Final Report

ADOT Project TOD04-04

Identification of Emissions Sources for Pinal County





PREPARED FOR

ARIZONA DEPARTMENT OF TRANSPORTATION

ADOT

PREPARED BY

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CHAPTER ONE
PROJECT SUMMARY

OVERVIEW

At the outset of this project, portions of Pinal County were designated as nonattainment for both PM_{10} and for SO2. If EPA formally recognizes recent PM_{10} measurements, the severity of Pinal County's nonattainment status may be increased and the County may be required to prepare plans that demonstrate how it will comply with the ambient air quality standards. Although the county has not been identified as a nonattainment area for Ozone, elevated levels of Ozone concentrations were observed at monitoring sites within the county, and there has been concern about how growth in the county would affect Ozone concentrations in the future.

Given the inevitable transportation changes associated with impending growth in Pinal County, there was a need for a method to assess how corresponding emissions changes might affect PM_{10} and Ozone concentrations in the county and at the monitor sites. The overall objective of the project was to develop methods or models that could be used in Pinal County to adequately address air pollution issues in the County. The research tasks addressed in the project objectives include the following:

- Collection of local travel activity data (e.g., speed, traffic counts, etc.),
- Collection of available monitoring and meteorological measurements,
- Selection of appropriate emissions and air quality models,
- Estimation of the growth in emissions from future growth in travel activity, and
- Development of an evaluation and forecasting tool for assessing PM_{10} air quality impacts from unpaved road travel in the central portion of Pinal County.

Because Pinal County is not currently classified as an 8-hour Ozone nonattainment area and considerable resources would be required to operate photochemical models to evaluate the significance of Ozone precursor emissions, the air quality modeling portion of the study focused on evaluating the impacts of PM_{10} emissions from unpaved road travel on downwind receptors. Analysis of Ozone was based on estimates of Ozone precursor emissions and not on estimates of Ozone concentrations.

The project team also assessed the cost and effectiveness of PM_{10} control measures for unpaved road and the costs, and benefits of technologically feasible measures were incorporated into a tool for evaluating unpaved roads. This tool was developed as a spreadsheet and designed for use by the County in identifying public unpaved roads having the greatest air quality impacts on existing or proposed residential areas and quantifying the costs and benefits of alternative emission control measures.

TASK REPORTS

The work in this project was conducted in six tasks. A summary of the work conducted in each of those tasks is provided in this chapter of the Final Report.

Task 1 - Define Geographical Scope and Analysis Parameters
Task 2 - Assemble and Collect Data
Task 3 - Prepare and Analyze Emissions Estimates
Task 4 – Prepare Project Reports
Task 5 - Prepare PM_{10} Attainment Plan Blueprint
Task 6 - Evaluate Unpaved Road Treatment Control Efficiency

Five reports were produced as deliverables in the project and each of those reports is contained as a chapter in the Final Report. They are as follows:

Chapter 2	Projected Changes in Ozone Precursors
Chapter 3	Spreadsheet Model for Computing PM_{10} Impacts from Unpaved Roads Travel
Chapter 4	Control Efficiency and Cost-Effectiveness of Unpaved Road Emission Control Measures
Chapter 5	Blueprint for Development of a PM_{10} Attainment Plan
Chapter 6	Measurement of PM_{10} Emission Factors from Unpaved Roads in Arizona to Determine the Efficiency of Dust Suppressants

Task 1 Define Geographical Scope and Analysis Parameters

DKS prepared background material for the first TAC meeting (September 15, 2004) and distributed the material to the TAC members. The materials included a statement of the scope of work. TAC members were asked for comments prior to the TAC meeting and were then given the opportunity to comment at the meeting. Several of the key TAC members were also contacted prior to the meeting to solicit comments and to set up a time for a one-on-one meeting either before or after the TAC meeting. One-on-one meetings were held with the following:

- Beverly Chenausky – ADOT
- Bill Leistor – CAAG
- Donald Gabrielson – Pinal County Air Quality Control District
- Kale Walch – Pinal County Air Quality Control District
- Doug Hansen – Pinal County Department of Public Works
- Mark Schlappi -- MAG (to issue the availability of information from MAG's regional model system)

The TAC meeting and the one-on-one meetings produced a significant modification of the scope of work. The feedback from the meetings indicated that the focus of the PM_{10}

analysis should shift from a quantitative identification of the source of emissions in the county, to an overall blueprint for how to evaluate PM_{10} emissions as part of attainment planning and to identification of the relationships between traffic volumes on unpaved roads and the level of PM_{10} emissions. The DKS team prepared a modified scope of work and submitted it to ADOT for consideration. The revised scope was accepted and the contract was modified. The revised scope established the geographic coverage as countywide, but with case-study analyses for PM_{10} analysis. The analysis timeframe was selected to be current conditions and a twenty-year future forecast.

In September 2005, ADOT requested assistance in evaluating the emission control efficiency of dust palliatives applied to two sections of the state highways. In response, DKS Associates and Sierra Research proposed to conduct emission monitoring of the treated sections of these roadways and the adjacent untreated sections in order to calculate the emission control efficiency. This task was added to the work scope and consultant contract.

Task 2 Assemble and Collect Data

Subtask 2.1 Assemble or Collect Demographic and Travel Data

The DKS Team monitored the collection of traffic counts being done under separate contract by ADOT and Pinal County. Members of the DKS Team collected the traffic counts and incorporated them into a GIS database. The DKS Team also monitored the development of model data for the full county roadway network. New short, medium and long range forecasts of population, employment, travel and pollutant emissions were developed by the Maricopa Association of Governments and the Arizona Department of Transportation for an area that includes Pinal County. These two sets of forecasts were the basis for two scenarios analyzed for the Ozone precursor assessment. The Maricopa Association of Governments (MAG) developed one set of forecasts and ADOT consultants for the Pinal Corridors Planning Model (PCPM) developed the other set of forecasts. While the forecasts were fairly similar in the existing population and employment estimates and the forecasts for population, the two sources are significantly different in the amount of growth expected in the employment in Pinal County. The two sets of population and employment forecasts were used in separate travel models to produce estimates of vehicle miles traveled for a base year (2004) and for future forecast years covering a twenty-year forecast period. These model forecasts were used as the source of travel activity data for the assessment of growth in Ozone precursor emissions.

Subtask 2.2 Assemble or Collect Unpaved Road Modeling Information

Sierra Research assessed air quality impacts from unpaved road travel in Pinal County using emission and pollutant dispersion models populated with local source and meteorological data. Emission analyses were performed using equations published in AP-42 or were developed by EPA contractors working the field of fugitive dust research. PM_{10} dispersion modeling was conducted using the EPA-approved ISCST3 model with options configured to support the analysis of fugitive dust emissions.

Fugitive PM_{10} emissions from unpaved road travel are dependent on several site-specific factors. In the AP-42 equation, such factors include the fraction of silt material (dust passing through a 200 mesh screen) within the layer of loose soil on the road surface, the moisture content of the road surface soil, the weight of the vehicle traveling the unpaved road, and the speed of the vehicle. Under this subtask, typical values of these parameters were determined through local data collection.

Agricultural soil maps and data developed by the U.S. Department of Agriculture were used to determine the number of significant soil types in the central portion of Pinal County under agricultural cultivation. Five major or distinct soil types spanning the range of local silt contents were selected and the spatial coverage of these soil types was determined. Unpaved roads with typical traffic levels in each soil region were identified through collaboration with the Pinal County AQCD and the Pinal County Department of Public Works. Surface soil samples were collected by Traffic Research & Analysis on at least one road in each of the five soil regions and analyzed for silt fraction, moisture content, and fine particle size distribution. Construction Inspection and Testing, Inc performed the sample analysis. Sample collection and analysis conform to the specifications of AP-42[1], Appendix C.

Traffic counts provided by TRA for each of the five roads that represent the five major or distinct soil samples were collected. Each count was of seven-day duration, and was conducted with equipment that will provide vehicle count, weight, and speed data. If possible, some counts were conducted on roads experiencing elevated truck traffic during the harvesting of nearby crops, while others were conducted outside of the harvest season to determine typical non-harvest unpaved road travel patterns.

Meteorological data recorded in Pinal County by the AQCD and others were collected and evaluated for completeness and adequacy with respect to use in dispersion modeling of unpaved road emissions. At a minimum, meteorological datasets must contain at least one year of hourly data on wind speed, wind direction, atmospheric stability, and temperature. Pinal County AQCD had collected meteorological data at three sites in the area of the study that satisfied the completeness requirements. Maps of soil regions and meteorological monitoring sites were used to select the most representative meteorological database for the dispersion modeling of unpaved roads within each soil region.

Task 3 Prepare and Analyze Emissions Estimates

The DKS Team prepared emission estimates for Ozone precursors from transportation sources and for PM_{10} from unpaved road travel. For PM_{10}, the DKS Team also used a dispersion model to produce estimates of PM_{10} concentrations at locations near unpaved roads. Emission estimates for Ozone precursors were developed in sufficient level of detail to track changes in future years. These planning level estimates helped the team to determine whether future growth in population, employment and travel in Pinal and adjacent counties is likely to lead to elevated Ozone readings in the future. The PM_{10} dispersion

[1] Compilation of Air Pollutant Emission Factors, AP-42, U.S. Environmental Protection Agency, January 1995

modeling results were used to configure a spreadsheet for use by Pinal County Air Quality Control District staff in evaluating PM_{10} impacts near unpaved roads for use in prioritizing road sections for future paving.

Subtask 3.1 Estimate On-road Ozone Precursors

The DKS Team used data assembled or collected in Task 2 to supplement modeling work done for northern Pinal County by ADOT and MAG. This formed the basis for estimating the Ozone precursors (ROG and NOx) using the EPA model MOBILE6. The estimates of emissions were developed by applying the VMT estimates derived from available travel models by estimated average rates of emissions per vehicle mile traveled. One model was developed by MAG for the most recent RTP update and the other by consultants for ADOT for use in the Pinal County Corridors Study.

Subtask 3.2 Evaluate Trends in Ozone Precursors

The Ozone analysis for the project was conducted by estimating the probable increase in Ozone precursors; volatile and organic compounds (VOC) and oxides of nitrogen (NOx). The estimates of emissions of these two Ozone precursors was developed by applying the VMT estimates derived separately from each of the two models compared by the estimated average rate of emissions per vehicle mile traveled. Average emission rates were derived using information from a recent MAG conformity analysis prepared for the Regional Transportation Plan Update. VOC and NOx emissions were estimated for 2006, 2016 and 2026 using the MAG forecast and the MAG average emission rates. The same emission rates were applied to the PCPM forecast for the years 2004 and 2030. With these estimates of precursor emissions the possible implications for growth in Ozone concentration was analyzed.

The conclusions from the analysis of Ozone precursors were that:

- There will be dramatic growth in population, employment, and travel in Pinal County;
- The nature of travel in Pinal County will change with more internal and heavy duty vehicles in the fleet mix;
- The average emission rates for VOC and NOx will drop; and
- Total emissions of VOC and NOx will almost certainly be lower in 20 years than they are today.

The results of the analysis of Ozone precursor forecasts were documented in a report contained in Chapter 2 of this document: Projected Changes in Ozone Precursors.

Although the analysis conducted in this task suggested that an increase in Ozone precursor emissions in Pinal County is unlikely over the next twenty years, periodic reassessment of the situation is probably warranted particularly for VOC emissions. Monitoring of growth rates, roadway plans and improvements, travel speeds and emissions rates will indicate whether any of the assumptions of this analysis are no longer valid and a new analysis conducted.

Subtask 3.3. Estimate Unpaved Road Emission Rates

The data collected from unpaved road traffic counts and surface soil sampling were used to develop emission factor equations for use in populating a matrix of emissions estimates in a spreadsheet tool for use by Pinal County AQCD in estimating PM_{10} impacts from unpaved road travel on downwind receptors in the agricultural district in central Pinal County. Surface soil characteristics were used to develop constants for use in the EPA emission factor equation for unpaved road travel. These characteristics include the silt and moisture contents of the surface soil. Averages of these values within each major soil type area were developed to produce zone-specific equations within the Pinal County study area.

The traffic count data were used by Sierra Research to develop vehicle weight profiles, speed ranges, and activity levels for unpaved road travel. The first two parameters are variables in the EPA emission factor equation, and the collection of these data will complete the process for developing soil region-specific versions of the equation for Pinal County. The vehicle count data were used by Sierra Research to determine variations between weekday and weekend travel, diurnal (hour to hour) variations, and the added contributions of harvest season travel, when heavy duty truck fractions will peak. The results of this analysis can be found in Chapter 3: Spreadsheet Model for Computing PM_{10} Impacts from Unpaved Roads Travel.

Subtask 3.4 Model Unpaved Road Emission Impacts

The western portion of Pinal County is extensively dedicated to agricultural production. Due to its rural nature with low traffic volumes, many of the local public roads in this area are unpaved. Because of rising home prices in neighboring Maricopa County, new residential construction is beginning to proliferate in portions of the agricultural district proximate to freeway access. The juxtaposition of new residential development to existing unpaved roads is raising concerns about air quality impacts from these roads on new residents.

Annually, the Pinal County Public Works Department paves a limited number of unpaved road segments to reduce maintenance costs and to respond to concerns about dust impacts. In the process of selecting road segments for paving, the Public Works Department solicits recommendations from the Pinal County Air Quality Control District (PCAQCD). In the past, PCAQCD has responded by identifying unpaved road segments that were the subject of dust complaints filed with the agency. PCAQCD desires to use a more objective tool for prioritizing unpaved roads for paving.

In responding to this need, Sierra Research developed a spreadsheet modeling tool to assist PCAQCD in prioritizing unpaved road segments for recommended paving within a study area consisting of the agricultural district. A description of the modeling tool and instructions for use are contained in Chapter 3: Spreadsheet Model for Computing PM_{10} Impacts from Unpaved Roads Travel of this document, together with a summary of cost-effectiveness data applicable to other means of treating unpaved road segments to reduce PM_{10} emissions.

Subtask 3.5 Analyze PM_{10} Control Measures

Control measures applicable to reduction of PM10 emissions from unpaved road travel were evaluated by Sierra Research for technical and economic feasibility in Pinal County. Candidate control measures were identified through a review of studies conducted by Sierra Research in serious PM_{10} nonattainment areas in the Pacific Southwest[2,3,4] Other sources of data on fugitive dust control measure feasibility and cost, including studies conducted for EPA and the South Coast Air Quality Management District, were also reviewed. The control efficiencies of the control measures deemed to be technologically feasible were added to the PM_{10} impact spreadsheet to enable Pinal County AQCD to assess the reductions in air quality impacts resulting from application of specific controls to any unpaved road being evaluated. A summary of the review of the cost effectiveness of the control measures is provided in Chapter 4: Control Efficiency and Cost-Effectiveness of Unpaved Road Emission Control Measures. At the conclusion of the spreadsheet development, a user's manual was drafted to assist Pinal County AQCD in the use of the spreadsheet tool. The spreadsheet tool and user guide can be found as Appendix A of the Final Report.

Task 4 Prepare Project Reports

In this task, the DKS Team provided documentation of all work completed and progress achieved in the project. The documentation took the form of quarterly progress reports, task-specific analysis memoranda, and this Final Report. These three forms of reporting were used to ensure that there was adequate communication with ADOT and the members of the Technical Advisory Committee. All methods used and data assembled or collected were described and submitted for review to allow the TAC to comment or suggest modification of the approach.

Task 5 Prepare PM_{10} Attainment Plan Blueprint

The DKS Team prepared a blueprint for the development of a PM_{10} attainment plan for central Pinal County. This work has been given the highest priority by Pinal County AQCD in anticipation of a forthcoming PM_{10} nonattainment designation by EPA. The ambient air quality data collected by the County AQCD indicate that exceedances of national 24-hour and annual ambient air quality standards for PM_{10} are frequent and persistent. As a result, AQCD officials expect that the central portion of Pinal County may be designated as a PM_{10} nonattainment area by EPA in the near future. If a nonattainment designation is declared, Pinal County will have 18 months to develop and submit to EPA a plan for attaining both

[2] Particulate Control Measure Feasibility Study, prepared for Maricopa Association of Governments by Sierra Research , January 1997
[3] Most Stringent PM_{10} Control Measure Analysis, prepared for Maricopa Association of Governments by Sierra Research , May 1998
[4] BACM Technological and Economic Feasibility Analysis, prepared for the San Joaquin Valley Unified Air Pollution Control District by Sierra Research , January 2003

PM_{10} standards. Failure to submit a plan within the allowed timeframe will result in sanctions being imposed on Pinal County. For this reason, Pinal County is desirous of researching and designing a blueprint now for the development of the attainment plan instead of compressing this initial investigation work into the statutory timeframe for plan development. Key goals of a successful planning effort are the approval by the Pinal County Board of Supervisors of the planning process, the approval by EPA of the completed plan, and approval by the regulated community in Pinal County of both the plan and the implementing emission control measures.

The report in Chapter 5 of this document, Blueprint for Development of a PM_{10} Attainment Plan, summarizes the investigations and findings of the work in this task. This report will be useful to Pinal County in identifying the studies needed to evaluate source-receptor relationships, evaluating candidate emission control measures, preparing an attainment demonstration, and drafting the PM_{10} attainment plan.

Subtask 5.1 Evaluate Pinal County PM_{10} Violations

Sierra Research reviewed and evaluated Pinal County PM monitoring data, limited supplemental PM studies, and local meteorological data to characterize the conditions that resulted in violations of 24-hour and annual PM_{10} ambient air quality standards in 2003 and 2004. PM_{10}, PM2.5, and meteorological data collected in Maricopa and Pima Counties were analyzed to gain information on the transport of coarse and fine fraction PM_{10} from these areas into Pinal County. These data were used to assess the relative contributions of directly emitted PM_{10} and secondary aerosol, high wind events, and localized source emissions to violation events in Pinal County. The information gained from this analysis was used to focus the subsequent task work relative to emission inventories and modeling on aspects critical to Pinal County's PM_{10} problems.

Subtask 5.2 Evaluate Other Serious PM_{10} Nonattainment Planning Processes

Under this task, Sierra Research reviewed the planning processes used to develop attainment plans in other serious PM_{10} nonattainment areas and the progress made toward attainment since plan implementation. The serious PM_{10} planning processes that were studied include those of Maricopa County/Arizona, Clark County/Nevada, San Joaquin Valley/California, and Coachella Valley/California. For each of these areas, PM_{10} attainment plans and supporting documents were reviewed to gain an overview of the air quality research, emission inventory compilation, and air quality modeling approaches used to characterize the PM_{10} problems and solutions that are relevant to Pinal County's PM_{10} violations. Monitoring data were reviewed to determine any trends in PM_{10} levels subsequent to implementation of attainment plans. Air quality planning staff at the agencies that prepared attainment plans and at EPA Region IX who evaluated and approved the plans, were interviewed by telephone to determine the strengths and weaknesses of the technical approaches in support of attainment planning. Information on the progress toward attainment of air quality standard was gathered and analyzed to provide information on the successes or failures of the inventory and modeling approaches used in these areas.

Subtask 5.3 Research Current Research and Planning Tools

The array of regional air quality models continues to grow as air quality planning agencies undertake research to understand the sources and dynamics of visible haze and PM2.5 problems. Although the regional models being applied to this effort are intended to cover domains larger than the agricultural portion of Pinal County and to be supported by meteorological databases more extensive and robust than any compiled to date in the County, one or more of these sophisticated tools were thought to hold promise in being able to forecast PM_{10} concentrations in a cost-effective manner and serve as the foundation for Pinal County air quality planning efforts. In this task, Sierra Research evaluated models for their potential benefit to Pinal County air quality planning including the Sparse Matrix Operator Kernal Emissions (SMOKE) emission inventory database system, the Community Multiscale Air Quality (CMAQ) regional dispersion model, and the Regional Modeling Systems for Aerosols and Deposition (REMSAD), among others. Sierra Research conducted a literature search to evaluate the utility of these new air quality planning tools for use in Pinal County, and case studies of air quality planning using these tools were reviewed.

Sierra Research also assessed the utility of using a Geographic Information System (GIS) platform to construct emission density data as a screening tool for assessing PM_{10} hotspots and the benefits of emission control measures. Under this task, Sierra Research reviewed the GIS capabilities in place in Pinal County and the potential for adding layers that would include emissions estimates. During the conduct of this research, the County adopted use of an emission inventory platform that accommodates inclusion of GIS data, obviating the need to complete further evaluation.

Subtask 5.4 Evaluate Emission Inventory Requirements

Sierra Research evaluated emission inventory requirements and the utility of the platform acquired by the PCAQCD during this study. The emission inventory requirements are established in EPA planning guidance which was carefully reviewed. Samples of emissions inventory data prepared by PCAQCD, Arizona Department of Environmental Quality, Western Regional Air Partnership, and EPA were reviewed to evaluate coverage and completeness. The data available were found to minimally satisfy EPA requirements. None of the emission inventory platforms nor emission databases, however, were found to be independently capable of forecasting compliance with the 24-hour PM_{10} ambient air quality standard. The use of micro-inventory databases and dispersion modeling at each violating monitoring site was concluded to constitute the best approach for evaluating source-receptor relationships and to guide the process of control measure analysis and selection.

Subtask 5.5 Recommend a Blueprint for PM_{10} Attainment Plan Development

Based on the information collected and evaluated in prior tasks, Sierra Research provided recommendations to Pinal County AQCD on the steps needed to develop a successful PM_{10} attainment plan. Key goals of a successful planning effort are the approval by the Pinal County Board of Supervisors of the planning process, the approval by EPA of the completed plan, and approval by the regulated community in Pinal County of both the plan and the implementing control measures. Critical to achieving these goals is the development of technical documentation supporting the need to control specific sources, the pursuit of a process to identify effective and affordable control measures, and implementation of an effective communication program designed to engage the regulated community and incorporate their ideas. These principles guided the recommendations developed by Sierra Research in a PM_{10} attainment planning process blueprint. At the conclusion of this task, a report covering each investigation and analysis performed under this task was drafted.

Task 6 Evaluate Unpaved Road Treatment Control Efficiency

As a supplemental task in the project, ADOT requested assistance in evaluating the emission control efficiency of dust palliatives applied to two sections of State Highways. In response, DKS Associates and Sierra Research contracted for emission monitoring of the treated sections of these roadways and the adjacent untreated sections and calculated the emission control efficiency.

ADOT has treated portions of State Highways 88 and 288 with three different dust palliatives. These treatments have noticeably reduced dust emissions, and ADOT desires to quantify the emissions reductions. The University of California Riverside has developed an instrumented vehicle capable of measuring dust concentrations behind the vehicle as it travels over paved and unpaved roads. These measurements can be used to calculate the emission rate of fine particulate matter, PM_{10} , from vehicle travel over unpaved roads. By testing adjacent sections of treated and untreated road, the emission reduction, or emission control efficiency, of dust palliative use can also be calculated.

Sierra Research conducted emission testing of treated and untreated road sections using the UC Riverside vehicle. The vehicle traversed the treated and adjacent untreated sections of Highways 88 and 288 to measure emissions and average the data over each segment. The vehicle was operated, and data were collected, by employees of UC Riverside. Each highway was traversed for eight hours. A report summarizing the approach and method of assessing PM_{10} emissions and estimate the precision of the measurement for each highway segment is available in Chapter 6. The report, titled Measurement of PM_{10} Emission Factors from Unpaved Roads in Arizona to Determine the Efficiency of Dust Suppressants, describes the vehicle-mounted emission assessment system, including details about the instrumentation and operating procedures. The results from this task will help ADOT and Pinal County to select dust palliatives for use on unpaved roads, in lieu of paving, that are effective and affordable.

CHAPTER TWO
PROJECTED CHANGE IN OZONE PRECURSORS

OVERVIEW

The analysis of predicted changes in Ozone precursors was initiated because of concern that growth in travel in Pinal County might result in violation of Ozone concentrations. At the start of the study, forecasts for the population growth in the county suggested that a four-fold increase in population was likely to occur over the next twenty years form the existing population of roughly 250,000. With this growth would certainly come a dramatic increase in vehicle miles of travel. The purpose of the work in this task of the project was to assess whether the growth in population and vehicle miles of travel was likely to result in an increase in the emissions of Ozone precursors over the next twenty years.

Ground level Ozone is a colorless gas produced when sunlight and heat stimulate reactions between volatile organic compounds (VOC) and nitrogen oxides (NOx). Ozone formation can occur as a result of VOC and NOx emissions anywhere within a regional air basin or even as a result of emissions blown in from another air basin. As a result, it is difficult to identify the source or location of the pollutant emissions that contribute to Ozone formation and the concentration at particular monitoring site. Elevated levels are generally recorded during the summer months and can aggravate respiratory problems, especially in sensitive groups. Sources of ground level Ozone precursors include passenger vehicles, truck, other gasoline powered motors, industrial processes and biogenic emissions from animals, plants and soil. Although not the only sources of precursor emissions for Ozone, traffic-related emissions are the primary source in Pinal County.

Two standards for Ozone concentrations have been developed: a one-hour standard and more recently an eight-hour standard. The one-hour standard in 0.12 parts per million (ppm) and can be exceeded only once in a year without violating the standard. The eight-hour standard requires that the three-year average of the fourth highest daily eight-hour maximum average be less than or equal to 0.084 ppm. Pinal County has not violated the one-hour standard in the past ten years. Pinal County and has also not violated the eight-hour standard since the standard was developed but has had three-year averages of the fourth highest day at the Apache Junction and Casa Grande monitoring stations just under the standard.

Because of the manner in which Ozone is formed, Ozone concentrations are a product of regional emissions of the precursor pollutants, sunlight, heat and meteorological conditions. The concentrations measured at a monitoring site cannot be attributed to the emissions of pollutant in the vicinity of the site. As a result, the focus of the work in this task was on how future emissions of VOC and NOx from on-road travel in Pinal County are likely to contribute to regional Ozone formation. Although the readings of Ozone concentrations at monitoring sites in Pinal County have raised the concern about Ozone in the county, the work in the task did not attempt to determine how changes in travel volumes would affect the concentrations that those sites. Because considerable resources are required to operate photochemical models to evaluate the significance of Ozone precursor emissions, analysis of Ozone was based on estimates of the Ozone precursor emissions and not on estimates of Ozone concentrations.

The Ozone analysis for the project was conducted by estimating the probable changes in VOC and NOx emissions over time as growth in population, employment and travel occur in Pinal County. The estimates of emissions were developed by applying the VMT estimates derived from available travel models by estimated average rates of emissions per vehicle mile traveled. There was not a single accepted source of forecasts of travel or growth for the county, but two forecasts were available for comparison. One set of forecasts was developed by the Maricopa Association of Governments (MAG) and one was developed by ADOT consultants for the Pinal Corridors Planning Model (PCPM). Average emission rates were derived using information from a recent MAG conformity analysis prepared for the Regional Transportation Plan Update. With these estimates of precursor emissions the possible implications for changes in Ozone precursor emissions was analyzed.

POPULATION AND EMPLOYMENT FORECASTS

Figure 1 provides a comparison of the future forecast of population in Pinal County as a percentage of existing (2006) population. The current population of Pinal County is roughly 250,000. Both the MAG forecast and the PCPM forecast estimate a 2026 population of roughly 1,000,000. That would constitute an average annual compound growth rate of roughly 6.5% in the MAG forecast and 6.9% in the PCPM forecast.

