as part of CRPAQS (identified later in Table 2-2) are shown in Figure 2-1. PM samplers operating on a schedule of one 24-hour sample every sixth day were deployed throughout the SJV Air Basin and surrounding regions during the 14-month study and were supplemented with more frequent monitoring at several key sites and more intensive sampling during the fall and winter when concentrations of PM10 and PM2.5 are highest. CE will seek the assistance of the District to acquire the necessary CRPAQS data from CARB.

Figure 2-1. San Joaquin Valley PM2.5 monitoring sites (CARB, 1998)



CE is aware that both sampling and analytical uncertainties associated with all ambient measurements exist. Therefore, in order for CE to generate a scientifically robust evaluation of the role of fugitive geological dust in the SJV Air Basin, CE will select only those measurements that have been fully validated for our analysis.

## 2.1 Methodology for Quantifying Fugitive Geological Dust Concentration

CE proposes to adopt the methodology utilized by Sisler and Malm (2000) in their analysis of data from the IMPROVE network to calculate the fugitive geological dust concentrations, [Soil], for PM samples based on XRF measurements of the major elements associated with geological material as follows:

$$[\text{Soil}] = 2.2 [\text{Al}] + 2.19 [\text{Si}] + 1.63 [\text{Ca}] + 2.42 [\text{Fe}] + 1.94 [\text{Ti}]$$

This formula, which represents a minor iteration to that used by Countess et. al. (1980) for the Denver Brown Cloud Study, assumes that the major elements associated with geological material are present as their predominant oxide forms, that FeO and Fe<sub>2</sub>O<sub>3</sub> are equally abundant, and that [K] equals 0.6 [Fe] for geological material.

## 2.2 Selection of PM Samples for Analysis

The particulate samplers deployed at the CRPAQS sites for collecting ambient particulates for subsequent chemical analysis included Minivols, sequential filter samplers (SFS), and multistage MOUDI cascade impactors. These samplers with their different sampling media and sampling frequency are listed in Table 2-1 by sampler code assigned by CARB. Since the bulk of fugitive geological dust is in the coarse size fraction (typically >80%), analysis of data collected with the Minivol sampler with the PM10 inlet will provide the best information on fugitive geological dust. A list of air quality measurements from CRPAQS sites available for CE's analyses is presented in Table 2-2.

Table 2-1. CRPAQS PM Measurement Methods

Sampler Code	Observable	Sampler	Frequency/Avg Time
b	Mass and elemental size distribution $\leq 15\mu\text{m}$	MOUDI with Teflon impaction media	Winter Episode Days 6-hr every third period
c	Ion size distribution $\leq 15\mu\text{m}$	MOUDI with Teflon impaction media	Winter Episode Days 6-hr every third period
d	Carbon size distribution $\leq 15\mu\text{m}$	MOUDI with aluminum impaction media	Winter Episode Days 6-hr every third period
g	PM10 mass and elements	Minivol with Teflon filters	Every 3 <sup>rd</sup> to 6 <sup>th</sup> day; 24-hr
h	PM10 ions and carbon	Minivol with quartz filters	Every 3 <sup>rd</sup> to 6 <sup>th</sup> day; 24-hr
B	PM2.5 mass and elements	Minivol with Teflon filters	Daily; 24-hr
C	PM2.5 ions and carbon	Minivol with quartz filters	Daily; 24-hr
L	PM2.5 mass and elements	SFS with Teflon filters	Annual: Daily; 24-hr Winter Episode Days: 3-8-hr
M	PM2.5 ions and carbon	SFS with denuder and quartz filters	Annual: Daily; 24-hr Winter Episode Days: 3-8-hr

### 2.2.1 PM10 Minivols

CE proposes to analyze all the available PM10 Minivol mass and element data (i.e., sampler code: g). From Table 2-2 one can see that PM10 Minivols were operated during the period 12/01/99 through 1/31/01 with a sampling schedule of one 24-hour sample every third day at the following seven sites throughout the SJV Air Basin: **Bakersfield, Corcoran, Fresno, Hanford, Modesto, Oildale, and Visalia**. These community exposure (CORE) sites were selected to represent short-term and long-term exposures to PM10 (and PM2.5) concentrations experienced by large populations that live, work, and play within 5 to 10 km surrounding the site. These CORE sites are beyond the zone of influence of a single source and are affected by regional, urban, and neighborhood scale source contributions. In addition, PM10 Minivols were deployed at 11 satellite sites (selected to be either source zone of influence sites or receptor zone of representation sites) that were centered around Corcoran to collect daily 24-hour PM10 samples during the Fall of 2000 (October 8 through November 14) in order to gain a better understanding of the effects of local fugitive dust sources on high PM10 concentrations in this portion of the Air Basin. According to the CRPAQS planning documents, the Fall study period was intended to bracket the time period associated with the peak cotton harvesting in the Corcoran area.

Source sites, located within 1 km of the Corcoran site, are intended to quantify near-maximum contributions from individual emitters (e.g., major roadway, construction site, agricultural activities) and, when coupled with measurements from nearby sites, estimate the zone of influence of these emitters. Receptor sites are intended to examine medium or neighborhood scale spatial variability around the Corcoran site. Their data are used to determine the extent to which the CORE site located in Corcoran represents community exposure at increasing distances from the CORE site. Source sites set up during the Fall included sites designed to monitor the impact on ambient PM10 concentrations of fugitive dust emissions from a paved road, an unpaved road, an unpaved railroad shoulder, a grain elevator, and cotton handling. No background PM10 monitoring sites were employed within the monitoring domain during CRPAQS. According to the CRPAQS planning documents, there is no location in central California that is not influenced by anthropogenic emissions. However, CE proposes to utilize the results of the PM2.5 Minivol deployed at the Olancho site selected to represent a background site to estimate background PM10 fugitive geological dust levels appropriate for the study domain (see next section).

### 2.2.2 PM2.5 Minivols

There were 35 sites where PM2.5 Minivols were deployed throughout the SJV Air Basin as part of the CRPAQS monitoring network compared to only 7 sites with PM10 Minivols, making for a very compelling argument to analyze the measurements from the PM2.5 Minivols in order to quantify the spatial variation in fine fugitive geological dust throughout the Basin. However, since only a small percentage (typically 15% to 25%) of the fugitive geological dust resides in the fine size fraction below 2.5 microns, quantifying the concentration of fine fugitive geological dust (based on XRF measurements of the major elements associated with geological material) may result in large uncertainties in the calculated values. This will be especially true for those cases where the ambient fugitive geological dust concentrations are low and the concentrations of elements associated with geological material approach the detection limit of the sampling/analytical methodology employed. For the base program, CE proposes to analyze the PM10 Minivol and PM2.5 Minivol mass and element data available from the four sites with collocated PM10 and PM2.5 Minivols (**Corcoran, Modesto, Oildale, and Visalia**) in order to

Table 2-2. CRPAQS Air Quality Measurements Available for CE's Analyses by Site

Site	Purpose	Sampler Type by Season						
		Annual <sup>a</sup>			Winter <sup>b</sup>			Fall <sup>c</sup>
		PM10 Minivol (g, h)	PM2.5 Minivol (B, C)	PM2.5 SFS (L, M)	PM2.5 Minivol <sup>d</sup> (B, C)	PM2.5 SFS (L, M)	MOUDI <sup>d</sup> (b, c, d)	PM10 Minivol (g, h)
Angiola	Anchor Site			X			X	
Bodega Bay	Anchor Site		X		X		X	
Bakersfield (CA St)	Anchor Site			X			X	
Bethel Island	Anchor Site		X			X		
Corcoran - Patterson	Anchor Site	X <sup>e</sup>	X <sup>e</sup>		X			X
Edwards Air Force Base	Anchor Site		X		X			
Fresno (First St)	Anchor Site			X			X	
Modesto (14 <sup>th</sup> St)	Anchor Site	X <sup>e</sup>	X <sup>e</sup>		X		X	
Sacramento - Del Paso Man	Anchor Site						X	
Sierra Nevada Foothills	Anchor Site		X			X		
Angles Camp	Intrabasin Gradient		X		X			
Altamont Pass	Interbasin Transport		X		X			
Bakersfield (Golden State)	Community Exposure	X <sup>e</sup>						
Residential area near BAC	Source: Woodburning		X		X			
Carrizo Plain	Intrabasin Gradient, Visibility		X		X			
China Lake	Visibility		X		X			
Clovis	Community Exposure		X		X			
Railroad Shoulder	Fall Source: Unpaved Shoulder							X
Paved dairy road	Fall Source: Paved Road							X
Unpaved dairy road	Fall Source: Unpaved Road							X
Edison	Intrabasin Gradient		X		X			
Dairy	Source: Dairy Animals		X		X			
Fellows	Source: Oilfields		X		X			
Foothills above Fellows	Intrabasin Gradient		X		X			
Fresno Motor Vehicle	Source: Motor Vehicles		X		X			
Residential area near FSF	Source: Woodburning		X		X			
Fresno (Drummond)	Community Exposure	X <sup>e</sup>						
Grain Elevator	Fall Source: Grain Elevators							X
Grain Elevator South	Fall Source Zone of Influence							X
Highway 43	Fall Southern Boundary							X
Hanford (Irwin St)	Com Expo, Fall North Boundary	X <sup>e</sup>						X
Helm	Intrabasin Gradient		X		X			
Kettleman City	Intrabasin Gradient		X		X			
Livermore Rincon Street	Interbasin Transport		X		X			
Mojave Poole Street	Community Exposure		X		X			
Merced Midtown	Community Exposure		X		X			
Oildale (Manor)	Community Exposure	X <sup>e</sup>	X <sup>e</sup>		X			
Olancho	Background		X		X			
Oregon Avenue	Fall Neighborhood Exposure							X
Pacheco Pass	Interbasin Transport		X		X			
Kern Wildlife	Rural, Intrabasin Gradient		X		X			
Pleasant Grove	Intrabasin Gradient		X		X			
Sacramento (T Street)	Community Exposure		X		X			
Selma	Community Exposure		X		X			
San Francisco (Arkansas St)	Community Exposure		X		X			
Sante Fe Street	Fall Source: Cotton Handling							X
Stockton Hazelton	Intrabasin Gradient		X		X			
SW Chowchilla	Interbasin Transport		X		X			
Tehachapi Pass	Interbasin Transport, Visibility		X		X			
Visalia (North Church St)	Community Exposure	X <sup>e</sup>	X <sup>e</sup>		X			
Yoder Street	Fall North Edge of Source Area							X

<sup>a</sup> Annual measurements (12/01/99 - 1/31/01): every sixth day for most parameters, daily for PM2.5 SFS units

<sup>b</sup> Winter measurements (12/01/00 - 2/3/01)

<sup>c</sup> Fall measurements (10/08/00 - 11/14/00)

<sup>d</sup> Winter measurements for 15 "episode" days

<sup>e</sup> Annual measurements (12/01/99 - 1/31/01): every third day

calculate the PM10/PM2.5 and CM/PM2.5 ratios of ambient concentrations of fugitive geological dust, where CM is the coarse mass concentration between 2.5 and 10 microns.

CE also proposes to analyze the PM2.5 Minivol data available from the one background PM2.5 monitoring site employed during CRPAQS that was located in Olancho to quantify the fine fraction of ambient fugitive geological dust concentrations at this background site. CE will use these results as well as the results from the four sites with collocated PM10 and PM2.5 Minivols to estimate the seasonal average and annual average PM10 fugitive geological dust concentrations for this background site.

At a later date, if authorized by the District, CE will analyze the PM2.5 Minivol data from the other 30 sites where PM2.5 Minivols were deployed to quantify the fine fraction of ambient fugitive geological dust concentrations at these sites. As part of this follow-on work, the average PM10/PM2.5 ratios of ambient concentrations of fugitive geological dust for the four sites with collocated PM10 and PM2.5 Minivols can be used to estimate the seasonal and annual average PM10 fugitive geological dust concentrations for these 30 sites.

### 2.2.3 PM2.5 Sequential Filter Samplers

PM2.5 sequential filter samplers (SFS) were deployed at three sites (**Angiola, Bakersfield, and Fresno**) to collect 24-hour samples every day between 12/1/99 and 1/31/01. In addition, PM2.5 SFS units were deployed to collect diurnal samples (3 to 8 hour duration) at these same three sites plus two additional sites (Bethel Island and Sierra Nevada Foothills) for 15 winter “episode” days between 12/1/00 and 2/3/01. Analysis of these high time resolution PM2.5 samples collected during the 15 winter “episode” days will allow one to study the diurnal variation in fine fugitive geological dust concentrations. However, quantifying the concentration of fine fugitive geological dust (based on XRF measurements of the major elements associated with geological material) will result in large uncertainties in the calculated values for those cases where the ambient fugitive geological dust concentrations are low, similar to the problems associated with analyzing measurements from the PM2.5 Minivols. For this reason, we recommend deferring a decision on analyzing PM2.5 SFS data for quantifying the diurnal variation in fine fugitive geological dust concentrations during the winter field study period until a later time. For the base program, CE proposes to quantify the daily fine fugitive geological dust concentrations for the Angiola, Bakersfield, and Fresno sites using the PM2.5 SFS data. CE will utilize the average PM10/PM2.5 ratios of ambient concentrations of fugitive geological dust for the four sites with collocated PM10 and PM2.5 Minivols (Corcoran [Patterson], Modesto, Oildale and Visalia) to estimate the seasonal and annual average PM10 fugitive geological dust concentrations for the non-urban Angiola site.

### 2.2.4 MOUDI Cascade Impactors

Multi-stage MOUDI cascade impactors were deployed during the CRPAQS field study at six sites for a limited period of time: 15 “episode” days in the winter study period. Furthermore, because the MOUDI samples were labor intensive to collect, they were collected on a staggered sampling schedule. Without continuous sampling during the 15 winter “episode” days, the MOUDI results can’t be used to determine the diurnal variation in the fugitive geological dust component. For these reasons, CE does not propose to analyze the MOUDI results.

## 2.2.5 PM Samples to be Analyzed for the Base Program

For the base program, CE proposes to analyze the PM10 and PM2.5 samples collected for quantifying mass and element concentrations from the CRPAQS CORE and satellite sites listed in Table 2.3.

Table 2-3. CRPAQS Air Quality Measurements to be Analyzed by CE for the Base Program

Site	Purpose	PM10 Minivol	PM2.5 Minivol	PM2.5 SFS
Bakersfield -1120 Golden State	Community Exposure	X <sup>e</sup>		
Corcoran - Patterson	Community Exposure	X <sup>c,e</sup>	X <sup>d,e</sup>	
Fresno - Drummond	Community Exposure	X <sup>e</sup>		
Hanford - Irwin Street	Community Exposure Fall North Boundary	X <sup>c,e</sup>		
Modesto - 14 <sup>th</sup> Street	Community Exposure	X <sup>e</sup>	X <sup>d,e</sup>	
Oildale - Manor	Community Exposure	X <sup>e</sup>	X <sup>d,e</sup>	
Visalia - North Church Street	Community Exposure	X <sup>e</sup>	X <sup>d,e</sup>	
Corcoran - Railroad Shoulder	Fall Source: Unpaved Shoulder	X <sup>c</sup>		
Angiola	Anchor Site (non-urban)			X <sup>a</sup>
Bakersfield – 5558 CA Street	Anchor Site (urban)			X <sup>a</sup>
Fresno – 3425 First street	Anchor Site (urban)			X <sup>a</sup>
Paved Dairy Road	Fall Source: Paved Road	X <sup>c</sup>		
Unpaved Dairy Road	Fall Source: Unpaved Road	X <sup>c</sup>		
Grain Elevator	Fall Source: Grain Elevators	X <sup>c</sup>		
Grain Elevator South	Fall Source Zone of Influence	X <sup>c</sup>		
Highway 43	Fall Southern Boundary	X <sup>c</sup>		
Oregon Avenue	Fall Neighborhood Exposure	X <sup>c</sup>		
Santa Fe Street	Fall Source: Cotton Handling	X <sup>c</sup>		
Yoder Street	Fall North Edge of Source Area	X <sup>c</sup>		

<sup>a</sup> Annual measurements (12/01/99 - 1/31/01): every sixth day for most parameters; daily for PM2.5 SFS units

<sup>b</sup> Winter measurements (12/01/00 - 2/3/01)

<sup>c</sup> Fall measurements (10/08/00 - 11/14/00)

<sup>d</sup> Winter measurements for 15 “episode” days

<sup>e</sup> Annual measurements (12/01/99 - 1/31/01): every third day

## 2.3 Analyses to be Performed for the Base Program

### 2.3.1 Temporal, Spatial and Chemical Variations

Temporal and Spatial Variations CE will calculate daily 24-hour as well as seasonal and annual PM10 fugitive geological dust concentrations for the seven CRPAQS community exposure sites where PM10 Minivols were deployed. CE will quantify the spatial variation in PM10 fugitive geological dust concentrations for each of these seven sites for daily 24-hour measurements as well as the seasonal and annual average results. CE will also quantify the spatial variation in PM10 fugitive geological dust concentrations for the 11 satellite (source zone of influence/receptor zone of representation) sites centered around Corcoran during the Fall of 2000. CE will compare the results from the period December 1999

through January 2000 with the results from the period December 2000 through January 2001 to determine the variability from one year to the next.

Chemical Variation Sources of fugitive dust of geological origin include farming operations, construction/demolition activities, paved and unpaved road dust that is mechanically resuspended by vehicles, as well as windblown dust from exposed geological surfaces. Countess et. al. (1980) observed that the relative contributions of the six major elements associated with geological material (Al, Si, K, Ca, Ti and Fe) measured in the ambient PM10 aerosol during the 1978 Denver Brown Cloud Study varied spatially as well as temporally.

For the base program, CE will investigate the temporal and spatial variations in the relative abundance of the elements associated with geological material for all the sites where PM10 Minivols were deployed. Specifically, we plan to calculate the relative abundance of each of the six major element associated with geological material (e.g.,  $[Al]/\{[Al] + [Si] + [K] + [Ca] + [Ti] + [Fe]\}$ ). These results will be used to determine if certain elements are enriched compared to site average values or network average values. In the case of potassium, which is present in soil as well as wood, an enriched  $[K]/[Fe]$  ratio would indicate the contribution from wood burning or forest fires. In their analysis of the IMPROVE network data, Sisler and Malm (2000) assumed that the  $[K]/[Fe]$  ratio in geological material is 0.6, whereas Countess et. al. (1980) observed an average  $[K]/[Fe]$  ratio for the Denver PM10 aerosol of 0.79 during the fall and winter months. This enhancement in potassium is consistent with the higher frequency of residential wood fires that occur during the fall/winter period. CE will calculate the  $[K]/[Fe]$  ratio for all the sites where PM10 Minivols were deployed. CE will also evaluate whether the variability in the relative abundance of the major elements associated with geological material and the variability in the  $[K]/[Fe]$  ratio is a function of season and whether certain of these elements are enhanced during high PM10 episodes. CE will compare the results from the period December 1999 through January 2000 with the results from the period December 2000 through January 2001 to determine the variability from one year to the next. As part of the base program, CE also proposes to examine the results from the five “source zone of influence” sites (unpaved railroad shoulder, paved dairy road, unpaved dairy road, grain elevators, cotton handling) centered around Corcoran to see if the variation in the relative concentration of the major elements associated with geological material from these sites can be used as an indicator of the sources of fugitive dust (agricultural dust, road dust, or mixed) at each CORE site.

### 2.3.2 Variation in the Ratio of Coarse to Fine Size Fractions of Fugitive Geological Dust

According to Pace (2001), USEPA’s source tests indicate that the ratio of freshly generated coarse fugitive geological dust to fine fugitive geological dust ranges from 5.7 for unpaved road dust; to 4.0 for agricultural tilling/harvesting, construction/demolition, and mining/quarrying; to 3.0 for paved road dust. Thus  $[Coarse]/[Fine]$  ratios based on field measurements of fugitive geological dust from the Minivols deployed throughout the CRPAQS network are expected to average between 3.0 and 5.7 for freshly generated fugitive geological dust. Since coarse particles deposit out of the atmosphere much faster than fine particles, the ratio of coarse to fine fugitive geological dust decreases as one moves further away from the source of freshly generated fugitive geological dust emissions; thus, this ratio is an indicator of the age of the aerosol (Countess, 2000). Therefore ratios lower than 3.0 are evidence that the coarse size fraction has preferentially deposited out of the atmosphere relative to the fine size fraction. Based on an analysis of data from the IMPROVE network, Countess (2000) observed that the ratio of coarse to fine fugitive geological dust was lowest in pristine wilderness areas far removed from local sources of fugitive

geological dust compared to areas impacted by nearby sources of fugitive geological dust. In several cases this ratio approached 1.0 compared to theoretical values of 3.0 to 5.7 for freshly generated fugitive geological dust. Thus, the ratio of coarse to fine fugitive geological dust, which is an indicator of the age of the resuspended fugitive geological dust, can be used as an indicator of the zone of influence for different sources and can help to distinguish high PM10 (or high PM2.5) episodes impacted by local sources of fugitive geological dust from those episodes impacted by distant (i.e., regional) sources of fugitive geological dust. Low coarse to fine fugitive geological dust ratios are consistent with distant sources while high ratios would indicate a higher local source contribution.

CE will utilize the data from the collocated PM10 Minivols and PM2.5 Minivols deployed at Corcoran, Modesto, Oildale and Visalia to evaluate the variation in the coarse to fine size fractions of fugitive geological dust. The coarse fraction will be calculated as the difference between the PM10 Minivol data and the PM2.5 Minivol data. CE will compare the results from the period December 1999 through January 2000 with the results from the period December 2000 through January 2001 to determine the variability from one year to the next.

## 2.4 Analyses to be Performed for Each PM Sampler for the Base Program

### 2.4.1 PM10 Minivols

For the samples collected with the PM10 Minivols, CE will calculate:

- the fugitive geological dust concentration in the PM10 size fraction, [PM10 Soil];
- the fugitive geological dust contribution to PM10 mass, [PM10 Soil] / [PM10];
- the relative abundance of each of the six major elements associated with geological material (Al, Si, Ca, Fe, K, Ti); and
- the potassium to iron ratio, [K]/[Fe].

CE will document the spatial, temporal and chemical (where applicable) variations observed for each of the analyses listed above. CE will examine the data to determine whether there is a “weekend/weekday effect” associated with the amount and relative contribution of fugitive geological dust to ambient levels of PM10. CE will compare the relative contribution of fugitive geological dust to ambient PM10 mass concentrations (as measured by the PM10 Minivols) with the estimates of fugitive dust contributions in the District’s PM10 emissions inventory.

### 2.4.2 PM2.5 Minivols

For the four sites that have both PM2.5 Minivol and PM10 Minivol measurements (Corcoran, Modesto, Oildale, and Visalia), CE will calculate:

- the fugitive geological dust concentration in the fine size fraction, [Fine Soil];
- the fugitive geological dust contribution to fine mass, [Fine Soil]/[PM2.5];
- the coarse mass concentration [CM], where [CM] equals [PM10] minus [PM2.5];
- the fugitive geological dust concentration in the coarse size fraction, [Coarse Soil], where [Coarse Soil] equals [PM10 Soil] minus [Fine Soil];
- the fugitive geological dust contribution to coarse mass, [Coarse Soil] / [CM]; and
- the ratio of coarse to fine fugitive geological dust, [Coarse Soil]/[Fine Soil].

CE will document the spatial and temporal variations observed for each of the analyses listed above. The ratio of coarse to fine fugitive geological dust measured in the ambient samples will be compared to EPA's estimates for freshly generated emissions of fugitive geological dust associated with roads, construction, and agriculture.

#### 2.4.3 PM2.5 Sequential Filter Samplers

For the three sites that have daily 24-hour PM2.5 SFS measurements (Angiola, Bakersfield, and Modesto), CE will investigate:

- temporal variations in fine fugitive geological dust concentration, [Fine Soil]; and
- fine fugitive geological dust contribution to fine particulate mass, [PM2.5 Soil] / [PM2.5].

CE will estimate the seasonal and annual average PM10 fugitive geological dust concentrations for the Angiola site utilizing the average PM10/PM2.5 ratios of ambient concentrations of fugitive geological dust for the four sites with collocated PM10 and PM2.5 Minivols.

#### 2.5 Optional Data Analysis Tasks

CE has identified four optional data analysis tasks that CE could perform if approved by the District in addition to the data analysis tasks to be performed as part of our base program described above. These four optional tasks are summarized briefly below.

Fugitive Dust Markers CE is aware that CARB expects the results of a "fugitive dust marker" study to distinguish between specific sources such as road dust, construction dust, and agricultural dusts associated with different crops and farming operations results from RJ Lee later this year. In the interim, if the District can provide CE with evidence that large amounts of earth moving activities associated with construction occurred within several kilometers of any of the CORE sites during CRPAQS, CE will examine the PM10 Minivol results to determine if the relative concentration of the major elements associated with geological material during periods of active construction is different from periods without active construction. CE will also examine the results from the four sites with collocated PM10 and PM2.5 Minivol to determine if the ratio of coarse to fine geological dust fractions is a function of the amount of construction activities.

Variation in CM/PM10 Ratio Both PM10 and PM2.5 beta attenuation monitors (BAM) were deployed at the Angiola, Bakersfield (California Street), and Fresno (First Street) sites during CRPAQS. These samplers operated every day during the study period with an averaging time of one hour. The results from these collocated samplers could be used to assess the diurnal and seasonal variations in the CM/PM10 ratio (i.e., the coarse aerosol fraction) at the three sites.

Effect of Wind Speed on Fugitive Dust Concentrations It is our understanding that CARB considers that there was little evidence that high PM10 concentrations were caused by high winds during the study period (private communication with Karen Magliano). However, an independent analysis may be warranted. Resuspended road dust, construction dust and agricultural tilling/harvesting dust generally tend to impact nearby monitoring sites much more than distant monitoring sites during low wind or stagnant wind conditions. However, high winds can cause these anthropogenic emissions to be lofted higher into the atmosphere and transported much longer distances. In addition to affecting the residence

time of anthropogenic fugitive dust emissions in the atmosphere, high winds can cause exposed soil surfaces to erode and generate large amounts of windblown fugitive dust that can be carried long distances from their source. If approved by the District, CE will investigate the effect of wind speed on ambient fugitive dust concentrations by examining the relationship between fugitive dust concentration and wind speed for sites with collocated PM10 Minivols and wind speed measurements. CE will examine these data to determine whether the higher fugitive dust concentrations occur during periods of high wind speeds (for example in excess of 15 mph). CE will also identify which sites appear to be impacted by high wind speeds more than others. CE will examine these data to determine if there is a relationship between high fugitive dust concentrations and wind speed and wind direction that, coupled with the coarse soil to fine soil ratio, allows us to determine whether it is possible to identify high PM10 concentration episodes caused by anthropogenic activities versus high PM10 concentration episodes caused by high winds.

Reconstructed Light Extinction If approved by the District, CE will adopt the methodology utilized by Sisler and Malm (2000) in their analysis of data from the IMPROVE network to reconstruct the atmospheric light extinction coefficient due to particles. CE will compare our reconstructed (i.e., calculated) light extinction values due to particles with actual field measurements of light scattering and light absorption.

### **3.0 STAFFING, MANAGEMENT, and REPORTING**

CE is proposing a streamlined organization for this project with minimal management oversight of staff and no sub-contractors. The data analysis efforts will be conducted by the two senior principals of Countess Environmental: Dr. Richard Countess and Susan Countess. These two individuals have worked together on many projects involving data analysis in the past. CE guarantees the availability of these two individuals to carry out the proposed data analyses according to the proposed schedule presented in Section 5.

CE will obtain the specific subset of measurements required for our analyses in common format (e.g., comma delimited, Excel, Access) from CARB's CRPAQS data manager. CE has up-to-date computer hosted data analysis and data management tools including in-house developed statistical templates. All work is performed on copies of original data to avoid corruption of the received data. Revision tracking tools are used when required. Work in progress is backed up daily onto portable media such as floppy or Zip disks.

CE will contact the District Project Officer weekly to review the status of this short duration project. CE will submit a monthly invoice to the District by the tenth of each month. CE will submit a draft final report to the District that will include all the analytical results in tabular and graphical formats, and a final report that addresses all the comments and incorporates suggested revisions within 15 days of receipt of District's comments on the draft final report.

### **4.0 QUALIFICATIONS and RESPONSIBILITIES of KEY PERSONNEL**

Dr. Richard Countess will direct the work and serve as the point of contact for technical matters with District personnel. Dr. Countess has an Ph.D. in Physical Chemistry from Rutgers University. He is an experienced air quality research scientist with a proven track record assisting both public sector and industry clients for over 20 years. He has served as principal investigator for studies addressing

atmospheric chemistry and air pollution with an emphasis on ambient chemically speciated particulate material. His areas of expertise include air quality measurements, emission factors development, modeling and interpretation of results. He has directed ambient PM10 characterization programs that included measurements of temporal and spatial variation in concentration, chemical composition, and size distribution, and calculations of source apportionment; developed resuspended dust emission inventories; designed PM10 emission control strategies; and designed and tested PM10 and size-segregated particulate matter sampling equipment. He has over 140 publications addressing criteria pollutants, air toxics, photochemical smog and visibility. Relevant publications are attached to his resume at the end of this proposal. His most recent experience includes:

- principal investigator for Western Regional Air Partnership's (WRAP) fugitive geological dust program to quantify the regional impact of fugitive dust emissions from wind erosion and mechanical resuspension of road dust on Class I areas in the West;
- expert witness in a class action suit involving exposure to fugitive geological dust resulting from construction and demolition activities in southern California; and
- principal investigator for developing a PM10 emissions inventory for fugitive geological dust sources for the South Coast AQMD's 1997 PM10 SIP and a PM2.5 emissions inventory for Los Angeles.

Susan Countess, a Senior ASQ Certified Quality Engineer with extensive credentials in data analysis and applied statistics, will perform the bulk of the data analyses (including generating data summaries and graphical presentation of results), and will be responsible for all contractual issues (including the submittal of monthly reports and invoices). Ms. Countess has an MS in Physical Chemistry from Rutgers University with over 20 years experience as a Quality Assurance professional in a variety of industries. Both Dr. Countess and Susan Countess will be responsible for preparing the draft final report and final report. Susan's most recent experience includes:

- analysis of data from the IMPROVE network to determine the spatial and temporal variation in fugitive geological dust at rural Class I sites in the West, and the relationship between coarse and fine crustal species as a function of distance from urban sources of fugitive geological dust;
- calculation of fugitive geological dust emissions for windblown dust and anthropogenically generated dust from the remediation of a large industrial site in southern California;
- data analysis and statistical support for an South Coast AQMD-sponsored program to evaluate remote sensing for monitoring emissions from heavy duty diesel vehicles; and
- data analysis and statistical support for the City of Los Angeles Remote Sensing Pilot Study, including designing templates for statistical tests of hypothesis.

## **5.0 PROJECT SCHEDULE**

According to Karen Magliano (private communication; 7/29/02), CARB has received all of the PM mass and speciation data from DRI (with the exception of the MOUDI data) in standard Excel spreadsheet format. Assuming that Countess Environmental can obtain validated CRPAQS data from CARB within a week of contract award, we anticipate that it will take one to two months to complete the data analysis tasks for the base program, with a draft report submitted to the District within a few weeks thereafter.

Based upon the expected delivery of data to begin the project, the report should be available no later than November 30, 2002.

## 6.0 BUDGET

Countess Environmental proposes to conduct the work for the base program for a “Fixed Price” contract of \$10,000 assuming the District waives professional liability insurance requirements for this paper study. If professional liability insurance is required, CE proposes to conduct the work on a “Time and Materials” (T&M) basis utilizing CE’s fully loaded hourly labor rates of \$65/hour for Dr. Richard Countess and \$40/hour for Ms. Susan Countess; other direct costs (ODC) will be billed at cost without markup. Our budget for the base program, presented in Table 6-1, assumes two one-day trips by private auto from CE’s offices in Westlake Village to the District’s offices in Fresno.

Table 6-1. T&M Budget for Base Program

	<b>Hrs</b>	<b>\$</b>
<b>Labor</b>		
Richard Countess	120	\$7,800
Susan Countess	160	\$6,400
Subtotal Labor		\$14,200
<b>Other Direct Costs</b>		
Travel		\$600
Repro/Mail/Phone		\$50
Subtotal ODC		\$650
<b>Total (Labor &amp; ODC)</b>		\$14,850

## REFERENCES

- CARB (1996). "Project Overview: 1995 Integrated Monitoring Study Design, Operations, Measurement and Post Field Activities," California Air Resources Board Report #026.22-98.2.
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# **WORKPLAN FOR CHEMICAL MASS BALANCE MODELING OF CRPAQS DATA FOR SJV PM SIP**

## **1.0 MODEL**

The EPA Chemical Mass Balance Model version 8.0 installed on a PC will be used for all modeling. Validation procedures outlined in the EPA "Protocol for Applying and Validating the CMB Model" will be followed. The steps are:

1. Determine the general applicability of the CMB model to the application at hand.
2. Setup the model by identifying and assembling the source types, source profiles, and receptor concentrations needed for model input. Make a preliminary application of the model to these data.
3. Examine the model's statistics and diagnostics to identify potential deviations from the model assumptions.
4. Evaluate problems that might result from problems with model input data.
5. Make model input changes which can be justified to resolve the identified problems and re-run the model.
6. Assess the stability of the model results and their consistency with the preliminary analyses.

## **2.0 AMBIENT DATA**

Attachment 1 summarizes the routine and CRPAQS measurements that are applicable to CMB source apportionment. All PM<sub>10</sub> 24-hour exceedances in the San Joaquin Valley from 1997 to 2000 based on the routine ARB/District monitoring network are listed in detail in Attachment 2. All sites with at least nitrate/sulfate and geological species data will be modeled with CMB8. Sites that do not have sufficient speciation data will be matched with an appropriate site/date that can be modeled based on representative meteorology and expected source contributions.

### **2.1 ROUTINE DATA**

PM<sub>10</sub> chemical composition data collected from the routine monitoring network between January 1, 1997 and December 31, 2001 will be used in the CMB8 analysis. The specific sites and dates are indicated in Attachment 3. CMB8 modeling will be performed for days leading up to exceedances for multiple sites in the region to examine spatial and temporal variability in source contributions.

## 2.2 CRPAQS DATA

### 2.2.1 Annual Measurements

Data will be available for 71 days from December 1, 1999 to February 3, 2001 at the seven sites shown below. All sites collected 24-hour PM<sub>10</sub> mass data. Sites and dates that correspond to PM<sub>10</sub> exceedance periods identified above will be modeled. Additional days that correspond to high geological contributions in the fall will also be modeled. These sites/dates for CMB modeling are listed in Attachment 4. In addition to CMB modeling of episode days, monthly averages for the seven sites will be modeled to develop annual average contribution estimates.

BGS	Bakersfield-Golden
COP	Corcoran-Patterson
FSD	Fresno-Drummond
HAN	Hanford-Irwin
M14	Modesto-14th
OLD	Oildale-Manor
VCS	Visalia-Church

### 2.2.2 Winter Intensive Field Study

Data are available for 15 forecast episode days from December 15, 2000 through February 3, 2001, including the January 1 through January 7, 2001 exceedance period. All sites collected diurnal PM<sub>2.5</sub> data. Focus will be on CMB8 modeling of PM<sub>10</sub> exceedance days.

<b>Anchor Sites</b>	
ANGI	Angiola
BAC	Bakersfield-California
BTI	Bethel Island
FSF	Fresno-First
SNFH	Sierra Foothill

PM<sub>2.5</sub> data at satellite sites are also available to supplement this dataset.

### 2.2.3 Fall Intensive Field Study

Data will be available from October 9, 2000 through November 14, 2000. Approximately 20 of these days have speciation data available (October 9, 14-24;

November 2-9). The sites consisted of a temporary anchor site at the Corcoran backbone monitor plus 25 satellite sites within and surrounding the city. All sites collected 24-hour PM<sub>10</sub> mass data. Since this data is supplemental to the core data, not all days will be modeled. Sites with possible speciated data for CMB modeling are:

<b>Anchor Sites</b>	
COP	Corcoran - Patterson

<b>Satellite Sites</b>	
CO5	Corcoran Railroad Shoulder
DAIP	Dairy – paved road
DAIU	Dairy – unpaved road
GRA	Grain Elevator
GRA S	Grain Elevator – South
H43	Highway 43
HAN	Hanford – Irwin
ORE	Oregon St
SFE	Santa Fe Street
YOD	Yoder Street

### 3.0 SOURCE PROFILES

Source profiles will be derived from the EPA source library, local geological and burning profiles collected during the 1988-89 Valley Air Quality Study, and recent motor vehicle profiles developed in Phoenix and Los Angeles. ARB is working with DRI to obtain newer wood burning, motor vehicle, and meat cooking source profiles. These will also be supplemented by soil profiles collected by U. C. Davis as part of their agricultural emission factor work for Technical Support Study 12. The source profiles used for this analysis are listed in Attachment 5.

Selection of the most appropriate source profiles to be used at each site will be based on trial CMB runs using selected samples from each site. The performance measures, as outlined in Section 5.0, will be used to determine the adequacy of each profile. Profiles appropriate to regional and site-specific activities, as well as the season of the year will be considered. Composite profiles may be generated to reflect the contribution of sources that cannot be distinguished individually, such as paved versus unpaved roads.

#### 4.0 CHEMICAL SPECIES

The chemical species to be used in the CMB analysis are listed below. If the presence or absence of a specific species causes a large difference in source contribution estimates, the species will be retained if all performance measures are within target ranges. If the performance measures are not within target ranges, the species will be evaluated for possible errors and may be removed from the input file. Additional species and carbon fraction profiles will be added, as they become available. This includes additional trace elements measured in newer source profiles, as well as elemental and organic carbon fractions.

Abbreviation	Name
TMAC	PM <sub>10</sub> Mass
N3IC	Nitrate
S4IC	Sulfate
N4TC	Ammonium
ALXC	Aluminum
SIXC	Silicon
CLXC	Chlorine
KPXC	Potassium
CAXC	Calcium
TIXC	Titanium
VAXC	Vanadium
CRXC	Chromium
MNXC	Manganese
FEXC	Iron
NIXC	Nickel
CUXC	Copper
ZNXC	Zinc
BRXC	Bromium
PBXC	Lead
PHXC	Phosphorus
ECTC	Elemental Carbon
OCTC	Organic Carbon
TCTC	Total Carbon

## 5.0 PERFORMANCE MEASURES

The following performance measures will be used to assess the adequacy of the CMB model runs:

Source Contribution Estimate (SCE) This is the contribution of each source type to the PM mass. Each SCE should be greater than its standard error.

Standard Error (STDERR) This is an indicator of the uncertainty of each SCE. The STDERR should be much less than the SCE.

T-Statistic (TSTAT) This is the ratio of the SCE to the STDERR. A value greater than 2.0 indicates the precision of the SCE is high and that the source is a significant contributor.

R-Square (R SQUARE) This measures the variance in the sample concentrations, which is explained by the model calculated species concentrations. A value less than 0.8 indicates that the selected sources do not account for the variance in the sample.

Chi Square (CHI SQUARE) This is a measure of goodness of fit, which is inversely proportional to the squares of the uncertainties in the source profiles and the receptor data. A CHI SQUARE greater than 4.0 indicates that one of the calculated species concentrations differs from the measured value by several uncertainty intervals.

Percent of Mass Accounted For (PERCENT MASS) This is the ratio of the sum of the SCEs to the measured mass of the sample. PERCENT MASS should be within 80% to 120%.

Uncertainty/Similarity Clusters (U/S CLUSTERS) This is an indicator of groups of source profiles which are either collinear or which have very high uncertainties.

Sum of Combined Sources (SUM OF CLUSTER SOURCES) This represents the sum of the SCEs in the U/S CLUSTER with the standard error of the sum. When the standard error is low, it suggests that a composite profile can be created to represent the cluster.

Ratio of Residual to its Standard Error (RATIO R/U) This indicates the difference between the calculated and measured species concentration (residual) divided by the uncertainty of the residual. An R/U value greater than +/- 2.0 indicates that one or more source profiles are contributing too much or too little to the species concentration.

Ratio of Calculated to Measured Species (RATIO C/M) This is the ratio of the calculated species concentration to the measured species concentration along with the standard error of the ratio. The ratio should be near 1.0.

## 6.0 PROCEDURES AND RESULTS

Model output and performance measures will be analyzed both individually and in aggregate to determine the applicability of the source profiles. Preliminary sets of source profiles will consist of at least one source profile from each source category. Final profile selection will result from interactive application of the CMB with evaluation of the performance measures listed in Section 5.0. Analysis will be repeated by eliminating source profiles that give negative estimates or those with standard errors that exceed the estimates.

Calculated contributions will be compared to measured ambient concentrations. Reasonable agreement between calculated contributions and measured ambient concentrations would indicate that all major source categories were included in the calculations, ambient and source profile measurements were fairly accurate, and source profiles were reasonably representative of actual emissions. Sensitivity matrices will be constructed to determine the source profiles with the most influence on species apportionment. Final analysis will include comparison to regional activities and current emission inventories, and will be done in conjunction with meteorological and climatological analysis.

Analysis of model output of days leading up to an exceedance, or from other sites in the area, will be also conducted. Information from these model runs will aid in determining if exceedance occurred from a general buildup of PM, or whether key emission sources in the region, or unique sources in the area of the monitoring site, were responsible.

## 7.0 ISSUES

- How much variation in source profiles used site-by-site, and sample-by-sample?
- How to relate results to days when data is not available.

## 8.0 SCHEDULE

<b>Task</b>	<b>Completion Date</b>
Prepare Databases	February and March 2002; on-going as new data becomes available
Sensitivity Testing	March through July 2002
Final Model Runs	August 2002
Write Report	August to September 2002

### Ambient Data for CMB Modeling

Selected monitoring sites in the San Joaquin Valley routinely collect chemical composition data. In addition, a comprehensive monitoring network, established as part of CRPAQS, collected chemical composition data from late 1999 through early 2001. Summarized below are routine and CRPAQS measurements that are applicable to CMB source apportionment.

#### 1) Routine Network Data.

The PM10 chemical composition data collected as part of the routine network utilized two different samplers: SSI sampler for measuring ions (NO<sub>3</sub>, SO<sub>4</sub>, NH<sub>4</sub>, K, CL) and carbon and dichotomous (dichot) sampler for measuring 30 elements by XRF. The input files were constructed by combining SSI and dichot data. The concentrations of elements measured on a dichotomous sampler were scaled based on the ratio of SSI PM10 to the total dichot concentrations. Concentrations that vary by more than 20% were flagged and reexamined to determine if the data was appropriate to CMB modeling. Table 1 summarizes chemical composition data collected as part of the routine network between 1/1/1997 and 12/31/2001 where both SSI and dichotomous samplers were operated concurrently. All dichotomous samplers, except Fresno-1<sup>st</sup>, were phased out at the end of 2000. Some monitoring sites, including Corcoran, Taft, and Visalia, did not collect total carbon data. These partial data records will be of more limited value for CMB modeling.

Table 1. Routine SSI and Dichot Chemical Composition Data Collected Between 11/97 and 12/31/2000

SITE_NAME	Measured Species		
	Nitrate/ Sulfate	Total Carbon	Geological
Bakersfield-5558 California	X	X	X
Corcoran-Patterson Avenue <sup>1</sup>	X		X
Corcoran-Van Dorsten <sup>2</sup>	X		X
Fresno-1st Street	X	X	X
Modesto-I Street <sup>3</sup>	X	X	X
Modesto-14th Street		X	X
Stockton-Hazelton Street	X	X	X
Taft College <sup>4</sup>	X		X
Visalia-N Church Street	X		X

<sup>1</sup> Measurement of geological species was discontinued after March 2000.

<sup>2</sup> Site active between January 1997 and September 1998.

<sup>3</sup> Site active between January 1997 and August 1998.

<sup>4</sup> Measurement of geological species was discontinued in February 2000.

Since it is not practical or necessary to model all of the available data, the criteria listed below were used to select only records applicable to modeling exceedances of the 24-hr standard:

- a) Each episode that resulted in a violation of the 24-hr standard was identified.
- b) Each episode was bracketed to include exceedance days, days prior to an exceedance, and days following the exceedance. The extent of this bracketing was determined on a case-by-case basis, determined by meteorology and data availability.
- c) All monitoring sites that collected data during an episode, even those that that did not exceed the standard, were selected for CMB modeling.

Attachment 3 includes a complete list of routine candidate sites applicable to modeling exceedances of the 24-hr standard.

2) CRPAQS PM10 Chemical Speciation Data.

The long-term routine monitoring network was supplemented by CRPAQS monitoring from late 1999 through early 2001. Unlike routine data that combines species from dichot and SSI samplers, the CRPAQS chemical composition data were collected using one type of sampler, a battery-powered Airmetrics Minivol sampler. Measurements of chemical species include 40 elements (Na to U), ions (Cl, NO<sub>3</sub>, SO<sub>4</sub>, Na, K, NH<sub>4</sub>), and organic and elemental carbon. The PM10 chemical composition data were collected as part of two programs described below:

- a) The annual satellite PM10 network consisted of 14 months of every-sixth-day, 24-hr sampling at seven PM10 sites. These data will be used to support the CMB modeling of exceedances of the 24-hr standard as well as annual standard. PM10 chemical composition measurements acquired at CRPAQS annual satellite sites are summarized in Table 2. Attachment 4 includes a complete list of sites along with the chemical composition data that were selected for CMB modeling following the criteria in Section 1 above.

Table 2. CRPAQS Chemical Composition Data  
Collected as Part of the Annual PM10 Program

SITENAME	Start Date	End Date	Obs Count
Bakersfield-1120 Golden	12/23/1999	2/3/2001	63
Corcoran-Patterson Avenue	12/5/1999	1/28/2001	65
Fresno Drummond	12/11/1999	1/28/2001	68
Hanford-Irwin St.	12/23/1999	1/28/2001	60
Modesto 14th St.	12/5/1999	1/28/2001	68
Oildale-Manor	12/5/1999	2/3/2001	58
Visalia Church St.	12/5/1999	1/28/2001	61

The input files for modeling exceedances of the annual average standard were generated using CRPAQS data for the year 2000. Monthly data

were averaged and formatted for CMB modeling. The monthly average data will serve as a basis for modeling exceedances of the annual standard.

- b) The satellite fall intensive network included six emissions source dominated monitoring sites. The chemical composition data were collected on selected days between 10/9/2000 and 11/9/2000. Since the PM10 concentrations collected as part of this program were below the level of the 24-hr PM10 standard (with the maximum PM10 concentration of 124 ug/m<sup>3</sup>) and these data are source emissions dominated they will only be used as supplemental information for CMB modeling. A complete list of data records collected as part of this program is also included in Attachment 4.

## Summary of PM10 Measurements Above the Federal 24-hour PM10 Standard for 1997 - 2001

County	Site Name	Max PM10	DATE	Monitor	PM2.5 as % of PM10	Percent of PM10 Mass			Sufficient Data to CMB Model?
						AmNitrat and Sulfa	Total Carbon	Geo-Logical	
10/25/97 - 11/6/97									
Kings	Corcoran-Patterson Avenue	199	11/6/97	Routine	17	10		47	Y
12/25/98 - 12/31/98									
Kern	Bakersfield-Golden State High	159	12/31/98	Routine					N
Tulare	Visalia-N Church Street	160	12/31/98	Routine		53		9	Y
1/9/99 - 1/15/99									
Kern	Oildale-3311 Manor Street	156	1/12/99	Routine		57			N
10/15/99 - 11/5/99									
Fresno	Fresno-Drummond Street	162	10/21/99	Routine					N
Kings	Corcoran-Patterson Avenue	174	10/21/99	Routine	36	19		35	Y
Stanislaus	Turlock-S Minaret Street	157	10/21/99	Routine					N
11/14/1999									
Kern	Bakersfield-Golden State High	183	11/14/99	Routine	73				N
12/17/99 - 1/1/00									
Kings	Corcoran-Patterson Avenue	174	12/17/99	Routine					N
Fresno	Fresno-Drummond Street	168.25	12/23/99	CRPAQS		40	28	26	Y
Kings	Hanford-S Irwin Street	155.63	12/23/99	CRPAQS		52	23	28	Y
12/26/00 - 1/7/01									
Fresno	Clovis-N Villa Avenue	155	1/1/01	Routine	84	50			N
Fresno	Fresno-1st Street	193	1/1/01	Routine	77	40	26	4*	Y
Fresno	Fresno-Drummond Street	186	1/1/01	Routine					N
Fresno	Fresno-Drummond Street	159.06	1/4/01	CRPAQS		37	33	18	Y
Kern	Bakersfield-5558 California Av	186	1/1/01	Routine	71	54	18		N
Kern	Bakersfield-5558 California Av	190	1/4/01	Routine	67	51	16		N
Kern	Bakersfield-5558 California Av	159	1/7/01	Routine	75	51	15		N
Kern	Bakersfield-Golden State High	205	1/1/01	Routine					N
Kern	Bakersfield-Golden State High	207.57	1/4/01	CRPAQS		51	18	23	Y
Kern	Bakersfield-Golden State High	174	1/7/01	Routine					N
Kern	Oildale-3311 Manor Street	158	1/1/01	Routine	89	61			N
Kern	Oildale-3311 Manor Street	195.19	1/4/01	CRPAQS		61	14	22	Y
Kings	Corcoran-Patterson Avenue	165	1/7/01	Routine	76	56			N
Kings	Hanford-S Irwin Street	185	1/7/01	Routine	53	57			N
Stanislaus	Modesto-14th Street	158	1/7/01	Routine	86	56	16		N
11/9/2001									
Kings	Hanford-S Irwin Street	155	11/9/01	Routine					N

a. The percent contribution from major categories of species was estimated by the following steps:

1. % Nitrate/Sulfate:  $((1.29 \times \text{non-volatilized nitrate}) + (1.38 \times \text{sulfate})) / \text{PM10} * 100$
2. % Total Carbon (TC) for routine data:  $(\text{Total Carbon (as measured on an SSI filter)} / \text{PM10 Mass}) * 100$
3. % Total Carbon (TC) for CRPAQS data:  $((1.4 \times \text{organic carbon}) + \text{EC}) / \text{PM10 Mass} * 100$
4. % Geological for routine data:

First each geological species was scaled to the level of the SSI mass by multiplying concentration of each species by the ratio of PM10 mass measured on SSI to PM10 mass measured on dichot. Next, the percent contribution was calculated as follows:

$$(((1.89 \times \text{aluminum Conc Scaled to SSI}) + (2.14 \times \text{silicon Conc Scaled to SSI}) + (1.4 \times \text{calcium Conc scaled to SSI}) + (1.43 \times \text{iron Conc scaled to SSI})) / \text{PM10 Mass}) * 100$$

5. % Geological for CRPAQS data (no scaling needed):

$$(((1.89 \times \text{aluminum}) + (2.14 \times \text{silicon}) + (1.4 \times \text{calcium}) + (1.43 \times \text{iron})) * 100$$

\* The percent contribution from geological is suspect due to a large difference between PM10 SSI mass and dichot mass (193 ug/m3 on SSI vs. 95 ug/m3 on dichot).

## PM10 Chemical Composition Data From The Routine Network

Site	Day of Week	Date	SSI PM10 ug/m3	% of PM10 Mass <sup>a</sup>				DICHOT Mass			
				SSI		Dichot <sup>b</sup>	Sum O Species	PM10 ug/m3	Fine ug/m3	% Fine	
				Nitr	Sul	TC					Geological
<b>Fall 1997</b>											
Bakersfield-5558 California Ave	2	11/3/97	73	11	16	51	79	65	18	28	
Bakersfield-5558 California Ave	5	11/6/97	87	7	10	63	80	87	15	17	
Bakersfield-5558 California Ave	1	11/9/97	53	20	17	34	71	58	25	43	
Bakersfield-5558 California Ave	4	11/12/97	30	19	23	20	62	31	20	65	
Corcoran-Patterson Avenue	6	10/31/97	102	14		51	65	90	23	26	
Corcoran-Patterson Avenue	5	11/6/97	199	10		48	58	180	31	17	
Corcoran-Van Dorsten Avenue	6	10/31/97	97	13		52	65	93	25	27	
Corcoran-Van Dorsten Avenue	5	11/6/97	154	12		40	53	155	29	19	
Fresno-1st Street	6	10/31/97	76	16	17	37	70	72	36	50	
Fresno-1st Street	5	11/6/97	92	17	12	39	68	85	36	42	
Modesto-I Street	6	10/31/97	21	15	19	45	79	20	6	30	
Modesto-I Street	5	11/6/97	44	23	14	31	67	41	20	49	
Modesto-I Street	4	11/12/97	29	25	21	9	54	35	26	74	
Stockton-Hazelton Street	6	10/31/97	27	11	19	47	77	25	8	32	
Stockton-Hazelton Street	5	11/6/97	32	17	16	35	67	34	14	41	
Stockton-Hazelton Street	4	11/12/97	25	23	20	17	60	27	18	67	
<b>December 1998</b>											
Bakersfield-Golden State Highway	5	12/31/98	159								
Visalia-N Church Street	5	12/31/98	160	53		9		139	115	83	
Bakersfield-5558 California Ave	3	12/22/98	44	39	20	10	70	48	40	83	
Bakersfield-5558 California Ave	2	12/28/98	112	49	18	11	78	115	89	77	
Bakersfield-5558 California Ave	5	12/31/98	148	54	14	9	77	151	122	81	
Bakersfield-5558 California Ave	7	1/9/99	93	47	17	9	74	90	67	74	
Fresno-1st Street	5	12/31/98	104	52	15	5	73	100	88	88	
Fresno-1st Street	4	1/6/99	36	33	28	6	67	41	36	88	
Modesto-14th Street	5	12/31/98	80	51	14	6	71	81	69	85	
Stockton-Hazelton Street	5	12/31/98	95	52	13	6	71	97	81	84	
<b>Mid January 1999</b>											
Oildale-3311 Manor Street	3	1/12/99	156	57							
Bakersfield-5558 California Ave	7	1/9/99	93	47	17	9	74	90	67	74	
Bakersfield-5558 California Ave	3	1/12/99	92	44	17	11	73	97	71	73	
Bakersfield-5558 California Ave	6	1/15/99	114	56	11	12	80	118	89	75	
Bakersfield-5558 California Ave	2	1/18/99	29	20	21	29	71	29	18	62	
Fresno-1st Street	4	1/6/99	36	33	28	6	67	41	36	88	

## PM10 Chemical Composition Data From The Routine Network

Site	Day of Week	Date	SSI PM10 ug/m3	% of PM10 Mass <sup>a</sup>				DICHOT Mass		
				SSI		Dichot <sup>b</sup>	Sum O Species	PM10 ug/m3	Fine ug/m3	% Fine
				Nitr	Sul	TC				
<b>Fall 1999</b>										
Fresno-Drummond Street	5	10/21/99	162							
Turlock-S Minaret Street	5	10/21/99	157							
Corcoran-Patterson Avenue	6	10/15/99	127	10			51		122	24 20
Corcoran-Patterson Avenue	5	10/21/99	174	19			35		170	61 36
Bakersfield-5558 California Ave	1	10/3/99	55	9	18		38	66	57	23 40
Bakersfield-5558 California Ave	4	10/6/99	39	12	13		47	71	41	11 27
Bakersfield-5558 California Ave	7	10/9/99	60	9	18		47	74	63	20 32
Bakersfield-5558 California Ave	3	10/12/99	60	10	17		50	77	59	16 27
Bakersfield-5558 California Ave	6	10/15/99	86	11	14		47	73	89	25 28
Bakersfield-5558 California Ave	5	10/21/99	104	14	14		48	76	97	34 35
Bakersfield-5558 California Ave	1	10/24/99	98	23	12		32	67	95	47 49
Bakersfield-5558 California Ave	4	10/27/99	108	26	12		38	75	105	45 43
Bakersfield-5558 California Ave	7	10/30/99	59	13	14		44	70	62	15 24
Fresno-1st Street	1	10/3/99	55	10	20		36	66	53	23 43
Fresno-1st Street	7	10/9/99	57	7	16		51	74	58	17 29
Fresno-1st Street	6	10/15/99	93	6	13		40	59	84	20 24
Fresno-1st Street	5	10/21/99	121	14	15		35	64	120	55 46
Fresno-1st Street	4	10/27/99	77	15	16		34	65	73	35 48
Modesto-14th Street	1	10/3/99	36	19	17		22	58	36	18 50
Modesto-14th Street	7	10/9/99	69	6	17		49	73	60	18 30
Modesto-14th Street	6	10/15/99	124	4	7		61	72	100	14 14
Modesto-14th Street	5	10/21/99	132	14	18		36	68	123	58 47
Modesto-14th Street	4	10/27/99	50	6	12		54	72	45	10 22
Stockton-Hazelton Street	6	10/15/99	123	3			62		92	13 14
Stockton-Hazelton Street	5	10/21/99	150	8			37		140	62 44
Stockton-Hazelton Street	4	10/27/99	33	11			49		32	9 28
<b>November 1999</b>										
Bakersfield-Golden State Highway	1	11/14/99	183							134 <sup>c</sup> 73
Bakersfield-5558 California Ave	2	11/8/99	15	15	20		33	69	12	5 42
Bakersfield-5558 California Ave	5	11/11/99	93	32	14		15	60	89	60 67
Bakersfield-5558 California Ave	1	11/14/99	138	45	10		12	68	133	90 68
Bakersfield-5558 California Ave	4	11/17/99	20	12	20		37	70	21	9 43
Bakersfield-5558 California Ave	7	11/20/99	22	10	23		11	43	26	20 77
Fresno-1st Street	3	11/2/99	77	16	14		36	66	84	38 45
Fresno-1st Street	2	11/8/99	15	10	33		22	66	14	8 57

## PM10 Chemical Composition Data From The Routine Network

Site	Day of Week	Date	SSI PM10 ug/m3	% of PM10 Mass <sup>a</sup>				DICHOT Mass		
				SSI		Dichot <sup>b</sup>	Sum O Species	PM10 ug/m3	Fine ug/m3	% Fine
				Nitr	Sul	TC				
Fresno-1st Street	1	11/14/99	124	37	12	9	58	135	105	78
Fresno-1st Street	7	11/20/99	19	9	26	9	44	23	18	78
Modesto-14th Street	3	11/2/99	85	11	14	39	65	83	33	40
Modesto-14th Street	1	11/14/99	67	27	16	8	51	74	57	77
<b>Winter 1999/2000</b>										
Corcoran-Patterson Avenue	4	12/8/99	58	9		44	53	52	17	33
Corcoran-Patterson Avenue	3	12/14/99	49	6		42	48	46	19	41
Corcoran-Patterson Avenue	6	12/17/99	174							
Bakersfield-5558 California Ave	1	12/5/99	61	12	21	31	65	61	35	57
Bakersfield-5558 California Ave	4	12/8/99	47	15	23	36	75	49	22	45
Bakersfield-5558 California Ave	3	12/14/99	41	10	34	28	72	41	25	61
Bakersfield-5558 California Ave	6	12/17/99	111	37	18	20	74	124	83	67
Bakersfield-5558 California Ave	2	12/20/99	97	37	19	17	73	102	69	68
Bakersfield-5558 California Ave	5	12/23/99	109	26	17	25	67	114	69	61
Bakersfield-5558 California Ave	1	12/26/99	109	34	17	14	65	104	79	76
Bakersfield-5558 California Ave	4	12/29/99	103	22	19	24	65	96	61	64
Bakersfield-5558 California Ave	3	1/4/00	71	8	24	28	60	80	49	61
Bakersfield-5558 California Ave	6	1/7/00	116	20	19	15	55	122	93	76
Bakersfield-5558 California Ave	2	1/10/00	63	6	21	29	55	65	38	58
Fresno-1st Street	4	12/8/99	51	9	24	26	59	52	31	60
Fresno-1st Street	3	12/14/99	71	4	37	18	58	75	56	75
Fresno-1st Street	7	1/1/00	113	37	18	8	63	112	94	84
Fresno-1st Street	6	1/7/00	138 <sup>d</sup>	30	25	13	68	69	49	71
Modesto-14th Street	4	12/8/99	35	9	26	20	55	32	21	66
Modesto-14th Street	3	12/14/99	39	5	33	18	57	32	22	69
Modesto-14th Street	2	12/20/99	124	18	15	9	42	115	78	68
Modesto-14th Street	7	1/1/00	50	31	20	9	61	49	38	78
Modesto-14th Street	6	1/7/00	80	9	20	18	47	79	58	73
Visalia-N Church Street	4	12/8/99	57	9		35		49	25	51
Visalia-N Church Street	3	12/14/99	53	7		36		48	26	54
Visalia-N Church Street	2	12/20/99	152	34		16		134	96	72
Visalia-N Church Street	7	1/1/00	130	29		12		100	77	77
<b>Winter 2000/2001</b>										
Bakersfield-5558 California Ave	1	12/17/00	50	43	16	13	72	55	38	69
Bakersfield-5558 California Ave	7	12/23/00	57	29	25	14	68	62	38	61
Bakersfield-5558 California Ave	3	12/26/00	88	32	24	18	73	93	61	66

**PM10 Chemical Composition Data From The Routine Network**

Site	Day of Week	Date	SSI PM10 ug/m3	% of PM10 Mass <sup>a</sup>				DICHOT Mass		
				SSI		Dichot <sup>b</sup>	Sum O Species	PM10 ug/m3	Fine ug/m3	% Fine
				Nitr	Sul	TC				
Bakersfield-5558 California Ave	6	12/29/00	140	39	19	19	78	144	98	68
Fresno-1st Street	3	12/26/00	92	22	36	7	64	85	73	86
Fresno-1st Street	2	1/1/01	193 <sup>d</sup>	40	26	4	70	95	72	76
Fresno-1st Street	1	1/7/01	141	42	23	11	77	126	102	81
Modesto-14th Street	4	12/20/00	80	20	33	13		81	62	77
Modesto-14th Street	3	12/26/00	75	18	37	9		75	62	83
<b>November 2001</b>										
Hanford-S Irwin Street	6	11/9/01	155							

**Comments/Footnotes:**

Highlighted records represent concentrations greater than 24-hr PM10 standard. Excedances for which we do not have nitrate/sulfate or geological data can't be modeled using CMB. Therefore, they are listed for information purposes only.

a The percent contribution from major categories of species was estimated by the following steps:

1. % Nitrate/Sulfate was estimated based on SSI data:

$$(((1.29 \times \text{non-volatilized nitrate}) + (1.38 \times \text{sulfate}))/\text{PM10}) * 100$$

2. % Total Carbon (TC) was estimated based on SSI data:

$$(\text{Total Carbon (as measured on an SSI filter)}/\text{PM10 Mass}) * 100$$

3. % Geological was estimated based on dichot data:

First each geological species was scaled to the level of the SSI mass by multiplying concentration of each species by the ratio of PM10 mass measured on SSI to PM10 mass measured on dichot. Next, the percent contribution was calculated as follows:

$$(((1.89 \times \text{aluminum Conc Scaled to SSI}) + (2.14 \times \text{silicon Conc Scaled to SSI}) + (1.4 \times \text{calcium Conc scaled to SSI}) + (1.43 \times \text{iron Conc scaled to SSI}))/\text{PM10 Mass}) * 100$$

4. Sum of Species represents a sum of %Nitrate/Sulfate, %total carbon, and %geological.

<sup>b</sup> Dichot chemical measurements were scaled to SSI level based on the SSI to dichot ratio.

<sup>c</sup> PM2.5 measured using FRM

<sup>d</sup> Difference between SSI PM10 measurement and Dichot PM10 measurement greater than 20%.

## PM10 Chemical Composition Data From The CRPAQS Network

Site	Day of Week	Date	CRPAQS PM10 ug/m3	% of PM10 Mass <sup>a</sup>				PM2.5		
				NitrSulf	TC	Geologica	Sum Of Species	Mass ug/m3	% of PM10	Monitor
<b>December 1999</b>										
Bakersfie	5	12/23/99	136	39	24	36	100	74	54	Routine
Bakersfie	4	12/29/99	98	44	25	30	100	64	66	Routine
Bakersfie	3	1/4/00	72	39	43	35	117	49	67	Routine
Corcoran-	5	12/23/99	141	50	20	31	101			
Corcoran-	3	1/4/00	68	30	28	40	99			
Fresno Dt	6	12/17/99	153	48	27	20	95			
Fresno Dt	5	12/23/99	168	40	28	26	95			
Fresno Dt	4	12/29/99	111	40	29	30	98			
Fresno Dt	3	1/4/00	76	39	36	23	98			
Hanford-I	5	12/23/99	156	52	23	28	103			
Hanford-I	4	12/29/99	121	45	26	32	103			
Hanford-I	3	1/4/00	82	35	35	34	105			
Modesto	6	12/17/99	112	41	39	15	95	93	83	Routine
Modesto	4	12/29/99	89	33	38	21	92	72	81	Routine
Modesto	3	1/4/00	51	44	39	22	105	45	88	Routine
Oildale-M	5	12/23/99	108	64	20	34	118			
Oildale-M	4	12/29/99	91	48	22	33	102			
Oildale-M	3	1/4/00	65	42	28	39	109			
Visalia Cl	4	12/29/99	96	54	26	26	107	72	75	Routine
Visalia Cl	3	1/4/00	62	38	39	26	103	51	82	Routine
<b>September 2000</b>										
Bakersfie	4	9/6/00	45	11	41	69	121			
Bakersfie	3	9/12/00	143	11	25	64	100			
Bakersfie	1	9/24/00	48	8	29	72	110			
Corcoran-	4	9/6/00	37	9	30	74	113			
Corcoran-	3	9/12/00	85	15	24	72	112			
Corcoran-	2	9/18/00	55	12	32	59	103			
Corcoran-	1	9/24/00	38	15	35	70	120			
Fresno Dt	4	9/6/00	37	11	47	77	135			
Fresno Dt	3	9/12/00	85	12	33	78	122			
Fresno Dt	2	9/18/00	65	11	35	72	117			
Fresno Dt	1	9/24/00	40	14	39	68	121			
Hanford-I	4	9/6/00	45	10	33	79	122			
Hanford-I	3	9/12/00	110	16	23	74	114			
Hanford-I	2	9/18/00	78	12	30	67	108			

Site	Day of Week	Date	CRPAQS PM10 ug/m3	% of PM10 Mass <sup>a</sup>				PM2.5		
				NitrSulf	TC	Geologica	Sum Of Species	Mass ug/m3	% of PM10	Monitor
Hanford-I	1	9/24/00	37	16	36	77	129			
Modesto	4	9/6/00	22	9	57	73	139	7	32	Routine
Modesto	3	9/12/00	64	12	23	76	112	18	28	Routine
Modesto	2	9/18/00	54	8	35	72	116	17	31	Routine
Modesto	1	9/24/00	22	14	36	77	128	10	44	Routine
Oildale-M	1	9/24/00	41	10	23	72	105			
Visalia C	4	9/6/00	51	9	29	35	74	10	20	Routine
Visalia C	3	9/12/00	100	20	19	68	107	30	30	Routine
Visalia C	2	9/18/00	60	10	22	57	89	18	30	Routine
Visalia C	1	9/24/00	25	19	38	53	111			
<b>Winter 2000/2001</b>										
Bakersfie	1	12/17/00	50	57	21	14	92	46	91	Routine
Bakersfie	7	12/23/00	72	30	26	12	67	44	61	Routine
Bakersfie	6	12/29/00	153	42	26	28	96	108	70	Routine
Bakersfie	5	1/4/01	208	51	18	23	92			
Bakersfie	4	1/10/01	20	27	40	35	102	13	65	Routine
Corcoran-	1	12/17/00	32	55	35	14	104	22	69	CRPAQS
Corcoran-	7	12/23/00	70	34	22	17	73	42	60	Routine
Corcoran-	6	12/29/00	111	50	22	20	92			
Corcoran-	5	1/4/01	138	57	17	19	93	99	72	CRPAQS
Corcoran-	4	1/10/01	21	30	31	18	79			
Fresno Di	1	12/17/00	37	49	29	7	85			
Fresno Di	7	12/23/00	85	38	28	12	79			
Fresno Di	6	12/29/00	120	42	28	19	89			
Fresno Di	5	1/4/01	159	37	33	18	87			
Hanford-I	7	12/23/00	62	41	33	14	88			
Hanford-I	6	12/29/00	101	43	23	20	86			
Hanford-I	5	1/4/01	106	56	24	21	101			
Hanford-I	4	1/10/01	11	47	37	16	99			
Modesto	1	12/17/00	24	29	47	8	84	19	82	CRPAQS
Modesto	7	12/23/00	44	26	52	8	86	38	86	Routine
Modesto	6	12/29/00	99	46	29	8	83			
Modesto	4	1/10/01	22	43	39	7	89	21	96	Routine
Oildale-M	1	12/17/00	49	54	20	13	87			
Oildale-M	7	12/23/00	48	48	21	11	80			
Oildale-M	6	12/29/00	133	45	18	25	87			
Oildale-M	5	1/4/01	195	61	14	22	97			
Visalia C	1	12/17/00	32	62	29	6	96	28	89	CRPAQS

Site	Day of Week	Date	CRPAQS PM10 ug/m3	% of PM10 Mass <sup>a</sup>			Sum Of Species	PM2.5		
				NitrSulf	TC	Geologica		Mass ug/m3	% of PM10	Monitor
Visalia C	7	12/23/00	81	39	23	14	76			
Visalia C	6	12/29/00	104	52	23	17	92	94	90	Routine

**Comments/Footnotes:**

Highlighted records represent concentrations greater than 24-hr PM10 standard.