Figure 1: Comparison of Future Forecasts of Population in Pinal County as a Percentage of Existing (2006) Population

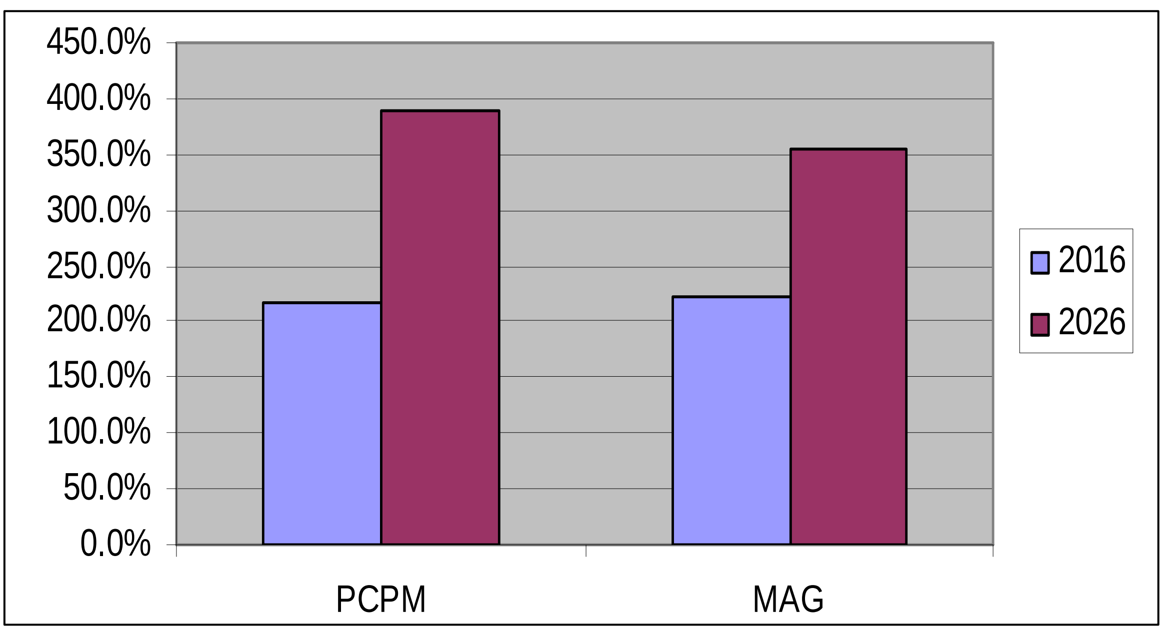
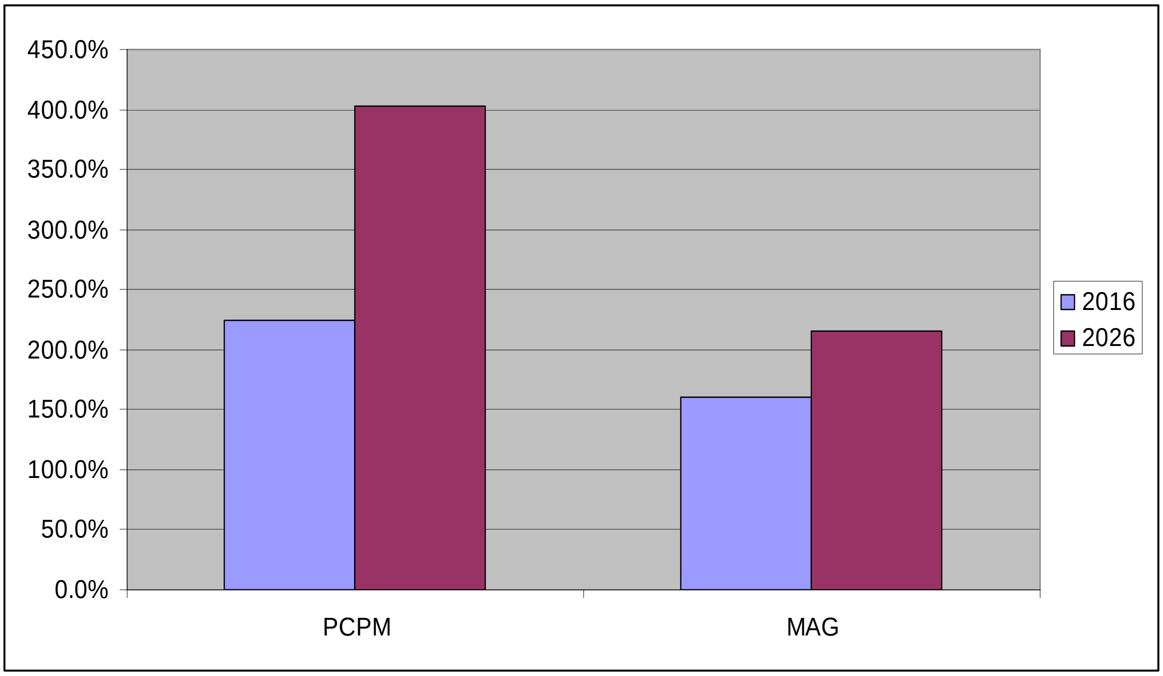


Figure 2 provides a comparison of the future forecast of employment in the county. The two forecasts provide somewhat different estimates of existing employment ranging from 50,000 to 70,000 and vary considerably in the 2026 forecast. The MAG forecast predicts roughly 100,000 jobs in the county while the PCPM forecast predicts roughly 300,000. The average annual compound growth rate in the MAG forecast is roughly 4% per year, while the PCPM average is 7.2% per year. The PCPM forecast maintains a constant ratio of population to jobs of roughly 3.6. The MAG forecast reflects an increase in the ratio from a current level of 5.6 residents per job to 9.2 residents per job in 2006.

Figure 2: Comparison of Future Forecasts of Employment in Pinal County as a Percentage of Existing (2006) Employment



TRAVEL FORECASTS

Travel forecasts from both models were available and also compared. Figure 3 illustrates the expected volume of traffic predicted by the MAG model in the form of vehicle miles traveled per day in the county. The change from 2004 to 2026 reflects an average annual rate of increase of 5.1%. This is in contrast to the average annual rate of growth in population in the MAG forecast of 6.5%. The lower rate of VMT growth reflects a higher percentage of future Pinal County travel remaining within the county as more employment is added. Figure 4 provides VMT estimates for 2004 and 2030 from the PCPM travel forecast. This change reflects an average annual growth of 5.8% per year compared to the PCPM average growth in population of 6.9% per year.

Figure 3: Estimated Growth in Travel Based on MAG Forecast

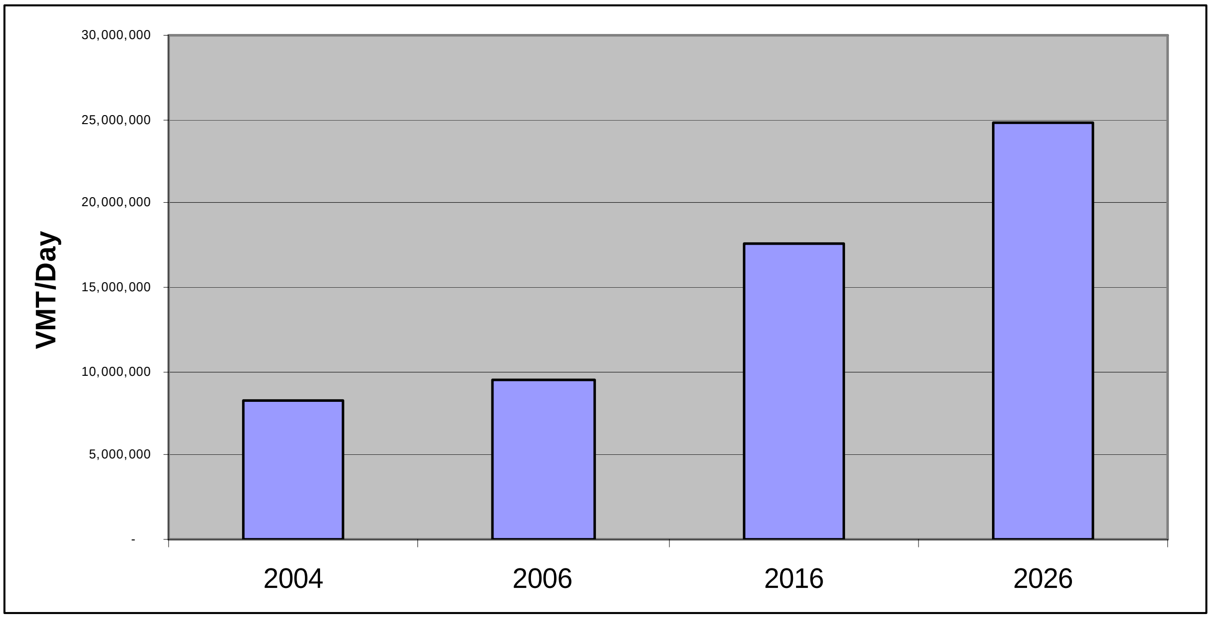
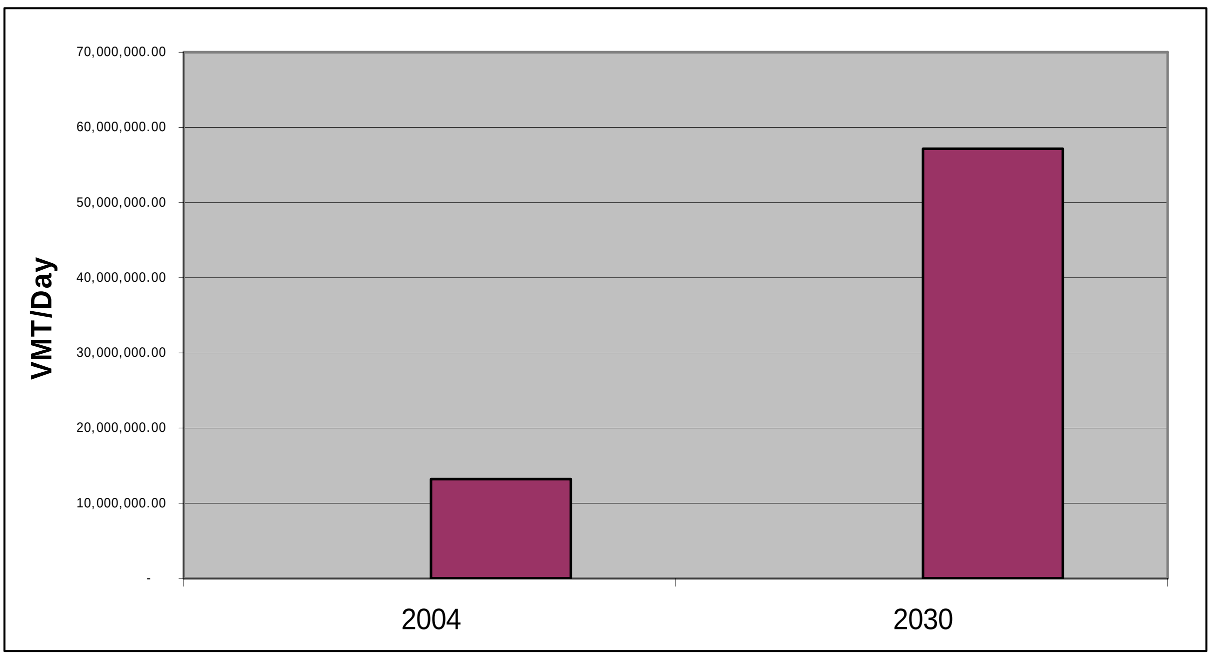


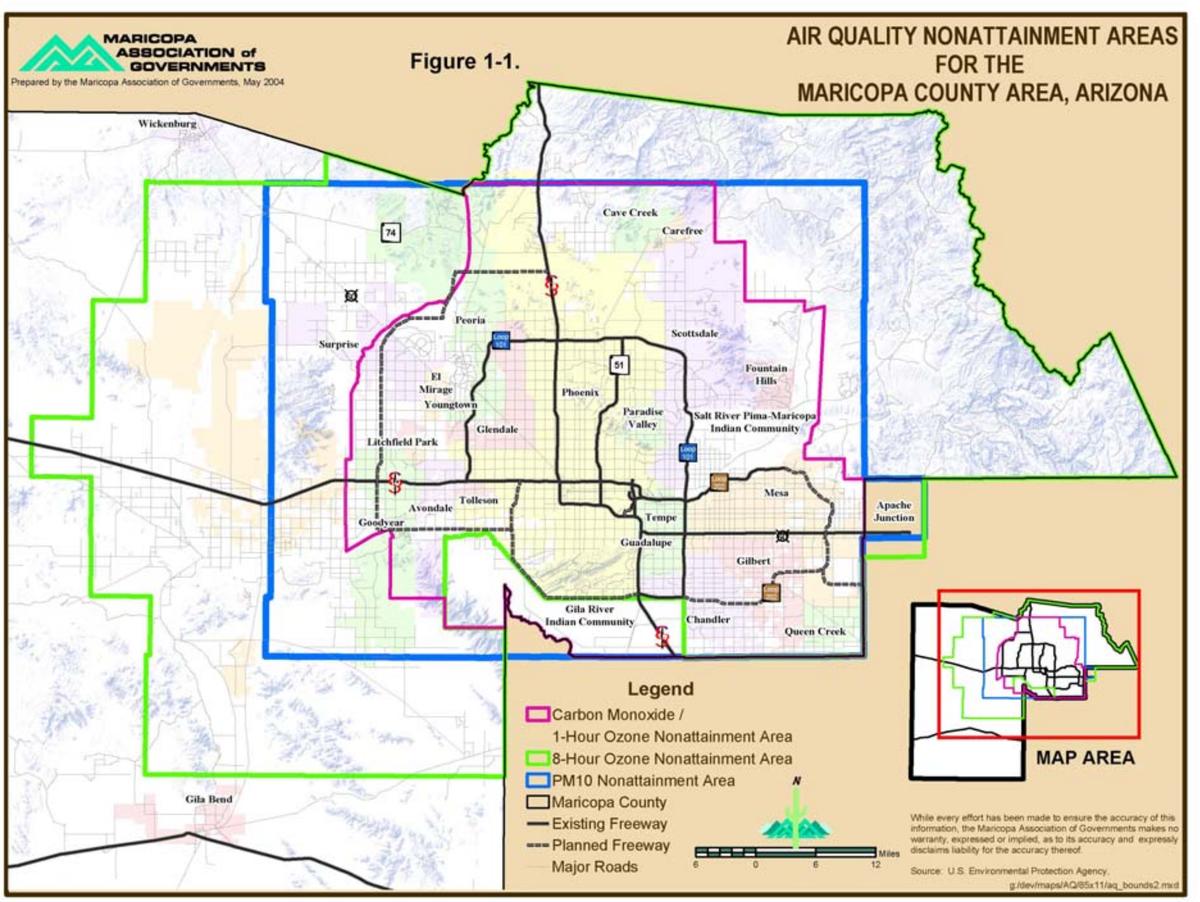
Figure 4: Estimated Change in Travel Based on PCPM Forecast – 5.8% per Year



ESTIMATION OF OZONE PRECURSOR EMISSIONS

The Ozone analysis for the project was conducted by multiplying the VMT estimates derived from each of the two models compared by the estimated average rate of emissions per vehicle mile traveled for both of the Ozone precursors. VOC and NOx emissions were estimated for 2006, 2016 and 2026 using the MAG forecast and the MAG average emission rates derived from the RTP conformity analysis. The same emission rates were applied to the PCPM forecast for the years 2004 and 2030. With these estimates of precursor emissions the possible implications for changes in Ozone precursor emissions was analyzed. Figure 5 shows the Maricopa County area non-attainment areas analyzed in the MAG conformity analysis. Two areas were treated separately: the core area inside the green line (the eight-hour non-attainment area) and the "donut" area which is portion of the eight-hour non-attainment area not in the one-hour non-attainment area. Although the donut area did not include Pinal County, the travel characteristics in the donut area were assumed to be more similar to Pinal County than the travel characteristics in the core area.

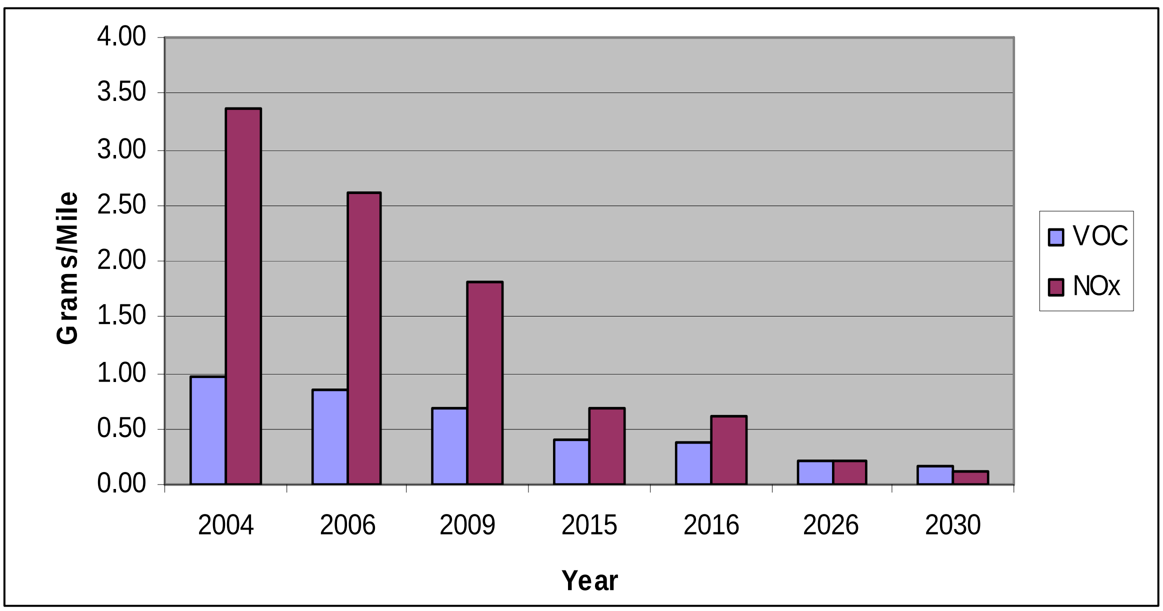
Figure 5: Maricopa County Area Non-Attainment Areas



By State law (HB 2538), an enhanced vehicle emissions and inspection program (I/M) applies to area covering most of the eight-hour Ozone non-attainment area in Maricopa County, as well as a large area in northeastern Pinal County. The emission rates provided by MAG assumed that I/M is in place in most of the "donut" and in all of the one-hour non-attainment area. Although emission rates in the portions of Pinal County not covered by the I/M program might have higher emission rates, the rate of annual decrease in emission rates should be similar because fleet replacement will result in cleaner vehicles over time. If a similar I/M program is instituted in the remainder of Pinal County not already covered, the reduction in emission rates from the present levels would be even greater than is reflect in the rate of decrease in the rates derived from the MAG data.

Figure 6 illustrates the average emission rate per vehicle mile traveled for VOC and NOx for each of the years in the MAG conformity analysis. As indicated in the figure, improvements in emissions in the vehicle fleet result in significant reduction in the average emission rate per vehicle mile traveled. NOx emissions are reduced by roughly 11.9% per year while the VOC emission rate is reduced 6.5% per year. This decrease may also be partially due to a reduced percentage of heavy-duty vehicles in the fleet as more resident-based travel occurs in the outlining areas. By way of comparison, the VMT increases from the two forecasts were between 5.1% and 5.8% per year.

Figure 6: Average Emission Rates by Year for the Donut Area



When the emission rates from the 8-hour Ozone non-attainment area are used the rates of reduction are slightly lower as indicated in Figure 7. Between 2004 and 2030 the average annual reduction in the NOx emission rate is 8.9% per year and for VOC is 5.8% per year. Although the Pinal County travel characteristics are likely to be more similar to the travel expected in the donut area, both sets of rates were used to produce emission estimates for the two population and travel forecasts to see if Ozone precursor emissions increased over time under any set of possible assumptions about rates.

Figure 7: Average Emission Rates by Year for the 8-Hour Non-Attainment Area

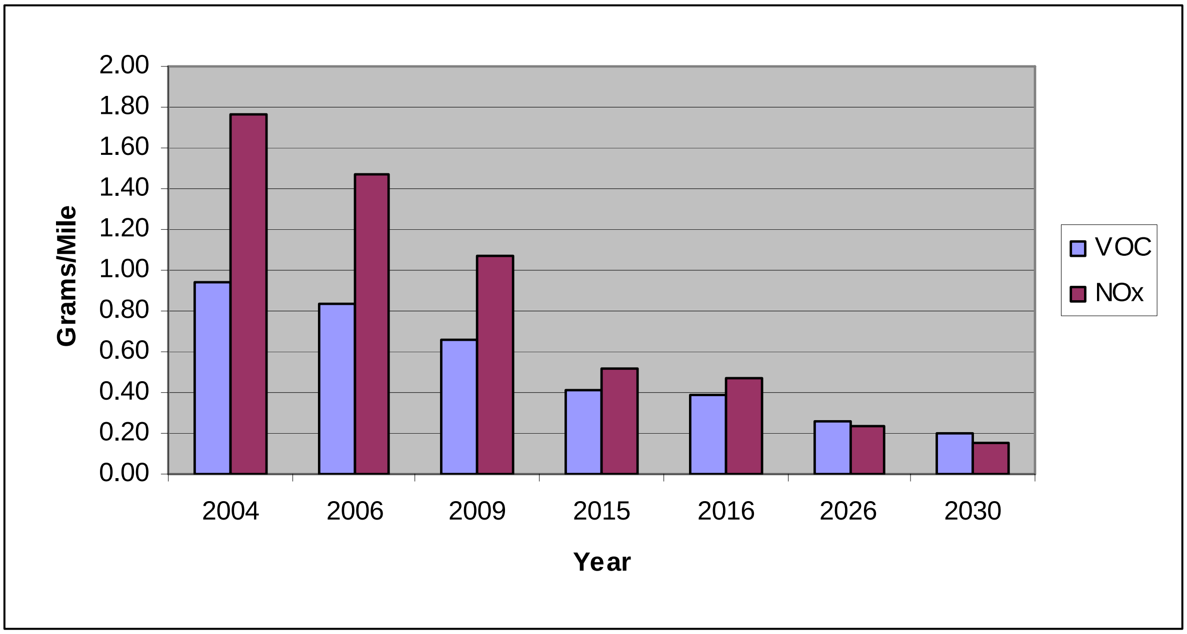


Figure 8 presents the results for the application of the donut area emission rates to the PCPM forecast. VOC emissions are expected to decrease by 26% while NOx emissions will decrease 84%.

Figure 8: Estimated Mobile Source Pollutant Emissions in Pinal County Based on PCPM Forecasts and Donut Area Rates

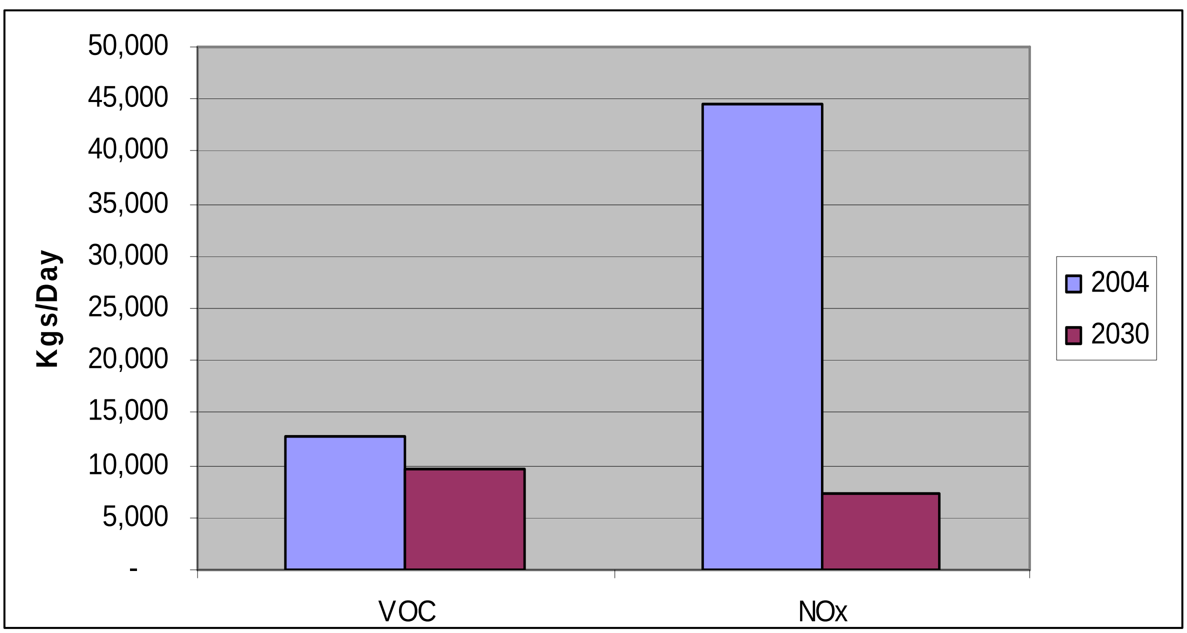


Figure 9 presents the results for the application of the 8-hour non-attainment area rates to the PCPM forecast. In this analysis the VOC emissions would be reduced by 11% while the NOx emissions would be reduced by 61%

Figure 9: Estimated Mobile Source Pollutant Emissions in Pinal County Based on PCPM Forecasts and 8-Hour Non-Attainment Area Rates

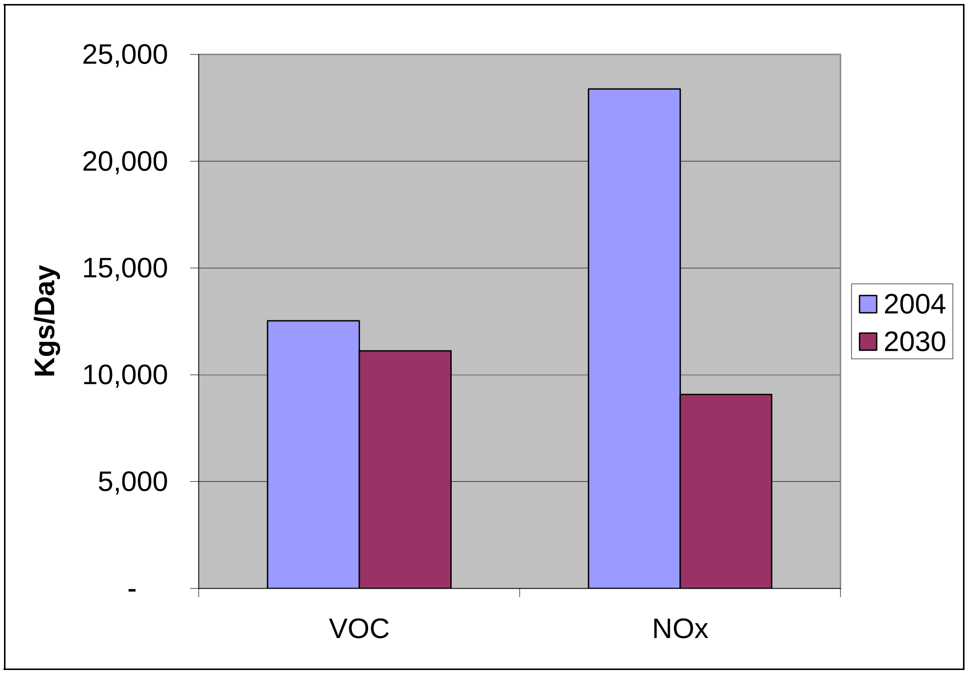


Figure 10 presents results of the application of the donut area emission rates to the MAG forecast and VOC emissions are reduced by 33% while the NOx emissions are reduced 81%. When the 8-hour non-attainment area rates are applied to the MAG forecast the reduction in VOC emissions would be 22% as indicated in Figure 11 and the reduction in NOx emissions would be 80%.

One additional factor that might affect future emission rates is the average speed of travel. Figures 12 and 13 illustrate how the emission rate for NOx and VOC respectively vary for a light duty gas vehicle on arterial roads and freeways. While the curves are fairly flat for both precursor emissions in speeds over 25 miles an hour they can vary significantly at lower speeds. Estimates of future speeds were not available from either of the two forecasting models because at the time of this project neither was being used to test alternative future roadway systems. The speeds for future years will ultimately depend on the degree to which roadway capacity is added, the degree to which trips are connected within the county, and the degree to which alternative modes of travel are provided. If the results of additional planning and travel modeling work for Pinal County suggest that average speeds are likely to be reduced over time, more detailed analysis of the effect on Ozone precursor emissions might be warranted.

Figure 10: Estimated Mobile Source Pollutant Emissions in Pinal County Based on MAG Forecasts and Donut Area Rates

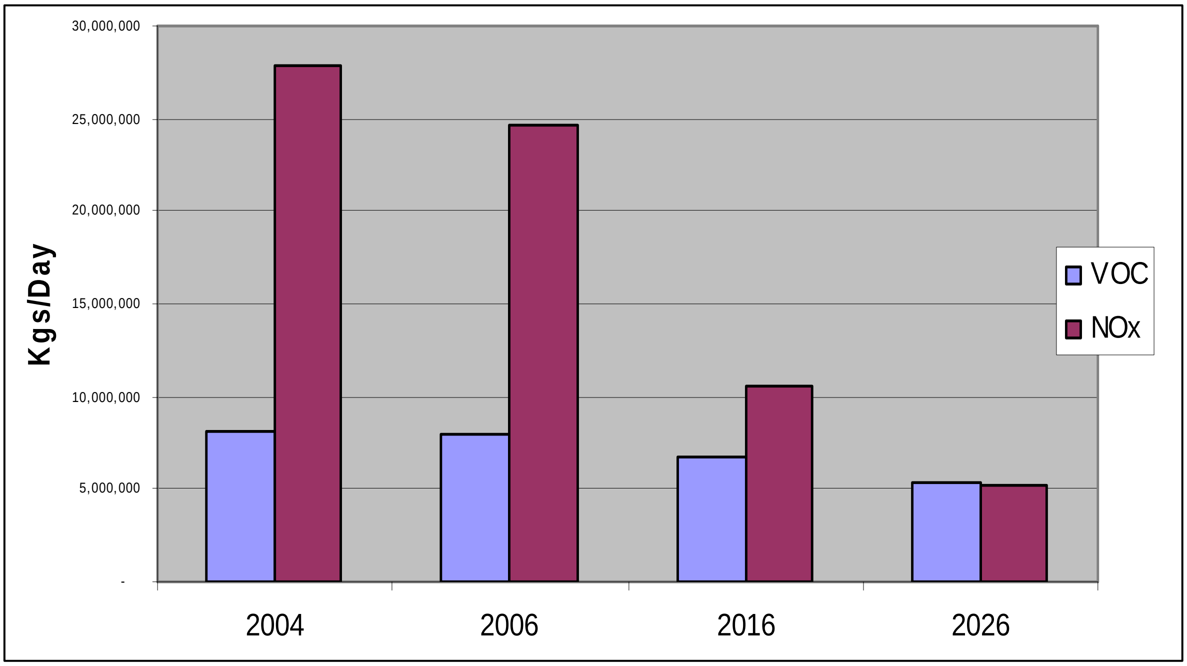


Figure 11: Estimated Mobile Source Pollutant Emissions in Pinal County Based on MAG Forecasts and 8-Hour Non-Attainment Area Rates

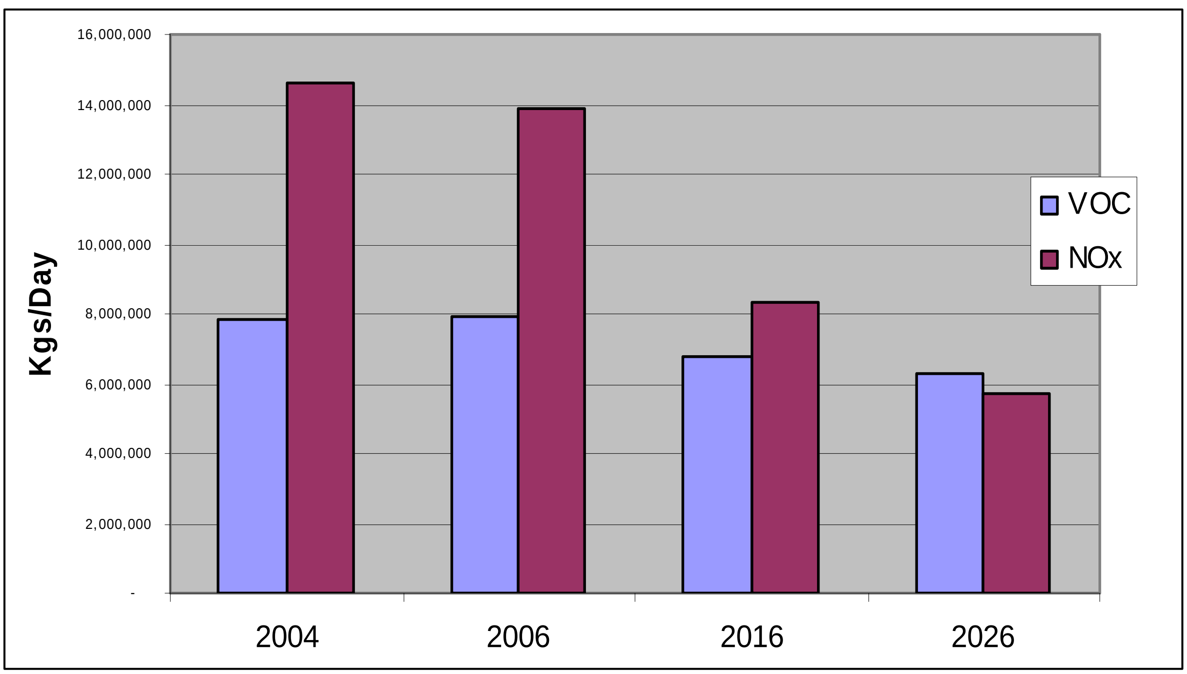


Figure 12: LDGV NOx Emissions by Average Facility Speed (Mobile6 National Fleet Defaults)

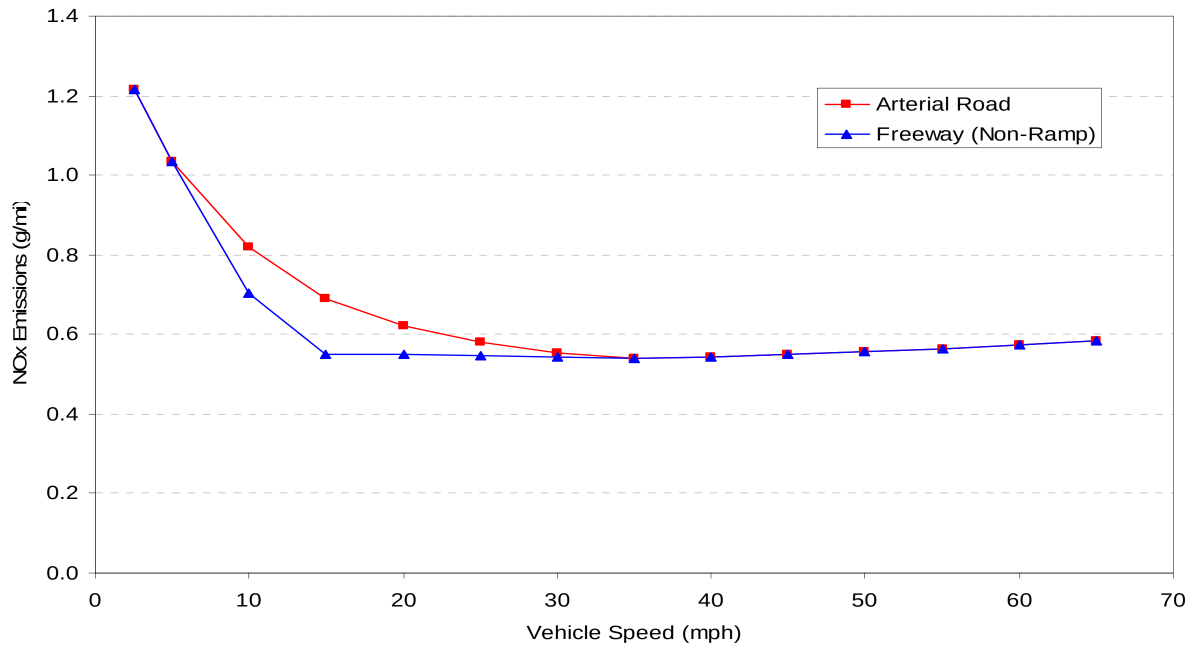
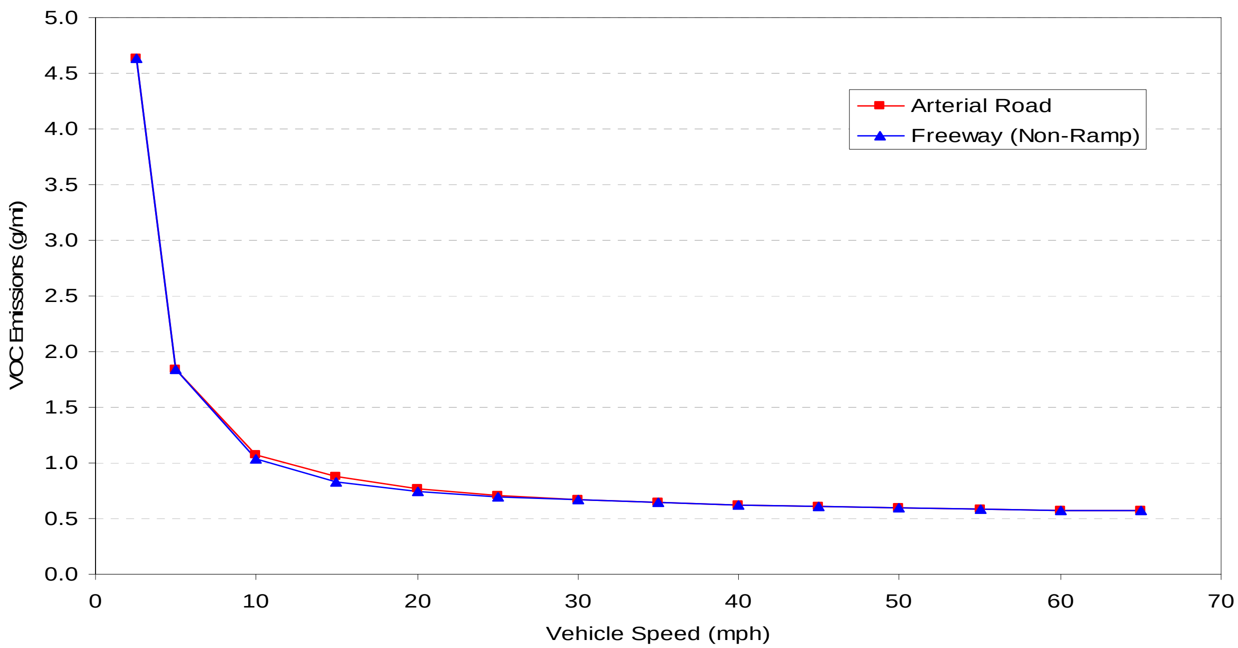


Figure 13: LDGV VOC Emissions by Average Facility Speed (Mobile6 National Fleet Defaults)

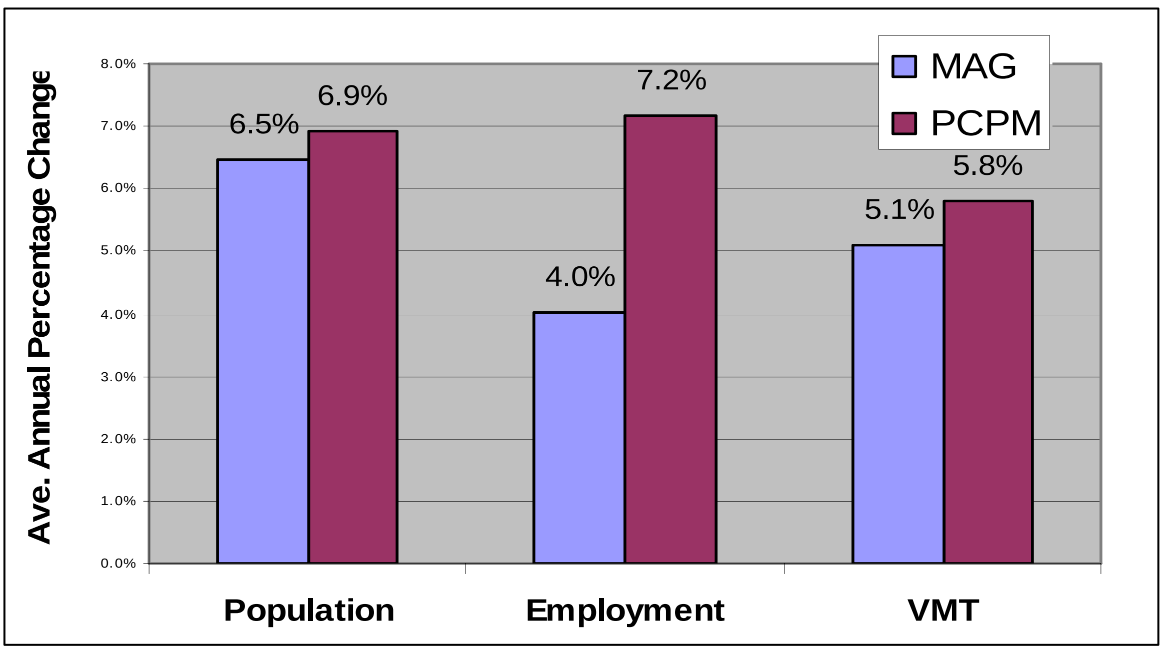


CONCLUSIONS ABOUT FUTURE OZONE PRODUCTION

Based on the analysis of Ozone precursor emissions, it seems unlikely that there would be an increase in Ozone as a result of travel within or though Pinal County between 2004 and 2030. In each of the scenarios tested using alternative travel forecasts and alternative emission rates the rate of reduction in emission rates was greater than the rate of growth in VMT. This comparison is provided directly in Figure 14. In both cases the rate of VMT growth is less than the annual rate of reduction in the precursor emission rates. In some cases the average annual rate of population and/or employment rate might exceed the VOC emission rate reduction but both travel models are predicting a slower rate of growth in VMT than in population. This is likely the result of a higher percentage of resident travel in the county as opposed to through trips and more trips being linked within the county as more employment and shopping areas emerge with growth in the county.

Although the analysis conducted in this tasks suggests that an increase in Ozone precursor emissions in Pinal County is unlikely over the next twenty years, periodic reassessment of the situation is probably warranted particularly for VOC emissions. Monitoring of growth rates, roadway plans and improvements, travel speeds and emissions rates will indicate whether any of the assumptions of this analysis are no longer valid and a new analysis conducted

Figure 14: Summary of Average Annual Growth Rates for Pinal County



* By comparison the average annual percentage reduction in VOC emission rates is 5.8% and 6.5% per year and NOx is between 8.9% and 11.9% per year.

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CHAPTER THREE
SPREADSHEET MODEL FOR COMPUTING PM_{10} IMPACTS FROM UNPAVED ROADS TRAVEL

OVERVIEW

The western portion of Pinal County is extensively dedicated to agricultural production. Due to its rural nature with low traffic volumes, many of the local public roads in this area are unpaved. Because of rising home prices in neighboring Maricopa County, new residential construction is beginning to proliferate in portions of the agricultural district proximate to freeway access. The juxtaposition of new residential development to existing unpaved roads is raising concerns about air quality impacts from these roads on new residents.

Annually, the Pinal County Public Works Department paves a limited number of unpaved road segments to reduce maintenance costs and to respond to concerns about dust impacts. In the process of selecting road segments for paving, the Public Works Department solicits recommendations from the Pinal County Air Quality Control District (PCAQCD). In the past, PCAQCD has responded by identifying unpaved road segments that were the subject of dust complaints filed with the agency. PCAQCD desires to use a more objective tool for prioritizing unpaved roads for paving.

In responding to this need, Sierra Research (Sierra) developed a spreadsheet modeling tool to assist PCAQCD in prioritizing unpaved road segments for recommended paving within a study area consisting of the agricultural district. The modeling tool design was outlined in a revised proposal submitted by DKS Associates to the Arizona Department of Transportation on October 13, 2004. A description of the modeling tool and instructions for use are contained in this report, together with a summary of cost-effectiveness data applicable to other means of treating unpaved road segments to reduce PM_{10} emissions.

METHODOLOGY DEVELOPMENT

Estimates of downwind impacts from unpaved road travel emissions are best determined, within the limits of the project budget, through the use of dispersion modeling. Other, more simplistic, computational approaches are less accurate, and ambient monitoring approaches that would be more accurate are too costly. The dispersion modeling approach has the ability to couple site-specific emission rates, meteorology, and geography to produce impact estimates that are sufficiently accurate to be used in the comparison of different road segments for paving prioritization. While this approach will produce impact estimates that are accurate only within a factor of two to measured impacts,1 this tool is not proposed to be

[1] Reliability and Adequacy of Air Quality Dispersion Models, GAO/RCED-88-192, U.S. General Accounting Office, August 1988.

used to determine compliance with air quality standards, but rather to serve as a screening tool in assessing comparative impacts from actual or projected traffic levels on selected road segments.

The existence of locally recorded meteorological data in the agricultural district of Pinal County enhances the accuracy of dispersion modeling as a tool for estimating unpaved road impacts. PCAQCD has recorded and archived meteorological data sufficient to serve modeling needs at three locations in this district: Cowtown, Casa Grande, and Eleven-Mile Corner. Analysis of the windroses from these three sites indicates similar wind patterns, with prevailing winds blowing from the west and east.

The prevalent alignment of unpaved roads along section lines in the agricultural district results in most unpaved roads running either due east-west or north-south. This factor simplified the number of dispersion modeling runs that were conducted to assess impacts for any individual road segment. In the design of this screening tool, we assumed that all roads of interest to PCAQCD were aligned in these two directions, which allowed us to limit the number of modeling runs needed to characterize dispersion patterns downwind of unpaved roads.

In the use of a screening tool, PCAQCD expressed interest in being able to evaluate PM_{10} impacts at varying distances downwind of unpaved road segments. This flexibility is needed to tailor the modeling analysis to actual or proposed juxtapositions of residential or workplace facilities and specific unpaved road segments. To avoid the need to run the dispersion model for each road segment to be studied, we conducted model runs for east-west and north-south road segments using each of the three meteorological databases developed by PCAQCD and unit emission rates. To facilitate use of the modeling results in evaluating impacts at variable distances, we used a curvefitting program to fit the modeling output to a mathematical equation that could be entered into the spreadsheet. The use of a mathematical equation to represent the modeling results will allow the user of the spreadsheet tool to enter the specific separation distance between a road segment and a selected receptor and compute the dilution factor that would be predicted by the dispersion model at that distance.

The spreadsheet modeling tool is designed to be interactive, relying on user selection of several key variables that serve as the basis for emission calculation and downwind impact assessment. By using a spreadsheet as the platform for calculations, the model will respond instantaneously to data input and change. Error protection routines are built into the spreadsheet to report unacceptable data entries including entries that are out of range.

The PM_{10} impacts downwind of an unpaved road are dependent upon the emission rate of the road segment, the meteorology of the area surrounding the road segment, and the separation distance between the receptor of interest and the downwind edge of the road segment. For this model, the emission rate of the road segment is calculated as the product of an emission factor, in units of pounds of emission per vehicle mile traveled (lb/VMT), and the daily traffic rate, in units of vehicles passing a single point on the road per day, which is also referred to as average daily traffic (ADT). The meteorology of western Pinal County is represented in the model by the hourly measurements of vital weather parameters recorded at three stations distributed across the central agricultural zone. The separation distance between road edge and receptor is a user input that can be entered in units of feet or meters in the spreadsheet model.

The emission factor for vehicle travel on unpaved roads derives from an emission equation published by the U.S. Environmental Protection Agency (EPA). This equation uses the silt (-200 mesh screen) content of loose surface soil, the surface soil moisture content, and the vehicle speed as independent variables. Data for each of these three variables were collected on five unpaved road segments in the western portion of Pinal County for use in this model. The model user can select one of these five road segments to represent the road segment of interest on the basis of similar soil type. The discussion of soil types is presented later under Emission Factor Development and Modeling Tool Use.

The meteorological database for use in the modeling analysis is a user option in the spreadsheet model. Three datasets collected by PCAQCD are available for use under this option: Cowtown, Casa Grande, and Eleven Mile Corner. Cowtown and Eleven Mile Corner represent the western and eastern thirds, respectively, of the agricultural district, while Casa Grande represents the middle portion of the study area covered by the modeling tool. The prevailing wind directions in this area are generally east and west due to jet stream flows and the east-west orientation of the agricultural district bounded by mountain ranges to the south and north. Due to these factors, meteorological conditions are assumed to be similar within each of the three longitudinally divided portions of the study area.

The downwind impacts of PM_{10} emissions from unpaved roads were evaluated using plume dispersion modeling. The modeling was performed using the CAL3QHCR model that is specifically designed to model emission dispersion from road segments. CAL3QHCR is a line source dispersion model selected by EPA as the recommended model to use in predicting inert pollutant concentrations from motor vehicles adjacent to roadway links and intersections. The model contains the CALINE3 dispersion model and uses hourly-averaged real meteorological data.

EMISSION FACTOR DEVELOPMENT

The emission equations for unpaved road travel developed by EPA are published in AP-42.2 The equation used in this analysis is designed to estimate particulate matter emissions from light-duty vehicle travel on unpaved roads. This equation has the following form:

$$E = [(k)(s/12)^a(S/30)^d/(M/0.5)^c - C][(365 - P)/365]$$

where: E = particulate matter emission rate, pound per vehicle miles traveled (lb/VMT)
k = particulate size factor (dimensionless)
= 1.8 for PM_{10}
s = surface material silt content (%)
S = mean vehicle speed, miles per hour (mph)
M = surface material moisture content (%)
a = empirical constant
= 1.0 for PM_{10}
c = empirical constant
= 0.2 for PM_{10}
d = empirical constant
= 0.5 for PM_{10}
C = PM_{10} emissions from vehicle exhaust, brake wear, and tire wear (lb/VMT)
P = number of precipitation days per year on which 0.01 inches or more rain falls (days/yr)

The three variables in this equation—silt content, moisture content, and vehicle speed—vary significantly from one unpaved road to another. Because of this variability, measurements of these parameters were made on representative roads in the agricultural district to increase the accuracy of the spreadsheet model.

The unpaved roads in the agricultural district are constructed of native material. As a result, the silt content of the roadbed soil is similar to that of the surrounding soil. To evaluate the variability of silt content in soils within the agricultural district, a soils map prepared by the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) was obtained and reviewed.3 The general soil map contained in this reference is presented in Figure 1.

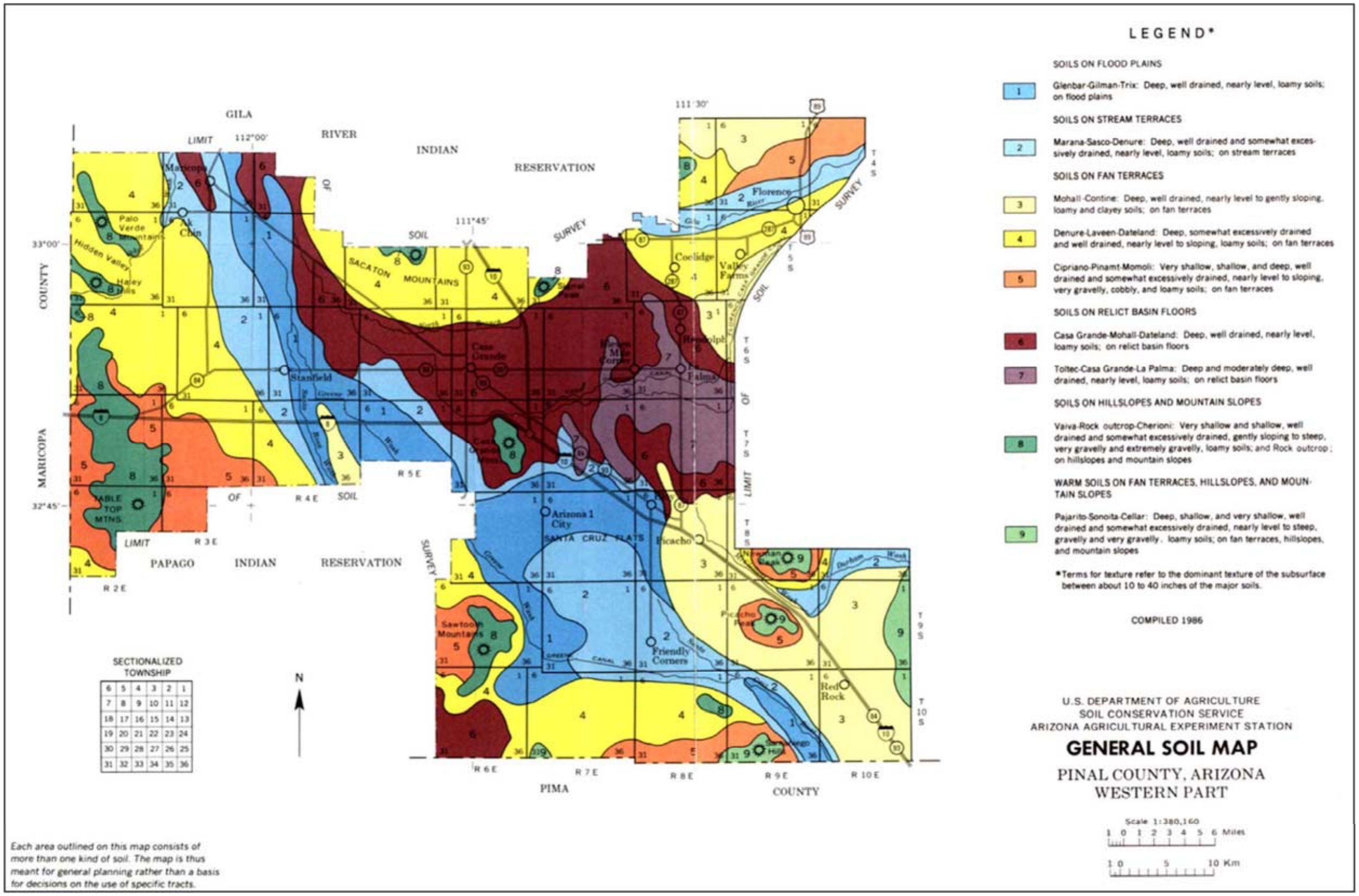
[2] Compilation of Air Pollutant Emission Factors, AP-42, Volume 1: Stationary and Area Sources, Fifth Edition, U.S. Environmental Protection Agency, January 1995.
[3] Soil Survey of Pinal County, Arizona, Western Part, U.S. Department of Agriculture Soil Conservation Service, November 1991.