- <sup>a</sup> The percent contribution from major categories of species was estimated by the following steps:
1. % Nitrate/Sulfate:  $((1.29 \times \text{non-volatilized nitrate}) + (1.38 \times \text{sulfate}))/\text{PM10Mass} * 100$
  2. % Total Carbon (TC):  $((1.4 \times \text{organic carbon}) + \text{EC})/\text{PM10 Mass} * 100$
  3. % Geological:  $((1.89 \times \text{aluminum}) + (2.14 \times \text{silicon}) + (1.4 \times \text{calcium}) + (1.43 \times \text{iron}))/\text{PM10Mass} * 100$
  4. Sum of Species represents a sum of %Nitrate/Sulfate, %TC, and % geological.

<b>SOURCE PROFILES USED IN CMB8 MODELING</b>				
<b>No</b>	<b>Name</b>	<b>Description</b>	<b>Source</b>	<b>Year</b>
<b>Geological Material.</b>				
<i>Agricultural Soil</i>				
01	SOIL01	STOCKTON PEAT SOIL	Houck, et.al, 1989	1989
03	SOIL04	VISALIA AGRICULTURAL SOIL (COTTON/WALNUT)	Houck, et.al, 1989	1989
04	SOIL05	VISALIA AGRICULTURAL SOIL (RAISIN)	Houck, et.al, 1989	1989
08	SOIL09	BAKERSFIELD AGRICULTURAL SOIL, ALKALINE	Houck, et.al, 1989	1989
09	SOIL10	BAKERSFIELD AGRICULTURAL SOIL, SANDY LOAM	Houck, et.al, 1989	1989
13	SOIL14	BAKERSFIELD AGRICULTURAL SOIL, WASCO SANDY LOAM	Houck, et.al, 1989	1989
14	SOIL15	BAKERSFIELD AGRICULTURAL SOIL, CAJON SANDY LOAM	Houck, et.al, 1989	1989
17	SOIL28	CROWS LANDING, AGRICULTURAL	Houck, et.al, 1989	1989
20	SOIL31	KERN, AGRICULTURAL	Houck, et.al, 1989	1989
23	FDALM1	ALMONDS, SOUTH KERN	TSS12	1997-98
24	FDALM2	ALMONDS, WEST FRESNO	TSS12	1997-98
25	FDALM3	ALMONDS, WEST KINGS	TSS12	1997-98
26	FDALM4	ALMONDS, NORTH MADERA	TSS12	1997-98
27	FDALM	ALMONDS, AVERAGE	TSS12	1997-98
28	FDCOT1	COTTON, WEST FRESNO	TSS12	1997-98
29	FDCOT2	COTTON, SOUTHWEST FRESNO	TSS12	1997-98
30	FDCOT3	COTTON, SOUTH KERN, BUENA VISTA RANCH	TSS12	1997-98
31	FDCOT4	COTTON, SOUTH KERN, KERN LAKE RANCH	TSS12	1997-98
32	FDCOT5	COTTON, WEST KINGS, STONELAND	TSS12	1997-98
33	FDCOT	COTTON, AVERAGE	TSS12	1997-98
34	FDGRA1	GRAPES, CENTRAL FRESNO	TSS12	1997-98
35	FDGRA2	GRAPES, CENTRAL MADERA	TSS12	1997-98
36	FDGRA3	GRAPES, EAST FRESNO	TSS12	1997-98
37	FDGRA	GRAPES, AVERAGE	TSS12	1997-98
38	FDSAF1	SAFFLOWER, WEST KINGS	TSS12	1997-98
39	FDSAF2	SAFFLOWER, SOUTH KERN, BUENA VISTA RANCH	TSS12	1997-98
40	FDSAF3	SAFFLOWER, SOUTH KERN, KERN LAKE RANCH	TSS12	1997-98
41	FDSAF	SAFFLOWER, AVERAGE	TSS12	1997-98
42	FDTOM1	TOMATO, NORTHWEST FRESNO	TSS12	1997-98

<b>SOURCE PROFILES USED IN CMB8 MODELING</b>				
43	FDTOM2	TOMATO	TSS12	1997-98
44	FDTOM3	TOMATO	TSS12	1997-98
45	FDTOM	TOMATO, AVERAGE	TSS12	1997-98
<i>Paved Road Dust</i>				
02	SOIL03	FRESNO PAVED ROAD	Houck, et.al, 1989	1989
07	SOIL08	VISALIA PAVED ROAD	Houck, et.al, 1989	1989
11	SOIL12	BAKERSFIELD PAVED ROAD	Houck, et.al, 1989	1989
18	SOIL29	CROWS LANDING, PAVED ROAD	Houck, et.al, 1989	1989
58	FDPVR1	URBAN PAVED ROADS	TSS12	1997-98
59	FDPVR3	RURAL PAVED ROADS	TSS12	1997-98
60	FDPVR4	RURAL PAVED ROADS	TSS12	1997-98
61	FDPVR	RURAL PAVED ROADS, AVERAGE	TSS12	1997-98
<i>Unpaved Road Dust</i>				
06	SOIL07	VISALIA URBAN UNPAVED	Houck, et.al, 1989	1989
10	SOIL11	BAKERSFIELD UNPAVED ROAD (OILDALE)	Houck, et.al, 1989	1989
12	SOIL13	BAKERSFIELD WINDBLOWN URBAN UNPAVED	Houck, et.al, 1989	1989
15	SOIL16	BAKERSFIELD UNPAVED ROAD (RESIDENTIAL)	Houck, et.al, 1989	1989
16	SOIL17	TAFT UNPAVED ROAD	Houck, et.al, 1989	1989
19	SOIL30	KERN UNPAVED ROAD	Houck, et.al, 1989	1989
21	SOIL1012	COMPOSITE OF SOIL 10 AND SOIL 12 PROFILES	Houck, et.al, 1989	1989
49	FDUPR1	AG UNPAVED ROADS, WEST FRESNO	TSS12	1997-98
50	FDUPR2	AG UNPAVED ROADS, WEST KINGS	TSS12	1997-98
51	FDUPR3	AG UNPAVED ROADS, SOUTH KERN	TSS12	1997-98
52	FDUPRA	AG UNPAVED ROADS, AVERAGE	TSS12	1997-98
53	FDUPR4	PUBLIC/RESIDENTIAL UNPAVED ROADS, CENTRAL KINGS	TSS12	1997-98
54	FDUPR5	PUBLIC/RESIDENTIAL UNPAVED ROADS, WEST KINGS	TSS12	1997-98
55	FDUPR6	PUBLIC/RESIDENTIAL UNPAVED ROADS, NW KINGS	TSS12	1997-98
56	FDUPRP	PUBLIC/RESIDENTIAL UNPAVED ROADS, AVERAGE	TSS12	1997-98
57	FDUPR	UNPAVED ROADS, AVERAGE	TSS12	1997-98
<i>Dairy/Feedlot</i>				
62	FDCTD	DAIRY, AVERAGE	TSS12	1997-98
63	FDCTF1	FEEDLOT, SOUTH KERN	TSS12	1997-98

<b>SOURCE PROFILES USED IN CMB8 MODELING</b>				
64	FDCTF2	FEEDLOT, SOUTH KERN	TSS12	1997-98
65	FDCTF	FEEDLOT, AVERAGE	TSS12	1997-98
66	VIDAIC	VISALIA DAIRY/FEEDLOT DUST	Houck, et.al, 1989	1989
<i>Fugitive Dust, Miscellaneous</i>				
05	SOIL06	VISALIA SAND AND GRAVEL	Houck, et.al, 1989	1989
22	SOIL7DAI	COMPOSITE OF SOIL 7 AND VISALIA DAIRY PROFILES	Houck, et.al, 1989	1989
46	FDDIS1	DISTURBED LAND, SALT BUILDUP, NORTH EDGE	TSS12	1997-98
47	FDDIS2	DISTURBED LAND, SALT BUILDUP, EAST EDGE	TSS12	1997-98
48	FDDIS	DISTURBED LAND, SALT BUILDUP, AVERAGE	TSS12	1997-98
67	FDSTA1	STAGING AREA	TSS12	1997-98
108	CDCEMT	NBS CEMENT DUST	Cooper, et.al., 1987	1984
111	MPGYPU	GYPSUM DUST, KILN, EL. PRC. (TOTAL FROM CASO4)	Cooper, et.al., 1987	1987
112	LIME	LIMESTONE	EPA	
113	SFCRUC	SANTA FE CRUDE BOILER (WESTSIDE KERN COUNTY OILFIELD)	Houck, et.al, 1989	1989
114	CHCRUC	CHEVRON RACETRACK CRUDE BOILER (KERN RIVER OILFIELD)	Houck, et.al, 1989	1989
115	MOTIBC	MODESTO TIRE POWER PLANT	Houck, et.al, 1989	1989
116	SCRRFC	STANISLAUS COUNTRY RESOURCE RECOVERY FACILITY	Houck, et.al, 1989	1989
<i>Construction Dust</i>				
104	FDCON1	CONSTRUCTION/EARTHMOVING, NW FRESNO	TSS12	1997-98
105	FDCON2	CONSTRUCTION/EARTHMOVING, CENTRAL MADERA	TSS12	1997-98
106	FDCON	CONSTRUCTION/EARTHMOVING, AVERAGE	TSS12	1997-98
107	FRCONC	FRESNO, HIGHWAY 40 CONSTRUCTION	Houck, et.al, 1989	1989
109	CDRKCR	ROCK CRUSHING, 1987 SCAB	Cooper, et.al., 1987	1987
110	CDSAPL	SANDBLASTING AND PLASTERING	Cooper, et.al., 1987	1987
<i>Resuspended Dust</i>				
131	RESUSP1	CECERT – ROAD RESUSPENSION VACUUMED FROM A ROAD IN BAKERSFIELD TEST 1	CRPAQS, DRI	2001
132	RESUSP2	CECERT – ROAD RESUSPENSION	CRPAQS, DRI	2001

<b>SOURCE PROFILES USED IN CMB8 MODELING</b>				
		VACUUMED FROM A RAOD IN BAKERSFIELD TEST 2		
133	RESUSP12	CECERT – ROAD RESUSPENSION AVERAGE OF TEST 1 AND TEST 2	CRPAQS, DRI	2001
<b>Wood/Agricultural Burning</b>				
<i>Residential Wood Combustion</i>				
68	BAMAJC	BAKERSFIELD CORDWOOD, MAJESTIC FIREPLACE	Houck, et.al, 1989	1989
69	MAMAJC	MAMMOTH LAKES CORDWOOD, MAJESTIC FIREPLACE	Houck, et.al, 1989	1989
70	MAFISC	BAKERSFIELD CORDWOOD, FISHER MAMA BEAR STOVE	Houck, et.al, 1989	1989
75	RWOOD	EPA RESIDENTIAL WOOD COMBUSTION	EPA	
77	BYSW4	BAY AREA WOOD SMOKE	BAAQMD	
78	WFIREC1	WOOD COMBUSTION PROFILE		
118	WBOAK	WOOD BURNING – OAK	CRPAQS, DRI	2001
119	WBTAMARA	WOOD BURNING – TAMARAK	CRPAQS, DRI	2001
120	WBEUCAL	WOOD BURNING – EUCALYPTUS	CRPAQS, DRI	2001
<i>Agricultural Burning</i>				
71	BAAGBC	BAKERSFIELD AGRI. BURN (WHEAT AND BARLEY)	Houck, et.al, 1989	1989
72	ELAGBC	EL CENTRO AGRI. BURN (WHEAT)	Houck, et.al, 1989	1989
73	STAGBC	STOCKTON AGRI. BURN (WHEAT)	Houck, et.al, 1989	1989
74	VIAGBC	VISALIA AGRI BURN (WHEAT)	Houck, et.al, 1989	1989
121	AGBWHEAT	AGRICULTURAL BURNING – WHEAT	CRPAQS, DRI	2001
122	WBALMOND	WOOD BURNING – ALMOND	CRPAQS, DRI	2001
123	AGBRICE	AGRICULTURAL BURNING – RICE	CRPAQS, DRI	2001
<b>Motor Vehicle, Oil/Refinery Combustion, Brake/Tire Wear</b>				
<i>On-Road Vehicles</i>				
76	MADIEC	MAMMOTH LAKES DIESEL TOUR BUSES (IDLING)	Houck, et.al, 1989	1989
80	MOVES1	MOVES-SS(NEA-E,WOB,T42,TVMT)	Cooper, et.al., 1987	1987
81	MOVES2	MOVES-SS(NEA-E,WOB,WOT,TVMT)	Cooper, et.al., 1987	1987
82	MOVES3	MOVES-SCAB(ARB-E,WOB,WOT,CM)	Cooper, et.al., 1987	1987
83	MOVES4	MOVES-SCAB(NEA-E,WOB,WOT,CM)	Cooper, et.al., 1987	1987
84	MOVES5	MOVES-SCAB(NEA-E,WB1,T42,CM)	Cooper, et.al., 1987	1987
85	MD5L2U3	DYNAMOMETER – 50% DIESEL, 20% LEADED, 30% UNLEADED	1987 Scenic Denver Study	1987
86	MD7515U	DYNAMOMETER – 75% DIESEL, 15% LEADED, 10% UNLEADED	1987 Scenic Denver Study	1987

<b>SOURCE PROFILES USED IN CMB8 MODELING</b>				
87	MD8510U	DYNAMOMETER – 85% DIESEL, 10% LEADED, 5% UNLEADED	1987 Scenic Denver Study	1987
88	MOVESA	SCAQMD MOTOR VEHICLE PROFILE A	SCAQMD	
89	MOVESB	SCAQMD MOTOR VEHICLE PROFILE B	SCAQMD	
90	MOVESE	SCAQMD MOTOR VEHICLE PROFILE E	SCAQMD	
91	MOVESF	SCAQMD MOTOR VEHICLE PROFILE F	SCAQMD	
92	PHRD	PHOENIX ROADSIDE PROFILE	Watson, et.al., 1991	1989-90
93	PHAUTO	PHOENIX AUTO DYNAMOMETER PROFILE	Watson, et.al., 1991	1989-90
94	PHDIES	PHOENIX DIESEL DYNAMOMETER PROFILE	Watson, et.al., 1991	1989-90
96	BYTUN4	BAY AREA, TUNNEL PROFILE	BAAQMD	
<i>Oil/Refinery Combustion/Ambient Air</i>				
79	DOILPO	DISTILLATE OIL COMBUSTION	Cooper, et.al., 1987	1987
130	REFINER	CECERT – AMBIENT AIR AROUND EQUILON REFINERY	CRPAQS, DRI	2001
<i>Brake/Tire Wear</i>				
95	BRAKES	BRAKES, SEMI-METAL BRAKEWEAR	Watson, et.al., 1991	1989-90
124	TIRE1	CECERT – TIRE 1, PASSENGER TIRE	CRPAQS, DRI	2001
125	BRAKE1	CECERT – BRAKE TEST 1	CRPAQS, DRI	2001
126	BRAKER	CECERT – BRAKE TEST 1 REPLICA	CRPAQS, DRI	2001
127	BRAKE1R	CECERT – AVERAGE OF BRAKE 1 AND REPLICA	CRPAQS, DRI	2001
128	BRAKE2	CECERT – BRAKE TEST 2	CRPAQS, DRI	2001
129	BRAKE1R3	CECERT – AVERAGE OF BRAKE 1, BRAKE1 REPLICA, AND BRAKE 2	CRPAQS, DRI	2001
<i>Secondary Particulates</i>				
97	AMSUL	AMMONIUM SULFATE		
98	AMBSUL	AMMONIUM BISULFATE		
99	H2SO4	SULFURIC ACID		
100	AMNIT	AMMONIUM NITRATE		
101	HNO3	NITRIC ACID		
102	NANO3	SODIUM NITRATE		
103	OC	PURE ORGANIC CARBON		
<i>Marine</i>				
117	MARINE	MARINE	Cooper, et.al., 1987	1979

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### 3e CMB Attainment Analysis Formulas Worksheet

Methodology	General Note	Geologic and Construction	Mobile	Organic Carbon	Vegetative Burning	Ammonium Nitrate	Associated Water	Ammonium Sulfate	Unassigned	Marine
Source Contribution	From CMB analysis of most similar day to design day	From CMB	From CMB	From CMB	From CMB	From CMB minus partition for trapped water	Partition from Nitrate - approx. 10%	From CMB	Unaccounted mass from CMB	From CMB
Design Day Contribution	Scaled from CMB mass to match total mass of design value	Proportional contribution from CMB as a share of the design value	<<same note applies	<<same	<<same	<<same	<<same	<<same	<<same	<<same
Natural Background	Portion not included in rollback analysis	5%	0%	20%	0%	0%	0%	0%	10%	100% because marine salts are a natural emission
Regional Background	Rolled back against Valleywide emission estimates - lower regional estimate in winter due to decreased mixing, stagnation events	5%	10% (20% fall)	10% (20% fall)	10% (20% fall)	10% (20% fall)	10% (20% fall)	5% (10% fall)	10%	0%
Local Contribution	Source contribution - natural background - regional background. Rolled back against "local" (county emission estimates)	90%	90% (80% fall)	70% (60% fall)	90% (80% fall)	90% (80% fall)	90% (80% fall)	95% (90% fall)	80%	0%
Associated Emissions Categories	Based upon appropriate seasonal or annual inventory	PM10 paved roads+ PM10 unpaved roads+ PM10 agricultural operations+ PM10 construction (+ PM10 windblown for annual)	PM10 onroad mobile+ PM10 offroad mobile	Total ROG this may also include a small portion of otherwise unassigned elemental carbon	PM10 residential burning + PM10 agricultural burning	Total E.I. NOx + soil Nox *Previous method set aside a portion from rollback calculations due to lack of Ag E.I. NOx and ammonia sources, we need to reassess this portion of the methodology	None	Total SOx	Rolled back in proportion to Total PM10 for annual analysis (Total PM10 minus windblown for episodic)	None
Rollback Approach	Combination of CMB and secondary modeling	Linear	Linear	Linear - Possible use of Proportional from secondary modeling - it uses a lookup table process that is linear, therefore not different from CMB linear	Linear	Proportional from secondary modeling - using information developed from analysis of IMS 95 and selected episodes	None	Proportional from secondary modeling - using information developed from analysis of IMS 95 and selected episodes	Linear	Used as an input by the secondary modeling as a reactant

# Photochemical Air Quality Modeling for the San Joaquin Valley PM<sub>10</sub> Attainment Demonstration Plan

## Introduction

A comprehensive Attainment Demonstration Plan of a State Implementation Plan (SIP) would require modeling of all components of the PM<sub>10</sub> mass. The particulate matter size distribution is multi-modal with a node around 2-3  $\mu\text{m}$  aerodynamic diameter (Seinfeld, 1985). This node divides the size distribution into coarse and fine modes. The coarse mode consists mainly of primary particles (i.e. directly emitted into the atmosphere from various sources) and the fine mode is mainly secondary (i.e. generated in the atmosphere from gaseous precursors). In general, there are small quantities of primary particles in the fine mode and secondary particles in the coarse mode. However, in the San Joaquin Valley primary emissions of wood smoke and vehicle exhaust accounts for the majority of the organic carbon in the atmosphere and it is in the fine mode.

The majority of primary particles in the San Joaquin Valley are characterized as coming from sources that entrain soil related components from activities such as agricultural operations, construction, and on and off-road motor vehicular activity. Secondary particle formation in the Valley is dominated by ammonium nitrate ( $\text{NH}_4\text{NO}_3$ ) (Watson *et al.*, 1998).

There are several ways to model the direct emission, secondary formation and dispersion of particulate matter. If a single source is contributing to PM<sub>10</sub> NAAQS violations with a significant coarse fraction and identification and emission strength of that source is known, then dispersion model, such as AEROMOD, can be used to evaluate control strategies for that source. The method can be extended to include a few major well-defined sources, but a combination of wind trajectory analysis coupled with Chemical Mass Balance (CMB) method becomes more informative as the number of sources increases and source strengths decrease. Multiple sources with low to medium source strengths are a more common cause of PM<sub>10</sub> NAAQS violations in the Valley than a well-defined single source with high strength. Thus, wind trajectory analysis coupled with CMB method is more appropriate to model the coarse fraction of PM<sub>10</sub>. The grid-based photochemical methods, albeit being more mathematically rigorous than CMB, are not suitable for the coarse fraction because the commonly used grid spacing (approximately 4-5 km) is too large compared to mean fall-off distances (typically less than 1 km) for larger particles. Due to the secondary nature of fine particles, CMB is not suitable for modeling the fine fraction and photochemical modeling is the only viable option. Thus we need to employ a combination approach.

The complementary suite of modeling methods we propose to employ for this Attainment Demonstration is based on a rollback approach with rollback of coarse fraction based on CMB with wind trajectory analysis. The rollback of fine fraction will be

based on fractions obtained through photochemical modeling. The procedure for conducting grid-based photochemical modeling is the subject of this document.

## **General Description of Photochemical Modeling**

This document describes the photochemical modeling techniques that will be used for this SIP and sources of input data, such as meteorology and emissions, to drive those models.

Secondary particulate matter is formed in the atmosphere from gaseous precursors. Ammonium nitrate ( $\text{NH}_4\text{NO}_3$ ) is a significant contributor to secondary particulate matter in the PM10 mass in the San Joaquin Valley. In the case of  $\text{NH}_4\text{NO}_3$  the gaseous precursors are ammonia and nitric acid ( $\text{HNO}_3$ ). While ammonia is mainly emitted into the atmosphere from various sources,  $\text{HNO}_3$  is a secondary gaseous product of the reactions between oxides of nitrogen ( $\text{NO}_x$ ) and volatile organic compounds (VOC) in the presence of sunlight. It is well established through the vast experience of ozone modeling that atmospheric chemistry is non-linear and the concentration of  $\text{HNO}_3$ , and hence the concentration of  $\text{NH}_4\text{NO}_3$ , is not linearly proportional to the concentrations of either  $\text{NO}_x$  or VOC. Thus, an essential component of developing emissions control strategies for  $\text{NH}_4\text{NO}_3$  involves photochemical modeling for both gas and particle phase.

There are other secondary particulate products measured in the San Joaquin valley. Two examples are secondary organic aerosols (SOA) and ammonium sulfate ( $(\text{NH}_4)_2\text{SO}_4$ ). The photochemical modeling described in this document will also simulate the formation of these two products. However, the representation of SOA in the modeling tools currently available is not very robust. Therefore, we will not emphasize the photochemical modeling of SOA and must use a proportional rollback approach for that pollutant. The representation of  $(\text{NH}_4)_2\text{SO}_4$  is robust but only minor amounts ( $\sim 5 \mu\text{g}/\text{m}^3$ ) of that pollutant is present in the San Joaquin Valley in observed episodes.

Two field studies were conducted in the San Joaquin Valley since 1995 and the first was a scoping study for the second. The first was the Integrated Monitoring Study of 1995-1996 (IMS-95) that covered a limited area (south of El Nido to north of Mettler) and gathered a limited set of field observations. A database containing IMS-95 observations is available to the general public together with documentation of extensive data analysis. The second was the California Regional Particulate Matter Study (CRPAQS) of 2000-2001 that covered the entire SJV extending from north of the Tehachapi Mountains to north of the northern boundaries of the SJV (Watson *et al.*, 1998). CRPAQS is perhaps the most comprehensive particulate matter field study to date in the world. The data of CRPAQS are still being analyzed and stored in a comprehensive database. It is our anticipation that the whole dataset will not be available in a quality assured form for photochemical modeling for this Attainment Demonstration. The difficulty lies in quality assurance of a very large set of meteorological data. However, we may be able to obtain enough data to drive

photochemical box-model simulations for selected areas, provided that emission inventories would be available in time.

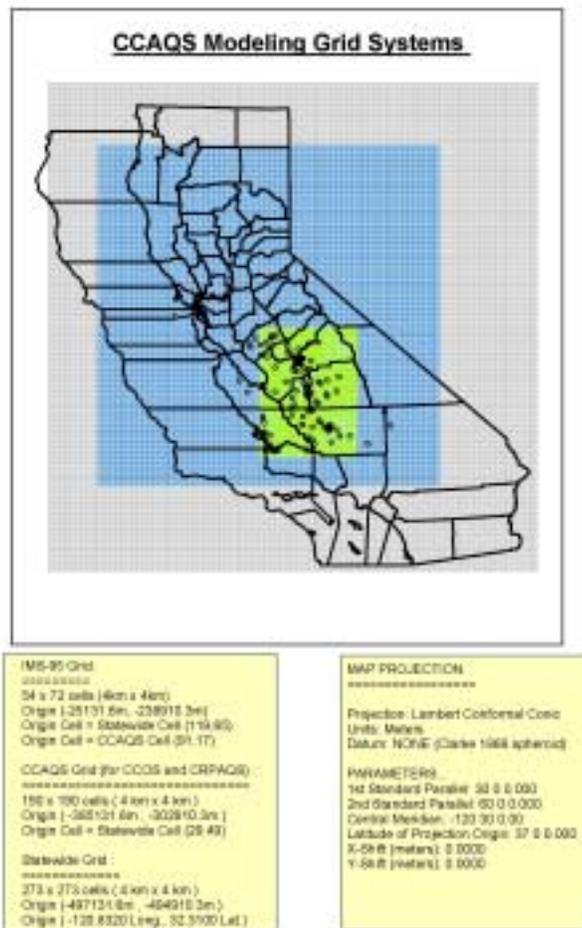


Figure 1: The grid systems for the California Air Quality Studies (CCAQS)

The modeling domain for IMS-95 covers approximately 215 km east to west and 290 km north to south and extends from the Coastal Range to the crest of the Sierra Nevada and from the Tehachapi Mountains to Merced. The innermost domain of Figure 1 shows the modeling domain. The grid resolution used will be four-kilometer grid squares (4 km by 4km). The vertical grid structure will contain two layers below the mixing height and three above. The top of the domain will be placed at 2 km above ground level. The entire modeling domain will be assumed to lie in the zone 10 of the Universal Transverse Mercator (UTM) coordinate projection even though about half of the domain lies in the UTM zone 11. The UTM coordinates of the origin of the modeling

domain will be 705.267 km Easting and 3858.607 km Northing. There will be 54 grid cells east to west and 72 in the north to south directions.

## **Emissions Modeling Methodology**

A spatially, temporally, and chemically resolved emissions inventory for the January 4-6, 1996 episode was developed for  $CO$ ,  $NO_x$ ,  $SO_2$ ,  $NH_3$ ,  $PM_{10}$ , and total organic gases ( $TOG$ ) for area-, motor vehicle-, and point sources. Day-specific emissions input data for use in generating this modeling inventory were not collected during the IMS-95 study period. The preparation of emissions inventories for this study using the EMS-95 emissions processing system (Version 2.01) is described in detail elsewhere (Hughes *et al.*, 1998).

**Ammonia Emissions.** A special ammonia inventory improvement project was undertaken via a CRPAQS contract with Environ. Although this project will not provide gridded hourly ammonia estimates for specific emissions categories, as expected, it will provide gridded, hourly estimates for combined categories of point, area, and mobile source emissions as well for fertilizer application, soils, domestic sources, and rwc.

**Mobile Sources.** Initially, gridded mobile source emissions for each episode day-of-week were estimated by spatially and temporally distributing EMFAC 2001, version 2.08,  $CO$ ,  $NO_x$ ,  $SO_2$ ,  $PM_{10}$ , and  $TOG$  emissions using hourly, grid cell ratios that were developed from SARMAP mobile source emissions. An effort to update mobile source emissions using DTIM and region-specific roadway networks is under way.

**Areawide and Stationary Sources.** Temporal inputs and emission estimates for  $CO$ ,  $NO_x$ ,  $SO_2$ ,  $PM_{10}$ , and  $TOG$  area and point sources were extracted from the California Emissions Inventory Development and Reporting System (CEIDARS). Area sources from the 1999 base year CEIDARS inventory was backcasted using the California Emissions Forecasting System (CEFS) and historical 1996 point source data were retained (ARB data reference RF#820). EMS-95 was used to process these average-day emissions estimates into gridded, hourly estimates for the January 4-6 time period. Spatial surrogates developed under a CRPAQS contract with Sonoma Technology were used to spatially distribute all area source emissions.

**Biogenic Emissions.** Biogenic emissions are assumed to be negligible due to low leaf biomass, low solar insolation, and low ambient temperatures during wintertime.

**Chemical Speciation and Particle Size Distribution.** A combination of ARB and UCD chemical speciation and particle size profiles for gaseous and particulate matter emissions were used.

## Meteorological Modeling Methodology

The meteorological input parameters to the UAM-Aero model are three-dimensional wind fields, temperature, relative humidity, and surface fields of fog. The model also requires the mixing height and solar irradiance for each grid cell for each hour. The meteorological measurements were conducted at several surface sites and six upper air sites. The six upper air stations were located at El Nido (ELN), Fresno (FEI), Mouth of the Kings River (MKR), Corcoran (COR), Bakersfield (BFK), and Mettler (MTL). Radar wind profilers with radio acoustic sounding systems were operated at ELN, MKR, COR, and MTL sites. Rawinsonde launches were conducted at FEI and BFK every four hours. All these sites measured wind vectors, temperature, and relative humidity.

**Wind Fields:** The 3-D wind fields were generated using a diagnostic wind model. First, the model was exercised to generate 2-D fields for each hour using the wind data available from 45 surface meteorological stations in the IMS-95 domain. California Air Resources Board, the California Irrigation Management Information System, and the National Climatic Data Center made these measurements. These 2-D fields were then interpolated in the vertical dimension using the wind data available from the six upper-air meteorological sites. Three dimensional wind fields were smoothed after interpolation using a 5-point averaging operator. Vertical velocity in each grid cell was specified such that wind-field divergence equals zero.

**Temperature, Relative Humidity:** The surface temperature and relative humidity (RH) data were available at the 74 surface meteorology stations. They were first interpolated to produce the 2D fields. These 2-D fields were then interpolated in the vertical dimension using the data available from six upper-air meteorology sites.

**Fog Fields:** The determination of clear, hazy, or foggy conditions were based on RH, despite its unreliability, since actual fog observations were very limited. An attempt was made to compare the resulting fog fields with those derived from satellite pictures. However, due to the poor resolution of the satellite pictures and the limited availability of them only for two hours per day, the comparison was inconclusive.

**Mixing Heights:** The mixing height was determined for each upper air station by examining the available vertical temperature profiles. The estimated mixing heights for were then used to interpolate mixing heights for the entire domain.

**Solar Radiation:** Total solar radiation and ultraviolet solar radiation were available for 28 measurement sites and they were interpolated over the modeling domain.

Interpolated surface meteorological fields with hourly time resolution were constructed over a grid system of 4~km by 4~km cells that covers the study area using the procedures developed by Harley *et al.* (1993) and the interpolation scheme described by Goodin *et al.* (1979). Three dimensional meteorology fields (wind, temperature, humidity) were created using five vertical layers spanning 1000 vertical meters in the

atmosphere. Both surface and three-dimensional meteorological fields were visualized after creation to identify obvious outliers and/or interpolation problems.

## **Air Quality Modeling Methodology**

**Domain Structure:** The modeling domain covers approximately 215 km east to west and 290 km north to south and extends from the Coastal Range to the crest of the Sierra Nevada and from the Tehachapi Mountains to Merced. The grid resolution used will be four-kilometer squares. The vertical grid structure will contain two layers below the mixing height and three above. The top of the domain will be placed at 2 km above ground level. There will be 54 grid cells east to west and 72 in the north to south directions.

**Initial and Boundary Conditions:** The boundary conditions used for gaseous and *PM* during this simulation are time and space dependent. They were obtained by interpolating all available observations for a given pollutant over the modeling domain and then extracting the concentrations for appropriate boundary cells. The initial conditions used for 0000 hours on the spin up day of January 03, 1996 were from the interpolated concentration field for that hour.

**The Selection of Air Quality Models:** There are two major levels of sophistication in secondary particulate matter modeling. They are based on the internal and external mixture approximations in representing particulate matter.

In the internal mixture approximation, the particles of same diameter have the same chemical composition regardless of the source. There is ample evidence to discredit this assumption, but its computational efficiency has made it a widely used method.

Due to the availability of codes and past experience with them, we will begin with the internal mixture approximation. A code based on this approximation, UAM-Aero is readily available and has been used in previous PM10 SIP submittals. We will reapply UAM-Aero to the IMS-95 database with improved emissions. We are collaborating with University of California at Davis to apply the Models3/CMAQ with a major modification to its aerosol modules. This code is also based on the internal mixture approximation. Due to the time limitation, our success with the modifications to Models3/CMAQ and its subsequent applications to IMS-95 is not guaranteed for this demonstration.

The external mixture approximation overcomes this limitation by keeping track of particulate emissions from individual source types. This gives the external mixture approximation the ability of direct source apportionment.

We also have access to a code based on the external mixture approximation. This code, CIT-UCD, was developed first at the California Institute of Technology and then improved at the University of California at Davis. It has been applied successfully in the South Coast air basin of California and currently we are adapting it to San Joaquin

Valley in collaboration with researchers at the University of California at Davis. This code is significantly more computationally intensive than those using the internal mixture approximation and we do not anticipate being able to use it routinely for this demonstration.

If the emissions inventories for CRPAQS become available in time, we will also conduct photochemical box-model simulations to quantify the precursor limitations of  $\text{NH}_4\text{NO}_3$ .

**Choice of Chemical Mechanism:** Selecting a chemical mechanism that represents both  $\text{NO}_x$  and VOC chemistry in detail is important because  $\text{HNO}_3$  is a secondary product whose precursors are  $\text{NO}_x$  and VOC and  $\text{HNO}_3$  is one of the gaseous precursors to  $\text{NH}_4\text{NO}_3$ . Almost all chemical mechanisms available have robust  $\text{NO}_x$  chemistry but the sophistication of VOC chemistry varies widely. Of the mechanisms available to ARB, those generated at the State-wide Air Pollution Research Center (SAPRC) of University of Riverside have the best representation of VOC chemistry. There are at least three different versions of SAPRC mechanisms. ARB already has the 1990 version implemented in the air quality models (Carter, 1990). There two newer versions, 1997 and 1999, are available but it would take a considerable amount of effort to update the codes to these levels. It is worth noting that for CRPAQS modeling we will use the latest version of SAPRC mechanism available at that time.

## **Model Performance Evaluation**

Once the base-case simulation is performed, the estimated emissions, meteorology, and air quality need to be compared with observations to assure that the modeling system (emissions, meteorology, and air quality) is a satisfactory representation of the episode modeled. Only with such an assurance one can use the modeling system to evaluate control strategies.

The rigorous comparison of model estimates with observations is termed model performance evaluation. These comparisons, in principle, should be done for emission, meteorology, and air quality estimates. However, there are difficulties in evaluating the performance of the emissions model, especially when measurements appropriate for that purpose is not made. That was the case in IMS-95. Thus, the emission model evaluation would be limited to quality assurance testing. Similar difficulties arise in evaluating the diagnostic meteorology field as well. Here, all the observations were used in constructing the meteorology fields, and thus, no independent observations are left for comparison. Therefore, meteorology model evaluation would also be limited to quality assurance testing.

It is possible, however, to conduct a rigorous evaluation of the air quality model performance despite the fact that some observations were used for initial and boundary conditions. The statistical metrics used for the comparison of estimates with observations are given in Appendix A. For gaseous pollutants the comparison is

straightforward. But, for particulate matter that has several components, the comparison will be done for the total mass as well as for the mass of individual components.

Unlike for ozone, there are no performance standards for particulate matter modeling. Thus, the acceptability of models estimates will be determined through a consensual process that involves US-EPA, CARB, and the San Joaquin Valley APCD.

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## Appendix A Statistical Measures for Performance Analysis

### Peak Estimation Accuracy

Paired Peak Estimation Equation A1:

$$A_{ts} = \frac{(c_e(x,t) - c_o(x,t))}{c_o(x,t)} \times 100\%$$

Where,  $C_o(x,t)$  is the peak concentration observed at location  $x$  at time  $t$  and  $C_e(x,t)$  is the model estimated concentration at the same location at the same time. Then  $A_{ts}$ , is a measure of the extent to which the observed and estimated peaks are paired in space and time.

Temporally Paired Peak Estimation: In the above expression if we relax the requirement that the modeled estimate should be in the same grid cell as the observation, we measure the models ability to reproduce the observed peak at the correct hour in the vicinity of the observed peak (e.g. 25 km radius).

Spatially Paired Peak Estimation: In equation (A1), if we relax the requirement that the model estimate should be at the same time as the peak observation, we measure the model's ability to reproduce the observed peak at the correct location at a reasonably close hour (e.g. within 3 hours).

Unpaired Peak Estimation: In equation (A1), if we relax the requirement that model estimate should be at the same location and hour as the observation, we measure the model's ability to reproduce the peak in the vicinity (say, 25 km radius) of the monitor at a reasonably close hour (e.g. within 3 hours).

### Bias

Mean Bias Error Equation A2:

$$MBE = \frac{1}{N} \sum_{i=1}^N (c_e(x_i,t) - c_o(x_i,t))$$

Where, N is the number of valid hourly observation-estimation pairs drawn from all valid monitoring data on the simulation day of interest.

Mean Normalize Bias Error Equation A3:

$$MNBE = \frac{1}{N} \sum_{i=1}^N \frac{(c_e(x_i, t) - c_o(x_i, t))}{c_o(x_i, t)} \times 100\%$$

This is similar to that in equation (A-2), but normalized with respect to the observation.

## Error

Mean Gross Error Equation A4:

$$MAGE = \frac{1}{N} \sum_{i=1}^N |(c_e(x_i, t) - c_o(x_i, t))|$$

Where, N is the number of valid hourly observation-estimation pairs drawn from all valid monitoring data on the simulation day of interest. Summing the absolute values of the difference prevents cancellation of errors.

Mean Normalized Gross Error Equation A5:

$$MNBE = \frac{1}{N} \sum_{i=1}^N \frac{|(c_e(x_i, t) - c_o(x_i, t))|}{c_o(x_i, t)} \times 100\%$$

This is similar to that in equation (A-4), but normalized with respect to the observation.

**Variance Equation A6**

$$\sigma^2 = \frac{1}{N} \sum_{i=1}^N |(c_e(x_i, t) - c_o(x_i, t))|^2$$

Variance is measure of spread of data. If the variance is low, then the difference between observations and estimation is small and vice versa.

**California Regional PM<sub>10</sub>/PM<sub>2.5</sub> Air Quality Study  
Objectives and Associated Data Analysis and  
Modeling Approaches**

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DRAFT: February 5, 1999

## **I. INTRODUCTION**

The overall goals of the California Regional PM<sub>10</sub>/PM<sub>2.5</sub> Air Quality Study (CRPAQS) are to: 1) provide an improved understanding of PM emissions, composition, and dynamic atmospheric processes; 2) establish a strong scientific foundation for informed decision making; and, 3) develop methods to identify the most cost-effective emission control strategies to achieve the PM<sub>10</sub> and PM<sub>2.5</sub> standards in central California. A suite of objectives have been identified in order to meet these overall study goals. The purpose of this document is to outline these objectives, identify the analytical methods that will be used to meet them, specify data needs for each proposed analysis method, and compare these to what is being collected as part of the field monitoring program. This document thereby provides not only a clear specification of study objectives and methods, but also establishes a feedback mechanism between objectives, data needs and planned aerometric and emissions measurements.

Both general and specific approaches are listed for meeting the stated objectives. Typically, about 5 to 10 different calculations, computations, or comparisons are described for implementing each specific approach. Specific data analysis approaches are drawn from the overall data analysis plan for the study (Watson 1996a) as well as the data analysis plan for the 1995 Integrated Monitoring Study (Watson 1996b). The assessments of current understanding, data needs, and principal knowledge gaps are drawn from historical data analysis and modeling reports (Lurmann 1996, Watson 1997) and from the various IMS95 data analysis reports (see comprehensive reference list at end of document). The discussion of data adequacy for each proposed method is based upon the proposed field monitoring campaigns described in detail in the study aerometric field monitoring program plan (Watson 1998). Tables 1 and 2 appended to this document provide a summary of the aerosol measurements that will be acquired at each type of site and the methods and averaging times that will be applied, while Table 3 summarizes the upper air meteorological monitoring network. Items addressing costs of added data acquisition/tradeoffs and recommendations are currently left blank. The Technical and Policy Committees will address these issues in defining the version of the field program that is ultimately implemented.

The proposed analyses are grouped into eight general categories with their associated objectives:

### **1. Characterization of PM**

- ◆ Characterize ambient PM<sub>2.5</sub>/PM<sub>10</sub> throughout the study: concentrations, chemical composition, and size distributions, including seasonal, temporal, and spatial variability.
- ◆ Characterize meteorological conditions associated with high PM concentrations.

- ◆ Characterize visibility, including seasonal, temporal, and spatial variability.
- ◆ Develop guidelines for assessing the extent to which adverse PM episodes are meteorologically driven vs. emissions-driven.

## **2. Atmospheric Processes Contributing to PM Formation**

- ◆ Develop a better understanding of key chemical and physical processes that contribute to elevated PM concentrations.
- ◆ Determine which precursors (VOC, NO<sub>x</sub>, NH<sub>3</sub>, HNO<sub>3</sub>, SO<sub>2</sub>) limit the formation of secondary aerosols, as a function of location and time of day.

## **3. Emissions Estimation and Verification**

- ◆ Develop reliable estimates of PM, VOC, NO<sub>x</sub>, and NH<sub>3</sub> emissions. For PM, determine chemical composition and size characteristics. For VOCs, determine chemical composition.
- ◆ Explain discrepancies between emission inventories and ambient measurements with respect to the relative amounts of PM derived from geological and combustion sources.
- ◆ Understand the role and contributions of biogenic emissions to secondary organic pollutant formation in central California.

## **4. Transport and Related Impacts**

- ◆ Determine the extent of transport of precursors and secondary pollutants between the San Joaquin Valley (SJV) and major California air basins - the Bay Area, the North Central and Central Coast areas, the Sacramento area, the southeast desert area, and the Sierra Nevada – and the contributions of these transported pollutants, by area of origin, to ambient PM concentrations in the receptor areas during each season of interest.
- ◆ Estimate the contributions of emissions from one portion of the southern Central Valley to ambient PM concentrations in other portions, where the Valley is divided into the Sacramento area, the North SJV (Modesto, Stockton), central SJV (Fresno), and south SJV (Bakersfield), as well as contributions within each sub-area (i.e. east side versus west side of Kern County).
- ◆ Estimate the contribution of pollutants transported from central California to visibility impairment in the southeast desert and in Class 1 areas, notably national parks and forests. Estimate the impacts on visibility impairment in these areas resulting from possible emissions reductions in the SJV.

- ◆ Develop procedures for assessing, for non-attainment areas, the upwind extent of the source region that should be subject to emissions reductions (i.e., the "zone of influence" issue) and its variation with chemical constituent and meteorological regime.

## 5. Model Adaptation and Evaluation

- ◆ Assess the degree of reliability of models for estimating ambient pollutant concentrations.
- ◆ Establish modeling capabilities for use in reliably estimating future air quality for hypothetical scenarios.

## 6. Emission Reduction Requirements and Impacts

- ◆ For monitoring sites located in central California having exceedances of the 24-hour and/or annual standards, determine which categories of sources contribute significantly to ambient concentrations, the relative proportion of their contributions, and the anticipated benefits of emissions reductions.
- ◆ Estimate the impact on ambient ozone concentrations of emissions reductions that are contemplated for reducing PM concentrations, and vice versa.

## 7. Attainment-related Concerns

- ◆ Determine the effects of meteorological variability on the likelihood of exceeding the standards. Assess the likelihood of "flip-flopping" into and out of attainment of the standards.
- ◆ Determine the extent to which high 24-hour average values contribute to exceedance of the *annual* average standard, regardless of whether the 24-hour average standard is exceeded. Assess the relative impacts of types of episodes on the annual average.
- ◆ Evaluate the extent to which the long-term PM monitoring networks represent levels to which larger populations are exposed under a variety of emissions and meteorological conditions.

## 8. CONCEPTUAL MODELS

### Objectives:

- ◆ Refine conceptual models that explain the causes of elevated PM concentrations and interactions among emissions, meteorology, and ambient PM

concentrations.

## II. DISCUSSION OF APPROACHES

### 1. Characterization of PM

Characterization analyses are expected to contribute to the successful completion of later topics as well.

#### **Objectives:**

- ◆ Characterize ambient  $PM_{2.5}/PM_{10}$  throughout the study: concentrations, chemical composition, and size distributions, including seasonal, temporal, and spatial variability.
- ◆ Characterize meteorological conditions associated with high PM concentrations.
- ◆ Characterize visibility, including seasonal, temporal, and spatial variability.
- ◆ Develop guidelines for assessing the extent to which adverse PM episodes are meteorologically driven vs. emissions-driven.

#### **General Approaches:**

Analyze data collected, (a) as a part of the study, (b) during the period of the study, but under other auspices, and (c) earlier, i.e., historical, data. Build on analyses conducted to date; see reports describing this work. Revisit selected past analyses in light of the availability of new data.

Conduct analyses stratified by meteorological characteristics and in turn emissions characteristics as appropriate. Approaches will include relational (such as regression), correlational, graphical (such as visual recognition of patterns), time series, and principal component (and similar) analyses.

Apply models to selected periods during the study and to selected historical periods. Compare results of modeling and data analyses.

#### **Specific Approaches:**

***1.1 Determine the fraction of  $PM_{10}$  that is  $PM_{2.5}$  and how this relationship changes with measurement site, season, and environmental conditions (i.e., T, RH).***

***Approach:***

Create  $PM_{2.5}/PM_{10}$ ,  $PM_{10}/\text{coarse}$ , and  $PM_{2.5}/\text{coarse}$  scatter plots and stacked time series plots of mass concentrations, silicon or aluminum, sulfur or sulfate, nitrate, ammonium, organic carbon, and elemental carbon. Assess these ratios for peak and non-peak periods and calculate comparability measures, including slopes, intercepts, correlation coefficients, average ratios, and ratios of averages for and between the different periods. List specific outliers from these measures, and compare the occurrence of these outliers with exceptional meteorological and emissions events that might be indicated in daily emissions activity surveys. Develop similar scatter plots and stacked time series plots using grid-based modeling results. Assess the consistency of measured and modeled results.

### ***Current Understanding:***

- On average, about 50% of  $PM_{10}$  is in the  $PM_{2.5}$  size fraction at all sites. For winter, however,  $PM_{2.5}$  is 70% to 80% of  $PM_{10}$ , and during fall  $PM_{2.5}$  is 50% to 60% of  $PM_{10}$  (Watson 1997).
- $PM_{10}$  and  $PM_{2.5}$  are highly correlated during different seasons, but their regression slopes are not consistent. There are some significant outliers from the predictive relationship, especially outside of winter (Watson 1997).
- During non-winter months, the highest concentrations of  $PM_{10}$  are dominated by crustal material and have little spatial homogeneity. The  $PM_{2.5}$  geological components of aluminum, silicon, iron, and titanium are about 10% of their corresponding values in the  $PM_{10}$  fraction. The  $PM_{2.5}$  fraction is dominated by nitrate, sulfate, ammonium, organic carbon and elemental carbon that account for 75% to 80% of the  $PM_{2.5}$  mass.
- Average  $PM_{2.5}$  ammonium, nitrate, and sulfate concentrations are similar among the urban and non-urban sites. The spatial homogeneity of  $PM_{10}$  and  $PM_{2.5}$  mass concentrations is similar, and is most homogeneous between the two major cities, Fresno and Bakersfield. Crustal contributions are not evenly distributed in the  $PM_{10}$  fraction but are more homogeneously distributed in the  $PM_{2.5}$  fraction (Watson 1997).
- Geological material in the  $PM_{2.5}$  fraction is highly correlated with geological material in the  $PM_{10}$  size fraction. Geological  $PM_{2.5}$  is in the smaller size fraction of the coarse mode rather than in the upper size range of the accumulation mode. On average 2% to 9% of  $PM_{2.5}$  mass is contributed by this coarse mode aerosol. For individual samples, the geological  $PM_{2.5}$  can approach 50% of the  $PM_{2.5}$  mass. This extreme usually occurs when  $PM_{2.5}$  concentrations are relatively low, however, and at non-urban sites (Watson 1997).

### ***Principal knowledge gaps***

$PM_{10}$  composition has been well characterized over the period 1988-98 at a limited number of sites and more extensively for limited periods of time, e.g., during IMS95.  $PM_{2.5}$  has been characterized at a more limited number of sites with dichotomous samplers and during special studies. The principal needs are to develop a longer

record of PM<sub>2.5</sub> composition at numerous sites and to maintain an adequate temporal record for PM<sub>10</sub>, permitting analysis of long-term trends and evaluation of weather-induced variations over time.

### ***Data needs***

Measure PM<sub>10</sub> and PM<sub>2.5</sub> at ~ 20 urban and rural sites for at least one year, with 24-hour time resolution and a sampling frequency between daily and once-per-six-days. Measure speciation and collect simultaneous meteorological measurements of hourly T, RH, WS, and WD.

### ***Adequacy of planned data acquisition***

PM<sub>10</sub> and PM<sub>2.5</sub> mass measurements will be obtained at over 125 and 65 ARB backbone sites, respectively. PM<sub>10</sub> ion analyses will be obtained at over 40 sites and complete PM<sub>2.5</sub> chemical speciation will be determined at over 25 sites. Complete PM<sub>2.5</sub> speciation will also be obtained at anchor and satellite sites at the requisite temporal resolution and frequency or better.

### ***Costs of added data acquisition and potential trade-offs***

### ***Recommendations***

#### ***1.2 Determine the day-to-day and diurnal variations in PM mass and chemical components and in PM precursor species concentrations.***

##### ***Approach:***

Calculate a nitrogen, sulfur, crustal material, and organic species balance for each sample. Plot PM<sub>10</sub> and PM<sub>2.5</sub> mass and composition and precursor species concentrations as a function of time for sites collecting data at a frequency greater than once per day and for sites collecting 24-hr data. Note similarities and differences between 1) diurnal patterns for PM<sub>10</sub> and PM<sub>2.5</sub> and their chemical components and 2) peak and non-peak days for PM<sub>10</sub> and PM<sub>2.5</sub> and their chemical components and assess dominant species in each size fraction by time of day and time of year. Plot spatial pie charts and describe spatial patterns as a function of time of day and time of year. Compare peak periods to periods of lower PM concentrations as a function of the time of day and location by site type or site environment. As appropriate, conduct similar analyses using grid-based modeling results and assess the consistency of measured and modeled values.

##### ***Current Understanding:***

- Exceedances of the PM10 and PM2.5 standards require a minimum buildup period of three to four days. Longer buildup periods translate into generally higher concentrations (Chow 1997).
- Significant diurnal variations in PM concentrations occur during the winter months. Urban sites exhibit the greatest variations, with up to a factor of 10 difference between highest nighttime concentrations and lowest daytime concentrations. Diurnal variations at rural sites are not as pronounced, with highest PM concentrations occurring midday. The diurnal pattern observed at urban sites was driven by organic and elemental carbon, while the rural pattern was driven by secondary ammonium nitrate (Chow 1997, Magliano 1998).
- Secondary ammonium nitrate concentrations peak midday at both urban and rural sites. Carbon concentrations peak midday at rural sites, and during the night at urban sites. Sulfate concentrations were highest midday at urban sites and at night at rural sites (Chow 1997, Magliano 1998, Kumar 1998).
- Temporal variability is greater than spatial variability for secondary aerosol species (Kumar 1998).
- NO and NO<sub>2</sub> diurnal patterns during the winter exhibit a pattern indicative of daytime NO to NO<sub>2</sub> conversion. NO fractions were generally highest at night and early morning while NO<sub>2</sub> fractions were highest midday and late afternoon (Kumar 1998).
- SO<sub>2</sub> diurnal patterns during the winter were fairly flat at urban sites, with a slight daytime peak at rural sites (Kumar 1998).

***Principal knowledge gaps:***

Diurnal variation of PM mass and species concentrations were studied during IMS95. The causes of diurnal variations are not well established, and may include emissions variations, mixing of aloft pollutants, photochemical production, and variation of mixing height. Enhanced understanding of these processes will contribute to the overall conceptual model.

***Data needs:***

Chemical and meteorological data of high (5 to 30 min) temporal resolution are needed from ~2 urban, ~2 near-urban, and ~2 rural sites. Fresh emissions can be identified as spikes, with plume width and distance indicated by spike duration. Mixing and photochemical production are indicated by simultaneity of concentration rise and fall among sites during mid-morning and mid-day, respectively; time lags among sites are indicative of surface transport. Measurements of both gas-phase and particulate species are needed.

***Adequacy of planned data acquisition:***

During the annual study, the portable DUSTRAK nephelometers will provide

measurements of a mass surrogate ( $b_{sp}$ ) at 5-minute resolution daily at 5 sites and once every six days at 31 sites. Additional 5 to 30-minute time resolution measurements of  $PM_{2.5}$  or  $PM_{10}$  mass, and some species such as nitrate and sulfate, will be available from the 5 to 13 sites during the winter study. Suitable contrasts can be made between the urban and rural sites. The progressive diminution of spikes from urban to near-urban to rural sites may be observable. The Angiola site may exhibit fall concentrations characteristic of the Corcoran sub-regional background.

**Costs of added data acquisition and potential trade-offs:**

**Recommendations:**

**1.3 Determine PM concentrations at the boundaries, and how they vary temporally and spatially. Determine natural background concentrations and composition (not influenced by anthropogenic sources), regional background (possibly influenced by anthropogenic sources) and boundary conditions.**

**Approach:**

Review and extend efforts conducted under IMS95. If needed, provide a clear definition of what is a boundary site and what is a background site (natural and regional) for use by data analysts and by modelers. The definition may change as a function of: 1) season, and 2) local versus regional considerations. All assumptions associated with the definitions need to be clearly defined. Plot PM mass and composition and precursor species concentrations at boundary sites. Evaluate differences between sites and compare to concentrations and chemical composition at source oriented and receptor sites. What fraction, as a function of location, does background contribute to receptor sites within the valley? How does the concentration at the boundaries vary during the day? Determine how boundary concentrations vary as a function of season and peak versus non-peak days. Indicate which sites act as boundary and which act as background sites. As appropriate, assess the consistency of regional modeling results and measurements at boundary sites.

**Current Understanding:**

- Clean air background and sources outside the region do not appear to play a significant role in determining Valley concentrations during fall and winter PM episodes (Collins 1998).
- Clean-air and non-anthropogenic background sites do not currently exist as part of ongoing or previous special study networks (Collins 1998).
- Elevated boundary sites experienced very low concentrations (50-10  $\mu g/m^3$ ) at

the onset of episodes, but eventually reach concentrations equaling concentrations at non-urban sites on the Valley floor by the end of the episode (Collins 1998).

***Principal knowledge gaps:***

The transition distances from sub-regional to regional background concentrations are not well known. Under winter stagnation conditions, air movement may be so limited that it is not meaningful to characterize sites as boundary or flux-plane sites; however, boundary concentrations at commencement of episodes can be characterized and compared with episode peaks. Non-anthropogenic background concentrations are unknown.

***Data needs:***

To characterize regional and sub-regional backgrounds, data are needed from IMS95 core sites, ~2-3 sites near the peripheries of each IMS95 urban saturation network domain (preferably, sites identified as sub-regional background sites by the IMS95 data analysis, such as C02), and ~4-6 rural Valley sites (e.g., the IMS95 sites southwest of Chowchilla or at Kern Wildlife Refuge). ~ 8 boundary sites will be needed (2 N, 2 E, 2 S, 2 W).

***Adequacy of planned data acquisition:***

Adequate numbers of boundary and rural sites are planned for the winter and annual studies. Satellite sites for the fall study and the annual-study rural sites are adequate for defining transitions from peak to regional background concentrations during fall. Angiola may experience concentrations typical of the fall Corcoran sub-regional background. The near-urban background sites around Fresno and Bakersfield (i.e., 10-20 km from the core sites) will help define the transition from urban peak through near-urban background to regional background concentrations.

***Costs of added data acquisition and potential trade-offs:***

***Recommendations:***

***1.4 Determine the relationships between peak PM concentrations and regional and synoptic meteorological variables.***

***Approach:***

Review and extend efforts conducted under IMS95 and SARMAP. For the CRPAQS study period, fully describe the meteorological situation for each PM or ozone episode of interest, using synoptic weather maps, hourly maps of winds,

temperature, relative humidity, and fog, and available PM measurements. Include in the description synoptic weather patterns, local and regional wind speeds and directions, changes in mixed layer depth, changes in relative humidity, and fog characteristics. Examine meteorology during the study periods and how key meteorological variables change as peak PM periods build and decline. Create spatial plots of surface and upper air layers of WS, WD, T, and RH and examine in detail the surface and upper air meteorological data during each study period to better understand flow above and within the mixed layer. Create hourly, interpolated wind fields. Analyze surface and upper air transport using 3-dimensional particle paths. Assess the consistency of meteorological model outputs with measured values of WS, WD, T, and RH, both near the surface and aloft. If tracer releases are conducted, reconcile particle paths with tracer concentrations. Research new meteorological field measurement and forecast techniques, such as satellite derived wind and temperature products and real-time MM5 output. Develop PM forecasting tools; such as new PM<sub>2.5</sub> forecast equations, forecast evaluation software, and graphical forecast maps. Compare findings with earlier meteorological characterizations and evaluate the representativeness of the study period.

***Current Understanding:***

- Maximum and annual average PM<sub>10</sub> are much higher during drought years. These years experience longer periods of high pressure between wintertime storms that allow primary and secondary contributions to build up. More surface moisture and vegetation during other parts of the year suppress dust. PM<sub>10</sub> levels are now much lower than they were during the 1987 to 1992 drought (Lehrman 1996).
- Morning and evening 850 mb temperatures from the Oakland sounding are the most reliable meteorological indicator of winter and fall PM exceedances. This is associated with persistent high pressure systems. Low to negative pressure gradients between Oakland and Reno or Las Vegas are also highly associated with the high pressure system (Lehrman 1996).
- The presence or absence of fog is not a reliable indicator of excessive PM. Intense fog attenuates PM levels by increasing deposition rates. Fogs form as a by-product of the limited mixing caused by high pressure after storms have deposited substantial surface moisture. They co-occur with, rather than serve as the major causes of, secondary nitrate formation. (Lehrman 1996, Watson 1997).
- A necessary condition for high PM concentrations during the winter is a wind speed below 2-3 m/s. However, a low wind speed in and of itself does not necessarily result in a high PM concentration (Carr 1998a).

***Principal knowledge gaps:***

The meteorological conditions that lead to high PM are qualitatively well-known. Quantitative statistical relationships have not been established, though regression-

based forecasting methods are being used and refined. Meteorological typing (e.g., through CART analysis) has not yet been undertaken. Frequencies of each type of meteorological condition and the associated probabilities of high PM are not yet established. The meteorological representativeness of the annual, fall, and winter CRPAQS studies will need to be evaluated.

***Data needs:***

Surface meteorological measurements are needed at all chemistry sites. Accurate measurement of wind speeds less than  $1 \text{ m s}^{-1}$  is needed. Also needed is accurate measurement of relative humidity. Upper-air data are needed to support calculation of mixing heights, pressure gradients, and 3D flows.

***Adequacy of planned data acquisition:***

Surface and upper-air meteorological siting is adequate.

***Costs of added data acquisition and potential trade-offs:***

***Recommendations:***

***1.5 Determine correspondence of elevated wind speeds and PM concentrations.***

***Approach:***

For PM or surrogate concentrations, calculate and plot average PM concentrations as a function of wind speed at each site. If possible, identify the wind speed threshold at which PM concentrations begin to increase. Examine these thresholds with respect to the threshold velocity for each type of wind measurement instrument. Sort wind speed data from sites near PM monitors by wind speeds and examine times and dates for clusters of below-threshold winds that correspond to a PM measurement. Determine the duration of wind-speed-induced events and estimate the minimum duration needed to make significant contributions to 24-hour average concentrations. Contrast high wind speed situations that do and do not correspond to high PM concentrations and postulate causes for lack of correspondence. Compare the measured PM and crustal source contribution estimates to similar meteorological conditions with low wind speeds. For samples that exceed the standards, determine how many contain significant contributions from geological sources. As appropriate, conduct similar analyses using grid-based modeling results and assess the consistency of measured and modeled values.

***Current Understanding:***

- Wind speeds at existing stations exceeding 8 m/s are necessary, but not sufficient, indicators to predict windblown dust emissions. Wind gusts can raise dust in areas without monitors, or they can be of short enough duration that gusts are averaged into less intense winds during an hour.

***Principal knowledge gaps:***

The frequency and extent of elevated PM concentrations due to high wind speeds are not well known.

***Data needs:***

High time-resolution meteorological and speciated PM data are needed.

***Adequacy of planned data acquisition:***

Adequate (5-minute) data will be available from the anchor sites.

***Costs of added data acquisition and potential trade-offs:***

***Recommendations:***

***1.6 Determine the spatial representativeness of receptor sites under various meteorological conditions and during peak and non-peak periods.***

***Approach:***

Review and extend results of IMS95 analyses. Use statistical analysis, such as spatial correlation analysis, cluster analysis, empirical orthogonal functions, and analysis of variance, and emissions activities as a function of distance from the receptor to obtain a better understanding of the relationships between/among sites and their surroundings over the course of a year. Determine the spatial representativeness of study and existing routine monitoring sites during both episode and non-episode conditions and by season. Evaluate whether site classifications, spatial representativeness, and spatial scales of influence change during the sampling periods, between the different sampling periods, under different meteorological conditions, or due to variations in source strength? Plot existing and study networks and overlay with the spatial scale each site represents. Compare to population distributions and locations of major source types/land-use types.

***Current Understanding:***

- During IMS95 spatial representativeness varied considerably among sites, days,

and chemical components. Averaged across all days, the mean fraction of the saturation monitoring domain which recorded concentrations within 20% of those at the core site were: Corcoran - 87%, Kern Wildlife - 79%, Bakersfield - 65% and Fresno - 44%. Population-based representativeness was approximately equal to or slightly greater than areal representativeness. High representativeness and high concentrations were correlated (Blanchard 1998).

- The Corcoran core site represented domain-wide average concentrations well. It did not however capture peak concentrations within the saturation network. Site C05 recorded PM<sub>10</sub> concentrations up to 130 ug/m<sup>3</sup> greater than concentrations at the core site (Blanchard 1998).
- The Bakersfield and Fresno core sites tended to better represent peak concentrations within their respective saturation networks. Differences between PM<sub>10</sub> concentrations at the core sites and the maximum saturation sites averaged less than 5 ug/m<sup>3</sup> (Blanchard 1998).
- During the winter population-based representativeness exceeding 90% was achieved by supplementing the core site with only two additional sites (Blanchard 1998).
- Spatial representativeness was greatest for secondary species and least for crustal and carbonaceous components (Blanchard 1998).

***Principal knowledge gaps:***

The spatial representativeness of receptor sites was well characterized using data from the IMS95, but conclusions are temporally limited.

***Data needs:***

Data are needed from saturation networks having sites spaced at a scale of ~ 10 km. Interpretation is most straightforward if sites are placed uniformly or randomly, and are not all source-oriented sites. Daily measurements of PM mass suffice, but speciation provides additional information about PM components.

***Adequacy of planned data acquisition:***

During IMS95, PM mass concentrations varied by 20 percent over distances of about 5 to 15 km from the core sites. During the fall CRPAQS study, it will be possible to characterize representativeness at scales of about 0.5 km (using DUSTRAK nephelometers) to 10 km (using portable PM samplers at 5 sites). DUSTRAK nephelometers will also be operated daily at 39 sites during the winter study, though the spatial scale will exceed 10 km. Approximately 3 to 6 PM<sub>10</sub> sites will be located in the vicinity of each of several cities (San Jose, Sacramento, Stockton, Fresno, and Bakersfield), permitting some assessment of spatial representativeness in each of those locations over the duration of the annual study.