The NRCS soil map indicates that five general soil map units cover the agricultural district. These units are differentiated by the hydrologic and geologic areas in which they are found. These areas include floodplains, stream terraces, fan terraces, and relic basin floors. The names of the soil units and the areas in which they are found are listed in Table 1. The numbers in parentheses represent the numerical designation assigned by NRCS to soil units for purposes of identification on the soil map.

Table 1: Geological Locations and Names of Western Pinal County General Soil Map Units

Geological Location	General Soil Map Unit
Flood Plains	Glenbar-Gilman-Trix (1)
Stream Terraces	Marana-Sasco-Denure (2)
Fan Terraces	Denure-Laveen-Dateland (4)
Relic Basin Floors	Casa Grande-Mohall-Dateland (6)
	Toltec-Casa Grande-La Palma (7)

Figure 1: Western Pinal County General Soil Map



Within each of these major soil map units are located several specific soil types. The NRCS soil map book reports agricultural silt content4 and wind erodability, among other characteristics, for each specific soil type found in the agricultural district. Within some major soil map units, the agricultural silt contents are relatively uniform, and for other map units the silt contents vary dramatically. Sierra, working with PCAQCD, identified the predominant soil types in each major soil map unit. PCAQCD, working with the Pinal County Public Works Department, identified one well-traveled unpaved road segment in a predominant soil type in each major soil map unit. The rationale for locating the unpaved road sampling site in a predominant soil type within each major soil map unit was to conduct sampling at a site that was most representative of soils throughout the major soil map unit. A list of these predominant soil types, together with data on agricultural silt content and wind erodability, underlying each selected unpaved road segment is presented in Table 2. A map showing the locations of the unpaved road segments selected for surface soil sampling is shown in Figure 2.

Table 2: Characteristics of Soils Underlying Selected Unpaved Road Segments

Selected Unpaved Road	Predominant Soil Type	Agricultural Silt Content	Wind Erodability*
Alsdorf Road	Casa Grande (4)	70% - 80%	5
Amarillo Valley Road	Dateland	25% - 35%	3
Curry Road	Casa Grande (3)	30% - 40%	3
Peters Road	Gadsden	80% - 90%	8
White & Parker Road	Trix	70% - 80%	4

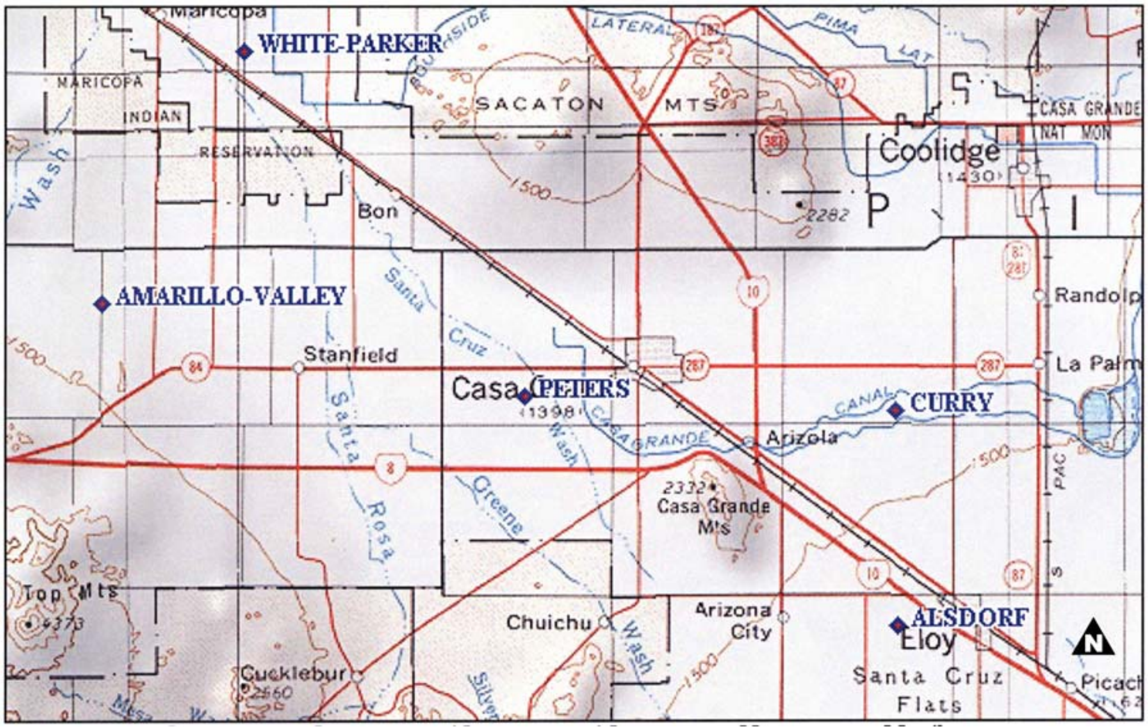
***** The wind erodibility scale varies from 1 (extremely erodible) to 8 (not subject to wind erosion).

At each of the selected unpaved road segments, samples of loose surface soil were collected by PCAQCD staff in early June 2005 in conformance with EPA sampling protocols.5 At stations located 0.5 miles apart over a two-mile section of unpaved road, all of the loose surface material was collected from within one-foot-wide strips running perpendicular to the road centerline. The loose material was collected with a whisk broom and dust pan and deposited into a lined plastic bucket. Samples from each of the five strips in a two-mile section were combined in the bucket, the plastic bag/liner was taped closed, and the cover on the bucket was sealed with duct tape. The buckets were labeled by road name, date, and sample collector, and shipped within 24 hours of collection via UPS to Professional Service Industries, Inc. (PSI), a soils laboratory in Tempe, Arizona.

[4] Agricultural silt content differs generically from unpaved road silt content (as used in emissions analyses) as agricultural silt content is measured by a wet sieve analysis method that allows soil clumps to be broken down into individual soil particles during the screening process, while unpaved road silt content is measured by a dry sieve analysis method that leaves soil clumps intact. As a result, silt contents reported in the agricultural context are generally higher than those reported in the air pollution context, even for the same soil type.

[5] Appendix C-1, Compilation of Air Pollutant Emission Factors, Volume 1, AP-42, U.S. Environmental Protection Agency, January 1995.

Figure 2: Locations of Unpaved Road Traffic Count and Soil Sampling Sites



PSI performed sieve and moisture content analyses on the shipped samples. For the first two samples collected (Alsdorf Road and Curry Road), these analyses were conducted within about one week of receipt by the laboratory. Because of personnel changes at the laboratory, however, the second set of samples collected (Amarillo Valley Road, Peters Road, and White & Parker Road) was not analyzed until about three weeks after receipt by PSI. Although the delay in analysis of the second set of samples could have allowed moisture in the soil to evaporate, the moisture contents of soil samples at the time of collection were undoubtedly very low, and the reported measurements indicate that moisture contents of the second set of samples were equivalent to or greater than those of the first set. For these reasons, we conclude that the delay in performing moisture content analyses of the second set of soil samples did not significantly affect the analytical results. The silt and moisture contents reported for each sample are listed in Table 3.

Table 3: Unpaved Road Surface Soil Silt and Moisture Content

Unpaved Road	Silt Content	Moisture Content
Alsdorf Road	2.60%	0.097%
Amarillo Valley Road	7.40%	0.106%
Curry Road	4.20%	0.154%
Peters Road	7.10%	0.306%
White & Parker Road	5.90%	0.477%

As the EPA emission factor equation for unpaved road travel also includes average vehicle speed as a variable, data on vehicle speeds were collected through the use of traffic counters. Traffic Research and Analysis, Inc. (TRA) of Phoenix, Arizona installed dual tube counters on each of the five unpaved road segments in late May 2005. Each of the counters was left in place for seven days except for the counter on Amarillo Valley Road. Due to a communication gap, the Pinal County Public Works Department graded the portion of this road where the counter was located, causing the counter to cease operation after four days. After being repaired, the counter completed a seven-day traffic count in the following week. The average vehicle speeds and average daily traffic counts for each unpaved road segment are presented in Table 4.

Table 4: Average Vehicle Speeds and Average Daily Traffic Counts

Unpaved Road	Average Vehicle Speed (mph)	Average Daily Traffic Count
Alsdorf Road	42.8	153
Amarillo Valley Road	40.7	174
Curry Road	40.5	646
Peters Road	34.1	252
White & Parker Road	40.5	118

Two other factors that are constants in the EPA equation, for the purpose of this spreadsheet tool, were derived from EPA estimates and local meteorological data. The factor "C" in the EPA equation represents PM_{10} emissions from vehicle travel that are not generated by travel over unpaved roads. These emissions include particulate matter emissions from the vehicle exhaust pipe, brake wear particles, and tire wear particles. Data reported in the EPA MOBILE6.2 mobile source emission factor model lists the total of these emissions for the average light duty vehicle to be 0.00016 pounds of PM_{10} per vehicle mile traveled. This factor is subtracted from the total emissions reported by roadside testing to isolate the contribution made by travel over unpaved soil surfaces. The factor "P" in the EPA equation represents the number of days per year when rainfall reduces unpaved road travel emissions to zero. Other research referenced in AP-42 indicates that this situation occurs on any day in which 0.01 inches or more of precipitation occurs. From long-term rainfall data collected at Stanfield and Casa Grande, as tabulated on a website maintained for the National Oceanographic and Atmospheric Administration by the Desert Research Institute,6 the annual average number of precipitation days in the agricultural district is 30 days per year. The precipitation day adjustment factor is used to adjust annual average emission factors only. The maximum 24-hour PM_{10} impacts are assumed to occur on a day with no measurable rainfall.

[6] Average Number of Days With Measurable Precipitation, Arizona, Western Regional Climate Center, NOAA and DRI, http://www.wrcc.dri.edu/htmlfiles/az/az.01.html, accessed on August 22, 2005

After entering the appropriate constants, the emission factor for each unpaved road segment studied was calculated by inserting the measured values of silt content, moisture content, and average vehicle speed into the EPA equation. The results of these calculations are presented in Table 5.

Table 5: Unpaved Road Travel Emission Factor

Unpaved Road	PM_{10} Emission Factor (lb/VMT)	
	Annual Average	Max. 24-Hour
Alsdorf Road	0.593	0.647
Amarillo Valley Road	1.341	1.247
Curry Road	0.850	1.461
Peters Road	1.144	1.038
White & Parker Road	0.952	0.926

DISPERSION MODELING ANALYSIS

For the purpose of estimating the downwind PM_{10} impacts from unpaved road travel in Pinal County, we selected the CAL3QHCR dispersion model. CAL3QHCR is a line source dispersion model selected by EPA as the recommended model to use in predicting inert pollutant concentrations from motor vehicles adjacent to roadway links and intersections. The model contains the CALINE3 dispersion model and uses hourly-averaged real meteorological data. CALINE3-based dispersion models are uniquely designed to emulate the turbulent plume mixing that occurs in vehicle wakes prior to plumes being transported downwind by local wind currents.

Because of the need for simplicity and the budget for this project did not allow for the incorporation of the CAL3QHCR model into the spreadsheet, the model was run using unit inputs and the results were incorporated into the spreadsheet to account for plume dispersion. The CAL3QHCR model relies on inputs of emission rate, roadway and receptor configuration, and meteorology. For the development of the spreadsheet tool, the model runs were conducted at unit average emission rates (1.0 gram per second per mile of road) in order to standardize the model results. Because the distribution of traffic on each monitored unpaved road followed a typical diurnal pattern, the traffic rates in the modeling input files were adjusted to follow the same pattern. The traffic distribution pattern for each monitored unpaved road was computed for each hour of the day as the sum of vehicle counts for that hour over the seven-day monitoring period divided by the total vehicle count for the week. The hourly fractions for all monitored roads combined were computed by weighting the hourly fractions for each road by the total vehicle count for that road and hour, summing these products together, and then dividing by the total vehicles counted on all roads and all days in that hour of the day. These resulting composite hourly fractions were then multiplied by an arbitrarily selected 1,000 vehicle per day total count to determine hourly vehicle counts for the modeling under each meteorological dataset.

The roadway sections that were modeled were configured to be 1.0 mile long and 24 feet wide. The average roadway width was estimated from field observation in Pinal County to consist of two 12-foot lanes. Two different road orientations were modeled – one with an east-west centerline and the other with a north-south centerline. Receptor locations were set at 25, 50, 100, 150, 200, 300, 400, and 500 meters from the downwind road edge on each side of the road.

Model runs were performed using each of the three meteorological databases. Two the databases, from Casa Grande (2004) and Eleven Mile Corner (2003), covered one full year each. The meteorological data collected at the Cowtown (2004) site, however, were missing 66 days of data between June 23 and August 27, 2004, due to instrument malfunction. In an attempt to determine whether the loss of data for this period would significantly influence the adequacy of the remaining data to provide representative results for annual and maximum 24-hour downwind PM_{10} impacts, we compared the PM_{10} modeling results from use of the 2004 Casa Grande meteorological database to use of the same database minus data for the June 23 to August 27 period. The modeling results for each of the maximum 24-hour averages were identical, and the results for the annual averages differed by less than 5.4% on average and by less than 10.0% for any single receptor point. The meteorological dataset containing the gap produced slightly higher annual averages to the west of north-south roads and to the south of east-west roads, and slightly lower annual averages to the east and north of modeled road segments. On this basis, we accepted the 2004 Cowtown meteorological database as being representative for use in assessing annual and maximum 24-hour PM_{10} impacts.

The CAL3QHCR modeling runs were conducted to estimate downwind impacts at regular intervals from 25 meters to 500 meters on each side of each road segment evaluated. Upon run completion, the impacts reported along each line of receptors by CAL3QHCR were processed through a curvefitting program.[7] The curvefitting program is designed to fit the modeled impact data to 23 different equation types and report the correlation coefficient (r2) for each type. Twenty-four sets of model output data were processed in this manner. The sets are combinations of the 3 meteorological datasets, the 2 roadway orientations, the 2 directions from each roadway segment in which receptors were positioned, and the 2 PM_{10} averaging periods (annual and maximum 24-hour) that serve as the basis for the national ambient air quality standards. Abbreviations were used for each of these parameters in formulating filenames for the curvefitting process and the spreadsheet tool:

[7] Curvefit, Version 2.11-B, Thomas S. Cox, July 1988.

Table 6: Coding for Dispersion Modeling Runs

Parameter	Option	Abbreviation
Meteorological Dataset	Cowtown	CT
	Casa Grande	CG
	Pinal Co. Housing/Eleven Mile Corner	PC
PM_{10} Averaging Period	Annual	A
	Maximum 24-Hour	D
Road Segment Direction	North-south	V (vertical)
	East-west	H (horizontal)
Receptor Row Direction*	Negative under UTM coordinate system	N
	Positive under UTM coordinate system	P

***** *A negative direction under the UTM coordinate system is either southerly or westerly. A positive direction is either northerly or easterly.*

Using this convention, for example, the files used to evaluate maximum 24-hour average impacts at the receptors west of a north-south road in the zone represented by the Eleven Mile Corner meteorological dataset would be designated as the PCDMV (Pinal County Housing/Day/Minus receptors/Vertically-oriented road) input file.

By fitting a curve to the modeling output data, and then installing the equation to that curve in the spreadsheet, the user is allowed to quickly compute air quality impacts within a range of receptors distances from an unpaved road. The curvefitting program identified the equation type and coefficients that, when combined with receptor distance as a variable, would duplicate the output of the CAL3QHCR model with the greatest accuracy. The coefficients, equation types, and correlation coefficients for the best fitting curves for each of the 24 input combinations for which dispersion models were run are displayed in Table 7.

Table 7: Curvefit Parameters for Each Dispersion Model Output

Model Run	Coef. A	Coef. B	Coef. C	Eqn. Type	r^2
Casa Grande Meteorological Database					
CGAMH	1.26E-06	5.97E+02	-0.4201	5	1.0000
CGAMV	1.83E+02	-4.43E+00	-2.34E+01	4	1.0000
CGAPH	1.291E-06	4.433E+02	-0.2252	5	0.9999
CGAPV	154.0	0.9988	-0.6911	3	0.9999
CGDMH	348.3	-4.069E+00	-2.48E+01	4	0.9996
CGDMV	2.98E+02	0.9985	-0.5969	3	0.9986
CGDPH	1.295	1.311E+03	-1.039E+04	2	0.9999
CGDPV	1.600	1.259E+03	-8.38E+03	2	0.9990
Cowtown Meteorological Database					
CTAMH	5.673E+01	-1.197E+00	-1.312E+01	4	0.9999
CTAMV	1.35E+02	0.9982	-0.6213	3	0.9999
CTAPH	168.8	-3.842E+00	-2.277E+01	4	1.0000
CTAPV	6.127E+01	-0.9418	-1.31E+01	4	0.9999
CTDMH	1.415E+00	1.50E+03	-1.23E+04	2	0.9998
CTDMV	1.05E+01	-1.36E-02	8.97E+02	1	0.9989
CTDPH	3.444	1.533E+03	-1.192E+04	2	0.9997
CTDPV	9.572E+00	-1.616E-02	7.64E+02	1	0.9940
Pinal County Housing Meteorological Database					
PCAMH	175.9	0.9987	-0.7417	3	0.9999
PCAMV	129.4	0.9986	-0.6692	3	0.9999
PCAPH	103.7	-1.836E+00	-1.582E+01	4	0.9999
PCAPV	118.3	-1.727E+00	-1.458E+01	4	0.9999
PCDMH	1.705	1.581E+03	-1.399E+04	2	0.9978
PCDMV	0.0000	-1.120E+03	0.3556	5	0.9997
PCDPH	178.8	-1.832E+00	-1.837E+01	4	0.9979
PCDPV	306.0	0.9992	-0.6018	3	0.9999
Equation Types					
1	Linear and Reciprocal: $Y = A + BX + C/X$				
2	Second Order Hyperbola: $Y = A + B/X + C/X^2$				
3	Hoerl Function: $Y = A * B^X * X^C$				
4	Log Normal Equation: $Y = A * e^{((\ln X - B)^2/C)}$				
5	Cauchy Function: $Y = 1/(A*(X + B)^2 + C)$				

SPREADSHEET TOOL DESIGN

The spreadsheet tool was designed to be representative, flexible, and fast for use in evaluating the downwind PM_{10} impacts from use of specific unpaved road segments in Pinal County. The users for which the tool was designed are PCAQCD staff who are tasked with recommending unpaved roads for paving by Pinal County Public Works Department. The tool was designed to provide an objective method for assessing the comparative PM_{10} impacts of unpaved roads on nearby receptors as residential development encroaches near these emission sources.

The spreadsheet tool layout consists of a cover worksheet and several support worksheets. The cover worksheet contains all of the user data entry and program output cells. The user entry data are designed to trigger responses from lookup tables in the support pages and to combine these responses into final answers. These lookup tables include lists of emission factors and unit PM_{10} air quality impacts computed by the curvefitting equations designed to represent the outputs of the CAL3QHCR modeling runs. A separate data entry cell in the cover worksheet asks the user to input the daily traffic count for the unpaved road being studied. The product of the emission factor, the unit air quality impact (at a downwind distance entered by the user), and the daily traffic count are calculated in one of the support worksheets and reported at the right center of the cover worksheet in terms of annual average and maximum 24-hour average PM_{10} impacts at the specified downwind distance from the road.

The supporting worksheets in the spreadsheet model contain calculations of PM_{10} emission factors and unit air quality impacts. The emission factor worksheet uses the silt content, moisture content, and vehicle speed measured on each of the five unpaved roads that were tested in each of the five major soil units to compute PM_{10} emission factors for each road in units of pounds of emission per vehicle mile traveled. When the user selects the major soil unit on the cover worksheet, this worksheet provides the emission factor for that soil type. The air quality impact worksheet computes the annual average and maximum 24-hour averge air quality impacts from a roadway emitting 1.0 gram per second of PM_{10} at the downwind distance entered by the user in the cover worksheet. The unit air quality impacts are then multiplied by the product of the emission factor representing a single vehicle per hour traveling over the unpaved road segment, as converted in units from pounds per mile per day to grams per mile per second, and the daily vehicle count entered by user to produce the air quality impacts at the traffic level and downwind receptor distance entered by the user. These air quality impacts are reported by the spreadsheet at the right center of the cover worksheet. The user can thus observe the changes in estimated air quality impacts that occur as different major soil types, meteorological datasets, roadway orientations, receptor locations, and traffic counts are entered by the user into the cover worksheet.

The user manual for the spreadsheet tool is presented in Attachment A.

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Chapter 3 – Attachment A

User Manual for Spreadsheet Model Used For Computing PM_{10} Impacts from Unpaved Road Travel in Pinal County, Arizona

Introduction

This spreadsheet tool is designed to enable the user to compute the downwind PM_{10} air quality impacts of vehicle travel over unpaved roads in the agricultural district of Pinal County, Arizona. The tool was developed at the request of the Pinal County Air Quality Control District and through funding provided by the Arizona Department of Transportation. The spreadsheet tool was created as an Microsoft Excel file and is designed to be used with version 2000 or higher.

PM_{10} concentrations downwind of an unpaved road are computed in this spreadsheet as the product of several different factors, several of which are entered by the user and others that are preprogrammed into the spreadsheet. Downwind pollutant concentrations are generally dependent upon three factors: the emission factor of the generating source, the activity rate of the source, and the dispersion rate of emissions downwind of the source.

The unpaved road travel emission factor chosen for this spreadsheet is the emission factor equation for light-duty traffic published by EPA in AP-42. This equation uses loose soil silt content, soil moisture content, vehicle speed, and the number of precipitation days per year as variables. The form of the equation, and the constants recommended by AP-42, are reproduced below:

$$E = [(k)(s/12)^a(S/30)^d/(M/0.5)^c - C][(365 - P)/365]$$

where:
- E = particulate matter emission rate, pound per vehicle miles traveled (lb/VMT)
- k = particulate size factor (dimensionless) = 1.8 for PM_{10}
- s = surface material silt content (%)
- S = mean vehicle speed, miles per hour (mph)
- M = surface material moisture content (%)
- a = empirical constant = 1.0 for PM_{10}
- c = empirical constant = 0.2 for PM_{10}
- d = empirical constant = 0.5 for PM_{10}
- C = PM_{10} emissions from vehicle exhaust, brake wear, and tire wear (lb/VMT)
- P = number of precipitation days per year on which 0.01 inches or more rain falls (days/yr)

The road travel activity rate is entered by the user into the spreadsheet. The units of activity are light-duty vehicles per day passing the midpoint of the road segment of interest. In unpaved road monitoring conducted in June 2005 on five unpaved roads in the agricultural district, daily average vehicle counts ranged from 118 to 644 vehicles per day over a one-week period.

To compute air quality impacts downwind of an unpaved road, the dispersion model CAL3QHCR was run with three locally collected meteorological datasets. The meteorological datasets were collected by PCAQCD at Cowtown (2004), Casa Grande (2004), and Pinal County Housing/Eleven Mile Corner (2003). Model runs were performed for one-mile lengths of unpaved roads running in north-south and east-west directions. The air quality impacts and downwind distances modeled under each meteorological dataset and roadway orientation were then processed through a curvefitting program to develop a mathematical equation that enables a user to interpolate the modeling results between the receptor locations specified in the modeling runs. The receptor locations varied between 25 meters and 500 meters in each direction from the center point of the road segment along a line perpendicular to the roadway centerline. The modeling runs were all conducted at unit PM_{10} emission rates of 1.0 gram per second per road mile.

The air quality impacts computed by the model are the product of the internally calculated emission factor and dispersion factor, and the activity rate entered by the user. The impacts are reported in units of micrograms per cubic meter ($\mu g/m^3$) for both annual average and maximum 24-hour PM_{10} concentrations.

Spreadsheet Use

The spreadsheet tool consists of four worksheets. All user entries should be made in the designated cells in the first worksheet named “DataEntry.” The remaining worksheets contain data and calculations that are used in computing the intermediate and final results, which are presented in yellow-highlighted cells in the “DataEntry” worksheet. Descriptions of the data entry sections, and limitations on values to be entered, are described below. Expanded descriptions of the spreadsheet components and development are presented above in the main report.

1. Check the Nearest Meteorological Monitoring Station

In this section of the “DataEntry” worksheet, enter an “x” into the box next to the meteorological monitoring station closest to the road segment being evaluated. The three monitoring stations are shown on the soil map at the bottom of this worksheet. Failure to check one of these boxes, or more than one of these boxes, will cause the spreadsheet to show the error message “#N/A” in the “Calculated PM_{10} Emission Factor” box.

1. Check the Nearest Meteorological Monitoring Station: (enter "x" in one box only)	
Cowtown	x
Casa Grande	
11-Mile Corner	

2. Enter the Major Soil Unit of the Area in Which the Unpaved Road is Located:

The soil map shown on the "DataEntry" worksheet covers the western portion of Pinal County. Five major soil units are found within that portion of this area under agricultural cultivation. The numbers and colors of these major soil units are shown in the legend to the left of the soil map. The soil unit numbers also appear in the larger font on the map itself. Enter the number of the major soil unit in which the unpaved road of interest is located in the box next to "Major Soil Unit No.:". The entry of a soil unit number not included in the legend will cause the spreadsheet to show the error message "#N/A" in the "Calculated PM_{10} Emission Factor" box. Correct entries in the boxes in sections 1 and 2 will result in the spreadsheet showing values for annual average and maximum 24-hour PM_{10} emission rates in the "Calculated PM_{10} Emission Factor" box. The values and formulas used to calculate these emission factors are contained in the "EmisFctr" worksheet of this spreadsheet.

2. Enter the Major Soil Unit Number of the Area in Which the Unpaved Road is Located:		
Major Soil Unit No.:	1	
Calculated PM10 Emission Factor:		
PM10 Emission Factor =	0.594	lb/VMT - Ann. Avg.
	0.647	lb/VMT - Max. Day

3. Select Orientation of the Unpaved Road:

Within the agricultural district, most unpaved roads run either north-south or east-west. The orientation is important because of the different air quality impacts governed by the prevailing wind directions. In one of the two boxes provided, check the orientation of the road to be evaluated. If the road of concern does not follow one of these two ordinal directions, select the direction that is closest to the orientation of the road centerline. If no orientation direction is selected, or if both boxes are checked, the modeled air quality impact will be reported as "#N/A".