***Costs of added data acquisition and potential trade-offs:***

## **Recommendations:**

### **1.7 Determine the spatial and temporal characteristics of visibility (total extinction and its components). Determine where, how much, how long, and how often visibility reduction occurs in the SJV, Class I areas, and in the Mojave Desert.**

#### **Approach:**

Review and extend analyses conducted for the IMS95 and for historical data. Determine diurnal variations in visual range, light scattering, and absorption, and total extinction. Plot monthly box-and-whisker plots of hourly light scattering and, light absorption, and total extinction at sites in central California, the Mojave Desert, and Class I areas where data are available from either nephelometers or human observers. Compare statistical deviations in diurnal patterns among the measurement sites and for peak and non-peak PM<sub>10</sub> and PM<sub>2.5</sub> periods and identify consistencies and inconsistencies with the current understanding of diurnal variations in emissions, transport, and vertical mixing. Identify differences in diurnal patterns with time of year. Tabulate the times and locations of hourly maxima, and examine daily time series plots of these situations to advance hypotheses for their causes. Quantify the degree to which the time-averaged aerosol sampling periods represent a constant level of light scattering and absorption in data sets corresponding to visibility measurements. Briefly describe each haze event and specify its' beginning and ending dates, its visual character, and its apparent spatial extent. Include events that available monitoring data, color slides, or time-lapse photos show to be uniform and regional as well as those that appear local and layered. Identify those events when it is possible that sources in the SJV may have made a perceptible contribution to haze at the surface and/or aloft in the Mojave Desert or Class I areas. As appropriate, assess the consistency of measured and model-derived visibility degradation estimates for selected periods during the study.

#### **Current Understanding:**

- During the winter, some fog events are valley-wide, while others affect only one end of the SJV or the other. Fog events at Stockton, Modesto, and Merced are similar to one another, while Fresno fog patterns are more similar to those in Bakersfield.
- Higher wintertime light scattering at night observed at rural sites compared to urban sites is due to the greater presence of fog outside the cities (Main 1998).
- There is a minimal effect on visibility in the desert during the winter due to aerosol generated in the SJV and other central California source regions. The SJV and the South Coast supply the majority of visibility reducing particles to the Mojave Desert during the summer (Main 1998, Watson 1997).

***Principal knowledge gaps:***

The spatial and temporal characteristics of visibility have been well characterized during IMS95 and in the historical (1988-95) database. There is a need to continue this characterization during the CRPAQS. The covariability of visibility and particulate mass at fine-time resolution are not known.

***Data needs:***

Some of the new ARB backbone sites are collocated with existing instrumentation, including ARB heated nephelometers. However, the existing ARB nephelometer network is not intended to provide quantitative data; if data from those nephelometers are used, the instruments must be calibrated and audited. There is a need to collocate open, unheated, and heated nephelometers to establish data comparability. Additional nephelometers are needed in Fresno, Kern Wildlife Refuge, Tehachapi Pass, Lake Isabella, the transport paths to Yosemite and Sequoia National Parks, China Lake, Mojave, and Edwards Telhill. Characterization of fine-time resolution covariability of nephelometer and particulate data will require sampling with ~5-10 minute resolution.

***Adequacy of planned data acquisition:***

Portable nephelometers will provide broad coverage (36 sites) during the annual study. The CRPAQS anchor and satellite sites will be sufficient, except along the transport path to Yosemite National Park. If calibrated and compared with unheated nephelometers, the existing heated ARB nephelometer data may be useful. High temporal resolution sampling is adequate: 5-min nephelometer, aethalometer, and particulate data will be available from 3 anchor sites throughout the annual study and 2 additional sites during the winter study.

***Costs of added data acquisition and potential trade-offs:***

***Recommendations:***

***1.8 Determine where, how much, how long, and how often different chemical constituents contribute to different levels of visibility reduction.***

***Approach:***

Using chemically-specified and size-segregated aerosol concentrations obtained during the study, apply a size-inversion model, and examine the aerosol size modes. Submit these distributions to a Mie-formulated extinction efficiency model and calculate extinction efficiencies as a function of relative humidity. Evaluate

changes in efficiencies for different assumptions including: 1) each chemical compound present as pure particles [external mixture]; 2) soluble species mixed together in each particle [internal mixture]; 3) ammonium sulfate around a carbon core; and 4) different formulations for changes in particle size with relative humidity. Compare efficiencies used to reproduce measured extinction (constant shape of size distribution) with those used to estimate effects of emissions reductions (constant number distribution). Calculate empirical extinction efficiencies by the multiple linear regression (MLR) method using different formulations of relative humidity dependence. Include collinear measures such as singular value decomposition to evaluate the validity of the MLR efficiencies. Compare the derived extinction efficiencies with those found in prior studies and with each other. Attach uncertainty intervals to uncertainties that can be propagated through calculations of chemical extinction. Compare predicted scattering coefficient values to measured light scattering and compare predicted light extinction values to light extinction inferred from human observer records. Compare findings with those of previous analyses.

***Current Understanding:***

- During the winter ammonium nitrate is the largest contributor to light extinction, with organic carbon, elemental carbon, and sulfate contributing substantially on some days. Crustal material is usually a small contributor during the winter (McDade 1998).
- During the winter, light scattering due to particles was the major contributor to total light extinction accounting for 75% at Bakersfield and 60% at Fresno. Most of the rest of the light extinction is due to absorption by particles (Main 1998).
- During the summer, organic carbon, elemental carbon, and ammonium sulfate are the largest contributors to light extinction, especially once concentrations reach the Mojave Desert where high temperatures and a dearth of ammonia cause available ammonium nitrate to evaporate (Watson 1997).

***Principal knowledge gaps:***

The contributions of different chemical constituents to visibility reduction have been estimated during IMS95 and in the historical (1988-95) database using empirical extinction efficiencies. There is a need to update these assessments using the CRPAQS data. Since size-resolved, chemically speciated data were obtained only at Bakersfield (10 samples) during IMS95, it is not known how well the derived RH-dependent extinction efficiencies apply to other monitoring locations or other seasons. Existing ARB nephelometer data from Sacramento, Stockton, and Modesto cannot be reconstructed adequately using extinction efficiencies that worked well during the IMS95; however, the difficulty may lie in the nephelometer data.

***Data needs:***

Size-resolved, chemically speciated data are needed to determine extinction according to Mie theory and to ascertain the generality of the empirical RH-dependent extinction efficiencies. Empirical extinction efficiencies can be applied to 24-hour resolution speciated site data. Accurate nephelometer data are needed.

***Adequacy of planned data acquisition:***

Size-resolved, speciated data are to be collected at Fresno using a MOUDI sampler during the winter study, so Mie-theory calculations can be done for that site and time period. Using existing extinction efficiencies, or efficiencies derived from the Fresno MOUDI sampler, extinction budgets can be constructed for anchor, satellite, and backbone sites, provided accurate nephelometer data are available for comparison.

***Costs of added data acquisition and potential trade-offs:***

***Recommendations:***

**2. Atmospheric Processes Leading to PM Formation**

**Objectives:**

- ◆ Develop a better understanding of key chemical and physical processes that contribute to elevated PM concentrations.
- ◆ Determine which precursors (VOC, NO<sub>x</sub>, NH<sub>3</sub>, HNO<sub>3</sub>, SO<sub>2</sub>) limit the formation of secondary aerosols, as a function of location and time of day.

**General Approach:**

Use available measurements to characterize the importance of suspension, advection, diffusion, and deposition processes and their influence on PM levels under various meteorological conditions.

Analyze gas- and aqueous-phase chemistry measurements to characterize the key processes that influence the development of secondary aerosols. Use these measurements to determine important factors that may limit aqueous-phase aerosol formation.

Apply methods developed for analyzing pollutant-limiting situations. The latter include those developed by Blanchard et al. (for both the gas phase and aerosol systems), Cardelino and Chameides (for ozone), and Stillman (for ozone).

**Specific Approaches:**

## **2.1 Examine suspension and deposition properties of wind blown dust.**

### **Approach:**

Using vertical measurements of PM, estimate the attenuation of PM concentrations with height as a function of wind speed adjacent to and at different downwind distances from windblown dust sources. Where particle size fractions are available, estimate differences in vertical extent for differing particle size ranges. Using upper air temperature and wind data, estimate the depths of mixed layers when wind speeds exceed thresholds. Calculate the degree to which surface emissions are diluted as they mix through this layer uniformly and according to vertical profiles. Determine how much and how long windblown dust emissions would persist to create constant concentration increments of  $10 \text{ ug/m}^3$ . Estimate potential transport distances that balance suspension and deposition for different levels within the boundary layer. For selected periods, assess the consistency of emissions and grid-based modeling results as they relate to the suspension and deposition of wind-blown dust.

### **Current Understanding:**

- Unknown

### **Principal Knowledge Gaps:**

Little is known.

### **Data Needs:**

Controlled experiments utilizing high time- and space-resolution sampling are needed.

### **Adequacy of Planned Data Acquisition:**

The planned experiments are adequate.

### **Costs of Added Data Acquisition and Potential Trade-offs:**

### **Recommendations:**

## **2.2 Determine how PM and precursor species disperse and dilute under low wind conditions and the role of diffusion versus advection.**

**Approach:**

Review and extend efforts conducted under IMS95. Characterize vertical and horizontal mixing and dispersion of pollutants during low wind speed conditions using data collected during appropriate study periods. Based on data analysis and modeling, and using meteorological data from the existing network, if adequate, estimate the role of diffusion versus advection under organized flow regimes during stagnant, low wind speed situations as potential mechanisms for pollutants to mix. Perform time series analysis and develop frequency distribution plots to determine by location in the valley the fraction of time wind speeds are below 1 m/s, 0.5 m/s, and 0.1 m/s. Based on the analysis indicate how low winds speeds are as a function of time of day, location in the valley, and PM<sub>10</sub> and PM<sub>2.5</sub> concentrations using data from all sonic anemometer sites. For selected periods, assess the consistency of wind estimates developed from meteorological models with the measured values.

**Current Understanding:**

- During stagnation events (wind speeds <1 m/s) diffusion processes tend to dominate over advection processes. The duration of stagnation events measured during IMS95 were typically less than 5 hours (Carr 1998b).

**Principal Knowledge Gaps:**

The frequency of low wind speeds will need to be determined during CRPAQS. Sporadic breakdown of nocturnal stable layers has been hypothesized and was observed during one of eleven 3-hour periods in IMS95; their long-term frequency and potential significance for pollutant movement are unknown but may not be as important as other mechanisms of pollutant dispersal.

**Data Needs:**

Low-threshold anemometers are needed. Nocturnal stable-layer breakdown can be studied with minisodar (1 minute temporal resolution, 5 m vertical resolution, 15 m lower limit).

**Adequacy of Planned Data Acquisition:**

Nine annual-study sites will have R. M. Young low-threshold anemometers (accuracy of +/- 0.25 m s<sup>-1</sup> at 0 to 5 m s<sup>-1</sup>). Conventional sodars (11 sites for annual or winter continuous study) will probably not have the sensitivity needed to identify sporadic breakdown of the nocturnal stable layer (specs for conventional sodars are given as 15 minute temporal resolution; 30-50 m vertical resolution; 50 m lower limit).

### **Costs of Added Data Acquisition and Potential Trade-offs:**

#### **Recommendations:**

### **2.3 Determine how well we understand dynamic atmospheric processes influencing the formation of secondary aerosols from primary aerosols and secondary aerosol precursors and their relationship to phase properties (liquid, solid, gas).**

#### **Approach:**

Examine gas, aerosol, and aqueous phase data collected during the study periods and calculate the fraction of nitrogen, sulfur, and carbon and their individual compounds in each phase relative to the total in all phases. Plot these data as a function of the time of day and environmental parameters (e.g., temperature and relative humidity). Statistically describe the data and use comparability statistics (e.g., ratios of selected chemical species, multiple regression, frequency distributions, cluster analysis) to obtain an understanding of the distribution of species among the phases. Using theory, calculate the phase distribution expected under equilibrium conditions and determine under what situations the atmosphere might be in equilibrium and indicate what chemical and physical mechanisms might be important for obtaining the phase distribution. State assumptions and indicate the importance of these mechanisms for improving mathematical models.

#### **Current Understanding:**

- During the winter, NO is oxidized to NO<sub>2</sub> and HNO<sub>3</sub> in the daytime via photochemical reactions. The aerosol phase is thermodynamically favored both day and night. However, the majority of nitrogen occurs in the gas rather than the particle phase. On average, during IMS95, only 12% of the NO<sub>x</sub> oxidized to nitrate in the urban areas, and only 30% in non-urban areas (Kumar 1998).
- During the winter, sulfate is formed primarily from daytime photochemistry in the urban areas, and from transport and fog reactions in non-urban areas. On average, during IMS95, gas-phase sulfur dominated at urban sites (77%), while particle-phase sulfur dominated at rural sites (78%) (Kumar 1998).
- During IMS95, NO<sub>x</sub> and SO<sub>x</sub> species were more oxidized at Kern Wildlife Refuge than at the urban sites (Kumar 1998).
- During the IMS95 winter program, the gas-phase accounted for approximately 95% of carbon, with gaseous alkanes the most abundant species (Kumar 1998).

#### **Principal Knowledge Gaps:**

The spatial and temporal variability of secondary inorganic aerosol over a full one-

year period has not been evaluated. The IMS95 data showed higher concentrations of nitric acid than were predicted by thermodynamic equilibrium models, possibly as a result of sampling bias under conditions of high relative humidity, but perhaps resulting from non-equilibrium conditions.

***Data Needs:***

The evaluation of phase distributions requires speciated PM measurements, along with gas-phase and liquid-phase concentrations. Gas-phase species include HNO<sub>3</sub>, SO<sub>2</sub>, and NH<sub>3</sub>. Aerosol species include sulfate, nitrate, and ammonium. Co-located meteorological measurements (T and RH) are needed for equilibrium calculations. High time resolution (< 1 hour) sampling can help in evaluating equilibrium.

***Adequacy of Planned Data Acquisition:***

During the annual study, sixteen satellite sites will have 24-hour resolution measurements of PM<sub>2.5</sub> ions plus NH<sub>3</sub> and HNO<sub>3</sub>, permitting evaluation of equilibrium (SO<sub>2</sub> will not be measured, so the phase distribution of sulfur cannot be determined at these sites). During the winter episodic study, high time-resolution (less than 10 minutes) measurements are planned for HNO<sub>3</sub>, SO<sub>2</sub>, NH<sub>3</sub>, sulfate, and nitrate, but not ammonium at 8 anchor or satellite sites. The lack of a high-resolution ammonium measurement may prove limiting. However, 3-8 hour measurement of ions, HNO<sub>3</sub>, and NH<sub>3</sub> will be collected on the 15 winter intensive days. Phase distributions of sulfur can be evaluated at Bakersfield, which will have an SO<sub>2</sub> monitor.

***Costs of Added Data Acquisition and Potential Trade-offs:***

***Recommendations:***

***2.4 Examine diurnal co-variation with PM of ozone and photochemical precursors and end products. Determine the significance of contributions to particulate end products and their contributions to elevated PM<sub>10</sub> and PM<sub>2.5</sub> concentrations.***

***Approach:***

Plot time series of ozone, oxides of nitrogen, VOCs (specific compounds where available), particulate nitrate, nitric acid, and PAN. Plot time series of organic carbon to elemental carbon ratios to assess the potential for secondary organic carbon formation. Examine available meteorological data and determine which afternoon peaks in photochemical end products are likely due to recent chemical

transformation and which result from transport from upwind areas. Determine whether or not photochemical end products associated with ozone formation are significant or insignificant contributors to PM concentrations that cause daily or annual exceedances. Employ process analysis techniques in conjunction with grid-based modeling to determine the significant contributors to PM formation in various parts of the study domain. Assess the consistency of these results with those developed from analyses of measured data. In planning this effort, determine what types of modeling approaches may prove useful, from grid to box models

***Current Understanding:***

- Ozone concentrations that exceed standards do not correspond to PM<sub>2.5</sub> concentrations that exceed standards. There have been some corresponding exceedances of the PM<sub>10</sub> standard, but these are not consistent nor are they associated with secondary pollutants that derive from ozone formation. While secondary nitrate and secondary organic aerosol are formed along with ozone, high temperatures keep most of the nitrate in the gas phase and favorable transport and dilution (relative to fall and winter) mitigate against the buildup of secondary organic aerosol (Watson 1997).

***Principal Knowledge Gaps:***

The rate of oxidation of NO<sub>x</sub> under varying conditions (T, RH, NO<sub>x</sub> concentration, ozone concentration) is not well quantified. Ozone can be a significant source of free radicals. Within similar ranges of T and RH, variations in concentrations of photochemical precursors and end products may affect the rates and amounts of secondary inorganic PM. Distributions of NO<sub>x</sub> and aerosol nitrate during IMS95 indicated that a lower fraction of NO<sub>x</sub> existed in oxidized form (12 to 30 percent) than was predicted by model calculations (oxidation rates of greater than 50 percent per day).

***Data Needs:***

High time-resolution measurements of a variety of gas-phase species are needed, including ozone, OH, CO, NO, NO<sub>2</sub>, NO<sub>y</sub>, PAN, HNO<sub>3</sub>, and SO<sub>2</sub>. NO<sub>2</sub> can be accurately measured with instruments employing photolytic converters and chemiluminescent reaction with ozone. CO can be of use as an inert tracer, useful for establishing loss rates of NO<sub>y</sub>.

***Adequacy of Planned Data Acquisition:***

Most of the necessary measurements will be taken at 5 winter sites, though not throughout the annual study. NO, NO<sub>y</sub>, and HNO<sub>3</sub> measurements are specified at 3 anchor and 2 winter continuous sites (BTI and SNFH). Ozone and ammonia will also be measured at the same 5 winter continuous sites. Measurements of PAN,

OH radical, and peroxide will be conducted at Angiola. Although PAN and NO<sub>2</sub> will not be explicitly measured (except PAN at Angiola), the planned measurement of NO, NO<sub>y</sub>, and HNO<sub>3</sub> (by difference of NO<sub>y</sub> with and without a nylon prefilter) will yield the sum of NO<sub>2</sub>, PAN, and organic nitrates. Measurements of CO and true NO<sub>2</sub> are lacking.

***Costs of Added Data Acquisition and Potential Trade-offs:***

***Recommendations:***

***2.5 Determine the extent of secondary organic formation and its variation as a function of season, time of day, and site.***

***Approach:***

Review ambient speciated organic gas phase (C<sub>2</sub>-C<sub>20</sub>) and speciated organic aerosol data for primary (anthropogenic and natural) and secondary organic species. Relate, if possible, secondary species to their primary precursor species based on known atmospheric chemical processes. Examine speciated organic aerosol data, TC/OC and TC/EC ratios, and oxidant formation potential as a function of photochemical activity, atmospheric stability and mixing depth, presence or absence of fogs, and distance from a source area to help better understand secondary organic gas phase and aerosol phase formation. Examine the relationship between primary and secondary aerosols as a function of meteorological variables (e.g., temperature, RH, solar radiation) and evaluate differences in spatial and temporal patterns. Also use the more abundant OC, EC, and TC data to support the analysis and provide a wider spatial estimate of the fraction of secondary aerosols.

***Current Understanding:***

- Although photochemical processes that lead to secondary organic aerosols are slower in the winter than during the summer, long residence times for precursors could result in secondary organic aerosols accounting for approximately 20% of total organic carbon during the winter (Strader 1998).
- The amount of secondary organic carbon during the winter IMS95 program were similar at both urban and rural sites, averaging approximately 4.5 ug/m<sup>3</sup> (Schauer 1998).
- Clouds and fog slow down the production of secondary compounds, reducing concentrations of secondary organic aerosol by a factor of two to three from clear sky levels (Strader 1998).

***Principal Knowledge Gaps:***

Estimates of secondary organic aerosol production during IMS95 are of limited temporal duration. Diurnal variations are not well characterized.

**Data Needs:**

High time-resolution measurements of organic and elemental carbon, gas-phase precursors (especially aromatics), and chemical species of organic particulate are needed over the course of the winter study and preferably throughout the year.

**Adequacy of Planned Data Acquisition:**

Adequate measurements of elemental and organic carbon, gas-phase carbon species, and particulate organic compounds will be made at 4 sites on 15 episode days during the winter study. Elemental and organic carbon will also be measured continuously (30 minute resolution) at the three anchor sites throughout the year, and five sites during the winter continuous study.

**Costs of Added Data Acquisition and Potential Trade-offs:**

**Recommendations:**

**2.6 Determine the mechanism(s) for introducing into the shallow mixed layer oxides of nitrogen emitted above that layer. Determine the important oxidants and the fractions of oxidants (ozone, peroxides, et al.) found above and within the shallow mixed layer.**

**Approach:**

Apply the Dye et al. (1995) objective analysis technique to the radar refractive index parameter and the RASS vertical virtual temperature measurements to determine hourly mixing depths. Examine selected corresponding vertical temperature plots from radiosonde sites, estimate mixed layer depths, and compare these with the mixing depths estimated from the radar profilers for hours with corresponding measurements. Determine how mixed layer depths change during the course of the day. Describe the correspondence between the diurnal evolution and apparent elevation of mixed layers seen in color slides and time-lapse videos and the mixing depths estimated from vertical temperature measurements. Examine available measurements within and above the mixed layer to determine under what conditions entrainment of oxides of nitrogen and other oxidants aloft contributes significantly to ground-level aerosol concentrations. Assess the consistency with observed values of mixing layer estimates derived from meteorological modeling. Examine the representation of elevated emissions of oxides of nitrogen by grid-based models in light of available measurements. Compare and contrast with the representation of

surface emissions of  $\text{NO}_x$ , for Fresno, Bakersfield, and other selected areas.

***Current Understanding:***

- The  $\text{NO}_x$  injected above the shallow surface layer may remain there for much of the night and early morning, with a greater potential for formation of nitric acid due to lower surface deposition losses. The coupling of the surface layer and the Valleywide layer midday may then provide a mechanism for bringing these emissions and their chemical end products together (Chow 1998, Watson 1998).
- Ozone levels above the surface layer are 30 to 40 ppb. There is sufficient ozone within the Valleywide layer to make it the dominant oxidant for aqueous phase conversion of sulfur dioxide to sulfate (Pandis 1998, Collett 1998a).

***Principal Knowledge Gaps:***

The potential rates of formation of nitric acid aloft are unknown, as are the rates of transport aloft and mixing between aloft and surface layers.

***Data Needs:***

Profiler and sodar measurements of vertical structure are needed. Surface and aloft measurements of gas-phase and aerosol species are needed at high (< 1 hour) to moderate (several hours) duration.

***Adequacy of Planned Data Acquisition:***

The planned data acquisition at Angiola and the Sierra foothills site will adequately provide both continuous chemical data ( $\text{NO}_y$ ,  $\text{HNO}_3$ ) and 3-to-8 hour resolution measurements (nitrate, sulfate). Some care will be needed when interpreting data from the Sierra foothills site, as the applicability of Visalia upper air measurements to the foothills site is unknown.

***Costs of Added Data Acquisition and Potential Trade-offs:***

***Recommendations:***

- 2.7 Determine whether the nitrate is ammonia-limited,  $\text{NO}_x$ -limited, or VOC-limited and the variation of this "limitation" with site and season. Determine where and when  $\text{HNO}_3$  formation is oxidant-limited.***

***Approach:***

Apply equilibrium models to total ammonia and total nitrate values available over

periods of constant temperature and relative humidity. Calculate the partition between ammonia gas, nitric acid gas, and ammonium nitrate particles. Compare these with measurements and evaluate how well the equilibrium model applies to the SJV situation during the IMS95 winter study periods. Examine model sensitivities to changes in temperature and relative humidity over available sampling intervals. Using the chemical equilibrium portion of these models, plot isopleths of constant ammonium nitrate concentrations as functions of total ammonia and nitrate. Identify the location of typical measurements on these plots and determine the amounts of ammonia or nitrate precursors that must be reduced before significant changes in ammonium nitrate concentrations would be observed. Classify each sample as to its limiting precursor. For each sample, reduce ammonium sulfate concentration by half, and to zero, examining the changes in ammonium nitrate with these reductions. Determine the extent to which further sulfate reductions might result in increases in ammonium nitrate concentrations. Apply the observations-based method of Blanchard (1997). Compare results to equilibrium modeling. Conduct sensitivity runs using the grid-based modeling system for selected periods to determine the limiting precursor associated with nitrate formation in various areas. Determine where and when nitric acid production is oxidant limited. Assess the consistency of the modeling results with those derived from analyses of the measured data.

***Current Understanding:***

- During the winter, ammonia is abundant and the formation of ammonium nitrate is limited by the availability of nitric acid. It is unknown whether the formation of nitric acid is NO<sub>x</sub> limited or oxidant limited (Kumar 1998, Pun 1998a).
- Ammonium nitrate formation is estimated to be insensitive to sulfate levels in the winter because of generally ammonia-rich conditions and the low sulfate levels compared to nitrate (Kumar 1998).

***Principal Knowledge Gaps:***

Spatial and temporal variations of ammonia and HNO<sub>3</sub> limitation are incompletely characterized. Oxidant limitation has not been studied.

***Data Needs:***

Speciated, multi-hour to 24-hour resolution measurements of PM<sub>10</sub> and PM<sub>2.5</sub> are needed, plus HNO<sub>3</sub> and NH<sub>3</sub>, at a variety of urban and rural sites over the course of a year. No receptor method exists for assessing oxidant limitation of HNO<sub>3</sub> formation. However, this question may be addressable through the analysis of high time-resolution data in a previous work element.

***Adequacy of Planned Data Acquisition:***

The continuous and 3-8 hour resolution measurements at 5 sites during the winter episodic study will be adequate. The 24-hour resolution measurements at anchor sites during the annual study are also adequate. Sixteen satellite sites appear to have sufficient 24-hour data during the annual study. Backbone sites lack gas-phase measurements ( $\text{HNO}_3$  and  $\text{NH}_3$ ). Fine time-resolution data (10 minutes) from the winter continuous study could be used from five anchor and up to 8 satellite sites if continuous measurements of aerosol ammonium and sulfate were made (fine time-resolution sulfate is already planned for the 5 anchor and 3 satellite sites; aerosol ammonium measurements are not planned at present).

**Costs of Added Data Acquisition and Potential Trade-offs:**

**Recommendations:**

**2.8 Determine the nature of changes in chemical composition and concentration of PM through the fog formation cycle. Determine how variations in concentrations of oxidants,  $\text{SO}_2$ , and  $\text{NO}_x$  in space and time influence aerosol formation in fog drops.**

**Approach:**

Plot changes in the distribution of species as a function of time noting if fog was present or not at the site or within reasonable transport times to the site. Determine the chemical composition of PM samples before, during and after fog events. Evaluate how the presence of fog alters both the chemical composition of PM species as well as the distribution of aerosol precursor species. Identify chemical and/or physical mechanisms that alter the size distribution and chemical composition of the aerosol during the course of a fog event. Conduct similar analyses using box and grid-based modeling results. Confirm that the physical and chemical mechanisms are appropriately represented in mathematical models and, if not, recommend changes in the mathematical models and additional experiments to verify these mechanisms.

**Current Understanding:**

- During IMS95 sulfate production inside the fog layer was mainly due to the reaction with hydrogen peroxide and catalyzed oxidation by iron and manganese (Pandis 1998).
- In urban areas, ozone is rapidly depleted in fogs, however in rural areas sufficient ozone is available to provide a continuing oxidant source for nitrate and sulfate formation (Pandis 1998).

**Principal Knowledge Gaps:**

Simulations using IMS95 data indicated that wet removal is the most important process occurring inside SJV fogs, leading to significant reductions of ambient nitrate, sulfate, and ammonium. Uncertainties in modeling results stemmed from lack of measurement of wet (fog) deposition fluxes, needed for model verification, and inaccuracies in ozone measurements at concentration below 5 ppbv. Scavenging and removal of organic aerosol by fog has not been investigated.

***Data Needs:***

Gas-phase measurements of ozone and H<sub>2</sub>O<sub>2</sub>, accurate at sub-ppbv concentrations, are needed. Aerosol and fog concentrations of sulfur, nitrate, and ammonium species are also needed. Liquid-water content and wet fluxes should be measured. Aloft as well as surface measurements are useful.

***Adequacy of Planned Data Acquisition:***

Various fog measurements are to be taken at ground level and 100 m at Angiola during the winter study, with additional surface measurements at Bakersfield and Fresno. The measurements are not specified in the field program plan, but will include size-resolved fog intensity and composition. Ozone (5 minute resolution) and peroxide measurements (30 minute resolution) will also be made at Angiola.

***Costs of Added Data Acquisition and Potential Trade-offs:***

***Recommendations:***

***2.9 Determine how acidification of drops due to aqueous phase acid production limits aerosol formation in fog drops.***

***Approach:***

Using chemical data taken at the surface and aloft, determine what oxidants are found above the mixed layer and their profiles within the mixed layer and the boundary layer. Identify dominant pathways for aerosol formation in the aqueous phase from observations of fog chemistry and measurements of oxidants (ozone and peroxides) and catalysts (Fe and Mn). Assess variations in these parameters in space (north-south, urban vs. rural, ground vs. aloft) to determine when and where aqueous phase aerosol formation is most important and what factors limit the rate of its formation. Examine the change in oxidant formation and distribution during the day as the mixed layer builds in the morning and lowers in the evening. What is the role of daytime vs. nighttime reactions and oxidants at the surface vs. oxidants aloft above the fog layer? What role do these oxidants play in the formation of HNO<sub>3</sub> and

sulfuric acid under clear and foggy conditions? For sulfur, this analysis should also consider the formation of S(IV)-aldehyde complexes like hydroxymethanesulfonate, which may limit aqueous phase sulfate production. Particularly for urban sites, quantify the extent of buffering present in size fractionated and in bulk fog samples and the buffering capacity, relative to  $\text{NH}_3$  uptake, to prevent fog drop acidification and thereby promote aqueous phase particle production. Identify compounds that are present and that provide buffering in the pH range of 4 to 7. Incorporate findings into a model of the effect of buffering on rates of sulfate production.

***Current Understanding:***

- Acid buffering in fog droplets is not completely accounted for by measured amounts of ammonia, bicarbonate, acetate, and formate. This additional buffering capacity supports rapid rates of sulfate production. While a specific substance has not been identified, organic solutes may be a possible group of compounds (Collett 1998b).

***Principal Knowledge Gaps:***

The compounds responsible for buffering winter fog droplets have not been identified, but are known to be in solution. Buffering can affect the rate of aqueous-phase sulfur oxidation.

***Data Needs:***

Further analysis of buffering requires collection of fog water, field titrations, and speciation of organic compounds, including measurement of phenols and humic acids. Measurements of ozone that are accurate below 5 ppbv are also needed to confirm the significance of the pH-dependent oxidation of sulfur by ozone.

***Adequacy of Planned Data Acquisition:***

Various fog measurements are to be taken at ground level and 100 m at Angiola during the winter study, with additional surface measurements at Bakersfield and Fresno. The measurements are not specified in the field program plan, but will include size-resolved fog intensity and composition. Ozone (5 minute resolution) and peroxide measurements (30 minute resolution) will also be made at Angiola.

***Costs of Added Data Acquisition and Potential Trade-offs:***

***Recommendations:***

***2.10 Determine how deposition, owing to fog droplet growth, balances the***

**creation of secondary aerosols in fog droplets. Determine the influence of drop size-dependence on the chemistry of aerosol formation and on deposition in fogs.**

**Approach:**

Examine fog chemistry as a function of fog droplet size. Compare 2- and 3-stage cloud collector data with bulk data. Evaluate enhancements of aqueous phase oxidation rates in the chemically heterogeneous fog drop population vs. the rates predicted from the average fog composition. Using measurements of fog droplet size taken as the fog forms and dissipates, plot quantities of major species (crustal material, nitrate, sulfate, ammonium, and organic and elemental carbon) in fog droplets deposited as a function of time throughout a peak period. Examine the non-uniform distribution of sulfate, nitrate, and organic species across the drop size distribution on estimates of removal by fog drop deposition. Include in the analysis the spatial variability (north to south, urban vs. rural) and determine whether the size-dependent nature of the chemistry is more important in one environment vs. another. Compare the deposition rates with rates of formation determined by the aerosol evolution model.

**Current Understanding:**

- Fog deposition is the main removal mechanism for soluble ammonium nitrate and precursor gases in fogs, removing up to 15% to 30% of the nitrate. Dry deposition removes an additional 1% of the nitrate. Fog deposition is slightly less than fog formation for sulfate, resulting in a small net increase in sulfate (up to 7%) (Collett 1998a).
- Droplet composition varies with drop size. Small drops are enriched in inorganic ions and are less alkaline than large drops. Nitrate is associated with smaller drops than sulfate (Collett 1998a).
- The enrichment of inorganic ions in small drops results in a lower sedimentation rate relative to that which would be estimated from average fog droplet composition (Collett 1998a).

**Principal Knowledge Gaps:**

Studies based upon IMS95 data showed that fog drop size affects chemical composition, rates of oxidation of S(IV), and deposition rates. However, a bulk aerosol and fog model also predicted oxidation and removal rates well. The adequacy of bulk simulations compared with size-dependent modeling has not been fully studied. Spatial variations in fog composition have not been characterized.

**Data Needs:**

Liquid-water content, size-dependent aerosol composition, and size-dependent fog

droplet composition measurements are needed. Gas-phase measurements of ozone and H<sub>2</sub>O<sub>2</sub>, accurate at sub-ppbv concentrations, are needed.