3. Select Orientation of the Unpaved Road: (enter "x" in one box only)	
North-South	x
East-West	

4. Select Direction of Receptor from Unpaved Road:

For a line source of infinite length with no bends, the air quality impacts will be uniform at all points equidistant from the edge of the source. Thus, the air quality impacts along a line perpendicular to the line source, such as an unpaved road, will represent impacts along any other line that is perpendicular to the road. Because air quality impacts will differ between one side of the road and the other, however, please indicate the direction from the road that the receptor of interest lies. Note that the appropriate alternatives appear in this section of the spreadsheet in response to the centerline orientation of the road selected in section 3 above. Failure to check one of the boxes in this section, or the checking of both boxes, will result in the modeled air quality impact being reported as “#N/A”.

4. Select Direction of Receptor from Unpaved Road: (enter "x" in one box only)	
West	x
East	

5. Enter the Separation Distance Between the Nearest Road Edge and the Receptor:

In order to compute the air quality impact, the separation distance between the receptor and the nearest road edge needs to be identified. Enter this distance in either meters (m) or feet (ft) in the appropriate box. Because the dispersion modeling using CAL3QHCR did not include any receptors that were closer than 25 meters to the road edge, the curvefitting equations will not accurately extrapolate any values for separation distances shorter than 25 meters. The equations will, however, fairly extrapolate air quality impacts at distances greater than 500 meters, the maximum separation distance used in the modeling. If a numerical value of 25 meters, 82.02 feet, or more is not entered into the appropriate box, or if values are entered into both boxes, the modeled air quality impact is reported as “#VALUE”.

5. Enter the Separation Distance Between the Nearest Road Edge and the Receptor: (enter value in one box only)		
Separation Distance	25	m
(value cannot be less than 25 m or 83 ft)		ft

6. Enter Number of Vehicles Per Day:

The activity rate in this spreadsheet model is dictated by the number of vehicles per day passing the point on the unpaved road segment closest to the receptor of interest. Enter the daily traffic count in the box. The model assumes an hourly distribution of traffic that is equal to the average recorded on the five unpaved roads tested in the agricultural district in June 2005. Failure to enter the number of vehicles per day will result in the modeled air quality impacts to be reported as "0".

6. Enter Number of Vehicles Per Day:		
Vehicles Per Day:	200	vehicles/day

7. PM_{10} Emission Rates and Air Quality Impacts:

Based on the data entered by the user in sections 1 through 6 of the "DataEntry" worksheet, the spreadsheet model will compute both annual average and maximum daily PM_{10} emissions rates and air quality impacts. The emission factors are reported in units of pounds of PM_{10} emitted per mile of road under the traffic levels specified by the user. The emissions rates for annual and maximum 24-hour averaging periods are different because the annual rate includes the precipitation factor that is not included in the calculation of the maximum 24-hour emission rate. Similarly, the annual average PM_{10} air quality impact is based on the annual average emission rate and the annual meteorological conditions, while the maximum 24-hour average impact is based on the maximum 24-hour emission rate and the meteorological conditions for the worst-case day.

Calculated PM10 Emission Rate:		
PM_{10} Emission Rate =	118.7	lb/mi-day - Ann. Avg.
	129.3	lb/mi-day - Max. Day
Modeled PM_{10} Impact at Receptor Site:		
Annual Impact:	**260.8**	**ug/m3 - Ann. Avg.**
Max. 24-Hr. Impact:	**749.4**	**ug/m3 - Max. Day**

The spreadsheet tool has been locked to prevent accidental modification of the support data or equations. This protection scheme does not require a password, however, to unlock. If the user desires to edit any of the support data, equations, or format of the spreadsheet, simply go to the Tools menu list in Excel, select Protection, and then select Unprotect Sheet to access all portions on an individual worksheet.

The spreadsheet tool has been designed to simply compute the air quality impacts of a single selected scenario of meteorological conditions, major soil type, roadway orientation, and daily traffic count. The resulting cover page can be printed to record the output of each scenario. Boxes are included in the left center of the cover sheet for entering the names of the road being evaluated and the nearest intersecting road. The spreadsheet pages are displayed in Attachment 1 for reference.

Spreadsheet Tool Worksheets

PM_{10} Air Quality Impact Model - Unpaved Road Travel in the Agricultural District of Pinal County, Arizona

1. Check the Nearest Meteorological Monitoring Station:
(enter "x" in one box only)

Cowtown	x
Casa Grande	
11-Mile Corner	

2. Enter the Major Soil Unit Number of the Area in Which the Unpaved Road is Located:

Major Soil Unit No.: 1

Calculated PM10 Emission Factor:

PM10 Emission Factor = 0.594 lb/VMT - Ann. Avg.
0.647 lb/VMT - Max. Day

3. Select Orientation of the Unpaved Road:
(enter "x" in one box only)

North-South	x
East-West	

4. Select Direction of Receptor from Unpaved Road: (enter "x" in one box only)

West	x
East	

5. Enter the Separation Distance Between the Nearest Road Edge and the Receptor:
(enter value in one box only)

Separation Distance (value cannot be less than 25 m or 83 ft): 25 m; ft

6. Enter Number of Vehicles Per Day:

Vehicles Per Day: 200 vehicles/day

Calculated PM_{10} Emission Rate:

PM_{10} Emission Rate = 118.7 lb/mi-day - Ann. Avg.
129.4 lb/mi-day - Max. Day

Modeled PM_{10} Impact at Receptor Site:

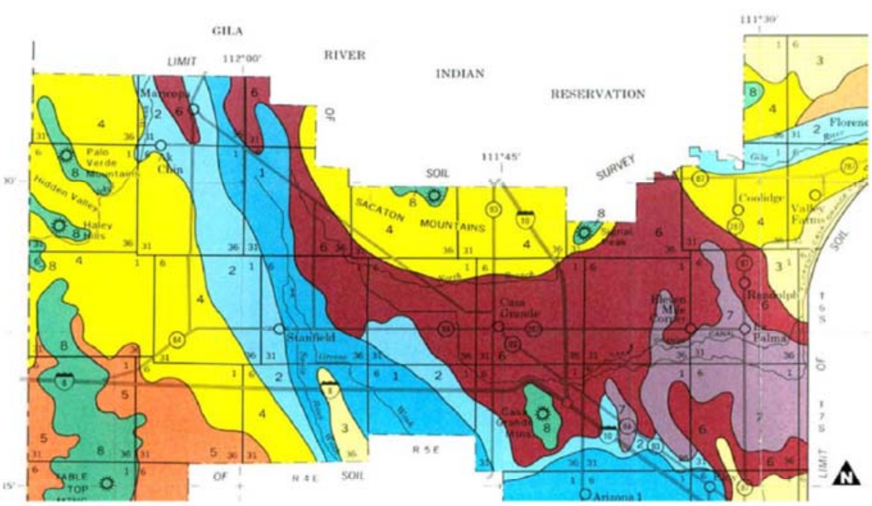
Annual Impact: 260.9 ug/m3 - Ann. Avg.
Max. 24-Hr. Impact: 749.7 ug/m3 - Max. Day

Road To Be Evaluated:

Nearest Intersecting Road:

Major Soil Unit Colors and Numbers

=1
=2
=4
=6
=7



UnpavedRoad_SpreadsheetTool_v1.0.xls, DataEntry 9/21/2005

Emission Factors

Project: Pinal County Unpaved Roads

Emission Factor

$E = [(k)(s/12)^a(S/30)^d/(M/0.5)^c - C](365 - P)/(365)$

where
E = size-specific emission factor (lb/VMT)
s = surface material silt content (%)
S = mean vehicle speed (mph)
M = surface material moisture content (%)
C = emission factor for vehicle fleet exhaust, brake wear, and tire wear (lb/VMT)
P = number of precipitation per year on which 0.01 in. or more of rain falls (day/yr)
a = 1 for PM_{10}
c = 0.2 for PM_{10}
d = 0.5 for PM_{10}
k = 1.8 for PM_{10}
C = 0.00016 lb/VMT
P = 30 day/yr

Unpaved Road Measurements

Road	Silt Content	Moisture Content	Mean Speed	Soil Area
Alsdorf Road	2.60%	0.097%	42.8	1
Amarillo Valley Road	7.40%	0.270%	40.7	4
Curry Road	4.20%	0.154%	40.5	7
Peters Road	7.10%	0.313%	34.1	2
White & Parker Road	5.90%	0.477%	40.5	6

		PM_{10} Emission Factor, lb/VMT	
Road	Soil Unit	(Ann. Avg.)	(Max. Day)
Alsdorf Road	1	0.594	0.647
Peters Road	2	1.145	1.247
Amarillo Valley Road	4	1.341	1.461
White & Parker Road	6	0.953	1.038
Curry Road	7	0.851	0.927

UnpavedRoad_SpreadsheetTool_v1.0.xls, EmisFctr 9/21/2005

Curve Fitting Equations

A = annual
D = 24-hr
M = minus, west or south
P = plus, east or north
V = north-south road
H = east-west road

Receptor Distance = 25 meters
Emission Rate = 14.96 gm/sec - Anı
= 16.30 gm/sec - Ma

User-Entered Selections

Facility	Minus/Plus	Vert/Hor
CT	M	V

Model Run	Best Fit Equation	A	B	C	Impact at Receptor Using Unit Emission Rate (ug/m^3)	Impact at Receptor Using Calc. Emission Rate (ug/m^3)
CGAMH	25	1.26E-06	5.97E+02	-0.4201	14.6	218.8
CGAMV	22	1.83E+02	-4.43E+00	-2.34E+01	15.0	224.4
CGAPH	25	1.291E-06	4.433E+02	-0.2252	17.3	258.3
CGAPV	19	154.0	0.9988	-0.6911	16.2	241.7
CGDMH	22	348.3	-4.069E+00	-2.48E+01	40.8	665.7
CGDMV	19	2.98E+02	0.9985	-0.5969	42.1	685.7
CGDPH	7	1.295	1.311E+03	-1.039E+04	37.1	604.9
CGDPV	7	1.600	1.259E+03	-8.38E+03	38.5	628.3
CTAMH	22	5.673E+01	-1.197E+00	-1.312E+01	12.8	192.0
CTAMV	19	1.35E+02	0.9982	-0.6213	17.4	260.9
CTAPH	22	168.8	-3.842E+00	-2.277E+01	18.9	282.7
CTAPV	22	6.127E+01	-0.9418	-1.31E+01	16.3	243.8
CTDMH	7	1.415E+00	1.50E+03	-1.23E+04	41.8	682.1
CTDMV	4	1.05E+01	-1.36E-02	8.97E+02	46.0	749.7
CTDPH	7	3.444	1.533E+03	-1.192E+04	45.7	744.8
CTDPV	4	9.572E+00	-1.616E-02	7.64E+02	39.7	647.4
PCAMH	19	175.9	0.9987	-0.7417	15.6	234.0
PCAMV	19	129.4	0.9986	-0.6692	14.5	216.8
PCAPH	22	103.7	-1.836E+00	-1.582E+01	20.6	308.5
PCAPV	22	118.3	-1.727E+00	-1.458E+01	22.1	330.6
PCDMH	7	1.705	1.581E+03	-1.399E+04	42.6	693.7
PCDMV	25	0.0000	-1.120E+03	0.3556	36.8	599.5
PCDPH	22	178.8	-1.832E+00	-1.837E+01	44.6	726.8
PCDPV	19	306.0	0.9992	-0.6018	43.2	704.6

UnpavedRoad_SpreadsheetTool_v1.0.xls, CurveFit 9/21/2005

CHAPTER FOUR
CONTROL EFFICIENCY AND COST-EFFECTIVENESS OF UNPAVED ROAD EMISSION CONTROL MEASURES

DUST CONTROL MEASURES

Controls for dust emissions from unpaved road travel take several forms, which include the following:

- Increasing the moisture content of unpaved road surface soils;
- Binding smaller particles to larger particles in unpaved road surface soils;
- Covering unpaved road surface soils with gravel; and
- Sealing unpaved road surface soils with pavement or other durable materials.

In the following sections, general information on each of these categories of control is presented. More detailed information is provided in Appendix A on controls that involve the application of dust palliatives applied to road surfaces.

INCREASING MOISTURE CONTENT

Moisture in the surface soils of unpaved roads causes particles to adhere to each other through the surface tension of connecting water droplets and the adhesion of droplets to dust particles. The moisture content of surface soils can be increased either through direct application of water to roadway surfaces, or through the attraction of water to deliquescent salts added to surface soils.

Water is available on a very limited basis, with respect to access, to road maintenance agencies in the rural portions of Pinal County. Because of the scattered distribution of supply points, the conveyance of water in tanker trucks to rural unpaved roads requires significant time and travel. Watering provides very short-term reductions in dust generation due to high surface evaporation rates during the dryer months of the year. When watering is feasible, regular, light watering is more effective than less frequent, heavy watering. (Bolander, 1999)

Unpaved road dust control can also be implemented by the application of deliquescent salts to roadway surfaces. Calcium chloride and magnesium chloride absorb moisture from the air to keep surface soils in which these chemicals have been mixed at higher moisture contents than untreated soils. At 77ºF and 30% humidity, for example, calcium chloride will absorb more than twice its own weight in water. (CPWA, 2005) The performance of chlorides depends on the percent of surface soil passing a 200-mesh screen, with recommendations between 10 and 20 percent. (Morgan, 2005) Potential disadvantages to the use of these salts are that roads may become slippery when wet and vehicle corrosion may occur. Additionally, prolonged rainfall will leach the salts from the roadway, potentially impacting groundwater and surface water quality, and attract wildlife, potentially causing safety concerns. The practical duration of an application of one of these salts is no more than one year. (Morgan, 2005) Sodium chloride, or common rock salt, is also deliquescent, and has been tested in a limited number of studies, but it is not as effective as calcium or magnesium chloride.

BINDING PARTICLES TOGETHER

The largest group of dust palliatives used on unpaved roads and airfields consists of chemicals that are designed to bind fine soil particles together or to larger particles. These chemicals fall into several subgroups, such as the following:

- Petroleum-based binders,
- Organic non-petroleum dust suppressants (lignins),
- Electrochemical stabilizers,
- Synthetic polymer products, and
- Pozzuolannic minerals (i.e. lime, cement, etc.).

<u>Petroleum-based Binders</u> – Petroleum-based binders used for dust suppression include emulsified asphalts, cutback asphalt, and Bunker C. These agents are used to coat surface soil particles with a thin layer of asphalt that binds the soil particles together and decreases their likelihood of becoming airborne. Some of these binders exhibit no adhesive properties, but instead increase the mass of fine particles, reducing their ability to become airborne. (Nevada DOT, 2003) Emulsified asphalt, because it is a mixture of asphalt and water in very small droplets, has the capability to penetrate unpaved road surfaces to coat more than just the surface particles, especially if the product is mechanically mixed into the top inch or two of road surface with a grader. Petroleum-based binders that contain fractions of lighter solvents, and especially those containing polycyclic aromatic hydrocarbons (many of which are carcinogens), can contaminate waterways if any migration of these lighter fractions occurs due to runoff.

<u>Organic Nonpetroleum Dust Suppressants</u> – Organic nonpetroleum dust suppressants include lignosulfonates, resins, and vegetable oils. Lignosulfonates derive from the manufacture of paper during which lignin is extracted from wood fibers. Lignin binds wood cells together and is a natural polymer. As a byproduct of paper manufacture, it occurs in solution with sodium, calcium, ammonium, or magnesium bisulphate. Lignosulfonates bind soil particles together due to a combination of chemical and physical interactions. Resins are usually synthesized as combinations of lignosulfonates and additives designed to neutralize adverse effects. Lignosulfonates are water soluble and will leach out of, or deeper into, roadway surface with rainfall. These products are also corrosive to aluminum and its alloys unless calcium carbonate is added. Lignosulfonates have a useful duration of a few months and work best with surface materials that have high fine contents and high plasticity indices in a dry environment. (CPWA, 2005) Because lignosulfonates are derivatives of sulfuric acid, the leaching of these palliatives by runoff can adversely impact watershed

areas by affecting the acidity of water sources. Lignosulfonates are reported to not bind well on roads that had been treated previously with chloride compounds. (Lunsford, 2001)

Electrochemical Stabilizers – Electrochemical stabilizers include sulphonated petroleum, ionic stabilizers, and enzymes. These products are intended to neutralize the ionic charges of clay-sized particles, thereby allowing electrostatic forces to bind the particles. To be effective, electrochemical stabilizers need to be worked into the road surface, requiring additional equipment and labor expense.

Synthetic Polymer Products – Synthetic polymer products include polyvinyl acrylics and acetates that are designed to bind soil particles together and form a semi-rigid film on the road surface. These products are formulated as either water soluble liquids or dry powders intended to be mixed with water. Because the products are applied in liquid form and are required to dry in binding soil particles together, care needs to be taken after application to assure that traffic will be diverted from application areas until curing is completed. Curing periods typically extend from 12 to 24 hours.

Pozzuolannic Minerals – Pozzuolannic minerals, such as lime and cement, are typically added to non-plastic road surface material to produce a thin crust. These stabilizers must be field mixed into the road material and compacted. These surfaces, once hardened however, cannot reharden once disturbed by abrasive forces, such as those created by roads being crossed by snow machines or by roads being rebladed.

COVERING OF UNPAVED ROAD SURFACE SOILS WITH GRAVEL

The abrasion of unpaved road surface soils and release of fugitive dust by unpaved road traffic can be reduced by the application of gravel to the road surface. Gravel provides a hard-wearing surface that protects soils from the abrasive forces of vehicle wheels. Traffic causes abrasion between the aggregates, however, which over time creates fine dust. The degradation is somewhat dependent upon the hardness of the aggregate. Gravel will not reduce the strength of vortex airflows behind passing vehicles from entraining loose soil particles into the air, however. In the absence of a well-constructed roadbase using crushed aggregate, surface gravel will be pushed down into the road surface by traffic, especially during wet conditions. If the road surface does not contain a sufficient quantity of fine material of high plasticity (cohesion) to hold surface gravel in place, traffic can also cause surface gravel to be expelled laterally from the road's driving lanes. To be effective over more than a short period of time, new gravel applied to a road must be anchored to the road surface by incorporation into a cohesive surface layer, whether by use of well-graded aggregate mixes or by use of soil adhesives (i.e., chip seals). Even washed, well-graded wear courses (like D-1) produce dust over time due to traffic wear causing aggregate degradation.

SEALING OF UNPAVED ROAD SURFACE SOILS WITH PAVEMENT OR OTHER DURABLE MATERIALS

The most effective, and expensive, method of controlling fugitive dust emissions from unpaved road surfaces is the application of pavement or other durable materials to the road surfaces. Asphalt concrete and Portland concrete wear courses, when applied to road surfaces, provide durable and effective traffic surfaces that prevent the abrasion of soil surfaces. Except for roadways carrying more than 250 to 500 vehicles per day, the use of paving to control dust emissions may not be cost-effective. (Bolander, 1999) Thin pavements, such as chip seals, have been applied to roads in Arizona, but these surfaces have fallen apart completely if exposed to frequent heavy truck traffic.

SELECTION GUIDES

Several publications found in the literature search for this study contain selection guides for choosing chemical dust palliatives on the basis of road traffic levels, soil type, and other parameters. These guides are presented in Appendix B.

BIBLIOGRAPHY

An extensive bibliography of unpaved road dust control literature has been compiled by Temple Stevenson for a report on dust control methods for unpaved mining roads in Wyoming's Powder River Basin. (Stevenson, 2004) This bibliography is reproduced in Appendix C.

COSTS AND BENEFITS

The costs of dust control on unpaved roads in rural Pinal County can be calculated on the basis of available market data, but the benefits of each control method will vary depending on the soil type, traffic level, and road design, among other factors. As a result, approximate costs for various control methods are presented here on the basis of delivery to and application in Pinal County. The control methods included in the cost analysis are limited to those that are technologically feasible in central Arizona. The range of control effectiveness for each of the control methods derives from the literature, not from studies conducted in hot climates.

The costs of dust control methods, per mile of treated roadway in Pinal County, are summarized in Table 1. Labor and equipment costs are based on data provided by the Maricopa County Department of Transportation. Detailed cost calculations are presented in spreadsheet format in Appendix D.

Table 1: Dust Control Method Costs and Effectiveness
($ per mile of road treated)

Dust Control Category	Specific Product	Control Cost ($ per mile of road treated)	Control Effectiveness Range	Control Duration
Moisture Increase	Watering	$31	0% - 50%*	0.5-1 hours
	Calcium Chloride	$18,000	0% - 70%**	6 months
Particle Agglomeration	EK-35	$16,000	0% - 99%***	1 year
	Lignosulfonate	$12,000	0% - 90%*	2 months
	Soil Sement	$18,000	0% - 84%****	1 year
Soil Coverage	Gravel	$16,000	0% - 30%*	1 year
	Asphalt Paving	$311,000	90% - 99%	20 years

* Orlemann, 1983
** Morgan, 2005
*** MRI, 2002
**** California ARB, 2002

LITERATURE CITED

Bolander, P. and A. Yamada, 1999, *Dust Palliative Selection and Application Guide*, U.S. Department of Agriculture Forest Service, http://www.dot.state.ak.us/stwddes/research/assets/pdf/dust_sag.pdf, accessed on December 20, 2005

California ARB, 2002, *Evaluation of The Air Quality Performance Claims For Midwest Industrial Supply, Inc. Soil Sement Dust Suppressant*, California Air Resources Board, http://www.arb.ca.gov/eqpr/midwest.htm, accessed on January 20, 2006

CPWA, 2005, *Dust Control for Unpaved Roads, A Best Practice by the National Guide to Sustainable Municipal Infrastructure*, Canadian Public Works Association, http://www.infraguide.ca/lib/Db2File.asp?fileid=4555, accessed on January 5, 2006

Lunsford, G.B., and J.P. Mahoney, 2001, *Dust Control on Low Volume Roads, A Review of Techniques and Chemicals Used*, prepared for Federal Highway Administration, http://www.dot.state.ak.us/stwddes/research/assets/pdf/fhwa_lt_01_002.pdf, accessed on January 5, 2006

Morgan, R.J., V.R. Schaefer, and R.S. Sharma, 2005, *Determination and Evaluation of Alternative Methods for Managing and Controlling Highway-Related Dust, Phase II – Demonstration Project*, Iowa State University, http://www.dot.state.ia.us/materials/research/reports/reports_pdf/hr_and_tr/reports/tr506.pdf, accessed on December 23, 2005

MRI, 2002, *Report of 3-Month Test of Dust Suppression Products – Preliminary Testing, Midwest Industrial Supply, Inc. EK35*, prepared by Midwest Research Institute for U.S. Environmental Protection Agency, http://www.epa.gov/etv/pdfs/vrvs/05_vr_ek35.pdf, accessed on January 10, 2006

Nevada DOT, 2004, *Construction Site Best Management Practices Manual*, http://www.nevadadot.com/reports_pubs/Water_Quality/pdfs/BMP_Section3.pdf, accessed on January 4, 2006

Orlemann, J.A., F.J. Kalman, J.A. Cummings, E.Y. Lim, 1983, *Fugitive Dust Control Technology*, Noyes Data Corporation

Sanders, T.G., and J.Q Addo, 1993, *Effectiveness and Environmental Impact of Road Dust Suppressants*, http://www.ndsu.nodak.edu/ndsu/ugpti/MPC_Pubs/html/MPC94-28.htm, accessed on January 4, 2006

Stevenson, T., 2004, *Dust Suppression on Wyoming's Coal Mine Haul Roads*, prepared for Industries of the Future Converse Area New Development, http://www-personal.ksu.edu/~sstevens/Dust%20Manual%20102704.pdf, accessed on January 4, 2006

U.S. Army, 2006, Dust Palliative Dichotomous Key, U.S. Army Clean Air Research Center, http://www.bah-abingdon-staging-site.com/CAARC/info_rep/pdf/dustchecklist.pdf, accessed on January 4, 2006

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CHAPTER FIVE
BLUEPRINT FOR DEVELOPMENT OF A PM_{10} ATTAINMENT PLAN

INTRODUCTION

In 1995, the Pinal County Air Quality Control District (PCAQCD) began monitoring PM_{10} concentrations in several communities across the county. At a few of these sites, occasional exceedances of the national 24-hour ambient air quality standard for PM_{10} were recorded on high wind days. These exceedances were not considered to be violations of the standard because the conditions under which these exceedances occurred qualified as exempt natural events under a Natural Event Action Plan (NEAP) developed by PCAQCD and approved the U.S. Environmental Protection Agency (EPA). At one of the sites, Eleven Mile Corner, a number of exceedances were recorded but not counted as violations because the monitor site did not comply with EPA siting guidelines.

In 2001, PM_{10} concentrations that were not exempt from consideration as violations of the national 24-hour standard began to be recorded. During this year, the monitor at the county fairground site at Eleven Mile Corner was relocated to a location on the grounds that did satisfy EPA siting criteria. In 2002, this monitor was subsequently relocated one mile north to another location that satisfied EPA criteria—the Pinal County Housing Complex, a rural residential facility. Several exceedances that could not be discounted under the NEAP were recorded in 2002 and subsequent years. In 2002, EPA declined to reapprove the NEAP submitted by PCAQCD.

In an experiment designed to monitor worse-case PM_{10} conditions in the county in 2001, PCAQCD located a special studies monitor in an area referred to as Cowtown. The monitor location is adjacent to cattle feedlots, a grain processing complex, active agricultural lands, a railroad, and a county highway. Because the monitor is surrounded by disturbed soil, it does not meet EPA siting criteria. The monitor does record frequent exceedances of the national 24-hour standard and continuous exceedances of the annual standard.

Because of the violations recorded at the Pinal County Housing Complex, PCAQCD anticipates that EPA will deem a portion of central Pinal County, where land uses include agricultural production, to be non-attainment for the PM_{10} 24-hour standard. The northernmost portion of Pinal County, including Apache Junction, is currently part of the Maricopa Area PM_{10} non-attainment of metropolitan Phoenix. A determination of whether the central portion of Pinal County violates the national annual standard cannot be made until all of the 2005 monitoring data collected at the Pinal County Housing Complex site is evaluated. Under current federal regulations, if EPA deems central Pinal County to be non-attainment for one or both of the PM_{10} standards, PCAQCD will be required to develop and submit to EPA an attainment plan. These regulations, however, have been proposed for modification, and the modifications may well make the requirements for a non-attainment plan in Pinal County moot. The details of this proposal are discussed in Section 1.

This study is intended to help PCAQCD map a course for the development of a PM_{10} attainment plan, should one be required by EPA. The study includes a summary of the contents of an attainment plan, which is presented in Section 2; an analysis of the PM_{10} air quality, which is discussed in Section 3; a review of the PM_{10} emission inventory for Pinal County, which is included in Section 4; a discussion of PM_{10} air quality modeling performed in the County, in Section 5; an analysis of the process and tools available for selecting control measures to include in the plan, which is included in Section 6; an evaluation of how to prepare a PM_{10} attainment demonstration, which is presented in Section 7; and a summary of the conclusions of the study, which is contained in Section 8.

PM_{10} PLANNING REQUIREMENTS

Under Section 110(a)(1) of the federal Clean Air Act (CAA), states must submit state implementation plans (SIPs) upon request of EPA. A complete SIP must contain provisions listed in Section 110(a)(2) and must comply with requirements of 172(c). A SIP must also satisfy Part D, Subpart 4 requirements for PM_{10} non-attainment areas.