***Adequacy of Planned Data Acquisition:***

Various fog measurements are to be taken at ground level and 100 m at Angiola during the winter study, with additional surface measurements at Bakersfield and Fresno. The measurements are not specified in the field program plan, but will include size-resolved fog intensity and composition. Ozone (5 minute resolution) and peroxide measurements (30 minute resolution) will also be made at Angiola.

***Costs of Added Data Acquisition and Potential Trade-offs:***

***Recommendations:***

**3. Emissions Estimation and Verification**

**Objectives:**

- ◆ Develop reliable estimates of PM, VOC, NO<sub>x</sub>, and NH<sub>3</sub> emissions. For PM, determine chemical composition and size characteristics. For VOCs, determine chemical composition.
- ◆ Explain discrepancies between emission inventories and ambient measurements with respect to the relative amounts of PM derived from geological and combustion sources.
- ◆ Understand the role and contributions of biogenic emissions to secondary organic pollutant formation in central California.

**General Approaches:**

Emissions databases will be developed to support a variety of activities including both source-oriented modeling and receptor modeling. In addition, a number of data analysis approaches have been applied in attempts to assess the accuracy of emission estimates. They include evaluation of ambient/emissions ratios for conditions where comparison should be favorable, remote sensing of motor vehicles for certain pollutants, roadside inspection of vehicles, temporal and spatial analyses (such as that of Lurmann and Main, 1992), analysis of long term ambient and emissions trends (Fujita, 1993), use of chemical mass balance to estimate emissions contributions, and model sensitivity studies.

The emissions work sponsored by CRPAQS is intended to build upon, and be integrated with, other ongoing efforts by U. C. Davis and the Air Resources Board. Priorities for emissions work are based on the following criteria:

- Relevance to modeling and data analysis needs: As noted above, several emissions measurements serve the needs of source, receptor, and emissions validation modeling. Specifically, source profiles are needed for all of these. Source profiles have the highest emissions project priorities.
- Large and significant contributors: Source categories that are known or highly suspected to be large contributors to PM<sub>2.5</sub> and PM<sub>10</sub> are in greater need of characterization than minor sources. These include mobile sources, ammonia, dust from farming operations, and windblown dust.
- Little is known about source emissions: A project that provides information where none exists is preferable to another study that adds to a database of studies already done.
- An information gap can be definitely filled for the immediate future: These projects plug a hole in the current inventory with information that is not likely to change over a decade or more.
- Specificity to the central California study area: It is unlikely that other sponsors will be found for sources and activity data bases specific to central California, and especially the San Joaquin Valley.
- Activity information: The activities that generate large quantities of emissions must be specific to field study periods if there is any expectation that ambient concentrations can be estimated by models. These data cannot be recovered after the study period.
- Emissions model development: Hardware and software (including data bases) needed by the ARB GIS inventory that specifically supports CRPAQS is needed to prevent delays in integrating data and estimating emissions.
- Non-duplicative of other applicable emissions studies: CRPAQS emissions projects complement, rather than duplicate, those being conducted by other agencies.

The specific projects which will be sponsored by CRPAQS are:

- *Develop Organic Speciation Profiles*
- *Develop Fugitive Dust Speciation Profiles*
- *Day-Specific Field Study Activity Data Collection and Micro-Inventory Preparation*
- *Conduct Ammonia Emissions Studies*
- *Determine Dust Suspension Characteristics*

- *Develop Traffic Count Estimates*
- *Characterization of On-Road PM Emissions*

Additional details on the proposed emissions projects can be found in the emissions plan (Magliano and Watson et al., 1999). Emissions-related tasks which address a data analysis component are described below.

### **Specific Approaches:**

#### ***3.1 Determine how well emissions data can be reconciled with ambient data.***

##### ***Approach:***

Compile and summarize emissions and ambient data. Prepare tables of day specific and period average primary particle, sulfur dioxide, oxides of nitrogen, and reactive organic gas emissions, by county/study domain area and major source type for the study periods. Identify similarities and differences between sites for peak and non-peak periods. Compile gridded emissions with as fine a resolution as possible for areas surrounding ambient routine and study monitoring sites. Compare ratios of ambient VOC/NO<sub>x</sub>, selected VOC species /NO<sub>x</sub>, selected VOC species/CO, PM/NO<sub>x</sub>, CO/NO<sub>x</sub>, and related PM components (e.g., Al/Si, Fe/Si, CO/Pb, CO/EC) to ratios derived from emissions data. Assess the comparability of ambient and emissions VOC and particulate speciation profiles. Apply principal component analysis and/or empirical orthogonal functions to ambient data to elucidate primary contributing sources. Compare CMB source contribution estimates with corresponding emissions estimates. Identify discrepancies between ambient and emissions data. Assess the degree to which the reconciliation methods are valid and identify areas where differences in results suggest inaccurately characterized or missing sources.

##### ***Current Understanding:***

- Emissions inventory ratios for PM/NO<sub>x</sub> and SO<sub>x</sub>/NO<sub>x</sub> are 1.5 to 4 times higher than ambient ratios, indicating that emissions for PM and SO<sub>x</sub> may be overestimated. Emissions inventory ratios for NMHC/NO<sub>x</sub> and CO/NO<sub>x</sub> are approximately 2 times lower than ambient ratios, indicating that NMHC and CO emissions may be underestimated (Chinkin 1998).
- Ambient and emissions ratios of NH<sub>3</sub>/NO<sub>x</sub> are within +/-25% agreement when emissions within an approximate 25 km radius of the ambient monitor are included in ratio analysis (Chinkin 1998).

##### ***Principal Knowledge Gaps:***

IMS95 and other studies indicate that emissions of PM and SO<sub>2</sub> may be

overestimated, while emissions of VOCs and CO may be underestimated. The conclusions were limited by the number of sites (6) having sufficient ambient data to compare with emissions, the variability of ambient concentrations between closely spaced sites (two in Bakersfield and two in Fresno), uncertainties associated with sites where transported pollutant concentrations may have exceeded the concentrations due to fresh emissions (Kern Wildlife Refuge), and the variability of results among sites. The emission source categories that may have been inaccurate are not known, especially since the ambient and emissions ratios of individual VOC species have not been examined. As emission estimates are checked and revised, further work will be needed to determine the consistency of revised emissions with ambient measurements.

***Data Needs:***

Emissions estimates and ambient measurements of PM, VOCs (total and individual species), NO<sub>x</sub>, SO<sub>2</sub>, CO, and NH<sub>3</sub> are needed. Monitoring locations should be in emission-source areas but not be dominated by nearby emissions. Ambient measurements of hourly resolution or better will be most useful, though samples of multi-hour duration will suffice. Multiple nearby (~ 2-5 km) monitoring locations are needed to check the spatial variability of the measurements.

***Adequacy of Planned Data Acquisition:***

Different ratio comparisons will be possible at different sites. The CRPAQS measurements will permit computation of fine-time resolution ratios involving SO<sub>2</sub> at Bakersfield and of ratios involving light and heavy hydrocarbons at 7 and 4 sites, respectively. Comparisons involving primary PM mass or NO<sub>x</sub> will be possible at the five winter anchor sites, while comparisons involving ammonia will be possible at those five sites plus an additional 8 satellite sites. Two of the five anchor sites (Bethel Island and the Sierra foothills) are not in emission source areas. VOCs will be sampled on 15 episode days and will have 3-6 hour resolution; other comparisons may be made using daily data from the winter study. CRPAQS is not deploying CO monitors, and the accuracies of the existing CO monitors need to be determined (detection limits of 100 ppbv or better are needed).

***Costs of Added Data Acquisition and Potential Trade-offs:***

***Recommendations:***

- 3.2 Determine the consistency of emissions estimates for the relative contributions of geologically derived materials to PM with those indicated by ambient measurements.***

***Approach:***

Stratify ratio comparisons by time of year, rainfall, and soil wetness and determine the existence of any discrepancies with emissions estimates. Identify how any such discrepancies vary by season. Identify and evaluate potential biases in activity levels or emission factors using source-oriented monitoring sites and dispersion models.

***Current Understanding:***

- Ambient- and emissions-based ratio comparisons of PM/NO<sub>x</sub> suggest that PM emissions may be overestimated. Comparison of CMB derived geological contributions to estimates of geological emissions further suggest that overestimation of geological emissions may be the primary cause of the overestimation (Chinkin 1998, Magliano 1998).
- The discrepancy between emissions and CMB geological source contributions is greatest during the winter, suggesting that seasonal changes in source activity and climatology may be inadequately represented in the inventory (Magliano 1997).

***Principal Knowledge Gaps:***

IMS95 and other studies indicate that geologically derived PM emissions may be overestimated, especially during winter. In part because different source categories of geological PM emissions were not resolvable, the emission sources that were overestimated are not known. As emission estimates are checked and revised, further work will be needed to determine the consistency of revised emissions with ambient measurements.

***Data Needs:***

Data described for the previous work element (3A) can be used as part of further efforts. New tracers of sources of geologically derived PM are needed.

***Adequacy of Planned Data Acquisition:***

The Fugitive Dust Characterization Study (FDCS, Watson 1997) will attempt to identify new tracers to permit resolution of different sources of geological materials. Information will be available for Corcoran, Angiola, and Fresno.

***Costs of Added Data Acquisition and Potential Trade-offs:***

***Recommendations:***

#### **4. Transport and Related Impacts**

##### **Objectives:**

- ◆ Determine the extent of transport of precursors and secondary pollutants between the San Joaquin Valley (SJV) and major California air basins - the Bay Area, the North Central and Central Coast areas, the Sacramento area, the southeast desert area, and the Sierra Nevada – and the contributions of these transported pollutants, by area of origin, to ambient PM concentrations in the receptor areas during each season of interest.
- ◆ Estimate the contributions of emissions from one portion of the southern Central Valley to ambient PM concentrations in other portions, where the Valley is divided into the Sacramento area, the North SJV (Modesto, Stockton), central SJV (Fresno), and south SJV (Bakersfield), as well as contributions within each sub-area (i.e. east side versus west side of Kern County).
- ◆ Estimate the contribution of pollutants transported from central California to visibility impairment in the southeast desert and in Class 1 areas, notably national parks and forests. Estimate the impacts on visibility impairment in these areas resulting from possible emissions reductions in the SJV.
- ◆ Develop procedures for assessing, for non-attainment areas, the upwind extent of the source region that should be subject to emissions reductions (i.e., the "zone of influence" issue) and its variation with chemical constituent and meteorological regime.

##### **General Approaches:**

Employ grid-based modeling and analysis of data collected at cross-sections of the Valley (flux planes) that lie between major metropolitan areas to assess the importance of transport.

Trajectory modeling with a visibility module could also be used to assess the effects of pollutants transported into the southeast desert. It is unlikely that modeling in the downwind or fringe areas - areas typically characterized by complex terrain, will have a database sufficient to support the effort at the spatial and temporal scales required. It would seem prudent to specify approaches to modeling and analysis suitable to meet the needs as early in the program as possible. Support should come from the Phase I modeling budget.

An approach for assessing the upwind extent of a source region should also be developed under the Phase I modeling budget.

##### **Specific Approaches:**

**4.1 Determine the transport of primary PM, precursors, and secondary PM within the SJV, between the SJV and adjoining air basins, and into Class 1 areas.**

**Approach:**

Review and synthesize all previously conducted tracer studies. Analyze new tracer data. Review findings from the characterization analyses of background and boundary sites. Carry out flux-plane and boundary transport estimates. Use empirical orthogonal functions or other spatial correlation analyses to identify geographical areas in which PM concentrations tend to co-vary. Use diurnal profiles to identify times of occurrence of peak concentrations. Compare with wind fields and determine if implied transport times are consistent with wind speeds. Compare results of data analyses with predictions of grid-based modeling.

**Current understanding:**

- During the summer, transport is typically down-valley, extending from the Bay Area into the Mojave Desert within a single day (Watson 1998).
- Well-defined transport between air basins is associated with the lowest PM concentrations, owing to dispersion and dilution during transport (Watson 1998).
- Three aloft layers were observed during IM95. The lowest layer extended from the surface up to 1000 meters. At night this surface layer was further divided into an inversion layer of 50 to 100 meters and a decoupled surface layer. The middle layer extended from 1000 meters to 2000 meters and was affected by regional terrain features. The upper layer extended above 2000 meters and was dominated by synoptic scale forcing (Dye 1998).

**Principal Knowledge Gaps:**

Transport among air basins (Bay area, SJV, Mojave Desert), within the SJV, and into Class I areas has been documented but not quantified. At present, it is not possible to quantitatively predict the expected air quality improvement in one region as air quality in other regions improves.

**Data Needs:**

Quantitative prediction, albeit with substantial uncertainty, will require well-designed inert-gas tracer experiments coupled with well-tested modeling.

**Adequacy of Planned Data Acquisition:**

Inert-gas tracer experiments are not planned. Model development and testing is discussed under other work elements.

**Costs of Added Data Acquisition and Potential Trade-offs:**

**Recommendations:**

**4.2 Determine whether the regional nature of secondary pollutants (e.g., ammonium nitrate and ammonium sulfate) is due: 1) to well-defined transport between upwind and downwind regions; 2) to slow diffusion over multi-day stagnation periods; or 3) to replication of analogous local processes throughout the domain.**

**Approach:**

Determine transport patterns from standard and micrometeorological measurements and calculate transport times from rural to urban areas during peak periods, and estimate the distance from rural locations from which ammonia has potentially originated to urban receptors. Examine land use and emissions maps to identify potential ammonia and NO<sub>x</sub> sources. Examine saturation measurements for ammonia/ammonium and NO<sub>x</sub>/HNO<sub>3</sub>/nitrate to determine gradients in ammonia, ammonium, HNO<sub>3</sub>, and nitrate with distance from urban and source-oriented measurement locations. Apply theory to estimate oxidation rates of NO<sub>x</sub> under different environmental conditions and compare these results to ambient data. Compare deposition and oxidation rates to transport times to determine ability of oxidized nitrogen (HNO<sub>3</sub>) to mix with ammonia and form ammonium nitrate. Estimate the potential for interaction of ammonia and oxidized NO<sub>x</sub> based on flow patterns. Assess the consistency of grid-based modeling results with those derived from data analyses.

**Current understanding:**

- Surface winds during the winter were not very representative of aloft transport conditions. Flows in the Valleywide layer above the surface layer were highly variable in direction, but of sufficient intensity to mix materials throughout the Valley and even into the Bay Area. There is no consistent transport direction from episode to episode however (Dye 1998, Watson 1998).
- Vertical changes in wind speed and direction are most important during winter. Afternoon mixing of surface emissions within the Valleywide layer, where wind speeds are consistently higher than at the surface during non-afternoon periods, could be the major mechanism for distributing primary emissions throughout the region, and for mixing emissions from urban and non-urban sources (Watson 1998).

**Principal Knowledge Gaps:**

Quantitative evaluation of the rates of transport and oxidation is lacking.

**Data Needs:**

Hourly time-resolution measurements of NO<sub>2</sub>, HNO<sub>3</sub>, aerosol nitrate, SO<sub>2</sub>, and aerosol sulfate are needed at a number of sites, having varying proximity to emission-source areas, allowing estimation of the oxidation rates of NO<sub>2</sub> and SO<sub>2</sub> (related studies are addressed in work elements 2C and 2D). Adequate spatial coverage is needed to permit contrasts to be observed in concentrations and relative fractions of gas-phase precursors and secondary aerosol species. Co-located surface and upper-air meteorological data are needed to characterize transport directions and distances.

**Adequacy of Planned Data Acquisition:**

The phase distributions of sulfur will be observable at Bakersfield, which will have an SO<sub>2</sub> monitor. All five winter-study anchor sites will have measurements of NO<sub>y</sub>, HNO<sub>3</sub>, and possibly true NO<sub>2</sub> (depending upon the final choice of measurement device). Since the spatial coverage of gas-phase measurements is limited, evaluations will need to rely on time series from single sites rather than spatial comparisons along trajectories.

**Costs of Added Data Acquisition and Potential Trade-offs:**

**Recommendations:**

**4.3 Determine the zone of influence of components of interest from various sources (e.g., PM<sub>10</sub> versus PM<sub>2.5</sub>, or primary particles vs. primary precursor gases).**

**Approach:**

Review and extend results of IMS95 analyses. Compare source contribution estimates from identifiable source categories based on CMB or other receptor analyses. Plot locations of major emissions sources and compare to calculated source contributions. Characterize and relate spatial patterns of emissions with those of PM mass and species concentrations. Examine changes in source contributions with time and compare to expected diurnal profiles of emissions sources. Use diurnal profiles to estimate transport distances and paths. Plot hourly wind roses for each day of sampling, and in conjunction with daily emissions activity data, attempt to verify source influences at a receptor site(s). Identify gradients between monitors in the downwind direction from the source, and determine dilutions with downwind transport. Estimate the mass emissions needed to provide incremental concentrations over background, and compare this to actual emissions.

**Current Understanding:**

- The distance scale for decay from peak to urban background values was about 5-10 km in the fall and 10-15 km in the winter. During the winter an urban-scale (10-15 km) influence exists, upon which the impact of local sources are superimposed. This urban-scale background concentration was approximately 40 ug/m<sup>3</sup>. During the fall, there appears to be a regional-scale (15-40 km) background concentration of approximately 100 ug/m<sup>3</sup> upon which local sources are superimposed. These local sources have scales of influence on the order of 1 km (Blanchard 1998).
- Substantial source influences occur for sources located within 5 to 15 km of a receptor site. A lower level of influence, but one which is more geographically widespread occur over an area 15 to 25 km from a receptor site (Blanchard 1998).
- During the fall sub-regional contributions are 60% to 90% of network average PM<sub>10</sub> concentrations with the remainder due to immediate local sources, primarily of geological material (Collins 1998).
- During the winter regional background contributions are 60% of average urban PM<sub>2.5</sub> concentrations with the remainder due to immediate local sources, primarily of organic and elemental carbon (Collins 1998).

**Principal Knowledge Gaps:**

Quantitative fractional contributions to receptor concentrations as a function of source-receptor distance are unknown.

**Data Needs:**

A combination of modeling and corroborative data analysis is needed. The data analysis requires ambient measurements of PM and components with 24-hour resolution and spatial resolution on the order of 10 km.

**Adequacy of Planned Data Acquisition:**

During the fall and winter CRPAQS studies, it will be possible to correlate and contrast emission densities with ambient measurements of b<sub>sp</sub> or PM mass at scales of about 0.5 km (using DUSTRAK nephelometers) to 10 km (using portable PM samplers). Approximately 3 to 6 PM<sub>10</sub> sites will be located in the vicinity of each of several cities (San Jose, Sacramento, Stockton, Fresno, and Bakersfield), permitting some assessment of spatial gradients and their relationship to emission densities in each of those locations over the duration of the annual study.

**Costs of Added Data Acquisition and Potential Trade-offs:**

**Recommendations:**

## 5. Model Adaptation and Evaluation

### **Objectives:**

- ◆ Assess the degree of reliability of models for estimating ambient pollutant concentrations.
- ◆ Establish modeling capabilities for use in reliably estimating future air quality for hypothetical scenarios.

### **General Approach:**

A preliminary description of the modeling methods to be used is provided in Magliano (1998). The modeling approaches to be undertaken to support Objectives 5 and 6 will follow these general methodologies. The data needs discussed in the following sections to support modeling are presented in a generic sense. Specific details of individual parameters and sampling frequencies needed to support grid-based modeling are discussed in Pun (1998b). A more detailed protocol for grid-based modeling must be developed to address issues such as the number of episodes to be studied and the role of "hands off" testing. More detailed protocols also need to be developed for receptor/rollback and annual average modeling.

General approaches to be pursued through modeling include: evaluate model performance for a range of episodic conditions. Base efforts on a protocol developed for conducting a reasonably rigorous evaluation, one that permits the model(s) to fail if it is (they are) flawed. Establish principles of the practice. For example, what is required to deem that a model is "ready to use"? How will the topic of "best available" vs. "good enough" be addressed? What will be "acceptable threshold significance levels"? What will be the role of sensitivity analysis? How will the topic of uncertainty be addressed? Will alternative base case (ABC) analysis be adopted for use? Develop a list of topics and derivative principles, again under the Phase I modeling budget. Specifically address uncertainty estimation and risk assessment. Develop and test emissions projection procedures through analysis of historical data.

Additional discussion of the important issues associated with reliable use of grid-based model and the ability of the aerometric monitoring program to provide the needed data is included in Appendix A.

### **Specific Approaches:**

#### ***5.1 Adapt the meteorological modeling system(s) for application to the study domain and evaluate its (their) performance.***

##### ***Approach:***

Apply the meteorological modeling system(s) to develop required inputs to the air quality models for selected episodes as well as an entire year (to support the annual-average modeling capability). Based on the results of data analysis activities, identify key meteorological phenomena that must be simulated by the modeling system. As specified in the modeling protocol, apply means for measuring model performance (e.g., suitable performance measures, graphical displays, etc.) and assess the adequacy of performance. Identify phenomena that are not adequately characterized and attempt to diagnose the possible causes. As appropriate, modify inputs or the formulation of modeling system in an effort to achieve adequate performance. If adequate performance cannot be achieved, assess the likely impact on the quality of performance that can be expected of subsequent air quality modeling efforts.

***Current Understanding:***

***Principal knowledge gaps:***

Both diagnostic and prognostic meteorological models have been applied in several studies to simulate conditions associated with summertime ozone episodes. However, there is little experience in using such models to replicate wintertime (air stagnation events), fall (high wind speed fugitive dust events), or conditions that occur during the spring. A detailed assessment of meteorological model performance is needed to assure that such models provide an adequate characterization of all key transport phenomena in the SJV.

***Data needs:***

Because diagnostic models employ a limited representation of atmospheric physics, their usefulness is highly dependent on the availability of a comprehensive meteorological database. While prognostic models provide a more complete description of atmospheric physics, they also benefit from the availability of pertinent observations, especially when data assimilation techniques are employed. Thus, meteorological data are needed for specifying model inputs as well as for evaluating model performance.

***Adequacy of planned data acquisition:***

There will be a considerable number of surface wind and temperature measurements collected during the full annual field program (including the winter and fall special study periods). The key issue is the availability of data aloft. The most comprehensive program will be mounted during the wintertime study, which should provide adequate data to support the development of model inputs if the data were used solely for that purpose. However, to provide a basis for independently evaluating meteorological model performance, it will be necessary to set aside (or reserve) a significant portion of the available data. The resulting reduction in available input data for use by a diagnostic model or for use in data

assimilation by a prognostic model may compromise the adequacy of the wind model results. This problem will only be exacerbated at other times of the year when even less upper air meteorological data will be collected. Careful consideration will have to be given to the use of the available upper air data and the trade-off between employing the data to develop wind and temperature fields versus using the data to facilitate the evaluation of model performance. The prognostic approach requires estimates of soil moisture content. Such data will only be collected at one site. The importance of such information and the adequacy of the current data collection plan needs to be examined.

***Costs of added data acquisition and potential trade-offs:***

***Recommendations:***

***5.2 Assess whether the air quality models provide reasonable estimates of primary and secondary gaseous and aerosol concentrations over the study domain.***

***Approach:***

As appropriate, adapt the modeling systems for simulation of selected fall and winter episodes associated with the conduct of special CRPAQS field measurement programs. In addition, adapt the annual-average modeling system for simulating conditions over an entire year. If appropriate, adapt an enhanced version of the annual-average modeling system to simulate a number of episodic days that represent typical meteorological regimes to provide an improved understanding of the accuracy and reliability of the full 365-day model simulations. In accordance with the modeling protocol, conduct an initial assessment of model performance to determine whether estimates of primary and secondary gaseous and aerosol concentrations are in reasonable agreement with the observations. Identify obvious failures in performance. If such problems are uncovered, diagnose the possible causes and attempt to rectify the deficiencies. To the extent possible, model estimates should exhibit minimum bias and should provide a reasonable representation of the spatial and temporal characteristics of gaseous and aerosol concentration fields. If a successful outcome can be achieved, proceed to the next phase of performance assessment. If some model deficiencies cannot be rectified, assess whether meaningful information can be derived from subsequent performance evaluation efforts.

***Current Understanding:***

***Principal knowledge gaps:***

Prior to adopting an air quality simulation model for use in assessing the possible impact of emission controls, it is necessary to demonstrate that the model

adequately represents all important physical and chemical phenomena in the study area. The first step in the model evaluation process is to ascertain whether the model provides reasonable estimates of the ground-level concentrations of gaseous and aerosol species. If significant systematic bias is exhibited in comparisons of calculated and measured values, then further diagnostic work will be needed to determine the cause of such biases discrepancies. Once reasonable concentration estimates are developed, more detailed performance assessments will be carried out, as discussed in Item C.

***Data needs:***

The initial assessment of model performance requires ground-level concentration measurements of gaseous and aerosol species at key locations throughout the modeling domain. This would include hourly averaged measured values for gaseous species that are monitored on a continuous basis (such as NO, NO<sub>2</sub>, and O<sub>3</sub>), and 24- and annual-average measured values for particulates.

***Adequacy of planned data acquisition:***

The comprehensive wintertime program will provide adequate measurements to assess model performance. Measurements of gaseous and particulate species will be made on a continuous basis at 5-8 sites and will be adequate for assessing model performance. However, particulate sampling will largely be on a 3-, 6-, and 12-day schedule during the annual measurement program. While it will be possible to assess model performance on the days for which sampling is carried out, the gaps in the data record may hamper efforts to diagnose model performance problems.

***Costs of added data acquisition and potential trade-offs:***

***Recommendations:***

***5.3 Assess whether the various components of the modeling systems adequately represent key phenomena associated with the formation, transport, and removal of gaseous and aerosol species.***

***Approach:***

Conduct pertinent analyses of available measurements and modeling results to address a prescribed set of questions derived from the results of data analysis activities. Address additional issues concerning the performance of the meteorological modeling system based on the air quality modeling results. Give particular attention to assessing the ability of the grid-based episodic modeling system to accurately represent windblown dust events that occur in the fall. Synthesize the results of diagnostic analyses of modeling results discussed earlier

in this document. Conduct a suite of sensitivity runs to establish how the model results respond to variations in key inputs. Identify deficiencies in the representation of key physical and chemical phenomena and, as appropriate, attempt to rectify the problems. Reevaluate model performance and identify in what manner any remaining deficiencies may limit the suitability of the modeling system for use in subsequent applications.

***Current Understanding:***

***Principal knowledge gaps:***

To fully assess the adequacy of model performance, it is necessary to examine how well the model simulates the formation, dispersion, and deposition of all key gaseous and aerosol species over a range of representative conditions. This is sometimes referred to as stressing the model. An effort should be mounted to rectify any shortcomings in model performance that are noted. If problems cannot be rectified in a satisfactory manner, appropriate caution should be exercised in the use and interpretation of any model application results (e.g., the effects of emissions controls).

***Data needs:***

Information will be needed to characterize key atmospheric processes throughout the study domain. Ideally, frequent measurements of gaseous and aerosol species would be made at ground-level and aloft in various areas of the modeling domain.

***Adequacy of planned data acquisition:***

The intensive character of the wintertime program will provide a suitable ground-level database. Since the data collection program aloft will be limited, it may not be possible to adequately assess model performance aloft except in those areas and at those times when such information will be available. The intermittent character of the ground-level particulate sampling program and the absence of sampling aloft during the remainder of the year will significantly limit model assessment and diagnostic activities.

***Costs of added data acquisition and potential trade-offs:***

***Recommendations:***

***5.4 Develop alternative base cases.***

***Approach:***

Analyze model sensitivity results to determine the group of key inputs. Develop estimates of the uncertainties associated with each of these key inputs. Identify alternative specifications for the key model inputs, wherein each input is within its range of uncertainty. Conduct model sensitivity runs with these various specifications of inputs and assess model performance. Identify those combinations of inputs that yield comparable results at the highest level of performance that can be achieved by each model.

***Current Understanding:***

***Principal knowledge gaps:***

The development of alternative base cases provides a means for estimating the uncertainties associated with modeling results. In addition, the robustness of model application results can be demonstrated by conducting simulations using alternative base cases. For example, model runs for a proposed emission control scenario can be carried out employing alternative base case inputs. If the results are consistent, confidence in the model results will be bolstered.

***Data needs:***

To develop alternative base cases, information will be needed concerning the uncertainties in the key model inputs. Measurements will also be needed of gaseous and aerosol species similar to those required to assess model performance.

***Adequacy of planned data acquisition:***

As long as information concerning measurement uncertainties is developed during the field program, it should be possible to develop alternative base cases.

***Costs of added data acquisition and potential trade-offs:***

***Recommendations:***

## **6. Emissions Reduction Requirements and Impacts**

**Objectives:**

- ◆ For monitoring sites located in central California having exceedances of the 24-hour and/or annual standards, determine which categories of sources contribute significantly to ambient concentrations, the relative proportion of their contributions, and the anticipated benefits of emissions reductions.

- ◆ Estimate the impact on ambient ozone concentrations of emissions reductions that are contemplated for reducing PM concentrations, and vice versa.

### **General Approach:**

Apply the suite of models selected for use in the study: 1) grid-based photochemical aerosol modeling for secondary pollutants for episodic simulation, 2) receptor modeling, coupled with background-corrected, speciated rollback for primary pollutants, and 3) both grid-based aerosol modeling and receptor/speciated rollback for annual average modeling.

### **Specific Approaches:**

#### ***6.1 Determine source contributions based on CMB source apportionment.***

##### ***Approach:***

Using the CMB receptor model, or other receptor methods, and measured source profiles, calculate source contributions and their uncertainties to measured PM concentrations. Examine the temporal and spatial variation of source contribution estimates with respect to known spatial and temporal distributions of emissions and determine consistencies and inconsistencies. Plot these contributions for each sample as stacked bar charts and compare the apportionments among sampling sites and sampling periods and for peak and non-peak days. Summarize the magnitudes of source contributions at each sampling site in frequency tables. Conduct sensitivity and randomized data tests to evaluate the magnitudes of uncertainties in apportionments. Compare source contributions among nearby sites for consistencies and inconsistencies. Classify each available sample by its major contributors and determine how many cases of peak PM concentrations are dominated by a single source type versus those that represent a superposition of sources.

##### ***Current Understanding:***

- During the fall, geological material is the largest contributor to PM10 concentrations (57%), followed by secondary ammonium nitrate (16%) (Magliano 1998).
- During the winter, secondary ammonium nitrate is generally the largest contributor to both PM10 and PM2.5 (30% to 50%), with significant contributions from mobile sources and residential wood combustion (20% to 35%) (Magliano 1998).
- Geological material source contributions were the primary cause of site-to-site variability during the fall, while carbonaceous source contributions were the primary cause of site-to-site variability during the winter (Magliano 1998).
- Secondary ammonium nitrate and sulfate contributions were very uniform across

all sites during both the fall and winter. The greatest variability in secondary ammonium nitrate concentrations was observed on episode buildup days during the fall (Magliano 1998).

- During IMS95, the largest contributors to organic carbon at Bakersfield and Fresno were hardwood and softwood combustion, followed by diesel exhaust, gasoline-powered motor vehicle exhaust, and meat cooking. In contrast, at Kern Wildlife Refuge only small contributions were seen from diesel exhaust and vegetative detritus, with the remaining organic carbon believed to be from secondary formation (Schauer 1998).

***Principal knowledge gaps:***

Alternative means are needed for estimating the possible contributions of the various sources in the SJV to aerosol formation. The chemical mass balance (CMB) technique is particularly attractive since it does not require use of emissions estimates, which may be subject to significant uncertainties.

***Data needs:***

To use the CMB approach, detailed measurements of aerosol composition are required in key areas of the study domain. In addition, source composition profiles are needed for each important source category.

***Adequacy of planned data acquisition:***

In the past, it has been possible to discern only a limited amount of information concerning source attribution in the SJV using the CMB approach. For example, it has not been possible to disaggregate the contributions of several different sources of fugitive dust. Special studies will be conducted in an effort to identify new indicator species for use in CMB analyses. It can be anticipated that the planned field activities will provide even better CMB results than have been available to date.

***Costs of added data acquisition and potential trade-offs:***

***Recommendations:***

***6.2 Apply the episodic photochemical-aerosol modeling system to estimate source attribution and to assess emissions control requirements and associated regulatory issues pertaining to attainment of the 24-hr PM standard.***

***Approach:***

In accordance with the modeling protocol, employ chemical and physical models

(such as box and trajectory models) to identify the most and least significant mechanisms for aerosol formation and to place upper and lower bounds on secondary aerosol contributions to PM<sub>2.5</sub> from different types of emissions (e.g., diesel vs. gasoline for secondary organic aerosol). Apply suspension/deposition models during fall episodic periods to assess the importance of sources of windblown dust. Employ the episodic grid-based modeling system (e.g., SAQM-AERO) to evaluate the effects of prescribed changes in precursor emissions from various source categories for selected wintertime episodes. If an adequate level of model performance can be demonstrated, also use the grid-based modeling system to study the effectiveness of emissions controls during selected episodes in the fall when fugitive dust may be an important contributor to PM levels. Identify the limiting precursor(s) and estimate the emissions reductions required to meet the 24-hour standard. Conduct simulations using the alternative base cases to develop estimates of the uncertainties associated with the emission reduction requirements. Evaluate the emissions projection capability as indicated in the modeling protocol. Examine the consistency of the episodic modeling results with those developed using data- or observation-based approaches.