Section 110(a)(2) sets forth the general requirements of an adequate air pollution control program. Section 172(c) summarizes the general requirements for the content of an acceptable non-attainment plan. The requirements of Section 172(c) include the following:

1 Implementation of all reasonably available control measures as expeditiously as practicable;

2 Demonstration of attainment of national ambient air quality standards;

3 Demonstration of reasonable further progress;

4 Implementation of a permitting system for new or modified major stationary sources;

5 Inclusion of enforceable emission limitations and control measures together with schedules for compliance by the applicable attainment date;

6 Compliance with Section 110(a)(2) requirements;

7 Demonstration of equivalency for the use of any modeling, emission inventory, and planning procedures not specified by EPA; and

8 Implementation of contingency measures if the area fails to make reasonable further progress or attain the ambient air quality standard by the applicable date.

Part D, Subpart 4 of the CAA establishes additional timeline requirements on the attainment of PM ambient air quality standards. These timelines were originally applicable to jurisdictions that demonstrated non-attainment with PM_{10} ambient air quality standards in 1990, when the latest amendments to the CAA were adopted. For jurisdictions that are deemed non-attainment for one or both of the PM_{10} standards now, plans are typically due to EPA within three years of nonattainment designation. This timing requirement, however, and the requirement for a nonattainment plan, may well be superceded by EPA action on a proposal published on January 17, 2006.

EPA is proposing to abolish the PM_{10} ambient air quality standard and substitute in its place a PM-coarse standard. The proposed standard would apply only to ambient particles with aerodynamic diameters between 2.5 and 10 microns. Furthermore, the PM-coarse standard is proposed to apply only within areas having a population of 100,000 or more where ambient PM-coarse is not dominated by emissions of windblown dust, agricultural activities, or mining operations. In metropolitan areas that are currently non-attainment for PM_{10}, such as the Maricopa area that includes the Apache Junction portion of Pinal County, the PM_{10} standard and requirements for progress toward attainment would continue in force until plans are approved by EPA for attaining the PM-coarse standard. In rural areas that are currently non-attainment for PM_{10}, such as the Hayden-Miami area that includes the northeastern corner of Pinal County, the PM_{10} standard would be revoked effective September 27, 2006.

Because the status of PM_{10} regulation is in a state of flux, EPA will probably not be designating any new PM_{10} non-attainment areas while the proposed changes in ambient air quality standards are under consideration. As a result, even if the monitoring data from the Pinal County Housing Complex site demonstrate three years of exceedances of the current 24-hour PM_{10} standard, EPA will most likely not act upon these data until after September 2006. If the final rulemaking does exempt areas from regulation in which PM-coarse air quality is dominated by windblown dust, agricultural activities, or mining operations, then the need for PM attainment planning in Pinal County may be moot.

PM_{10} AIR QUALITY

PM_{10} has been monitored at a number of sites in Pinal County during 2002 through 2004, the most recent three-year period for which data are available. These monitors were located at sites intended to satisfy EPA monitoring criteria prescribed in federal regulations (40 CFR 58, Appendix D). This guidance requires state and local air quality regulatory agencies to address six basic monitoring objectives:

1 To determine the highest concentrations expected to occur in the area covered by the network;

2 To determine representative concentrations in areas of high population density;

3 To determine the impact on ambient pollution levels of significant sources or source categories;

4 To determine general background concentration levels;

5 To determine the extent of regional pollution transport among populated areas and in support of secondary ambient air quality standards; and

6 To determine the welfare-related impacts in more rural and remote areas (such as visibility impairment and effects on vegetation).

The design of the Pinal County PM_{10} monitoring network is intended to satisfy all of these objectives.

EPA regulations define the designations of ambient air quality monitoring stations and, for one group, the number of stations. Networks of monitoring stations operated by state and local agencies are referred to as SLAMS (State and Local Air Monitoring Station) networks. No requirements on the minimum number of SLAMS stations are prescribed. In urban areas designated as metropolitan statistical areas (MSAs), a subset of the SLAMS sites are required to be designated as National Air Monitoring Stations (NAMS). Each MSA is required to have a minimum of two NAMS stations. Since there are no MSAs located in Pinal County (the minimum population for an MSA is 50,000 in a single community and 100,000 in the metropolitan area), none of the monitoring stations are required to be designated as NAMS. EPA policy also recognizes SPMs (Special Purpose Monitors), which are established for short term monitoring purposes.

It is unclear whether the PM_{10} monitors operated by PCAQCD are SLAMS or SPMs. As the agency reports in its 2004 air quality monitoring report:

> *It appears that the EPA has not utilized the SIP process to expressly designate SLAMS monitoring sites. In some cases EPA has relied upon grant agreements under Section 105 of the Clean Air Act as the vehicle for spelling out SLAMS requirements and approving SLAMS network designs. Pinal County Air Quality does not receive Section 105 grant funding directly from the EPA, and thus Pinal County's monitors are not covered by an express agreement designating these local units as SLAMS monitors.*

While PCAQCD intends that many of its PM_{10} monitors be designated as SLAMS sites, two of the monitors in its network are proposed to be designed as SPM sites. These sites are located at the City of Maricopa County Complex and at Cowtown.[3] Data recorded at these SPM sites, however, may be deemed by EPA as indicative of attainment status. In a policy memo, EPA has stated that "U.S. EPA is obligated to consider all publicly available, valid (i.e., collected in accordance with 40 CFR 58), and relevant data in the NAAQS regulatory process." Thus, all of the PM_{10} monitoring data collected by PCAQCD should be considered to be eligible for use in determining nonattainment status by EPA except that which was not collected in accordance with 40 CFR 58. In the 2004 annual air quality monitoring report, PCAQCD indicates that the Cowtown site does not comply with 40 CFR 58 because the sampler is surrounded by disturbed soil.

A tabulation of the PCAQCD PM_{10} monitoring sites during 2002 through 2004 is presented in Table 1.

PM_{10} monitoring data reported by PCAQCD to EPA are stored in EPA's AQS (Air Quality Subsystem) portion of the former AIRS database. Summary data from the AQS are available online. From this site, data on the estimated number of exceedances of the 24-hour PM_{10} standard at monitoring sites in Pinal County were extracted. Table 2 presents these data for 2002 through 2004.

The highest 24-Hour PM_{10} measurements recorded from 2002 through 2004 at each SLAMS and SPM station are presented in Table 3.

The AQS database reports that no exceedances of the annual PM_{10} standard occurred at the SLAMS sites during 2002 through 2004. However, the measurements collected by PCAQCD in 2003 through 2005, prior to quality control review, indicate that one of the co-located Pinal County Housing Complex monitors recorded a three-year average of 63.7 $\mu g/m^3$, which exceeds the annual PM_{10} standard of 50 $\mu g/m^3$. At the Cowtown site, the annual PM_{10} averages were 262 $\mu g/m^3$ (2002), 170 $\mu g/m^3$ (2003), and 132 $\mu g/m^3$ (2004).

Table 1: Pinal County Air Quality Control District PM_{10} Monitoring Sites - 2002 – 2004

Station	2002	2003	2004
State and Local Monitoring Stations			
Apache Junction Fire Station		x	x
Apache Junction Maintenance Yard	x	x	x
Casa Grande Downtown	x	x	x
Coolidge Maintenance Yard	x	x	x
Eloy City Complex	x	x	x
Mammoth County Complex	x	x	x
Pinal Air Park	x	x	x
Pinal County Housing Complex	x	x	x
Riverside Maintenance Yard		x	x
Stanfield County Complex	x	x	x
Special Purpose Monitors			
(City of) Maricopa County Complex			x
Cowtown Road	x	x	x
Riverside Maintenance Yard	x		

Table 2: Estimated Number of Violations of 24-Hour PM_{10} NAAAQS at SLAMS and SPM Stations in Pinal County

Station	2002	2003	2004
State and Local Monitoring Stations			
Apache Junction Fire Station	-	0	0
Apache Junction Maintenance Yard	0	0	0
Casa Grande Downtown	0	0	0
Coolidge Maintenance Yard	0	0	0
Eloy City Complex	0	0	0
Mammoth County Complex	0	0	0
Pinal Air Park	0	0	0
Pinal County Housing Complex	12	12	6
Riverside Maintenance Yard	0	0	0
Stanfield County Complex	13	6	0
Special Purpose Monitors[1]			
Cowtown	196	150	105

Notes: [1]Data for the Riverside Maintenance Yard are reported in the SLAMS section. No data are reported for the (City of) Maricopa County Complex site as that station commenced operation in December 2004.

Table 3: Highest 24-Hour PM_{10} Concentrations at SLAMS and SPM Stations in Pinal County

Station	2002	2003	2004
State and Local Monitoring Stations			
Apache Junction Fire Station	-	103	35
Apache Junction Maintenance Yard	62	95	-
Casa Grande Downtown	69	99	52
Coolidge Maintenance Yard	106	106	35
Eloy City Complex	146	154	46
Mammoth County Complex	53	89	30
Pinal Air Park	62	108	30
Pinal County Housing Complex	166	289	155
Riverside Maintenance Yard	-	101	34
Stanfield County Complex	352	171	80
Special Purpose Monitors			
Cowtown	1,391	718	600

The data in Table 2 suggest that three monitoring sites recorded exceedances of the 24-hour PM_{10} standard in the recent past. These sites were the Pinal County Housing Complex, the Stanfield County Complex, and the Cowtown sites. Analysis of monitoring data from each of these sites is presented below.

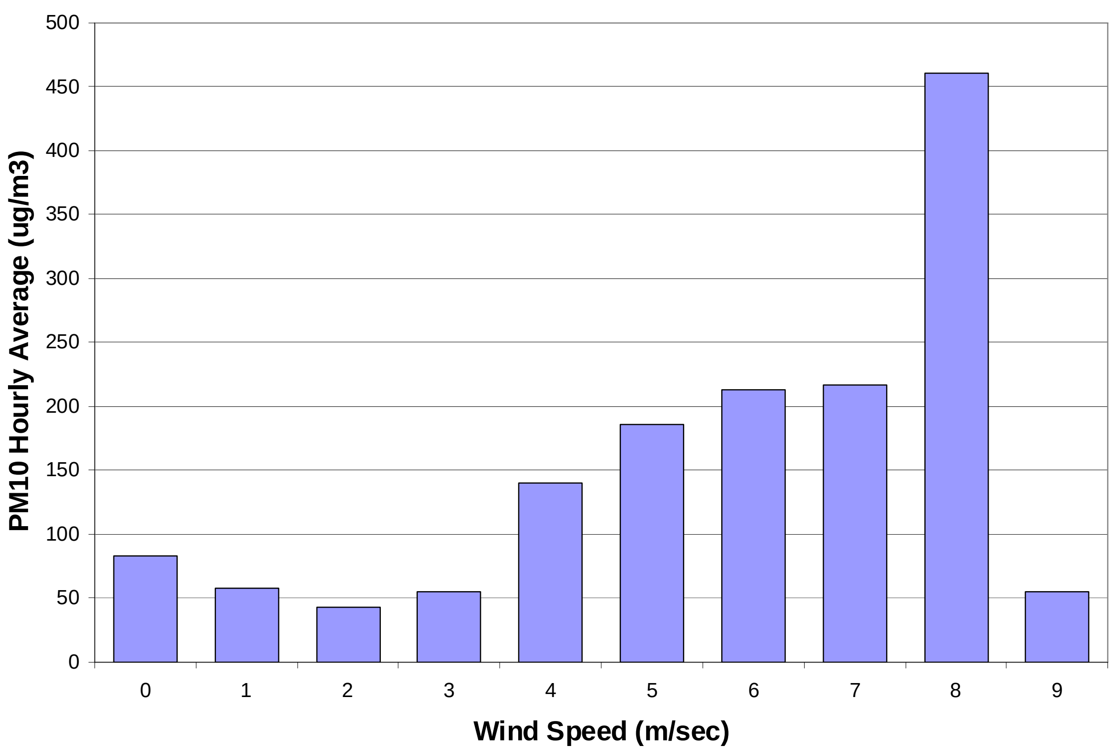
Pinal County Housing Complex

The Pinal County Housing Complex monitoring site is surrounded by sparsely vegetated desert land that is occasionally traversed by offroad vehicles or the vehicles of residents of a nearby residential housing complex. The monitor is located within a fenced area that houses the sewer lift station for the housing complex. The housing complex lies approximately 300 feet southeast of the monitor. A small dairy, two cotton gins, and the Pinal County Fairgrounds are approximately one mile to the south of the monitoring site.

PM_{10} data are currently collected at this site by both high volume filter-based samplers and a continuously recording tapered element oscillating microbalance (TEOM) monitor. Meteorological parameters are also measured by instruments mounted on a 3-meter tower. The continuously recorded data from the TEOM and the meteorological tower were evaluated to provide preliminary relationships between hourly average PM_{10} concentrations and wind speed and direction.

Figure 1 shows the relationship between PM_{10} concentration and wind speed at the Pinal County Housing Complex site in 2005. This relationship was developed by sorting hourly averaged PM_{10} concentrations by hourly wind speed range and averaging the concentrations measured within each range. Wind speed ranges were set to span 1 meter per second (m/sec) values from 0 m/sec to 9.7 m/sec (the highest wind speed recorded).

Figure 1: Average Hourly PM_{10} vs. Wind Speed – Pinal County Housing Complex, 2005



These data suggest a strong relationship between PM_{10} concentration and wind speeds above 2 m/sec. This relationship indicates that windblown dust is a significant contributor to higher PM_{10} concentrations measured at this site. The higher average PM_{10} concentrations at the lowest wind speeds of 0 and 1 m/sec, in comparison to 2 m/sec, indicate that localized sources, such as off-road vehicle use, may be impacting the monitoring site during periods of stagnant wind condition. In an attempt to identify other relationships between PM_{10} concentrations and wind speeds, several other statistical comparisons of these data were performed. A tabulation of these PM_{10} concentration statistics in relation to wind speed ranges is presented in Table 4.

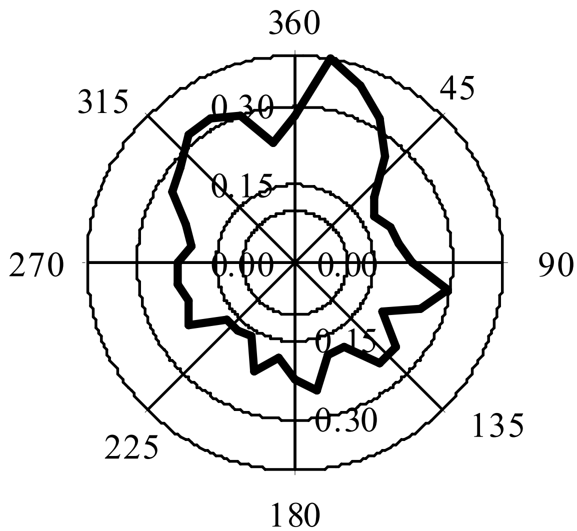
The peaking of PM_{10} maxima at 5 m/sec suggests that disturbed soil areas contributing to windblown dust impacts at the monitoring station have limited reservoirs of entrainable particles. If the soils near the monitoring station consisted of unlimited reservoirs, PM_{10} emissions would be proportional to wind speed, suggesting that soils need not be disturbed to contribute to windblown dust and that saltating particles bouncing over soil surfaces provided the driving force that released fine particles for entrainment. If the reservoirs of fine particles in surface soils are limited, then the primary force releasing fine particles most probably is anthropogenic disturbance. This result, if true, would suggest that reduction of soil disturbance by motor vehicles, or the treatment of disturbed surfaces to bind fine particles to larger ones, would reduce PM_{10} concentrations at this site.

Table 4: 2005 Pinal County Housing Complex PM_{10} – Wind Speed Relationships

Wind Speed (m/sec)	PM_{10} Mean (µg/m^3)	PM_{10} Std. Dev. (µg/m^3)	PM_{10} Coef. of Variation	PM_{10} Maximum (µg/m^3)	Hour Count (# hours)
0.00 – 0.99	82.5	89.7	109%	972	2,802
1.00 – 1.99	57.8	58.9	102%	719	3,700
2.00 – 2.99	42.6	46.1	108%	938	1,248
3.00 – 3.99	55.2	148.2	269%	2,334	549
4.00 – 4.99	140.2	555.0	396%	5,903	245
5.00 – 5.99	185.7	694.6	374%	6,850	99
6.00 – 6.99	213.2	343.8	161%	1,531	39
7.00 – 7.99	216.6	195.7	90%	607	19
8.00 – 8.99	460.8	112.6	24%	619	5
9.00 – 9.99	55.1	NA	NA	55	1

Analyses of the relationship between PM_{10} concentrations and wind direction were also conducted. Using a conditional probability function (CPF) statistical method, the probabilities of hourly PM_{10} concentrations measured when the wind blows from each of 36 compass quadrants being in the highest 30% of PM_{10} concentrations recorded during the year were plotted. A copy of this plot is presented in Figure 2. This figure indicates that PM_{10} concentrations at this monitoring site are not dominated by emissions from any single source or from sources located in any single arc upwind of the monitoring site.

Figure 2: High PM_{10} Probability by Wind Direction Sector – Pinal County Housing Complex



Stanfield County Complex

The Stanfield County Complex monitoring site is located within the small community of Stanfield, approximately 15 miles west of Casa Grande, between a county office complex and a county park. The current population of Stanfield is 650, and the primary economy is agricultural production. The monitoring site is adjacent to an unpaved access road, but otherwise there are few disturbed soil areas near the monitor. The community of Stanfield is surrounded by agricultural fields under active cultivation. PCAQCD has operated a filter-based monitor on a six-day schedule at the site since 1988, but no hourly PM_{10} data nor meteorological data have been collected at this site. As a result, no analysis of the relationship between PM_{10} concentrations and wind speed or wind direction were undertaken as a part of this study.

The peak PM_{10} concentrations appear to occur as a result of isolated events and elevated concentrations occur on schedules that vary from year to year. During 2003, for example, the median concentration of 54 24-hour readings was 35.2 $\mu g/m^3$ and the mean was 45.8 $\mu g/m^3$. Values above the mean were recorded continuously between May 9 and July 14, and elevated concentrations were recorded for a period in late October due to transported smoke from California wildfires. During 2004, the median of 60 24-hour concentrations was 31.7 $\mu g/m^3$ and the mean was 34.0 $\mu g/m^3$. During this latter year, concentrations above the mean were scattered across each month of the year except December. These results suggest that episodic sources produce peak PM_{10} concentrations at this monitor, and that some peaks are due to natural events.

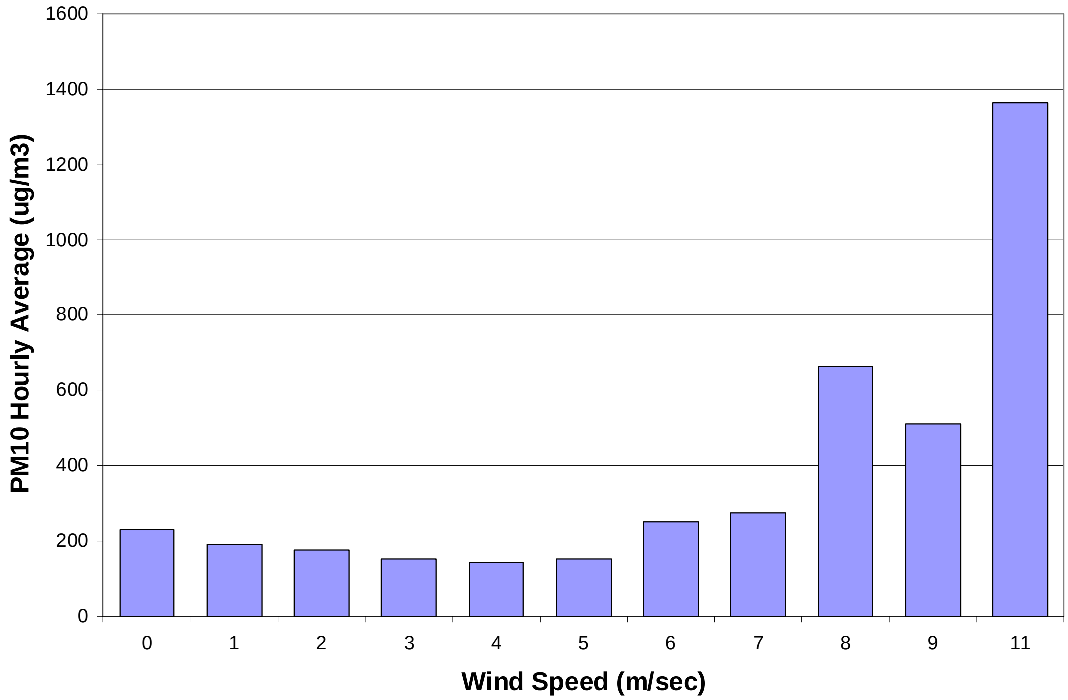
Cowtown

Cowtown is an informal name for a cattle feedlot area located approximately four miles southwest of the City of Maricopa. The monitoring site is located approximately 0.5 miles north and across a major highway and rail line from three feedlots and a grain-processing complex. Agricultural fields under active cultivation lie immediately northeast of the monitoring site.

PM_{10} data are currently collected at this site by both high volume filter-based samplers and a continuously recording tapered element oscillating microbalance (TEOM) monitor. Meteorological parameters are also measured by instruments mounted on a 3-meter tower. The continuously recorded data from the TEOM and the meteorological tower were evaluated to provide preliminary relationships between hourly average PM_{10} concentrations and wind speed and direction.

Figure 3 shows the relationship between PM_{10} concentration and wind speed at the Cowtown site in 2005. This relationship was developed by sorting hourly averaged PM_{10} concentrations by wind speed range and averaging the concentrations measured within each range. Wind speed ranges were set to span 1 meter per second (m/sec) values from 0 m/sec to 11.5 m/sec (the highest wind speed recorded).

Figure 3: Average Hourly PM_{10} vs. Wind Speed - Cowtown, 2005



These data suggest a rather uniform relationship between PM_{10} concentration and wind speeds up to 8 m/sec. This relationship suggests that windblown dust is not a significant contributor to higher PM_{10} concentrations measured at this site except at the highest 1% of wind speeds measured. To better understand these relationships, several other statistical comparisons of these data were performed. A tabulation of these PM_{10} concentration statistics in relation to wind speed ranges is presented in Table 5.

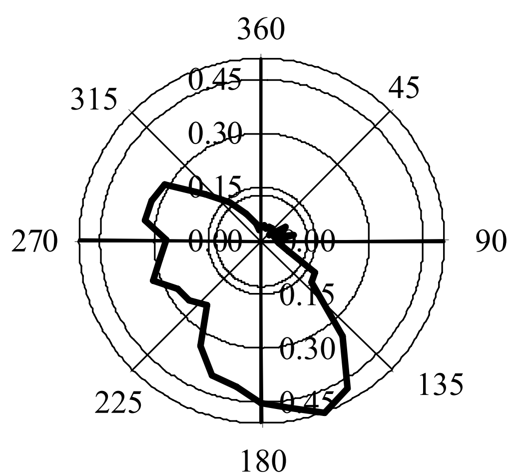
The highest maximum concentrations occurring at very low wind speeds suggest that PM_{10} concentrations at the Cowtown site are dominated by nearby emission sources whose impacts are the highest when winds during relatively stagnant conditions blow from these sources to the monitor. Elevated coefficients of variation reported at low wind speeds also suggest that the dominating sources are confined within discrete ranges of wind direction and not scattered around the compass, as is suggested by the distributions at the Pinal County Housing Complex site.

Analyses of the relationship between PM_{10} concentrations and wind direction were also conducted. Using a conditional probability function (CPF) statistical method, the probabilities of hourly PM_{10} concentrations measured when the wind blows from each of 36 compass quadrants being in the highest 30% of PM_{10} concentrations recorded during the year were plotted. A copy of this plot is presented in Figure 4. This figure indicates that sources to the south and southwest of the Cowtown monitoring site, where the feedlots and grain mill operation are located, significantly impact PM_{10} concentrations at the monitor.

Table 5: 2005 Cowtown PM_{10} – Wind Speed Relationships

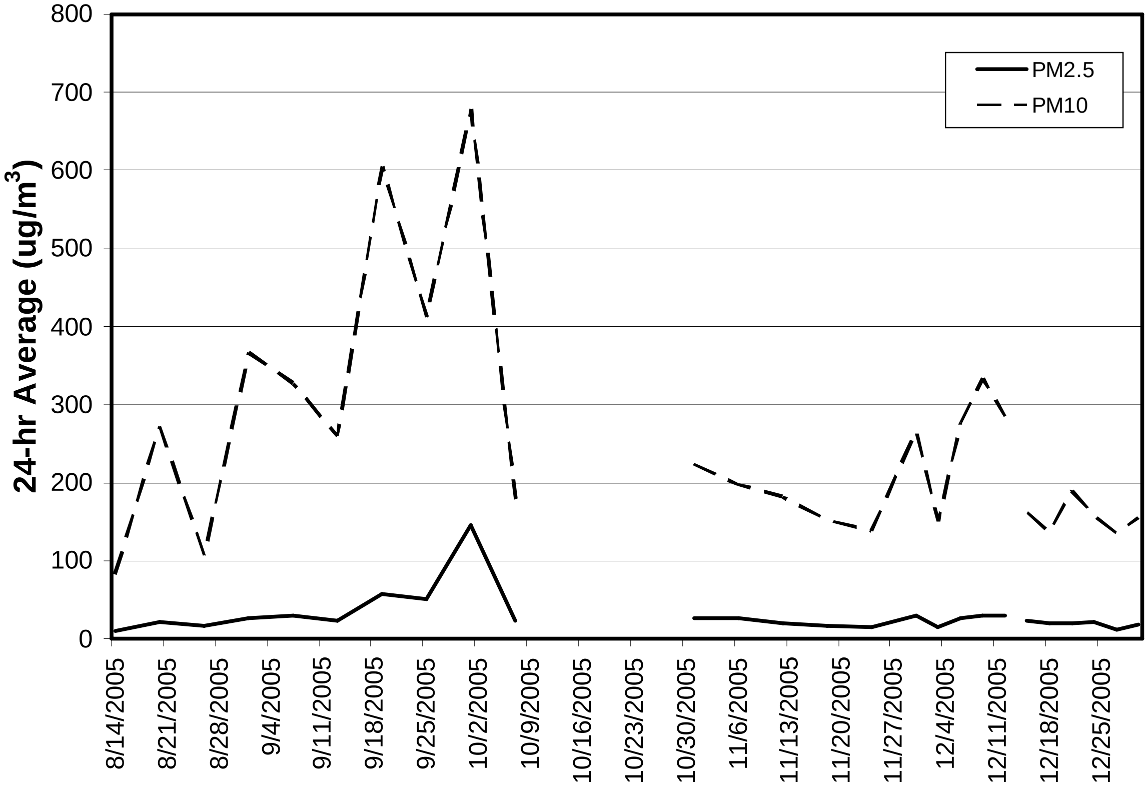
Wind Speed (m/sec)	PM_{10} Mean (µg/m^3)	PM_{10} Std. Dev. (µg/m^3)	PM_{10} Coef. of Variation	PM_{10} Maximum (µg/m^3)	Hour Count (# hours)
0.00 – 0.99	228	467	2.05	6445	939
1.00 – 1.99	189	357	1.89	4675	3825
2.00 – 2.99	174	294	1.68	3170	2315
3.00 – 3.99	151	229	1.52	1970	866
4.00 – 4.99	142	230	1.63	1987	422
5.00 – 5.99	150	163	1.08	861	183
6.00 – 6.99	250	369	1.48	1817	119
7.00 – 7.99	275	612	2.22	3876	45
8.00 – 8.99	664	1093	1.65	4628	19
9.00 – 9.99	509	395	0.78	988	6
11.00 – 11.00	1362	NA	NA	1362	1

Figure 4: High PM_{10} Probability by Wind Direction Sector – Cowtown



In July 2005, PCAQCD commenced monitoring $PM_{2.5}$ at the Cowtown site. This monitoring was performed using a filter-based FMR sampler operating every sixth day. The comparison of these data to PM_{10} measurements show an r^2 correlation of 0.85. A plot of these data are shown in Figure 5.

Figure 5: Cowtown PM2.5 vs. PM_{10}



To determine whether Cowtown $PM_{2.5}$ concentrations correlated better with those monitored at other sites in the county, we compared $PM_{2.5}$ data from the Cowtown, Casa Grande, and Apache Junction monitoring sites. These comparisons, for the period of July through December 2005, showed r^2 correlation coefficients of 0.20 for Cowtown-to-Apache Junction $PM_{2.5}$ and –0.03 for Cowtown-to-Casa Grande $PM_{2.5}$. These analyses indicate that $PM_{2.5}$ concentrations at the Cowtown site are influenced significantly by local source emissions that do not transport to areas to the east such as Casa Grande or to the northeast at Apache Junction. This analysis also indicates that $PM_{2.5}$ is not a significant contributor to PM_{10} concentrations measured at the Cowtown monitoring site.

PM_{10} EMISSION INVENTORY

A 2002 emission inventory for Pinal County has been prepared by the Western Regional Air Partnership (WRAP). For this analysis, only primary PM_{10} data were extracted from the WRAP inventory. Primary PM_{10} is defined for this inventory in the manner that the term is used in EPA's National Emission Inventory for 2002 as the combination of filterable and condensable particulate matter smaller than 10 microns. Although the inventory also contains data on filterable PM_{10} emissions, this parameter is not fully reported for all source categories. For several facility point source entries, for example, only primary PM_{10} is listed in the WRAP inventory. Primary PM_{10} emission inventory data were also evaluated in this section as this is the pollutant form to which EPA attaches more weight in the development of PM_{10} nonattainment plans, even though the continuous TEOM monitors from which data were analyzed in the previous sections record concentrations of essentially filterable PM_{10}. The WRAP 2002 emission inventory for Pinal County reports filterable PM_{10} to constitute 95.2% of primary PM_{10}.

Primary PM_{10} emissions are tabulated for major inventory categories and several significant subcategories in Table 6.

Table 6: Pinal County 2002 Primary PM_{10} Emission Inventory

	Primary PM_{10} Emissions	
	(tons/yr)	% of Total*
Point Sources		
Metal Mining	1,265	6.21%
Manufacturing	117	0.57%
Electrical Utility	172	0.84%
Municipal Landfill	15	0.07%
Other	49	0.24%
Subtotal	1,618	7.94%
Area Sources		
Fuel Combustion	89	0.44%
Paved Road Use	769	3.77%
Unpaved Road Use	4,073	20.0%
Non-Road Construction	768	3.77%
Road Construction	4,714	23.1%
Mining & Quarrying	761	3.73%
Open Burning	906	4.45%
Agricultural Tilling	5,008	24.6%
Cotton Ginning	124	0.61%
Other	233	1.14%
Subtotal	17,445	85.6%
Wildfires	868	4.26%
On-Road Mobile	242	1.19%
Nonroad Mobile	208	1.02%
Grand Total	20,381	100%

*Totals may not add due to rounding.

The primary PM_{10} emission inventory is dominated by fugitive dust sources included in the area source grouping. This outcome corresponds with the PM_{10} monitoring data that demonstrate the significant variability in annual average and maximum 24-hour concentrations between reporting stations. If emissions of fine PM_{10} (i.e., $PM_{2.5}$) from combustion sources dominated the emission inventory, PM_{10} concentrations would be more uniform across the county. PM_{10} emitted by fugitive dust sources tends to impact ambient concentrations primarily within a few miles of emission sources.

Recently, PCAQCD began using a new emission inventory software package recommended by the Arizona Department of Environmental Quality. This package, developed by Lakes Environmental Software (Lakes Environmental), provides a GIS-based platform for spatially locating emissions from stationary, area, and mobile sources. Data on episodic sources such as open burning and windblown dust can also be maintained in the software. While the software does include several EPA emissions estimation models, which can be used to compute emissions from limited source types, it does not possess the capability of computing PM_{10} emission rates from fugitive dust sources. These emissions rates must be manually entered by the user or imported from other databases.

Emission inventory platforms like that developed by Lakes Environmental provide a tool for cataloging emission sources by many different parameters, including location. Because of its geographical positioning system (GPS) capabilities, fugitive dust sources such as active agricultural parcels, can be spatially identified in the inventory, and the set of such sources near a monitoring site, or a sensitive receptor, can be extracted from the inventory. With modification, emission equations for windblown dust (in the case of disturbed soils) or motor vehicle travel PM_{10} emissions (in the case of unpaved road use) can be stored in the inventory and used to compute emissions with the entry of appropriate activity data. Such activity data for agricultural parcels would include the roughness height of the disturbed soil surface and the silt content of the soil. Because silt content varies across the central agricultural region, and because surface roughness may vary on an individual field by season, collection and entry of these data countywide would require significant staff resources. Some utility does exist, however, for maintaining this level of source detail for parcels in microinventory areas surrounding monitoring sites recording violations of the 24-hour standard. While useful for region-wide analysis—which is more appropriate for $PM_{2.5}$—an alternative use of this software would be to focus on representing microinventory areas adjacent to monitoring sites.

PM_{10} AIR QUALITY MODELING

Very limited air quality modeling of PM_{10} emissions has been conducted in Pinal County. In the absence of any need to evaluate source-receptor relationships as part of an air quality planning effort, the modeling of PM_{10} ambient air quality has not been a priority of PCAQCD or any other air quality regulatory agency. The limited modeling that has been done either supports stationary source permitting or initial source-receptor investigations.

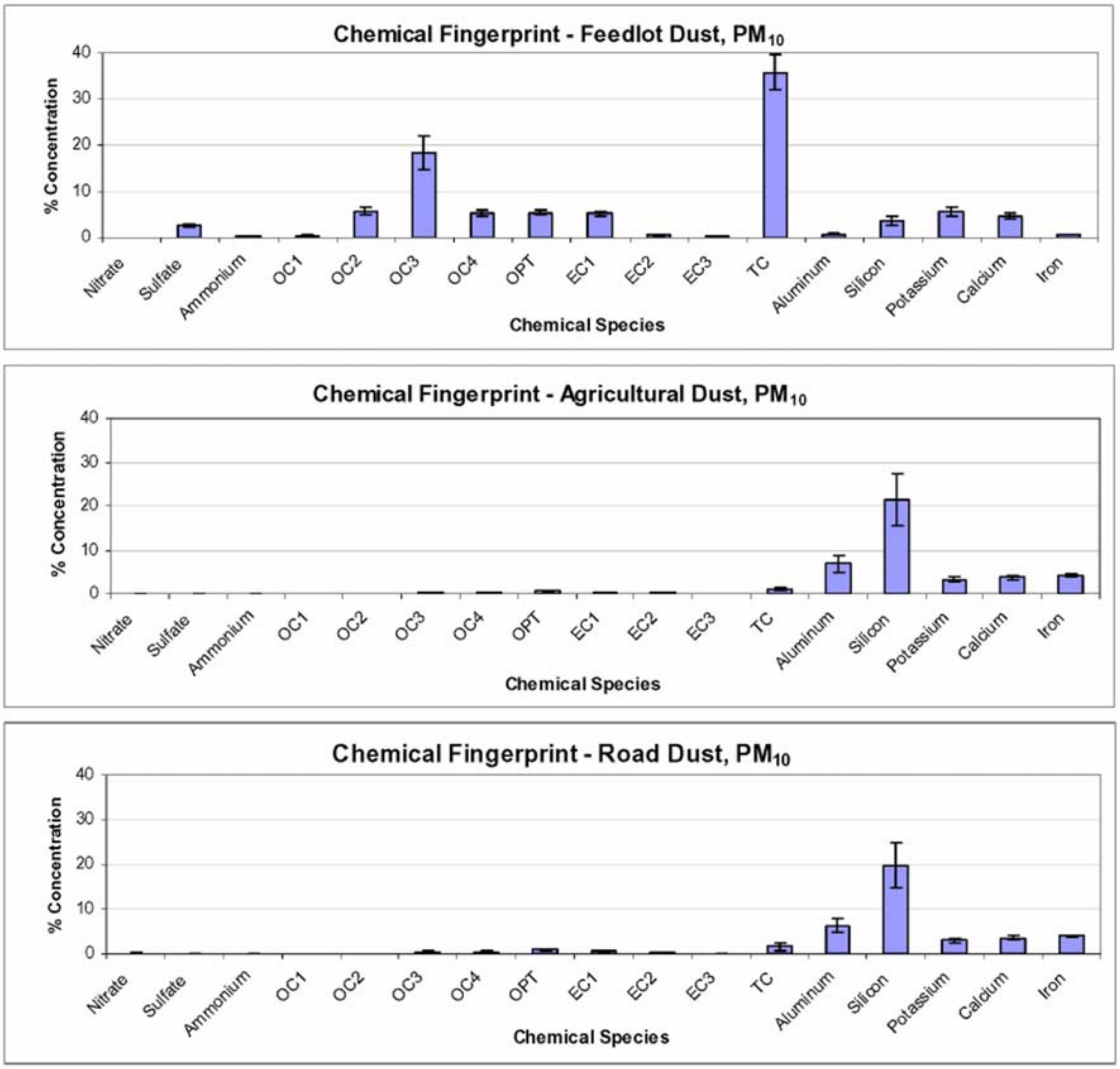
Proposed major stationary sources, or major modifications of existing stationary sources (i.e., facilities or modifications having the potential to emit 100 tons per year or more of any criteria pollutant), are required to be evaluated for downwind ambient air quality impacts using EPA-approved dispersion modeling. For sources of PM_{10}, the increases in downwind concentrations are not allowed to exceed 17 $\mu g/m^3$ - annual average or 30 $\mu g/m^3$ - 24-hr average. All of the major stationary sources and major modifications approved by PCAQCD have demonstrated compliance with these downwind requirements through dispersion modeling.

The second PM_{10} air quality modeling effort undertaken in Pinal County in the past few years was the analysis of PM_{10} source-receptor relationships at five PM_{10} monitoring sites using chemical mass balance (CMB) methods. Ambient PM_{10} and $PM_{2.5}$ samples were collected at Casa Grande, Coolidge, Cowtown, Pinal County Housing, and Stanfield in October and November of 2003. Soil samples were collected from feedlots, agricultural lands, and unpaved roads near the Cowtown monitoring site.

Ambient PM_{10} was collected at the monitoring sites on Teflon and quartz fiber filters. The Teflon filter were analyzed by X-ray fluorescence spectrometry for 40 elemental species and weighed for mass. The quartz filters were analyzed for the cations Na^+ and K^+ by atomic absorption, for ammonium (NH_4^+) by automated colorimetry, and for the anions SO_4^{2-}, NO_3^-, and Cl^- by ion chromatography, and the eight species of elemental and organic carbon by thermal/optical reflectance carbon analysis. The soil samples were resuspended onto Teflon and quartz fiber filters and analyzed in the same manner as the ambient filters to produce compositional fingerprints of these soils.

The results of these analyses were used by Desert Research Institute (DRI) to perform a CMB analysis allocating ambient PM_{10} concentrations to fingerprinted sources. Because other sources not unique to Pinal County also contribute to local air quality there, the fingerprints of PM_{10} emissions from other sources, such as motor vehicle exhaust, vegetative burning, and coal power plants, were selected by DRI from archives of source signatures for use in the analysis. The constituent analysis of local soils indicated that agricultural dust at the Cowtown site was compositionally almost identical to unpaved road dust in the same vicinity and, thus, very difficult to differentiate in the ambient samples. The feedlot dust was found to have much greater organic and total carbon contents, and much less silicon, than the agricultural and unpaved road dusts. Figure 6 compares the primary constituents in these three soil samples.

Figure 6: PM_{10} Surface Material Chemical Fingerprints



The CMB analysis indicated that soil-based emissions were the greatest contributor to PM_{10} measured at the five monitoring sites. Geological soil provided the highest contributions at four of the monitoring sites, and feedlot soil produced the highest impacts at the Cowtown site. At sites other than Cowtown, feedlot soil produced the second highest impacts, even though feedlots and dairies were located several miles from the monitoring sites. PCAQCD staff hypothesized that the use of cow manure as a fertilizer on nearby agricultural fields may have enhanced the feedlot soil signature at these sites.

A study of cattle feedlot downwind ambient PM composition was conducted in the San Joaquin Valley in September 1972. This study reports similar ratios of calcium and potassium to silicon in ambient PM downwind and close to feedlot corrals that are repeated in the resuspended dust from feedlot soil at Cowtown. The San Joaquin Valley study, however, reports that PM emissions from a feedlot decrease rapidly and are almost undetectable at a distance of 750 meters downwind of the feedlot boundary.

CONTROL MEASURE SELECTION

The Clean Air Act requires that non-attainment plans assure the implementation of all reasonably available control measures as expeditiously as practicable. In serious area PM_{10} non-attainment areas, plans must assure the implementation of Best Available Control Measures (BACM). BACM is defined as:

> *…the maximum degree of emissions reduction of PM_{10} and PM_{10} precursors from a source …which is determined on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, to be achievable for such source through the application of production processes and available methods, systems, and techniques for control of each pollutant.*

BACM is to be applied to each significant emission source category. A significant emission source category is one that produces PM_{10} impacts that are greater than 1 $\mu g/m^3$ – annual average, or 5 $\mu g/m^3$ – 24-hour average, at an approved monitoring site recording exceedances of national ambient air quality standards. Any source category that produces PM_{10} impacts below these thresholds is considered to be de mimimis and exempt from the application of BACM controls.

The feasibility of any BACM candidate control measure is evaluated in a two-step process. In the first step, a measure is evaluated for technological feasibility. Measures are typically disqualified on technological grounds if resources with limited availability—such as water—would be consumed, if adverse environmental impacts would occur, or if significant energy demands would result. A candidate measure may also be infeasible if it violates a statute or regulation.

The second step in the feasibility analysis is the test of economic feasibility. Economic feasibility is determined through the calculation of a measure's cost-effectiveness and the comparison of this value to a cost-effectiveness ceiling adopted as agency policy. For example, the San Joaquin Valley Unified Air Pollution Control District has adopted a cost-effectiveness ceiling of $5,700 per annual ton of PM_{10} reduced as a determinant in the analysis of control equipment in Best Available Control Technology decisions and in the analysis of control measures for BACM decisions. The cost-effectiveness value for a control measure is the ratio of annualized control measure cost to the annual emission reductions achieved by the application of the control measure to a particular area source. The general methodology of calculating a cost-effectiveness ratio is presented in the WRAP Fugitive Dust Handbook. Emission reductions can be calculated through a series of alternate emission factors and emission factors equations. Control measure costs likewise can be calculated using regional default data or locally collected cost data. Sources of cost data include BACM studies conducted for other serious PM_{10} non-attainment areas and cost analyses prepared by private and public agencies.

PM_{10} ATTAINMENT DEMONSTRATION

The critical analysis required in any attainment plan is the demonstration of attainment with ambient air quality standards. For compliance with PM_{10} standards, this analysis typically includes an assessment of the relationships between source emissions and air quality at the violating PM_{10} monitors and a plan for reducing emissions from these sources by a sufficient degree to reduce cumulative PM_{10} impacts at these monitors to air quality standard levels.

A number of analytical approaches are available to quantify the relationships between source emissions and impacts. These include the use of computation methods to quantify emissions from individual sources and compute impacts at discrete downwind monitoring locations (dispersions modeling) and, conversely, to evaluate the composition of collected particulate and relate this composition to source emission profiles (receptor modeling). Other approaches use meteorological data to map trajectories backwards in time to identify contributing sources, and saturation monitoring to spatially map the gradient of PM_{10} concentrations between suspected contributing sources and affected monitoring sites. The selection of an analytical approach should be based on the data resources available.

EPA guidance requires that the most accurate analytical methods for which input data are available be used to identify the significance of source emission impacts at monitoring sites where violations of air quality standards are expected. EPA, in ranking analytical methods, recommends ". (1) use of receptor and dispersion models in combination (preferred); (2) use of dispersion models alone; and (3) use of two receptor models, with control strategy developed using a proportional model."

The modeling methods employed by other serious PM_{10} non-attainment areas are instructive of approaches that have been accepted by EPA. The serious PM_{10} non-attainment areas evaluated in this study include Maricopa County, Arizona; Clark County, Nevada; and San Joaquin Valley, California. In each of these areas, fugitive dust emissions contribute significantly to violations of the PM_{10} standards.

The PM_{10} non-attainment plan for Maricopa County, Arizona, was approved by EPA on January 14, 2002. The Maricopa County plan used a gridded photochemical dispersion model approach to demonstrate attainment of the PM_{10} annual standard and a microscale dispersion modeling approach to demonstrate attainment of the 24-hour standard. A portion of annual PM_{10} is produced by the conversion of gaseous pollutant emissions into particles, and the use of a photochemical model was useful in forecasting emission trends for this component as future gaseous emission control measures were implemented. Because this methodology is resource intensive with respect to data collection and analysis, and because aerosols do not contribute to Pinal County PM_{10} air quality to the same extent, this methodology is not recommended for use by PCAQCD.

To determine compliance with the 24-hour PM_{10} standard, the Maricopa Association of Governments submitted to EPA a microscale analysis of fugitive dust source emissions developed by the Arizona Department of Environmental Quality. This analysis uses different dimensions for the microscale modeling domains at different monitoring sites. The domains were chosen after screening dispersion modeling analysis to include all fugitive dust sources that would have significant impacts (e.g., greater than 5 $\mu g/m^3$ – 24-hour average impacts) at each applicable monitoring site. The domains varied from an approximate 0.17 mile radius to a 3.0 mile radius. Windblown dust from disturbed soil areas was a significant source because the 24-hour design day was a high wind day at each of the monitoring sites. The concept of using pre-screening to differentiate significant from less-than-significant sources was approved by EPA and is a good tool for use by PCAQCD in selecting microscale domain dimensions.

The Clark County, Nevada PM_{10} non-attainment plan was approved by EPA on May 3, 2004. The non-attainment plan used an emission inventory rollback method to demonstrate attainment of the annual and 24-hour PM_{10} standards. Only one monitoring site, at the J.D. Smith School, recorded an exceedance of the annual standard during the baseline period. This site and five others reported exceedances of the 24-hour standard. Clark County Department of Comprehensive Planning (CCDCP) concluded from analysis of monitoring data that PM_{10} impacts at violating monitoring sites were driven by sources located within 2 kilometers of each monitoring site. CCDCP assumed the non-background portion of measured PM_{10} was proportional to the individual emission contributions of sources with the 2-kilometer microinventory area. Background was assumed to be equal to the lowest PM_{10} measurement recorded at any monitoring site on the design day or year plus an annual average aerosol contribution of 3.5 $\mu g/m^3$ as determined by Desert Research Institute through chemical mass balance modeling. The emissions reductions estimated for application of candidate control measures, as a fraction of the total emission inventory of each microinventory area, were applied to the design day and year PM_{10} concentrations to demonstrate attainment. EPA Region IX approved this approach in recognition of the difficulty in parsing fugitive dust source contributions using receptor models and the corresponding uncertainty in emission factors and activity levels used in dispersion modeling. This approval suggests that use of a microinventory rollback approach may be the most cost-effective method of determining necessary emission reductions and demonstrating future attainment in Pinal County.

The San Joaquin Valley PM_{10} non-attainment plan was approved by EPA on April 28, 2004. The plan's air quality data indicate that exceedances of the 24-hour PM_{10} standard were determined to occur in fall and winter months in this region during periods of low wind velocity. These exceedances were dominated by secondary aerosol formed through the interaction of NOx from combustion sources and ammonia emitted by agricultural operations. Chemical mass balance data were used to quantify the contribution of primary and secondary particulate sources at each monitoring site recording exceedances, and the attainment demonstration was performed using a modified rollback method.

Because EPA guidance requires the use of two receptor models if dispersion modeling is not used, the San Joaquin Valley Unified Air Pollution Control District used a correlation coefficient approach to verify CMB analyses. For this planning effort, a Classification and Regression Tree (CART) model was used to correlate PM_{10} and $PM_{2.5}$ concentrations with meteorological conditions. At each of the three monitoring sites studied, atmospheric stability correlated best with high PM_{10} concentrations, and visibility correlated best with high $PM_{2.5}$ concentrations. Not surprisingly, high $PM_{2.5}$ also correlated well with nighttime low temperatures conducive to the formation of ammonium nitrate.

Because the San Joaquin Valley 24-hour PM_{10} exceedances occur during the fall and winter when secondary aerosol is the primary constituent, the attainment demonstration modeling approach will be of little use in evaluating peak PM_{10} source-receptor relationships.

CONCLUSIONS

An acceptable PM_{10} non-attainment plan must contain all of the elements prescribed by the federal Clean Air Act. These elements primarily include an emission inventory, the implementation of Best Available Control Measures, and a demonstration of attainment.

The emission inventory prepared by PCAQCD and WRAP for Pinal County satisfies minimum CAA emission inventory requirements. The emission inventory platform developed for use in Arizona by Lakes Environmental will extend the capabilities for emission analysis, but will not readily facilitate compliance with CAA attainment demonstration requirements.

The choice of BACM will be dependent on the conclusions made by PCAQCD on the cost-effectiveness of each candidate measure. Estimates of control measure effectiveness and cost can vary significantly depending on the research data used in computing cost-effectiveness. The choice of a cost-effectiveness ceiling is also a policy choice to be made by PCAQCD with EPA's concurrence.

The demonstration of attainment will require additional studies and analysis. Impacts at each of the Cowtown, Pinal County Housing, and Stanfield monitoring sites, if continuing to demonstrate non-attainment in 2005, should be evaluated first by construction of microinventories of significant sources. This work should be performed through the mapping of potentially significant sources within a 300-meter radius (an impact zone found to contain most significant sources in microscale inventory modeling in the MAG and San Joaquin Valley regions), the determination of maximum activity rates or disturbance levels, and the modeling of emissions from these sources on high concentration days. The results of such modeling can be used to determine whether the microinventory radius should be increased to capture other significant sources (i.e., those with the potential to produce impacts at the monitor in excess of 5.0 $\mu g/m^3$ – 24-hour average) or whether the initial microinventory area is sufficient.

When site investigations cannot locate potentially significant sources, other means of source-receptor analysis may be required. Two methods discussed earlier have the potential to identify the wind directions or the meteorological conditions under which elevated concentrations occur. The first is the use of the CPF statistical method to identify the upwind directions in which significant sources are located. The second is the use of the CART statistical method to determine the set of meteorological conditions under which elevated concentrations are more probable. A third approach would be to install a video camera at the monitoring site that was activated during periods of high PM_{10} concentrations to record images of the area surrounding the monitor or of the area upwind of the monitor.

The use of chemical speciation methods to identify significant sources has very limited value in the central Pinal County area. The emission inventory and the limited CMB study conducted in this area indicate that fugitive dust sources dominate local PM_{10} concentrations. CMB cannot be used directly to distinguish the separate contributions of such sources because of the strong similarities in elemental signatures of dust emissions.

Spatially distributed monitoring, however, can be used to map the gradient of PM_{10} concentrations in an area affected by several fugitive dust sources. Such monitoring, referred to as saturation monitoring, is conducted using self-contained PM_{10} samplers such as MiniVols. EPA retains an inventory of MiniVols for loan to state and local air quality regulatory agencies for saturation studies. Such samplers, when deployed in a network surrounding a monitoring site for simultaneous single day monitoring, can add information about the local PM_{10} gradient that cannot be fully elucidated from the analysis of hourly PM_{10} and meteorological data recorded at the monitoring site.

Once the impacts of significant sources in the microinventory areas have been quantified, then appropriate control measures can be developed to demonstrate attainment. The pool of research data on the effectiveness of alternative fugitive dust control measures continues to expand every year. Bibliographies of these research studies are also published periodically in compendiums such as the WRAP Fugitive Dust Handbook and other documents.

Finally, the development of a PM_{10} attainment plan should borrow heavily on EPA's actions on plans developed by other serious nonattainment areas. The Technical Support Documents prepared by EPA staff in review of these plans identify the logic by which EPA approves or rejects components of submitted plans. These TSDs constitute a trove of policy and technical information that will help guide the preparation of any plan prepared for Pinal County.

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CHAPTER SIX
MEASUREMENT OF PM_{10} EMISSION FACTORS FROM UNPAVED ROADS IN ARIZONA TO DETERMINE THE EFFICIENCY OF DUST SUPPRESSANTS

PROJECT DESCRIPTION AND OBJECTIVES

Background

The expression contained into the EPA document AP-42 for predicting emission rates and has been widely used all over the country to estimate the fraction of PM_{10} originating from paved roads:

$$E = k(sL/2)^{0.65} (W/3)^{1.5} \text{ g/VKT} \quad (1)$$

where:

E = PM emission factor in the units shown
k = A constant dependent on the aerodynamic size range of PM (1.8 for $PM_{2.5}$; 4.6 for PM_{10})
sL = Road surface silt loading of material smaller than 75µm in g/m^2
W = mean vehicle weight in tons
VKT = vehicle kilometer traveled

Equation (1) was derived by measuring the total flux across roadways using a PM_{10} monitoring array and based solely on surface silt loading.

We developed an alternative technique using a vehicle equipped real-time PM sensors to measure concentrations in front of the vehicle and in its rear wake (Fitz and Bufalino, 2002; Fitz et al. 2005a,b). In this approach the PM_{10} concentrations are measured directly on moving vehicles in order to improve the measurement sensitivity for estimating the emission factors for vehicle on paved roads. Optical sensors are used to measure PM_{10} concentrations with a time resolution of approximately two seconds. Sensors were mounted in the front and behind the vehicle in the well-mixed wake. A special inlet probe was designed to allow isokinetic sampling under all speed conditions. The emission factors are based on the concentration difference between front and back of the test vehicle and the frontal area. The test system has been designated as SCAMPER (System of Continuous Aerosol Monitoring of Particulate Emissions from Roadways)

This SCAMPER technique is useful for quickly surveying large areas and for investigating hot spots on roadways caused by greater than normal deposition of PM_{10} forming debris. While there is an AP-42 equation for unpaved roads that has silt content as an independent variable, the SCAMPER approach directly measures emissions and does not depend on independent variables. The approach is therefore as valid for unpaved roads as for paved roads.