***Current Understanding:***

***Principal knowledge gaps:***

Source-based air quality simulation modeling is one of the alternative means that will be used to examine episodic source attribution and emission control issues in the SJV. The data available to support previous aerosol model application studies in the SJV have not been adequate to yield sound model applications results.

***Data needs:***

The ability to examine source attribution and emission control issues using source-oriented modeling will be directly linked to the collection of an adequate database to characterize key physical and chemical phenomena in the SJV and to the success of model performance evaluations. Assuming adequate performance can be demonstrated, information will be needed to support the development of future emissions estimates and to characterize the possible impacts of alternative emission control scenarios.

***Adequacy of planned data acquisition:***

The extensive measurement program planned for the wintertime study will provide the best database to support episodic modeling. Thus, it is anticipated that the ability to use source-oriented modeling to examine attribution, emission control, and other regulatory issues will be greatest for winter conditions. Whether the models can be used for other periods must await the results of performance evaluation studies.

**Costs of added data acquisition and potential trade-offs:**

**Recommendations:**

**6.3 Apply the annual-average photochemical-aerosol modeling system to assess emissions control requirements and associated regulatory issues pertaining to attainment of the annual PM standard.**

**Approach:**

In accordance with the modeling protocol, employ the grid-based, annual-average aerosol modeling system to simulate the influence of changes in precursor emissions on annual PM levels. If appropriate, based on the results of the model performance assessment, examine the consistency of the modeling results derived from the simulation of an entire year with those derived from the exercise of an enhanced version of the grid-based model run for up to 60 episodic days which represent typical meteorological regimes that occur in the SJV. Employ the grid-based modeling system to evaluate the effects of prescribed changes in precursor emissions from various source categories. Identify the limiting precursor(s) and estimate the emissions reductions required to meet the annual standard. Conduct simulations using the alternative base cases to develop estimates of the uncertainties associated with the emission reduction requirements. Evaluate the emissions projection capability as indicated in the modeling protocol. Examine the consistency of modeling results with those developed using data- or observation-based approaches.

**Current Understanding:**

**Principal knowledge gaps:**

Source-oriented air quality simulation modeling is one of the alternative means that will potentially be used to examine source attribution and emission control issues pertaining to annual-average particulate air quality in the SJV. As indicated in Item B above, the data available to support previous aerosol model application studies in the SJV have not been adequate to yield sound model applications results.

**Data needs:**

The ability to examine source attribution and emission control issues using source-oriented modeling will be directly linked to the collection of an adequate database to characterize key physical and chemical phenomena in the SJV and to the success of model performance evaluations. Assuming adequate performance can be demonstrated, information will be needed to support the development of future emissions estimates and to characterize the possible impacts of alternative emission control scenarios.

***Adequacy of planned data acquisition:***

The database that will be available to support annual particulate modeling will not be as extensive as that to be developed for the wintertime special measurement program. Thus, whether source-oriented modeling can be used to examine attribution, emission control, and other regulatory issues must await the results of performance evaluation studies. An assessment of the adequacy of efforts to develop future emissions estimates and to characterize the possible impacts of alternative emission control scenarios must await the publication of planned emissions activities.

***Costs of added data acquisition and potential trade-offs:***

***Recommendations:***

**7. Attainment-related Concerns**

**Objectives:**

- ◆ Determine the effects of meteorological variability on the likelihood of exceeding the standards. Assess the likelihood of "flip-flopping" into and out of attainment of the standards.
- ◆ Determine the extent to which high 24-hour average values contribute to exceedance of the *annual* average standard, regardless of whether the 24-hour average standard is exceeded. Assess the relative impacts of types of episodes on the annual average.
- ◆ Evaluate the extent to which the long-term PM monitoring networks represent levels to which larger populations are exposed under a variety of emissions and meteorological conditions.

**General Approaches:**

Apply data analysis approaches employed by Chock (19\_\_), Fairley and Blanchard (1991), and Fairley (199\_) to estimate the influence of meteorological variability on attainment requirements. Using different weightings of meteorological scenarios modeled for the annual average, "recreate" alternative annual averages. Refer also to analyses conducted for determination of whether episodes are emissions or meteorologically driven.

Apply methods used by Magliano (1997) and the SJVUAPCD (1997) to address the issue of which is the controlling standard. Also, stratify annual record by episodic

periods, group episodes according to meteorological characteristics, and adapt the approaches cited for assessing relative impacts. In addition, apply the annual average models.

### **Specific Approaches:**

#### ***7.1 Determine annual and 24-hour PM concentrations that must be achieved to ensure compliance with current PM standards.***

##### ***Approach:***

Use data simulation methods to estimate ambient concentrations that must be achieved to ensure compliance. For sites that are just meeting PM standards under typical high-PM conditions, estimate probabilities of exceeding current standards as a result of highly unfavorable meteorology. What are the typical maximum PM concentrations that must be achieved each year to ensure that excess violations do not occur in years with highly adverse meteorological conditions? Adapt and apply simulation methods used by Chock (199\_) and Fairley (199\_) to estimate ozone exceedance probabilities. Estimate annual average PM using different frequencies of episode types.

##### ***Current Understanding:***

- 

##### ***Principal Knowledge Gaps:***

The variability of annual averages and high-percentile concentrations over many years with different meteorological conditions is not known.

##### ***Data Needs:***

A long-term data record (> ~10 years) is needed to ensure that a wide range of meteorological conditions are included. Statistical procedures can be applied for decomposing data time series into long-term trend, multi-year variability, and short-term variability.

##### ***Adequacy of Planned Data Acquisition:***

The CRPAQS alone cannot address this question, but can contribute to the long-term temporal record (see work element 1A).

##### ***Costs of Added Data Acquisition and Potential Trade-offs:***

##### ***Recommendations:***

**7.2 Determine the extent to which reducing the largest 24-hour PM concentrations also reduces the annual average, the extent to which reducing all PM concentrations reduces annual averages, and the extent to which reducing different chemical components reduces annual averages.**

**Approach:**

For each site within central California that shows annual average PM<sub>10</sub> or PM<sub>2.5</sub> exceedances, recalculate the annual average with the following modifications: 1) reducing all 24-hour concentrations in excess of 150 ug/m<sup>3</sup>, 100 ug/m<sup>3</sup>, 75 ug/m<sup>3</sup>, and 55 ug/m<sup>3</sup> for PM<sub>10</sub> and in excess of 65 ug/m<sup>3</sup>, 50 ug/m<sup>3</sup>, 35 ug/m<sup>3</sup>, and 25 ug/m<sup>3</sup> for PM<sub>2.5</sub> to those values respectively, 2) reducing all 24-hour average concentrations by 10%, 20%, 30%, 40%, and 50% after reducing all PM<sub>10</sub> and PM<sub>2.5</sub> exceedances to the respective standard level, 3) reducing ammonium sulfate, ammonium nitrate, and remaining mass concentrations by 10%, 20%, 30%, 40%, and 50%. Identify the levels at which the annual standards are achieved and how this level varies from site to site. For each site, plot the frequency of occurrence by month, of values that exceed 50 ug/m<sup>3</sup> for PM<sub>10</sub> and 15 ug/m<sup>3</sup> for PM<sub>2.5</sub>. Explain differences and similarities between sites. Determine what additional reductions are needed at each site after 24-hour average standards are met.

**Current Understanding:**

- The few highest PM concentrations do not drive the annual average for PM<sub>10</sub> or PM<sub>2.5</sub>. Numerous concentrations which are more than twice the respective annual average standards (i.e., >30 ug/m<sup>3</sup> for PM<sub>2.5</sub> and >100 ug/m<sup>3</sup> for PM<sub>10</sub>) appear to be what contribute to exceedances of the annual standards (Magliano 1996, SJVUAPCD 1997).

**Principal Knowledge Gaps:**

Quantitative assessment of trends in distributions of PM concentrations is needed.

**Data Needs:**

The CRPAQS alone cannot address this question, but can contribute to the long-term temporal record (see work element 1A).

**Adequacy of Planned Data Acquisition:**

**Costs of Added Data Acquisition and Potential Trade-offs:**

**Recommendations:**

## 8. Conceptual Models

### Objectives:

- ◆ Refine conceptual models that explain the causes of elevated PM concentrations and interactions between emissions, meteorology, and ambient PM concentrations.

### General Approaches:

What are the causes of excessive PM<sub>10</sub> concentrations in the SJV? What is the influence of meteorology, emissions, chemistry, and deposition on PM concentrations? What differences are observed for PM and PM components and precursors species among urban, rural, and industrial area? What are the chemical processes for the formation of secondary aerosols, especially during foggy conditions when the photochemical process may be limited? What is the influence of fog on PM concentrations? What is the spatial influence of primary emissions and secondary aerosol precursors during each conceptual model scenario? What controls the annual average PM concentrations; peak 24-hr values or moderate range PM concentrations? What chemical species are most important for controlling the annual average and does it vary as a function of the time of the year? What modifications are needed to conceptual models? What knowledge gaps still exist and what data are needed to fill those gaps? What are recommendations for future field, modeling, and data analysis studies? What statements can be made regarding priority for emissions controls for primary aerosol and secondary precursor aerosol species? If a new PM standard is promulgated, where and when might it be exceeded, what are the major chemical components, and what its relationship, from a chemical, spatial, and temporal aspect, to the existing PM standard?

Synthesize data from other analyses. Update understanding of conceptual models. Provide detailed descriptions of case studies for each conceptual model.

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#### IV. SUMMARY OF PROPOSED FIELD MEASUREMENTS

**Table 1**  
**CRPAQS Field Study Monitoring Sites**

Site ID	Name	Annual <sup>c</sup>	Winter or Summer Additions <sup>d</sup>	Fall Additions <sup>e</sup>	Purpose
ACP	Angels Camp	Sat-ABC	Sat-15 Ep Days		Intrabasin Gradient
AGBR	Agricultural fields, with emphasis on burning	Sat-ABCD	Sat-15 Ep Days		Source, Agdust/Burning
ALT	Altamont Pass-Tracy	Bac-E (3rd day)	Bac-15 Ep Days		Intrabasin Gradient
ALT1	Altamont Pass	Sat-AB	Sat-15 Ep Days		Interbasin Transport
ANGI	Angiola-ground level	Anc-AGHIJKLMNOP Sat-D	Anc-QRSTUVWXZabe		Intrabasin Gradient Vertical Gradient Visibility
ANGI1	Angiola-2,10,25,50 m	Anc-I			Vertical Gradient
ANGIT	Angiola-100 m	Anc-I	Anc-AGQRST		Vertical Gradient
ATL	Atascadero-Lewis Avenue	Bac-E(6th day)			Community Exposure
BAC	Bakersfield-5558 California Street	Anc-AGHIJKLMNOP Bac-E(everyday)F Sat-D	Anc-QRSTUVWXYe		Community Exposure Visibility
BARS	Barstow	Sat-A			Visibility
BGS	Bakersfield-1120 Golden State	Bac-E(3rd day)F Sat-fgh(6th day lag)	Bac-15 Ep Days		Community Exposure
BLIS1	D.L. Bliss State Park	Bac-F(3rd day)i			Visibility
BQUC	Bouquet Canyon		Sat-A (summer)		Interbasin Transport Visibility
BRES	Residential area near BAC, with woodburning	Sat-ABC	Sat-15 Ep Days		Source, woodburning
BRV	Bruceville-Elk Grove	Bac-E(3rd day)	Bac-15 Ep Days		Community Exposure
BSE	Bakersfield (Southeast)	Bac-E(3rd day)	Bac-15 Ep Days		Source
BTI	Bethel Island	Sat-ABCD	Anc- GHIJKLMNOP QRSTUWXYZ		Interbasin Transport
C1-26	Corcoran-Saturation			Sat-f	Receptor
C27-31	Corcoran-Saturation minivol			Sat-fgh	Receptor
CAJP	Cajon Pass		Sat-A (summer)		Interbasin Transport Visibility
CANT	Cantil		Sat-A (summer)		Intrabasin Gradient Visibility
CARP	Carrizo Plain	Sat-AB	Sat-15 Ep Days		Intrabasin Gradient Visibility
CCD	Concord-2975 Treat Blvd	Bac-E(everyday)F	Bac-15 Ep Days		Source

Site ID	Name	Annual <sup>c</sup>	Winter or Summer Additions <sup>d</sup>	Fall Additions <sup>e</sup>	Purpose
CHL	China Lake	Sat-A			Visibility
CHM	Chico-Manzanita Avenue	Bac-E(6th day)F	Bac-15 Ep Days		Community Exposure
CLO	Clovis-908 N Villa Avenue	Bac-E(3rd day)F	Bac-15 Ep Days		Source
COA	Coalinga	Sat-A	Sat-15 Ep Days		Intrabasin Gradient
COP	Corcoran-Patterson Avenue	Bac-E(3rd day)F Sat-fgh(6th day lag) Sat-D	Bac-15 Ep Days		Community Exposure
COV	Corcoran-Van Dorsten			Sat-f	Receptor
CRD	Crows Landing	Sat-A	Sat-15 Ep Days		Intrabasin Gradient
CSS	Colusa-100 Sunrise Blvd	Bac-E(3rd day)	Bac-15 Ep Days		Intrabasin Gradient
DOLA1	Dome Land Wilderness	Bac-F(3rd day)			Background Visibility
DUB1	Dublin	Sat-A	Anc-BCGQRS		Intrabasin Gradient
EDI	Edison	Sat-AB	Sat-15 Ep Days		Intrabasin Gradient
EDW	Edwards Air Force Base	Sat-ABCD	Anc-GJK (summer only)		Intrabasin Gradient Visibility
ELM	El Rio-Mesa School #2	Bac-E(3rd day)F			Intrabasin Gradient
FCW	Fremont-Chapel Way	Bac-E(3rd day)	Bac-15 Ep Days		Source
FEDL	Feedlot or Dairy	Sat-ABCD	Sat-15 Ep Days		Source, Animals
FEL	Fellows	Sat-ABCD	Sat-15 Ep Days		Source, Oilfields
FELF	Foothills above Fellows	Sat-ABC	Sat-15 Ep Days		Intrabasin Gradient
FRER	Fresno (south Fresno gradient site)	Sat-ABC	Sat-15 Ep Days		Intrabasin Gradient
FRES	Residential area near FSF, with woodburning	Sat-ABCD	Sat-15 Ep Days		Source, woodburning
FSD	Fresno Drummond	Sat-fgh(6th day lag)			Community Exposure
FSE	Fresno (Southeast)	Bac-E(3rd day)	Bac-15 Ep Days		Source
FSF	Fresno-3425 First Street	Anc-AGHIJKLMNOPSat-D Bac-E(everyday)F	Anc-QRSTcd		Community Exposure Visibility
GVL	Grass Valley-Litton Building Site	Bac-E(6th day)			Community Exposure
HAN	Hanford-Irwin St.	Sat-fgh(6th day lag)			Community Exposure
HDB	Healdsburg-Limeric Lane	Bac-E(6th day)			Source
HELM	Helm-Central Fresno County	Sat-ABC	Sat-15 Ep Days		Intrabasin Gradient
JAC	Jackson-201 Clinton Road	Bac-E(3rd day)			Intrabasin Gradient

Objectives and Associated Data Analysis and Modeling Approaches  
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Site ID	Name	Annual <sup>c</sup>	Winter or Summer Additions <sup>d</sup>	Fall Additions <sup>e</sup>	Purpose
KCG	Keeler-Cerro Gordo Road	Bac-E(3rd day)			Source
KCW	Kettleman City	Sat-AB	Sat-15 Ep Days		Intrabasin Gradient
KRV	Sierra Nevada Foothills-Kings River Valley	Sat-A	Sat-15 Ep Days		Interbasin Transport
KWF	Kern Wildlife	Sat-ABCD	Sat-15 Ep Days		Intrabasin Gradient
LCR	Lancaster-West Pondera Street	Bac-E(3rd day)F			Community Exposure
LKL	Lakeport	Bac-E(6th day)			Intrabasin Gradient
LTY	South Lake Tahoe-3337 Sandy Way	Bac-E(6th day)F			Source
LVF	Livermore Old First Street	Bac-E(everyday)F Sat-D	Bac-15 Ep Days		Interbasin Transport
M14	Modesto-14th Street	Sat-fgh(6th day lag)			Community Exposure
MAG	Mammoth Lakes-Gateway HC	Bac-E(3rd day)F			Source
MIS	Modesto-1100 I Street	Bac-E(3rd day)F Sat-D	Anc-AGQRS Bac-15 Ep Days		Community Exposure
MOJ	Mojave-923 Poole Street	Bac-E(3rd day)F			Community Exposure
MRM	Merced-Midtown	Bac-E(3rd day)F	Bac-15 Ep Days		Community Exposure
NLT	North Lake Tahoe (near Tahoe City)	Bac-E(6th day)			Source
OLD	Oildale-Manor	Sat-fgh(6th day lag)			Community Exposure
OLW	Olancho	Sat-ABCDU	Sat-15 Ep Days		Background Visibility
PAC1	Pacheco Pass	Sat-AB	Sat-15 Ep Days		Interbasin Transport
PAG	Point Arguello	Bac-E(3rd day)			Background
PARN	Point Arena	Bac-E(3rd day)F Sat-U	Anc-AGQRS Bac-15 Ep Days		Background
PINN1	Pinnacles National Monument	Bac-F(3rd day)i			Background Visibility
PIR	Piru-2 mi SW	Bac-E(6th day)			Intrabasin Gradient
PLE	Pleasant Grove (north of Sacramento)	Sat-ABC	Sat-15 Ep Days		Intrabasin Gradient
POL	Portola	Bac-E(3rd day)F			Intrabasin Gradient
PORE1	Point Reyes National Seashore	Bac-F(3rd day)i			Background Visibility
RED	Redwood City	Bac-E(3rd day)	Bac-15 Ep Days		Source
RGI	Ridgecrest-Las Flores Avenue	Bac-E(3rd day) Sat-D			Community Exposure
ROS	Roseville-151 North Sunrise Blvd	Bac-E(6th day)F	Bac-15 Ep Days		Intrabasin Gradient

Objectives and Associated Data Analysis and Modeling Approaches  
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Site ID	Name	Annual <sup>c</sup>	Winter or Summer Additions <sup>d</sup>	Fall Additions <sup>e</sup>	Purpose
S13	Sacramento-1309 T Street	Bac-E(everyday)F Sat-D	Bac-15 Ep Days		Community Exposure
SAL	Salinas	Bac-E(3rd day)F	Bac-15 Ep Days		Source
SBC	Santa Barbara-3 West Carillo Street	Bac-E(6th day)F			Community Exposure
SCQ	Santa Cruz-2544 Soquel Drive	Bac-E(3rd day)	Bac-15 Ep Days		Community Exposure
SDP	Sacramento-Del Paso Manor	Anc-AG Bac-E(3rd day)F Sat-D	Anc-QRS Bac-15 Ep Days		Community Exposure
SEQU1	Sequoia National Park	Bac-F(3rd day)i			Background Visibility
SFA	San Francisco-10 Arkansas Street	Bac-E(3rd day)F	Bac-15 Ep Days		Source
SGS	San Andreas-Gold Strike Road	Bac-E(6th day)			Intrabasin Gradient
SJ4	San Jose-4th Street	Anc-AG Bac-E(everyday)F Sat-D	Anc-QRS Bac-15 Ep Days		Community Exposure
SJT	San Jose-528 Tully Road	Bac-E(everyday)	Bac-15 Ep Days		Community Exposure
SLDC	Soledad Canyon		Sat-A (summer)		Interbasin Transport Visibility
SLM	San Luis Obispo-Marsh Street	Bac-E(6th day)			Source
SNFH	Sierra Nevada Foothills	Sat-ABCD	Anc- GHIJKLMNOPQRSTU VWX		Vertical Gradient Intrabasin Gradient Visibility
SOH	Stockton-Hazelton Street	Bac-E(3rd day)F	Bac-15 Ep Days		Community Exposure
SOLA1	South Lake Tahoe	Bac-F(3rd day)i			Visibility
SQV	Squaw Valley-New Site	Bac-E(3rd day)			Source
SRF	Santa Rosa-837 Fifth Street	Bac-E(3rd day)	Bac-15 Ep Days		Community Exposure
SST	Sacramento-Health Department Stockton Blvd	Bac-E(everyday)	Bac-15 Ep Days		Community Exposure
STL	Santa Maria-Library	Bac-E(6th day)			Source
SWC	SW Chowchilla	Sat-ABC	Sat-15 Ep Days		Intrabasin Gradient
TEH2	Tehachapi Pass	Sat-AB	Sat-15 Ep Days		Interbasin Transport Visibility
TEJ	Tejon Pass	Sat-A	Sat-15 Ep Days		Interbasin Transport
TRU	Truckee-Fire Station	Bac-E(3rd day)F			Source
UKC	Ukiah-County Library	Bac-E(6th day)F			Community Exposure
VCS	Visalia-North Church Street	Bac-E(3rd day)F Sat-fgh(6th day lag)	Bac-15 Ep Days		Community Exposure
VIA	Victorville-Armagosa Road	Bac-E(3rd day)F			Intrabasin Gradient

Site ID	Name	Annual <sup>c</sup>	Winter or Summer Additions <sup>d</sup>	Fall Additions <sup>e</sup>	Purpose
VJO	Vallejo-304 Tuolumne Street	Bac-E(3rd day)	Bac-15 Ep Days		Interbasin Transport
WAG	Walnut Grove-ground level	Sat-A	Anc-GIQRST		Vertical Gradient
WAGT	Walnut Grove-300 m agl		Anc-AGIQRT		Vertical Gradient
WLKP	Walker Pass	Sat-A	Sat-15 Ep Days		Interbasin Transport
WLN	Woodland	Bac-E(3rd day)	Bac-15 Ep Days		Community Exposure
YAS	Yuba City-Almond Street	Bac-E(6th day)F	Bac-15 Ep Days		Intrabasin Gradient
YOT		Bac-F(3rd day)i Sat-DU	Bac-15 Ep Days		Background Visibility
YOY	Yosemite Village	Bac-E(3rd day)			Intrabasin Gradient

<sup>a</sup>Anc=Anchor network, Bac=PM<sub>2.5</sub> Backbone network, Sat=Satellite network. See Table 2 for measurement code definitions.

<sup>b</sup>Bac sites sample every day unless indicated every third or sixth day. Speciation monitors operate every sixth day. Filter measurements at Backbone PM<sub>10</sub> sites operate every 6th day, but 3-days later than the Bac schedule.

<sup>c</sup>Annual period is from 12/1/1999 through 1/31/2001

<sup>d</sup>Winter unless otherwise designated. Winter period is 60 consecutive days from 11/16/2000 through 1/31/2001. Summer period is 62 consecutive days from 7/1/2000 through 8/31/2000.

<sup>e</sup>Fall period is 60 consecutive days from 9/1/2000 through 10/30/2000.

\*Fall Minivol sites to be moveable at 14-day intervals in response to review of nephelometer data at other sites in the neighborhood-scale network.

**Table 2**

**CRPAQS Field Study Measurement Methods and Frequencies**

<b>Code</b>	<b>Observable and Method</b>	<b>Frequency</b>	<b>Avg Time</b>
A	Light scattering/PM <sub>2.5</sub> mass (TBD portable nephelometer)	daily@Anc at least 6th day@Sat Winter 15 Ep days	5-min 5-min 5-min
B	PM <sub>2.5</sub> mass, elements, ammonia (Minivol with Teflon/citric acid & Grav, XRF, AC)	6th day@Sat Winter 15 Ep days	24-hr 24-hr
C	PM <sub>2.5</sub> ions, carbon, nitric acid (Minivol with -quartz-NaCl & IC, AC, AA & TOR)	6th day@Sat Winter 15 Ep days	24-hr 24-hr
D	PM <sub>2.5</sub> Organic compounds (Minivol-Teflon coated glass fiber & GC/MS)	6th day@Sat Winter 15 Ep days	24-hr 24-hr
E	PM <sub>2.5</sub> mass, elements (FRM single with Teflon & Grav, XRF on 10 days)	daily&3rd day@Bac	24-hr
F	PM <sub>2.5</sub> elements, ions, carbon (EPA or IMPROVE speciation sampler)	6th day@Bac	24-hr
G	Light absorption/elemental carbon (aethalometer)	daily@Anc	5-min
H	PM <sub>2.5</sub> organic and elemental carbon (TBD continuous carbon analyzer)	daily@Anc	30-min
I	Particle size distribution (optical particle counter)	daily@Anc	5-min
J	PM <sub>10</sub> mass (ambient T and RH TEOM)	daily@Anc	10-min
K	PM <sub>2.5</sub> mass (ambient T and RH TEOM)	daily@Anc	10-min
L	PM <sub>2.5</sub> mass and elements (sequential sampler with Teflon filter)	daily@Anc Winter 15 Ep days	24-hr 3-8-hr <sup>a</sup>
M	PM <sub>2.5</sub> ions and carbon (sequential sampler with denuder -quartz--NaCl cellulose)	daily@Anc Winter 15 Ep days	24-hr 3-8-hr <sup>a</sup>
N	NO <sub>2</sub> (high sensitivity chemiluminescent monitor)	daily@Anc	5-min
O	NO <sub>y</sub> (TBD high sensitivity chemiluminescent monitor with external converter)	daily@Anc	5-min
P	O <sub>3</sub> (ultraviolet absorption monitor)	daily@Anc	5-min
Q	PM <sub>2.5</sub> nitrate (TBD continuous monitor)	daily@Anc	10-min
R	Nitric acid (TBD continuous monitor)	daily@Anc	5-min
S	Ammonia (TBD continuous monitor)	daily@Anc	5-min
T	PM <sub>2.5</sub> sulfate (TBD continuous monitor)	daily@Anc	5-min
U	Light hydrocarbons (canister & GC/FID)	6th day@Sat Winter 15 Ep days	24-hr 5 to 8-hr <sup>b</sup>
V	Heavy hydrocarbons (TENAX & GC/TSD/FID)	Winter 15 Ep days	5 to 8-hr <sup>b</sup>
W	PM <sub>2.5</sub> organic compounds (Teflon coated glass fiber/PUF/XAD & GCMS)	Winter 15 Ep days	5 to 8-hr <sup>b</sup>
X	Aldehydes (DNPH & HPLC)	Winter 15 Ep days	5 to 8-hr <sup>b</sup>
Y	SO <sub>2</sub> (TBD high sensitivity continuous monitor)	daily	5-min
Z	Hydrogen peroxide (peroxydaze enzyme)	daily	30-min
a	Free radicals (TBD continuous monitor)	daily	10-min
b	PAN (TBD continuous luminol or GC/EC)	daily	30-min
c	Ion size distribution (MOUDI with Teflon & IC, AC)	Intermittant on Winter 15 Ep days	> 6-hr
d	Carbon size distribution (MOUDI with aluminum & TOR)	Intermittant on Winter 15 Ep days	> 6-hr

Code	Observable and Method	Frequency	Avg Time
e	Aerosol Time of Flight Mass Spectrometer	Intermittant on 15 Ep days & during Fall	5-min
f	Light scattering/PM <sub>10</sub> mass (TBD portable nephelometer)	daily on Fall Ep days@Sat	5-min
g	PM <sub>10</sub> mass, elements, ammonia (Minivol with Teflon/citric acid & Grav, XRF, AC)	6th day w 3-day lag@Sat daily on Fall Ep days@Sat	24-hr 24-hr
h	PM <sub>10</sub> ions, carbon, nitric acid (Minivol with quartz-NaCl & IC, AC, AA & TOR)	6th day w 3-day lag@Sat daily on Fall Ep days@Sat	24-hr 24-hr
i	IMPROVE PM <sub>10</sub> module D (Teflon)	3rd day@Bac	24-hr

<sup>a</sup>Sequential samples from 0000-0500, 0500-1000, 1000-1300, 1300-1600, 1600-2400 PST

<sup>b</sup>Sequential samples from 0000-0500, 0500-1000, 1000-1600, 1600-2400 PST

**Table 3**  
**CRPAQS Upper Air Meteorological Measurements**

Site	Name	Purpose	Radar	RASS	SODAR	Rawinsonde
ACP	Angel's Camp	Interbasin Transport			WC	
ANGI	Angiola	Intrabasin Transport	A	A	WC	
BAC	Bakersfield-California	Urban Heat Island				WE
CRO	Crows Landing	Intra& Interbasin Transport	A	A		
EDI	Edison	Interbasin Transport	A	A		
EDW	Edwards AFB	Desert Mixed Layer	A			A
ELN	El Nido	Intrabasin Transport	A	A	WC	
FSF	Fresno-First Street	Urban Heat Island				WE
HUR	Huron	Intrabasin Transport	A	A		
LGR	Lagrange	Upslope/ Downslope Flow	WC	WC	WC	
MCK	McKittrick	Intrabasin Transport	A	A		
MEN	Mendota	Intrabasin Transport	WC	WC	WC	
MKR	Mouth Kings River	Upslope/ Downslope Flow	A	A	WC	
MON	Monterey	Offshore/ Onshore Transport	A	A		
MTL	Mettler	Southern Valley Barrier	WC	WC	WC	
NTD	Point Mugu USN	Offshore/ Onshore Transport				A
OAK	Oakland Airport	Offshore/ Onshore Transport				A
RBF	Red Bluff	Northern Valley Barrier			WC	
RIC	Richmond	Offshore/ Onshore Transport			A	
RSA	Rosamond	Interbasin Transport	A	A		

*Objectives and Associated Data Analysis and Modeling Approaches*  
*DRAFT: February 5, 1999*

<b>Site</b>	<b>Name</b>	<b>Purpose</b>	<b>Radar</b>	<b>RASS</b>	<b>SODAR</b>	<b>Rawinsonde</b>
SAC	Sacramento	Intrabasin Transport	A	A		
SAM	Santa Maria	Interbasin Transport	WC	WC		
SJO	San Jose	Intrabasin Transport	WC	WC	WC	
TRA	Travis AFB	Intrabasin Transport	A	A	WC	
VBG	Vandenberg AFB	Offshore/ Onshore Transport				A
VIS	Visalia	Intrabasin Transport	A	A		
WIL	Williams	Northern Valley Barrier	WC			

## APPENDIX A

### **Identification of Important Issues and Fallback Positions In the Event that a Photochemical Grid Model With an Adequate Aerosol Mechanism is Unavailable**

The purpose of this memo is to try to determine whether the field program plan and the proposed data analyses will be adequate to address issues that would primarily be addressed through use of a (photochemical grid) model. In doing this exercise, we first asked which model or models might be critical and yet questionable with regard to their availability for use. Our decision was that the most problematic model would be the photochemical grid model with an aerosol mechanism. Other models have been used to address many of the issues associated with PM-10, especially with primary particulate matter. The grid model is needed to determine:

1. Limiting precursor for situations in which nitrate is the limiting component of ammonium nitrate
2. Source attribution of secondary aerosols, especially ammonium nitrate
3. Radius of Influence for sources of precursor of secondary aerosols
4. Transport and relative impact of transported versus local secondary aerosols as well as primary fine particles
5. Conversion of gaseous hydrocarbons to secondary organic aerosols
6. Prediction of emission reductions on future particulate concentrations
7. Effects of precursor reductions for PM 2.5 on other criteria pollutants and standards

Our assessment is very preliminary. It is really done to force us to review the adequacy of the plan to date to provide information that could be used in lieu of a grid model if model performance is found to be inadequate. We suggest that this memo is a dynamic document that will be modified to by others.

Limiting precursor for situations in which nitrate is the limiting component of ammonium nitrate. In trying to answer this question, we have already asked Christian Seigneur to provide more information on the need for measurements of both nitrogen species and oxidants that could elucidate the predominant wintertime nitric acid formation mechanism. The oxidant measurements are difficult to make, but it is our understanding that these measurements will be attempted at the core site at Angiola. One of our questions is whether making these measurements at a single site will be sufficient to gain an understanding of this question for other areas in the Valley as well as the Bay Area. Are the results transferable? Is there a probability that the information from the single site will allow development of an "observational" model similar to that developed for ozone which might depend on indicator species that are not difficult to measure? Can any of this information be determined by smog chamber experiments or by doing a set of chemistry simulations to see the effects of different precursor concentrations? Without some input from others, we are not sure that there is a backup position for this issue.

Source attribution of secondary aerosols, especially ammonium nitrate. This is a difficult question. There does not seem to be a clear set of measurements that can provide this information directly. It may be possible to understand relative contributions of surface and elevated emissions of NO<sub>x</sub> through a well-designed tracer experiment coupled with meteorological information from both tower and sounder/profiler measurements. But none of that information will provide any direct information about the chemical transformation of NO to HNO<sub>3</sub>. Some additional information may be gained if there are air quality measurements made aloft on the tower and through use of aircraft with appropriate air quality instrumentation. Synthesis of the experimental information may be the fallback position.

For secondary organic aerosols, the situation does not appear as bleak. There will be gaseous measurement of hydrocarbon precursors. Work has been ongoing at Cal. Tech. and other universities to develop chemical mechanisms for secondary organic aerosol formation. Some of this work has been done using smog chambers. It may also be possible to carry out a chemical mass balance approach using source profiles and the types of analytical analyses that have been developed at Cal. Tech.

Radius of Influence for sources of precursors of secondary aerosols. The problem that may not be answered by any of the above is the "radius of influence" for the secondary emissions. This may be addressed indirectly through use of a prognostic meteorological model, or other type of meteorological approach (statistical) if it can be shown that the meteorological model can meet performance expectations, which are undefined at present. Data needed for input and evaluation of the meteorological model appear to be included in the field plan with the inclusion of multiple wind and temperature measurements at the tower along with surface and sounder/profiler/RASS measurements. Understanding of the meteorology associated with the build-up of secondary aerosol leading to high concentrations may be the only viable option.