Objective

The primary objective of this project was to determine the effectiveness in dust suppressants on unpaved state highways in Arizona.

Approach

We used the CE-CERT developed SCAMPER (System of Continuous Aerosol Monitoring of Particulate Emissions from Roadways) to determine vehicle PM emission factors by measuring the PM concentrations in front of and behind the vehicle using real-time sensors. This system was used to measuring PM_{10} emission rates on state routes 88 and 288 on sections that were treated with a dust suppressant and on contiguous untreated sections. The efficiency of the dust suppressant was then calculated from the difference between the mean emission rates for each type of road segment.

This SCAMPER has five major components:

1) Sampling Inlet

> An inlet for the real-time PM sensors was used that allowed sampling as isokinetically as possible over the full range of vehicle speeds. This involves a bypass flow system that is adjusted to vehicle speed with a PC using GPS speed data.

2) PM_{10} Sensors

> DustTrak optical PM sensors with PM_{10} inlets are used.

3) Sampling Trailer

> From our studies to determine concentrations in the vehicle wake the sampling position behind the vehicle was optimized. This position required using a trailer to mount the sampling inlet. The trailer was designed to disturb the vehicle wake as little as possible. In addition, the trailer holds the bypass flow system.

4) Position Determination

> A Garmin GPS Map76 global positioning system was used to determine vehicle location and speed.

5) Data Collection

A PC was used to collect data from GPS and PM_{10} measuring devices. Data was stored as two-second averages. The PC also was used to automatically adjust the sample inlet bypass flow to maintain isokinetic particle sampling using a 10-second running average of vehicle speed based on the GPS.

Figure 1 shows front and rear photographs of the SCAMPER. The tow vehicle is a 1995 Chevrolet Suburban with a custom trailer with an extended hitch.

Figure 1: Photographs of the Front and Rear of the SCAMPER.

FIELD MEASUREMENTS

Field measurements of PM_{10} emission rates were made on two different state highways, routes, SR88 and SR288. Figure 2 is a map showing the location of these routes that were used with respect to Phoenix, AZ. In this map the emission rates are represented as circles with the shading becoming darker as the emission rates become larger. The emission rates will be discussed in more detail in section 4. Figures 3 and 4 show more detailed maps of the portions used on states routes 88 and 288, respectively. Figure 5 shows the SCAMPER being used on SR88. The SCAMPER test vehicle was operated at speeds consistent with safe operation and that observed of other vehicles.

The segment of state route 88 between mile point 220.1 and mile point 227.5 was treated with Envirotac II Acrylic copolymer at a rate of 1 gallon per 36 square feet. To the west the road was paved and to the east it was unpaved gravel. The section between miles 226.5 and 227.5 was first treated in late 2003 and the section between miles 220.1 and 226.5 was treated in May 2005. The SCAMPER testing was conducted from Tortilla Flats (GPS coordinates 33.5268 by –111.3896) eastbound on paved road to mile 220.1 (GPS coordinates 33.5483 by –111.2563) where the road transitioned from paved to treated gravel. The treated section ended at mile 227.5 and the SCAMPER vehicle continued eastward on untreated gravel until reaching GPS coordinates 33.5829 by –111.22143 where it turned around and headed westbound back to Tortilla Flats. Four circuits were completed on October 10, 2005. On one circuit filters were installed on the DustTrak inlets to confirm that there was no significant signal due to the extreme bouncing that occurred on these unpaved rough roads.

In 2004 the segment of SR 288 between mile points 274.7 and 280.5 was treated by milling 6in of the base material that was treated with a 1:1 ratio of SS1 followed by an application of CRS II Emulsified liquid at a rate of 0.5 gallon per square yard and then 28 pounds per square yard of 3/8 in chips. The road was untreated gravel on both sides of the treated section. The SCAMPER test route consisted of a circuit starting on the south approximately 1/4mile from the treated section (GPS coordinates of 33.7468 by –110.9624), covering the treated section (GPS coordinates 33.7496 by –110.9650 at the southern end and 33.7879 by –110.9714 at the northern end) and continue north on the gravel for another quarter mile (GPS coordinates of 33.7935 by –110.9719.

Figure 2: Map of the Test Segments Used on SR88 and SR288.

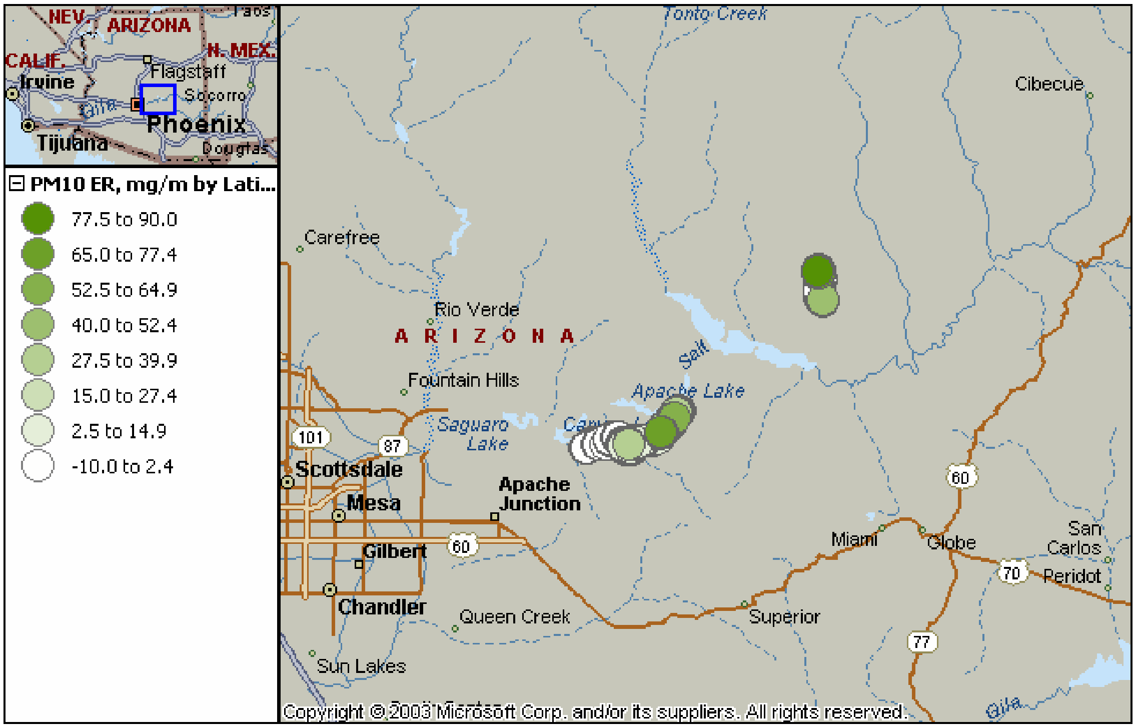

Figure 3: Map of the Test Segments Used on SR88

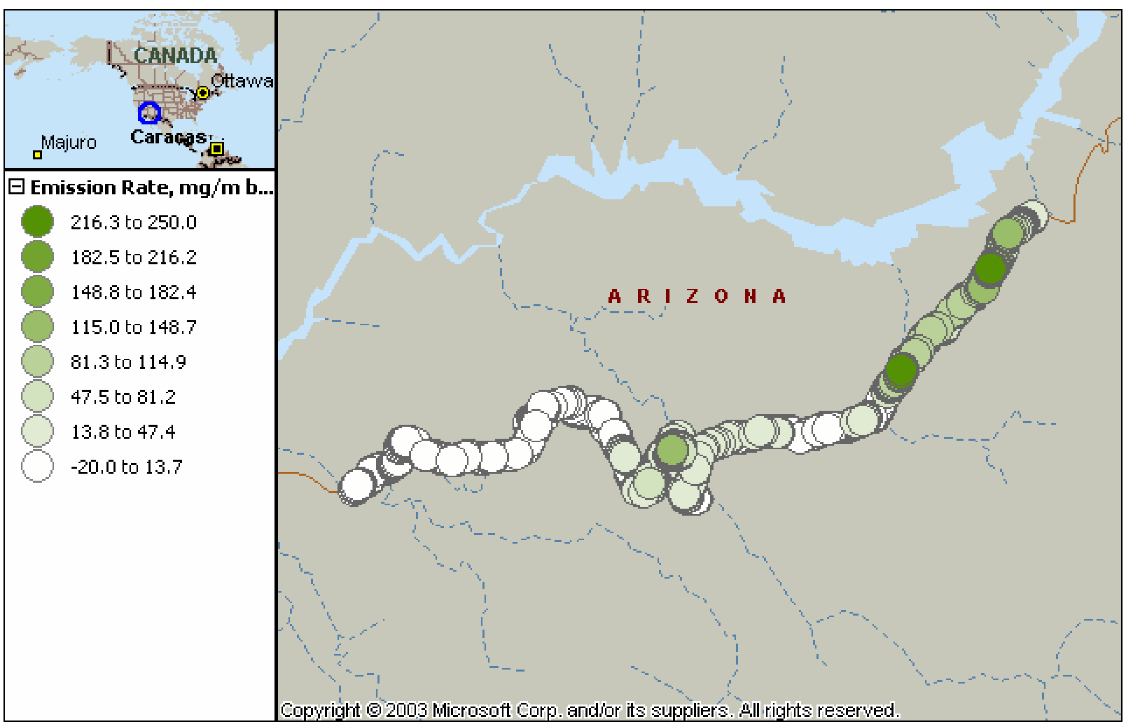

Figure 4: Map of the Test Segments Used on SR288

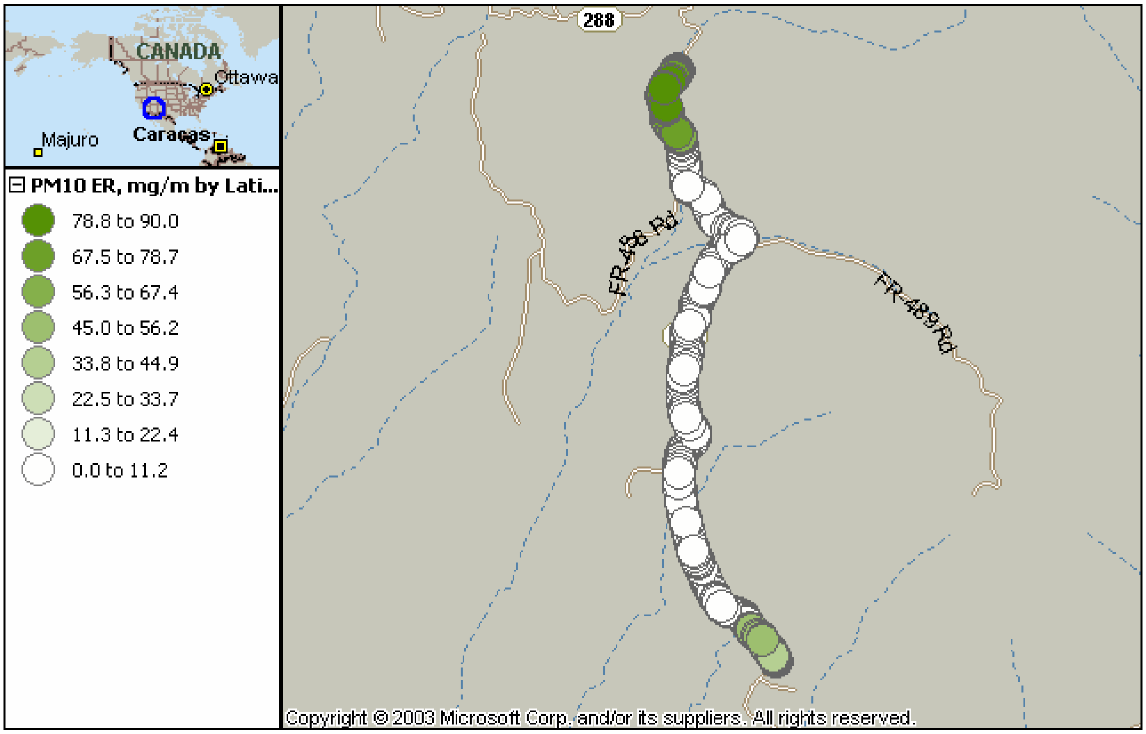

Figure 5: Photograph of the SCAMPER Testing SR88.

DATA QUALITY

Data Capture

The data capture form the DustTrak analyzers was 100% for the testing of SR88 but the rear analyzer stopped working during four segments of the last two circuits of SR288. The problem appears to be due to the harsh ride caused the rough road. Typically the instrument would simply stop working after hitting a particularly severe bump, most likely due to a brief interruption of power. There were also instances of spikes due to hitting bumps where the analyzer kept working. As described in the next section, these were removed during data processing. Additional vibration isolation appears to be needed for testing rough, unpaved roads.

DustTrak Drift

The zero of the DustTrak was determined before, after, and at least once during the test runs. The drift during the course of the each test day was less than a few thousandths of a mg/m3, near the 0.001 mg/m3 detection limit of the instrument. The data for each test run was corrected for zero offset using the mean zero response for that day.

Data Validation

The data acquisition system recorded all data digitally with 100% capture. As mentioned above, we found that the output of the rear DustTrak occasionally spiked, either positive or negative, most likely due to physical shock. These spikes always showed up on two consecutive seconds. These were unlikely to be associated with an actual PM_{10} concentration as concentrations rarely change to that degree in less than one second. This two-second characteristic of this noise spike is also expected from the internal averaging and output characteristics of the DustTrak. On the time constant we selected (which is the shortest available) the DustTrak output is a two-second running average that is updated every second. A large spike in a one-second period will therefore show up as two smaller spike for two consecutive seconds. To filter this noise we tabulated the data as 5-second running medians. Two-second spikes therefore would be removed from the data set. At the same time we calculated the running medians we also corrected for the zero response for each analyzer.

Data Summary

The net PM_{10} concentration is determined by subtracting the concentration from the front DustTrak from that of the rear. Since the DustTrak data is noisy at the shortest time constant, we plotted the data as a 10-second running average of the 5-second running medians. We have found that this period of a running average produces higher quality data although the time resolution is not as great. This is an inherent limitation of the DustTrak instrument. We then multiplied the net PM_{10} concentration by 3.66m2, the frontal area of the test vehicle, to obtain the PM_{10} emission rate in units of mg/m.

The following subsections describe each day of data collected. This is accomplished with a time series plot and a location plot. The time series plots give good overviews of the data, especially for comparison with other test days. Since the speed varies from day to day, the location data, however, is approximate. The location plots are useful to pinpoint hot spots, but it is difficult to compare data with other days. The combination of the two presentations therefore gives a comprehensive view of the data. The data are also summarized as segment means.

SR88 October 10, 2005

Figure 3 summarizes the data on a map. Progressing from left to right the emissions increase as the SCAMPER transverses paved, treated unpaved, and untreated unpaved. Figure 6 shows the time series of PM_{10} emission rates calculated as a running ten-second average for periods when the running average speed was greater than 10 mph. The units are in mg/m. The data from treated and untreated unpaved roads are highlighted, as are the paved road sections. Table 1 summarizes the data. The average emission rate of the treated gravel section was approximately five times lower than the untreated gravel section. In both cases the average speed was near 20 mph. Spikes in the emission rate are observed at repeatable times for both treated and untreated sections, likely indicating road surfaces containing higher fractions of finer soil. Based on the reproducibility of the segment emission rate data, the precision of the measurements for both the treated and untreated sections was high, especially considering the potential operational variability from run to run. While standard deviations should not be calculated from three test runs, the precision of the measurement is about 20%, which is consistent with our much larger database from paved road measurements.

Figure 6: Time Series Plot of PM_{10} Emissions During the Test Conducted on SR88 October 10, 2005.

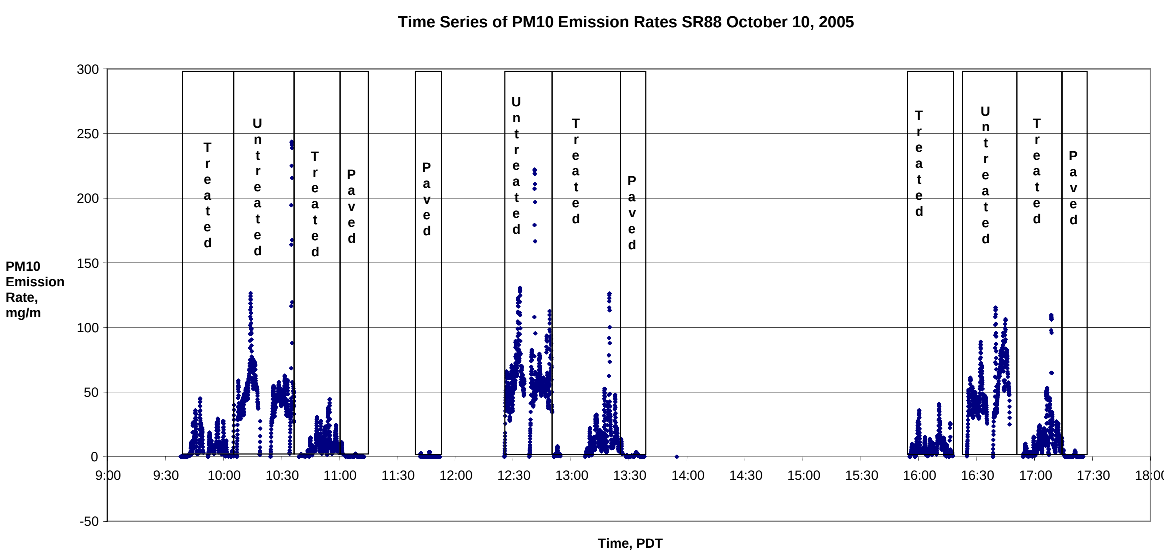

Table 1: Summary of Mean PM_{10} Emission Rates for the Test Route on SR88 on October 10, 2005

Means	Circuit1	Circuit2	Circuit3	Circuit4	Overall Means
Treated Time Eastbound	09:41-10:06			15:55-16:18	
Treated Mean ER Eastbound	**8.9**	**ND**	**ND***	**8.1**	**8.5**
Treated Mean Speed Eastbound	19.8	NA	NA	20.1	20.0
Untreated Time Eastbound	10:07-10:19	12:26-12:36		16:25-16:35	
Untreated Mean ER Eastbound	**51.6**	**60.5**	**ND***	**42.8**	**51.6**
Untreated Mean Speed Eastbound	17.1	18.7	NA	19.6	18.5
Untreated Time Westbound	1034-10:37	12:38-12:50		16:38-16:47	
Untreated Mean ER Westbound	**47.2**	**61.4**	**ND***	**63.0**	**57.2**
Untreated Mean Speed Westbound	17.5	16.6	NA	20.9	18.3
Treated Time Westbound	10:39-11:02	12:51-13:27		16:54-17:15	
Treated Mean ER Westbound	**8.5**	**13.8**	**ND***	**13.3**	**11.9**
Treated Mean Speed Westbound	19.0	18.9	NA	20.8	19.6
Paved Road Westbound Time	11:03-11:13	13:29-13:38		17:16-1725	
Paved ER Westbound to Tortilla Flats	**0.3**	**0.7**	**ND***	**0.3**	**0.4**
Paved Speed Westbound to Tortilla Flats	33.1	32.9	NA	33.5	33.1
Paved Road Eastbound Time	11:42-11:52				
Paved ER Eastbound from Tortilla Flats	**0.3**	**ND***	**ND***		**0.3**
Paved Speed Eastbound from Tortilla Flats	31.8	NA	NA		31.8
Untreated Overall Mean Emission Rate, mg/m					**54.4**
Treated Overall Mean Emission Rate, mg/m					**10.5**
Paved Road Overall Mean Emission Rate, mg/m					**0.4**
ND No Data-Rear DustTrak failed partway into test					
ND* Filtered air control					
NA-Not Applicable					

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Figure 4 summarizes the data on a map. The higher emissions at the top and bottom of the section are from the unpaved segments while the much lower ones are clearly seen in the middle. Figure 7 shows the time series of PM_{10} emission rates calculated as a running ten-second average for periods when the running average speed was greater than 10 mph. The units are in mg/m. The data from treated and untreated unpaved roads are highlighted. Table 2 summarizes the data. The average emission rate of the treated gravel section was approximately sixty times lower than the untreated gravel section. In addition, the average speed on the untreated sections was nearly half that of the treat section (15.5 vs 32.5 mph). Spikes in the emission rate are observed at repeatable times for only untreated section, likely indicating road surfaces containing higher fractions of finer soil. The PM_{10} emission rate from the treated section was nearly as low as the asphalt paved portion of SR88. Since SR88 had a higher traffic density than SR288, the emissions from its paved segment are expected to be lower than if a segment of SR288 were paved. We therefore conclude that the PM_{10} emissions from the treated portion of SR288 are what would be expected of asphalt pavement. Based on the replicate circuits, the precision of the measurement is also approximately 20%.

Figure 7: Time-Series Plot PM_{10} Emissions During the Test Conducted on SR288 on October 11, 2005

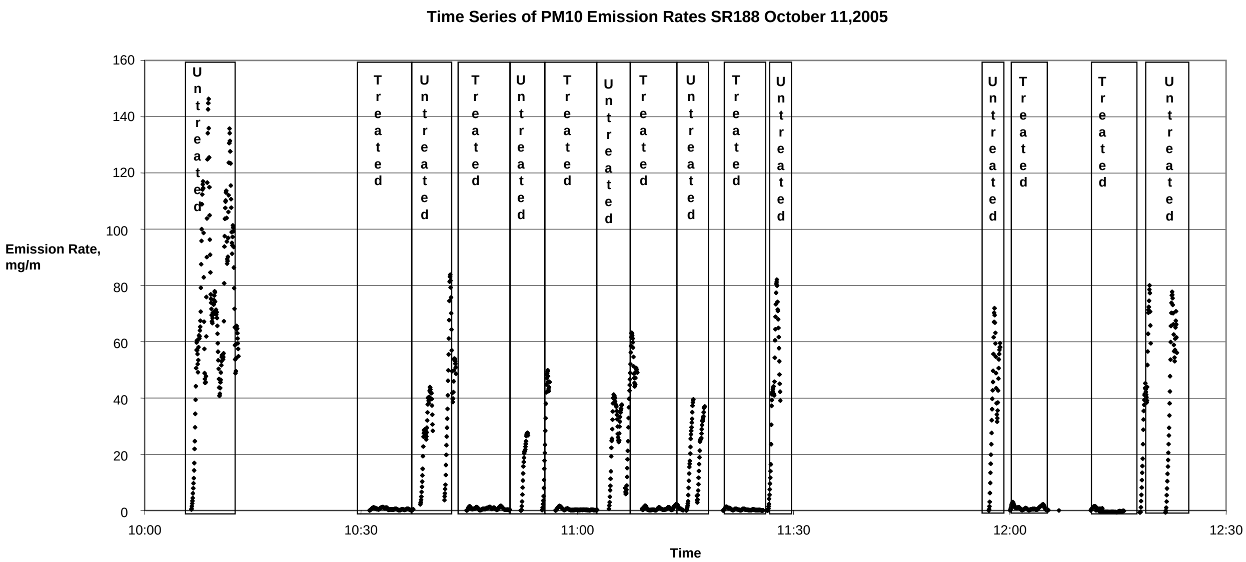

Table 2: Summary of Mean PM_{10} Emission Rates for the Test Route on SR288 on October 11, 2005

Means	Circuit1	Circuit2	Circuit3	Circuit4	Circuit 5	Overall Means
South Untreated Time Northbound	10:05-10:13	10:53-10:56	11:17-11:18	11:45-11:46	12:08-12:10	
South Untreated Mean ER Northbound	**72.9**	**29.4**	**22.7**	**ND***	**ND**	**41.6**
South Untreated Mean Speed Northbound	19.1	13.2	12.5	NA	NA	14.9
Treated Time Northbound	10:31-10:37	10:57-11:03	11:20-11:26	11:40-11:52	12:11-12:17	
Treated Mean ER Northbound	**0.5**	**0.4**	**0.4**	**ND***	**0.5**	**0.4**
Treated Mean Speed Northbound	30.6	32.1	32.9	NA	33.5	31.9
North Untreated Time Northbound	10:38-10:40	11:04-11:06	11:26-11:28	11:52-11:54	12:19-12:20	
North Untreated Mean ER Northbound	**26.8**	**28.7**	**40.2**	**ND***	**39.3**	**31.9**
North Untreated Mean Speed Northbound	13.6	26.6	14.1	NA	15.7	18.1
North Untreated Time Southbound	10:40-10:43	11:07-11:08	11:35-11:36	11:57-11:59	12:23-12:24	
North Untreated Mean ER Southbound	**48.9**	**40.3**	**ND***	**39.8**	**45.4**	**43.0**
North Untreated Mean Speed Southbound	15.2	15.3	NA	15.2	15.7	15.2
Treated Time Southbound	10:45-10:52	11:09-11:15	11:37-11:42	12:00-12:05	12:26-12:31	
Treated Mean ER Southbound	**0.7**	**0.7**	**ND***	**0.9**	**ND**	**0.8**
Treated Mean Speed Southbound	30.9	32.4	NA	34.9	NA	32.7
South Untreated Time Southbound	10:52-10:53	11:15-11:16	11:43-11:44	12:07-12:08	12:32-12:33	
South Untreated ER Southbound	**16.4**	**18.0**	**ND***	**ND**	**ND**	**17.2**
South Untreated Speed Southbound	12.8	12.9	NA	NA	NA	12.8
Untreated Overall Mean Emission Rate, mg/m						**36.1**
Treated Overall Mean Emission Rate, mg/m						**0.6**
ND* = No Data- filtered air control						
ND = Rear DustTrak broke						

SUMMARY AND CONCLUSIONS

The effectiveness of using dust suppressants to reduce PM_{10} reduction from unpaved roads was quantified for segments of SR88 and 288. The suppressant applied to SR88 five months ago reduced PM_{10} emissions by a factor of five. The suppressant applied to SR288 a year ago reduced PM_{10} emissions by a factor of sixty. The SCAMPER has been shown to collect reliable emission rates from unpaved roads with a precision of approximately 20%. Additional vibration isolation should be added to increase data capture for future measurements on unpaved roads.

REFERENCES

Fitz, D.R.and C. Bufalino. 2002. Measurement of PM_{10} emission factors from paved roads using on-board particle sensors. Air and Waste Management Association Symposium on Air Quality Measurement Methods and Technology – 2002. San Francisco, CA November 13-15.

Fitz, D.R., Bumiller, K., Etymezian, V., Kuhns, H., and Nikolich, G. 2005a Measurement of PM_{10} Emission Rates from Roadways in Las Vegas, Nevada using a SCAMPER Mobile Platform with Real-Time Sensors. Presented at the U.S. Environmental Protection Agency's 13th Annual Emission Inventory Conference: Transforming Emission Inventories, Meeting Future Challenges Today. Las Vegas, NV April 12-14.

Fitz, D.R., Bumiller, K., Etymezian, V., Kuhns, H., and Nikolich, G. 2005b Measurement of PM_{10} Emission Rates from Roadways in Las Vegas, Nevada Using a Mobile Platform and Real-Time Sensors and Comparison with the TRAKER. Presented at 98th Annual Air and Waste Management Association Meeting. Minneapolis-St. Paul, MN, June 21-24.

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