Determination of transport and relative impact of transported versus local secondary aerosols as well as primary fine particles. Most of the instrumentation and analyses, as well as the possibility of using a prognostic met. model, may allow an understanding of surface and aloft winds. If aircraft are used to make aerometric measurements above the fog layer (or at multiple altitudes for fog-free situations), estimates of flux can be made (note that the present configuration of SAQM does not allow for non-homogeneous flux planes). At the same time, consideration should be given to identification of tracers of opportunity that may identify transport patterns. We have not taken into account any potential tracer experiments, as these are currently being evaluated as to their possible utility and probability of success. Decisions on use of tracers will have to be factored into these issues as the decisions are made.

Conversion of gaseous hydrocarbons to secondary organic aerosols. As noted above, there is ongoing work being done on chemical mechanisms. It is anticipated that this work will continue. It will lead to rate constants that may possibly be used to determine the conversion of gaseous species under various conditions (temperature, solar

radiation, etc.). These can then be applied to the different source profiles.

Prediction of the effect of emission reductions on future particulate concentrations:

This issue is specifically aimed at the secondary aerosols. Previous analyses have suggested that the annual standard may be the controlling standard. However, those same analyses, as well as the discussion in the modeling protocol recognize that information on how secondary aerosols will respond to reduction of precursors is still driven by episodic modeling. Thus, if the aim of this memo is only to identify a fallback position for photochemical aerosol modeling, then there is none. Rather, the fallback should be that the above analyses, when synthesized, provide a weight of evidence that the path being taken will reduce fine particulate levels. One very central decision will have to be which of the various paths should be pursued if there are multiple approaches to reducing fine particulate. For example, it may be that reductions of wood smoke could provide the reductions needed for attainment, rather than going after other types of reductions that currently cannot be quantified.

Effects of precursor reductions for PM 2.5 on other criteria pollutants and standards:

There are a number of concerns about how this issue is addressed. One of the problems is that CCOS is a very problematic effort, especially when considering the technical versus regulatory timing issue, the available funds and whether those funds are sufficient, the use of a out of date (SAQM) model, etc. If enough information is developed from the above analyses to determine if ammonium nitrate is a primary target for reduction to meet the federal standards, and whether NO<sub>x</sub> is the precursor to reduce, then we need to revisit the ozone strategy that is being pursued by various districts for the California Clean Air Act. There may be conflicts between the ozone and fine particle strategies that will need to be resolved.

# Draft

## Plan of Air Quality Modeling for the California Regional PM<sub>10</sub>/PM<sub>2.5</sub> Study

This is a working document developed by the Technical Committee of the San Joaquin Valleywide Air Pollution Study Agency. The purpose of the document is to provide a conceptual framework to guide Technical Committee development of modeling efforts for the study. Opinions stated in the document are subject to revision from the findings of the study and should not be considered as a statement of an official position of the Study Agency or any of its members.

Last major review and revision: September 7, 2001.

*Attachments:*

*Attachment 1 "Particulate- Matter Modeling Questions for CRPAQS"*

*Attachment 2 "Near-Term Plan for the CRPAQS Modeling Program"*

## The Draft Plan of Air Quality Modeling for the California Regional PM<sub>10</sub>/PM<sub>2.5</sub> Study (CRPAQS)\*

### 1. Introduction:

- The models capable of simulating particulate matter and visibility are still in their infancy compared to those capable of simulating ozone. Therefore, the models development/improvement will be a key aspect of this plan
- CRPAQS will yield the most comprehensive database available for performance evaluation of models for particulate matter and visibility
- The evaluated models can be used for regulatory programs for particulate matter and regional visibility
- The modeling proposed in this document could also be useful in other SIP related activities such as smoke management and air-quality forecasting
- This plan will be fully consistent with the issues raised in the Data Analysis Questions for CRPAQS (June 12, 2001). Every attempt will also be made to be consistent with the modeling plan for CCOS to optimize resource utilization.
- There are two attachments to this document. They are the “Particulate- Matter Modeling Questions for CRPAQS” (Attachment 1) and the “Near-Term Plan for the CRPAQS Modeling Program” (Attachment 2).
- A sub committee of the CRPAQS Technical Advisory Committee will refine this document and its attachments before they are presented to the full committee and the Policy Committee.
- After the initial data analysis and modeling is concluded, a synthesis phase will occur. During that phase new data analysis and modeling tasks may be identified. Thus, this document will be revised periodically to include additional modeling tasks that may be identified in later stages.

### 2. Objectives of the Modeling Program:

- Development and evaluation of one or more modeling systems capable of simulating the comprehensive observations made during the field study. The key components of this objective are:
  - Identification and assessment of spatial and temporal scales relevant to modeling particle size as well as other physical phenomena such as sub-regional meteorology. Exploration of modeling techniques to address the scale issue appropriately,
  - A comprehensive review/synthesis of particulate matter and visibility modeling applications to date,

- A comprehensive review of data gathered during the field study and a determination of level of modeling needed/feasible,
  - Evaluation and further development of meteorological, emissions, and air-quality components of the modeling system,
  - Performance analysis of each component of the modeling system using existing and new metrics,
  - Further mechanistic and sensitivity testing of each component of the modeling system, and establishing uncertainty and confidence levels, and
  - Identification of techniques related to long-term (monthly, seasonal, and annual) modeling.
- Usage of modeled results to refine the conceptual model already being refined by data analysis. Identification of further data analysis and modeling tasks to aid the refinement.
- Usage of the modeling systems developed to identify and evaluate emissions control strategies. The key components of this objective are:
    - Determination of precursor (VOC, NO<sub>x</sub>, NH<sub>3</sub>, HNO<sub>3</sub>, and SO<sub>2</sub>) limitations in particulate matter formation (both in time and space),
    - Assessment of the nature of transport within and among air basins,
    - Development of particulate formation potentials of precursors (similar to ozone forming potential scales of volatile organic compounds), and
    - Determination of methodology to assess the reliability of modeled results for emissions control scenarios.
- Consideration of other modeling related issues. The key components of this objective are:
    - Evaluation of uncertainty in model inputs and outputs (e.g., using probabilistic/stochastic methods),
    - Evaluation of other techniques appropriate for spatial or temporal scales relevant to modeling, and
    - Evaluation of issues (e.g., monitoring, data analysis) related to long-term modeling (e.g., monthly, seasonal, annual averages).

### **3. Modeling Philosophy:**

- Review all available modeling applications for particulate matter and visibility. Identify the current state-of-science.
- Critically review and document the appropriate uses, strengths, and limitations of each modeling technique for short and long-term

applications. This would include emissions, meteorology, and air-quality components of the modeling system. To cover the issue of spatial and temporal scales appropriately, a variety of choices for each component of the modeling system would be considered.

- Begin modeling with the current state-of-science despite the fact that it may not be what we desire. This may include using receptor techniques (e.g., the Chemical Mass Balance method with possible ARB-proposed modifications), other suitable techniques including statistical methods and internal-mixture models (e.g., UAM-AERO) with diagnostic meteorological winds and currently available emissions data (with improved source profiles). This is a warm up process to get the system in place. While we will not emphasize the results of these warm-up runs, they can be valuable in identifying weakness of the current state-of-science. More information on this exploratory modeling is provided in “Near-Term Plan for the CRPAQS Modeling Program” (Attachment 2).
- Identify weaknesses of the current state-of-science and make improvements as necessary.
- Some of the weaknesses are already known. Begin improvements in these areas now.
- Keep the regulatory time line in mind and strive to be able to use the best models available when needed, but at the same time have one or more fallback options developed. For example, for air quality, strive to be able to use the grid-based source-oriented external mixture approximation when needed, but carry forward in parallel the Chemical Mass Balance method and the grid-based internal mixture approximation.
- Federal modeling guidance for particulate matter has a provision to use “weight of evidence” together with modeled results. Thus ensure that the modeling is consistent with data analysis conducted to provide weight of evidence.
- Be fully informed of any emerging modeling techniques for particulate matter and visibility. This includes both incremental developments of existing methodologies and new approaches.

#### **4. Current Status of the Modeling System and Future Improvements Needed:**

This section contains a brief description of the current status of the modeling system (emissions, meteorology, and air quality models) available to simulate particulate matter and visibility. It also outlines the appropriate use, the expected accuracy, and known deficiencies of the modeling system and possible improvements. This section is intended as a starting point for a full review of the current status.

#### 4.1 Emissions:

- The current system used by the Air Resource Board, the Emissions Modeling System (EMS-95/2000), is a well-tested model for emissions processing and it is fully capable of serving all emissions data modeling needs of both CRPAQS and CCOS. It is based on ARCInfo and SAS. It is difficult to use, but in-house expertise exist.
- A fallback emissions modeling system could be the Sparse-Matrix Orthogonal Kernel (SMOKE) model. This system depends on ARCInfo for initial spatial gridding, but it is FORTRAN based and independent of EMS-95/2000. This model is less developed than EMS-95/2000, but it is relatively easy to use. SMOKE is being currently updated by MCNC for the regional haze modeling efforts of the Western Regional Air Partnership (WRAP) to address the visibility issues in the West. Air Resources Board has also funded a project to update SMOKE to be able to use the enhanced granularity of California emissions inventories. Thus, any major update to SMOKE may not be needed for CRPAQS/CCOS modeling. Limited in-house expertise exists and the use of SMOKE would enhance the compatibility with a few other major modeling efforts.
- The basic input data for emissions models are the grid structure; identities, description, and locations of emission sources (spatial surrogates if the sources are too numerous); their temporal emission profiles (including seasonality) and rates; speciation profiles (for gases and size-fractionated particulate matter). Except for the grid structure, other inputs have significant uncertainties. There are several CRPAQS/CCOS efforts are in place to remedy this situation, but further efforts in this area may be needed.
- Due to the need for constant interaction among air quality and emissions modelers and the need for numerous perturbations of the modeling emissions inventory to answer “what-if” questions, it is recommended that emissions modeling be conducted in-house.

#### 4.2 Meteorology:

- Meteorology can either be diagnostic or prognostic. Each has its strengths and weaknesses. Some of the current grid-based PM models (such as UAM-AERO, and Kleeman’s model) are based on diagnostic meteorology and others (such as Models-3/CMAQ) are based on prognostic meteorology.
- There are several diagnostic wind models with varying sophistication and all them rely on the availability of a dense set of meteorological measurements at the surface and aloft. While there techniques may not be suitable for a large region with sparse

measurements, it could be sufficient for a small region with a reasonably dense set of measurements.

- The prognostic meteorological modeling methods are more appropriate for large regions with sparse set of measurements. The leading prognostic meteorological model for air quality applications seems to be the Mesoscale Model 5 (MM5). The performance of MM5 during wintertime is largely unknown.
- There may be situations (e.g., calm wind conditions) that would render both diagnostic and prognostic methods inappropriate. In such cases, other techniques, such as statistical methods, may be needed.
- In evaluating the performance of meteorological models, we generally employ a statistical comparison of measured vs. simulated quantities (e.g., wind speed and direction, temperature, relative humidity etc.). The large-scale physical features (e.g., eddies, marine-layer intrusion, up-slope/down-slop winds, etc.) of the measured/simulated fields receive less attention. Development of rigorous techniques to evaluate model's ability to reproduce such large-scale features is highly desirable.
- It may be advisable to compare the predictions of the preferred meteorological model with at least one other leading meteorological model. For diagnostic methods, this would be a relatively easy task as the models are readily available and most of the models use compatible input data formats. There are several candidate prognostic models, such as MM5, RAMS, ARPS, and University of Wisconsin Model for inter-comparisons. However, some of these models are not readily available and significant resources and technical expertise are needed to exercise them. Therefore, the inter-comparison of prognostic meteorological models would be a major undertaking and should be closely coordinated with CCOS modeling efforts. The desired outcome of these inter-comparisons is an assessment of uncertainty due to variability in meteorological fields.
- It is anticipated that the applications of various model components to different spatial scales would require the generations of meteorology fields for several different spatial scales. It may be prudent to ensure, when feasible, that fields for these various spatial scales are compatible with each other so that the simulated results for different scales are comparable to each other.
- Other meteorology-related parameters that may need improvements are diffusion coefficients and deposition velocities for particles. Data analysis (e.g., measurements at the Angiola Tower, MOUDI measurements etc.) and model sensitivity testing could provide an assessment of relative importance of these parameters. The advection/diffusion solvers may also need improvements.

- In-house expertise exists to run both diagnostic and prognostic meteorological methods. A combination of in-kind resources and outsourcing may be needed to develop prognostic meteorological fields for several episodes and to conduct thorough model performance evaluations and inter-comparisons.

#### 4.3 Air Quality:

- There exists a spectrum of methods to simulate particulate matter mass. They include the Chemical Mass Balance method, methods based on the internal-mixture approximation, and methods based on the source-oriented external-mixture approximation.
- There are several efforts to incrementally improve the existing state-of-science. We are not aware of any new paradigms being developed.
- The Chemical Mass Balance method is useful for primary particles and there may be ways to parameterize the secondary particle formation. The Chemical Mass Balance method is an important component of the modeling system as grid-based photochemical models are currently unable to fully replace this method.
- It is now well established that the gas and particle phases are linked through chemistry and, when the mass of the secondary particulate matter is significant, the photochemical modeling approach should be inclusive of both phases. And, models should use the best available science for both phases. (This excludes approximate methods such as Regulatory Modeling System (REMSED) and any model using the gas-phase CB-IV mechanism.)
- The photochemical models can be used in two different modes. They are the equilibrium box model mode that can be used to elucidate important chemical features at the local scale and the regional grid-based mode that can be used to represent emissions, transport, and chemistry at the regional scale.
- The most realistic particulate matter model available today is the source-oriented external mixture approach being developed by Professor Michael Kleeman at UCD. We expect that code to be available for routine simulations (probably conducted in-kind) in a time frame consistent with the SIP timeline. CRPAQS is seen as the major sponsor of development and implementation of that model in central California. It is critical that we fully support Professor Kleeman's approach.
- The fallback should be, despite its known limitations, the grid-based internal-mixture method.
- A combination of in-house and external expertise would be needed to carry out air quality modeling. It is expected that the in-house

expertise and resources will be developed to support all SIP-related routine simulations.

#### **4.4 Performance and Uncertainty:**

- Several statistical metrics used for the performance analysis meteorology and air quality models. However, these metrics may not be fully adequate to assess the performance of model component they are intended for. For example, the ability of meteorology model to simulate large-scale phenomena such as land/sea breeze is not quantitatively evaluated. For air quality models, the focus of evaluation is the peak values of ozone and its precursors. Therefore, the further development of metrics to evaluate the performance of components of the modeling system is needed.
- Both the US-EPA and the California Air Resources Board prescribe model performance criteria for ozone. However, such criteria for particulate matter or precursors to either ozone or particulate matter do not exist.
- Several limited attempts were made in the past to quantify the uncertainty in modeled results. These uncertainties stem from various sources such as uncertainties in emission estimates, assumptions made in numerical solvers, incompleteness of measurement to determine initial and boundary condition, and uncertainties in measurements themselves. A systematic determination of uncertainties in each component of the modeling system and their contribution to the uncertainty of the modeled result for the air quality is needed. To accomplish this daunting task, a combination of uncertainty and sensitivity analysis will be needed.

#### **5. Operational Issues:**

This section address the operational issues in modeling that were not addressed elsewhere in the document. They include constructing long-term averages, computer resources, technology transfer among participants, visualization and presentation of modeled results, and public access to modeled results.

- **Constructing Long-term Averages:** The existing regulations require the assessment of attainment of NAAQS for 24-hour and annual averages. The current episodic methodology used for modeling addresses the 24-hour standard only. The construction of the annual average would require, in theory, exercising an air quality model for at least one year and preferably for three years.

However, there are no input data or computational capabilities to support such attempts. Thus, we are forced to explore other methods to construct long-term (monthly, seasonal, and annual) averages.

- **Computer Resources:** The computational needs are directly proportional to the complexity of the models used. Current level of computational capabilities may be sufficient to support metrology, emissions, and air quality (internal mixture) simulations. But, ARB computers are now dedicated to ozone SIP work and would not be available for CRPAQS simulations. We are now assessing the computational needs and associated costs to support CRPAQS data analysis and modeling for the next three years in consultation with stakeholders. A higher level of computational resources would be needed to support air quality modeling using the external mixture approximation and to construct long-term averages. We will consider those issues in constructing the budget.
- **Technology Transfer:** While some of the stakeholders would be directly involved in modeling activities, a technology transfer process from external contractors to in-kind participants would be needed. We propose to accomplish this in a continuous manner by gradually increasing our participation in the external projects. This would also allow us to better assess the future computer needs in a step-wise manner.
- **Data Presentation and Visualization:** It is our intention to make visual and tabulated summaries of modeling results available to the technical committee in via a webpage. A process to accomplish this task is now being developed at ARB. We will solicit input from all stakeholders in the near future.
- **Accessibility of Data:** While modeled results would be available to the technical committee on a continuous basis, the Release Procedures put in place by the CRPAQS Policy Committee would determine public's access to the data.
- **Use of Modeled Results to Support the Development of State Implementation (SIP) Plans for Particulate Matter and Visibility:** The SIP development is a regulatory process involving the Air Resources Board and Air Quality Management Districts. We anticipate that ARB and District staff to support SIP development will carry out modeling tasks beyond the scope of this document. While the Technical/Policy Advisory Committees of CRPAQS will be involved in the SIP process in an advisory capacity, the scope of SIP modeling and data release procedures will be finalized by ARB in consultation with the Districts.

## Attachment 1

### Particulate-Matter Modeling Questions for CRPAQS

This questionnaire is presented as an addendum to the "The Draft Plan of Air Quality Modeling for the California Regional PM<sub>10</sub>/PM<sub>2.5</sub> Study (CRPAQS)" (Kaduwela *et al.*, 2001). This document is also a companion for the "Data Analysis Questions for CRPAQS" (Magliano *et al.*, 2001).

Presented in this document are the preliminary questions that would guide the modeling effort of CRPAQS. Due to the interaction between data analysis and modeling, we expect these questions to be updated/modified as we progress. Also, due to the fundamental nature of some of the questions, some of the same questions that appeared in the document "Data Analysis Questions for CRPAQS" will appear here.

#### 1. WHAT ARE THE AVAILABLE TOOLS FOR PARTICULATE MATTER AND VISIBILITY MODELING AND WHAT ARE THEIR STRENGTHS AND WEAKNESS?

This is a survey question and the expected end product is a review of available tools.

- 1.1. What are the available diagnostic and prognostic meteorological models? Are they adequate/suitable for CRPAQS modeling? If not, what additional research and/or development are needed?
- 1.2. What are the available emissions models? Do we have sufficiently resolved emissions data to drive these models? What current efforts to update emissions data are in place? What additional efforts would be needed?
- 1.3. What are the available air quality models available? Are they adequate/suitable for our purpose? If not, what additional research and/or development are needed? Do we have enough information on boundary conditions, deposition velocities, solar intensity, etc., to drive these models?

**Primary Analysis: In-House ARB and External (RFP)**

## **2. WERE ENOUGH METEOROLOGICAL DATA COLLECTED TO DRIVE AND EVALUATE DIAGNOSTIC/PROGNOSTIC METEOROLOGICAL MODELS AND DO SIMULATED METEOROLOGY FIELDS REPRESENT REALITY?**

- 2.1. From a modeling perspective, how adequate and valid are current methods for measuring meteorological variables at the surface and aloft? Did the meteorological methods used provide adequate resolution? (This questions is very similar to 1.3 in “Data Analysis Questions for CRPAQS.”)
- 2.2. Were the precision, accuracy, bias, consistency, and time-resolution of measured meteorology data sufficient to determine initial and boundary conditions, to perform data assimilation, and to evaluate model performance?
- 2.3. How well do simulated meteorological fields represent the following phenomena: 1) transport and dispersion under low wind speed/stagnation conditions; 2) frequency, spatial extent, and intensity of fogs; 4) down-valley and cross-valley flows; 5) up-slope and down-slope flows; 6) mixed-layer depths, vertical distributions of winds, temperature, and relative humidity; 7) marine layer intrusion; 8) large-scale eddies; and 9) wind gusts above suspension thresholds? (This question is very similar to 3.3 in “Data Analysis Questions for CRPAQS.”)
- 2.4. The ability of models to reproduce above-mentioned large-scale physical features of the meteorology fields was not evaluated rigorously in the past except for limited attempts for summer time simulations. Do we need to develop techniques capable of such evaluations and how?
- 2.5. By analyzing simulated meteorology fields (using trajectory analysis) can we gain a qualitative understanding of the “zone of influence” of a monitor for various pollutants? (This question is similar to 4.4 in “Data Analysis Questions for CRPAQS.”)
- 2.6. What are the transport pathways (surface and aloft) within and between air basins in central California? When is transport between air basins associated with elevated PM concentrations? When does transport shutdown, and how cohesive is the transport under various meteorological scenarios? What is the role of the nocturnal jet and eddy structures in transport of pollutants? What is the role of advection versus diffusion? (This question is identical to 5.2 in “Data Analysis Questions for CRPAQS.”)

### **Primary Analysis: In-House ARB, and Air Districts**

### **3. HOW WELL COULD WE CONSTRUCT THE MODELING EMISSIONS INVENTORIES? WHAT QUALITY ASSURANCE AND VERIFICATION PROCEDURES NEEDED?**

- 3.1. Do we already have an adequate set of source profiles and activity data?  
Did we conduct adequate measurements to evaluate existing source profiles and activity data?
- 3.2. Did we conduct sufficient measurements to fill the significant gaps in source profiles and activity data?
- 3.3. Do different methods of data processing yield significantly different modeling inventories? If so, why?
- 3.4. How do we verify emissions estimates? What are the complications due to secondary PM formation? How rigorous/appropriate are the statistical methods available for the verification of emissions estimates?
- 3.5. Some of the compounds that received less attention in ozone modeling inventories due to their negligible reactivities (e.g., large organic molecules) may be important in secondary organic particulate matter formation. How do we ensure that compounds important to particulate matter formation are not excluded from the inventory and were sufficient field measurements conducted to assist this process?
- 3.6. How does photochemical reactivity of emissions inventories correlate with that of ambient measurements?

#### **Primary Analysis: In-House ARB, Air Districts, and External (RFP)**

### **4. WERE ENOUGH AIR-QUALITY DATA COLLECTED TO DRIVE AND EVALUATE AIR-QUALITY MODELS?**

- 4.1. Were the precision, accuracy, bias, consistency, and time-resolution of air-quality measurements sufficient to determine initial and boundary conditions and to evaluate model performance?
- 4.2. Is it necessary to spin-up the model to minimize the influence of initial conditions? If yes, for how long? Are there other methods to minimize the influence of initial conditions besides spin-up?
- 4.3. How do we define and determine regional background levels?

- 4.4. How large should the modeling domain be to minimize the influence of boundary conditions? Is there a danger of making the domain too large when there is no data for four-dimensional data assimilation of meteorology fields?
- 4.5. If the modeling domain extends far into the Pacific Ocean, what are the oceanic background levels that can be used as boundary conditions?
- 4.6. Should the boundary conditions be static or dynamic? If dynamic, do we have measurements to support such a choice?
- 4.7. In lieu of appropriate measurements, how do we evaluate the effects of alleged trans-boundary effects (such as long-range transport from Asia)? (E.g., increased values for upper air boundary conditions etc.) Or, are these effects too small ( $\sim 1 \mu\text{gm}^{-3}$ ) to be considered? What are the findings of the scientific investigations into this transport effect?
- 4.8. Do we have enough information to determine deposition velocities for all modeled species? The current model for deposition is based on an analogy to resistance in electrical circuits. Is this an appropriate model, especially in light of recent challenges to it?

**Primary Analysis: In-House ARB, Air Districts, and External (RFP)**

**5. HOW WELL DO AIR-QUALITY MODELS PREDICT MEASURED POLLUTANT CONCENTRATIONS (GASEOUS CONCENTRATIONS, TOTAL MASS OF  $\text{PM}_{10}$  AND  $\text{PM}_{2.5}$ , AND MASS OF COMPONENTS OF  $\text{PM}$  ETC.)?**

- 5.1. What are the criteria for model performance, so that the models can be used in a predictive mode for control strategy assessment?
- 5.2. Should we evaluate the performance for total mass or mass of individual chemical species or both? Since the regulations are focused on total mass, should the performance for total mass have more importance?
- 5.3. How well can air quality models predict size distribution of  $\text{PM}$ ?
- 5.4. Should all air-quality models satisfy the same set of performance criteria or should there be model-specific criteria?
- 5.5. During performance analysis, are we placing too much emphasis on model's ability to predict observed peak values? Should the models ability to simulate other features of the measured field (e.g., the spatial extend of the episode etc.) receive equal attention? Do current

performance metrics allow for such evaluations and, if not, how can we improve them?

**Primary Analysis: In-House ARB, US-EPA, and External (RFP)**

**6. HOW DO WE STRESS-TEST AIR-QUALITY MODELS?**

- 6.1. Would the stress-testing methods developed for ozone models adequate for comprehensive models? If not, what additional stress-testing methods are needed?
- 6.2. What are the various process analysis techniques available and which of those should be installed in our air quality models?
- 6.3. Are there other ways to ensure that models are performing adequately for correct reasons?

**Primary Analysis: In-House ARB, and External (RFP)**

**7. WHAT ARE THE OTHER QUESTIONS COMMON TO BOTH DATA ANALYSIS AND MODELING?**

- 7.1. How much of  $PM_{10}$  is composed of  $PM_{2.5}$  and how does this relationship change by measurement site and season? How accurately can  $PM_{2.5}$  concentrations be deduced from  $PM_{10}$  measurements? How important is the crustal component in  $PM_{2.5}$ ? How does this vary spatially? (This is question 2.4 in "Data Analysis Questions for CRPAQS.")
- 7.2. How do PM and PM precursor species vary vertically? (This is question 2.5 in "Data Analysis Questions for CRPAQS.")
- 7.3. How frequent must measurements be acquired and with what duration to represent changes in mass and chemical concentrations throughout the day? How should temporal resolution be balanced with spatial resolution? (This is question 3.2 in "Data Analysis Questions for CRPAQS.")
- 7.4. What are the data-analysis tasks required to support long-term (monthly, seasonal, or annual) modeling of emissions, meteorology, and air quality?
- 7.5. Which sources contribute to PM concentrations based on CMB source apportionment? How do these sources vary temporally and spatially? How does the source apportionment vary by size? (This is question 4.1 in "Data Analysis Questions for CRPAQS.")

7.6. What is the zone of influence of PM? How does this vary by chemical constituent and by size? What are the temporal and spatial variations in zone of influence? (This is question 4.4 in “Data Analysis Questions for CRPAQS.”)

**Primary Analysis: In-House ARB/Districts, and External (RFP)**

**8. HOW DO WE USE THE RESULTS OF EACH COMPONENT OF THE MODELING SYSTEM TO REFINE THE CURRENT CONCEPTUAL MODEL?**

8.1. Do conclusions reached with modeled results agree with those of data analysis tasks? If not, what is the process for reconciliation?

8.2. What secondary data analysis and modeling tasks do we anticipate in the refinement process?

**Primary Analysis: In-House ARB, Air Districts, and External (RFP)**

**9. HOW DO WE USE AIR-QUALITY MODELS TO PROPOSE/EVALUATE CONTROL STRATEGIES?**

9.1. Are the ozone-based methods to propose/evaluate control strategies still valid? Are there more efficient ways?

9.2. Is it possible to assign “particle forming potentials” (or “reactivities”) to various precursors? If yes, can we generate a reactivity-based inventory for control strategy purposes?

**Primary Analysis: In-House ARB**

**10. HOW DO WE MODEL LONG-TERM (SEASONAL, ANNUAL) AVERAGES?**

10.1. What are the methods currently used for long-term averaging? How can we improve them?

10.2. What are the input data needs? Can we extend the length of a modeling period (that includes one or more episodes) using data from routine measurement networks?

10.3. What are the computational needs? Would we need to make simplifying assumptions to models to conduct long-term modeling?

**Primary Analysis: In-House ARB and External (RFP)**

**11. TO WHAT EXTEND DO WE UTILIZE THE US-EPA'S MODELING GUIDANCE FOR PM AND REGIONAL HAZE?**

- 11.1. To what extent is regional haze an issue in various subdomains of the modeling domain?
- 11.2. What aspects of the guidance do we strongly agree with?
- 11.3. What aspects of the guidance do we agree with in general (but would like to have improved)?
- 11.4. What aspects do we strongly disagree with (and believe that they should be redacted)?

**Primary Analysis: In-House ARB, Air Districts, and Technical Committee**

**12. WHAT IS THE ROLE OF CORROBORATIVE ANALYSIS? WHAT ARE THE AVAILABLE CORROBORATIVE ANALYTICAL METHODS?**

**Primary Analysis: In-House ARB, Air Districts, and External (RFP)**

## Attachment 2

### Near-Term Plan for the CRPAQS Modeling Program

#### Time Line:

The CRPAQS field program has just concluded and we expect that the quality assured data would begin to arrive in the next few months. We expect the initial PM modeling to begin in the fall of 2001 and to continue until the modeling for both PM (~2006) and Regional Haze SIP (~2008) planning is completed.

#### Availability of Modeling Tools:

Currently the Chemical Mass Balance (CMB) and grid-based internal-mixture photochemical models (e.g., UAM-AERO, Models-3/CMAQ) are available. Further development of both CMB and internal-mixture approaches are envisioned. Professor Michael Kleeman at the University of California at Davis (UCD) is now developing a source-oriented external-mixture photochemical model. This model development, partly funded by CRPAQS, is expected to be completed in time for PM and Regional Haze SIP planning. Apart from the above approaches, we are unaware of any new approaches being developed for particulate matter modeling.

#### Continuation of IMS-95 PM Modeling:

Preliminary UAM-AERO simulations were conducted for the January 4-6, 1996 episode of IMS-95. Results of these simulations were not publicized due to severe limitations in emissions inventories and model formulation.

We propose to revisit IMS-95 modeling as an exploratory excise for CRPAQS. While the limited special extend of the study area and the lack of comprehensive measurements to assign initial and boundary conditions still remain as limitations, the quality of the emissions inventory and the model formulation have improved since the last modeling attempt. The ARB staff is currently collaborating with UCD researchers (Professor Michael Kleeman's group) to improve the speciation of emissions. The staff also plans to collaborate with other UCD researchers (Professor Anthony Wexler's group) to develop state-of-science versions of UAM-AERO and Models-3/CMAQ.

We also plan to develop a prognostic meteorology fields for this episode using MM5. The performance of MM5 for winter episodes are largely unknown expect for one of the IMS-95 episodes conducted by Seaman *et al.* We will review the results of that work and simulate the January 4-6, 1996 episode. We will also use the results of IMS-95 Technical Studies to the extend possible.

There are several advantages to this exploratory modeling exercise. First, it will provide an opportunity for the Technical Committee and ARB/District staff to familiarize themselves with the current status and issues of particulate matter and visibility modeling. Given that particulate modeling requires significantly more technical expertise than ozone modeling, we emphasize this familiarization as a very important preparation for the full-scale modeling. This exercise will also allow participants to solve model implementation problems and better assess the resources needed for full-scale modeling. Foundation to address several model performance issues could also be laid out during the exploratory modeling. Finally, it will also reveal some limitations in input data (e.g., emissions inventory) that needs to be addressed before full-scale modeling can begin.

A major disadvantage of the exploratory modeling is that it could consume resources without significant output. Thus, we propose not to allocate significant resources for exploratory modeling. For example, some the computers currently available to ARB/District staff can be used for this purpose on a lower priority basis. Staff time can also be prioritized and other cost effective methods (such as using graduate students or postdoctoral fellows) can also be used.

#### **Near-Term Resource Needs for PM Modeling:**

Two major resources are needed for PM modeling. They are people with adequate technical abilities and special-purpose computers to exercise the models.

PM modeling is inherently more complicated than ozone modeling and more advanced technical knowledge is needed to develop and exercise PM models. Professors Kleeman, and Wexler are acknowledged experts in PM modeling. Thus, it is highly recommended that ARB/District staff exploit their proximity and work in collaboration with the UCD faculty. To jump-start initial modeling work, it is also recommended that CRPAQS directly support one or more graduate students/postdoctoral fellows. An estimated annual cost of a graduate student and a postdoctoral fellow are about \$50k and \$60k respectively. Method of hiring could be by creating temporary positions at ARB, using the Hornet Foundation at the California State University at Sacramento, or by contracting with UCD.

The proposed student/postdoctoral funding will be structured as if the student/postdoctoral fellow is a direct sole-source contractor for the study. A detailed work statement will be developed together with associated deadlines. The tasks in the work statement will be directly linked to those in "Particulate-Matter Modeling Questions for CRPAQS" (Attachment 1).

PM models require computational power beyond that is typically needed for ozone modeling. It is also anticipated that the computers currently at ARB would continue to be utilized for ozone modeling and would not be readily available for CRPAQS modeling. Thus, it is expected that substantial financial resource would be needed to support computer needs of particulate matter and visibility modeling. A budget estimate for the first three years of the modeling program is now being developed. It is based on the tasks outlined in "Data Analysis Questions for CRPAQS" (Magliano *et al.*, 2001) and "Particulate-Matter Modeling Questions for CRPAQS" (Attachment 1).