Emission Factor Documentation for AP-42, Section 13.2.1

Paved Roads

Measurement Policy Group
Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency

January 2011

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NOTICE

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SECTION 1

INTRODUCTION

The document "Compilation of Air Pollutant Emissions Factors" (AP-42) has been published by the U.S. Environmental Protection Agency (EPA) since 1968. Supplements to AP-42 have been routinely published to add new emission source categories and to update existing emission factors. AP-42 is periodically updated by EPA to respond to new emission factor needs of EPA, State, and local air pollution control programs and industry.

An emission factor relates the quantity (weight) of pollutants emitted to a unit of activity of the source. The uses for the emission factors reported in AP-42 include:

1. Estimates of area-wide emissions.

2. Estimates of emissions for a specific facility.

3. Evaluation of emissions relative to ambient air quality.

The purpose of this report is to compile the existing background report and supplements into a single report, provide an update of the background information from test reports and other information to support preparation of a revised AP-42 section to replace existing Section 13.2.1, "Paved Roads," dated November 2006.

The principal pollutant of interest in this report is "particulate matter" (PM), with special emphasis placed on "PM_{10}" - particulate matter no greater than 10μmA (micrometers in aerodynamic diameter) and $PM_{2.5}$. PM_{10} and $PM_{2.5}$ form the basis for the current National Ambient Air Quality Standards (NAAQSs) for particulate matter. PM_{10} and $PM_{2.5}$ thus represent the two size ranges of particulate matter that are of greatest regulatory interest. Nevertheless, formal establishment of PM_{10} and $PM_{2.5}$ as the standard basis is relatively recent, and many emission tests have referenced other particle size ranges. Other size ranges employed in this report are:

TSP Total Suspended Particulate, as measured by the standard high-volume (hi-vol) air sampler. TSP was the basis for the previous NAAQSs for particulate matter. TSP consists of a relatively coarse particle size fraction. While the particle capture characteristics of the hi-vol sampler are dependent upon approach wind velocity, the effective D50 (i.e., 50% of the particles are captured and 50% are not) varies roughly from 25 to 50 μmA.

SP Suspended Particulate, which is used as a surrogate for TSP. Defined as PM no greater than 30 μmA. SP also may be denoted as "PM_{30}."

IP Inhalable Particulate, defined as PM no greater than 15 μmA. Throughout the late 1970s and the early 1980s, it was clear that EPA intended to revise the NAAQSs to reflect a particle size range finer than TSP. What was not clear was the size fraction that would be eventually used, with values between 7 and 15 μmA frequently mentioned. Thus, many field studies were conducted using IP emission measurements because it was believed that IP would be the basis for the new NAAQS. IP may also be represented by "PM_{15}."

FP Fine Particulate, defined as PM no greater than 2.5µmA. FP also may be denoted as "$PM_{2.5}$."

This background report consists of five sections. Section 1 provides an introduction to the report. Section 2 presents descriptions of the paved road source types and emissions from those sources as well as a brief history of the current AP-42 emission factors. Section 3 is a review of emissions data collection and analysis procedures; it describes the literature search, the screening of emission test reports, and the quality rating system for both emission data and emission factors. Section 4 details the development of paved road emission factors for the draft AP-42 section; it includes the review of specific data sets and the results of data analysis. Section 5 presents the AP-42 section for paved roads.

SECTION 2

SOURCE DESCRIPTION

Particulate emissions occur whenever vehicles travel over a paved surface, such as public and industrial roads and parking lots. These emissions may originate from material previously deposited on the travel surface, resuspension of material carried by the vehicle, deposits from undercarriages, engine exhaust gases or tire and brake wear. Depending on the road surface characteristics, vehicle mix, the most significant emissions may arise from the surface material loading (measured as mass of material per unit area), or a combination of engine exhaust, brake and tire emissions. Surface loading is in turn replenished by other sources (e.g., pavement wear, deposition of material from vehicles, deposition from other nearby sources, carryout from surrounding unpaved areas, and litter). Because of the importance of the surface loading, available control techniques either attempt to prevent material from being deposited on the surface or to remove (from the travel lanes) any material that has been deposited.

2.1 PUBLIC AND INDUSTRIAL ROADS

While the mechanisms of particle deposition and resuspension are largely the same for public and industrial roads, there can be major differences in surface loading characteristics, emission levels, traffic characteristics, and viable control options. For the purpose of estimating particulate emissions and determining control programs, the distinction between public and industrial roads is not a question of ownership but rather a question of surface loading and traffic characteristics.

Although public roads generally tend to have lower surface loadings than industrial roads, the fact that these roads have far greater traffic volumes may result in a substantial contribution to the measured air quality in certain areas. In addition, public roads in industrial areas can be often heavily loaded and traveled by heavy vehicles. In that instance, better emission estimates might be obtained by treating these roads as industrial roads through the use of a silt loading and average vehicle weight appropriate for the road segment. In extreme cases, public roads, industrial road, or parking lots may have such a high surface loadings that the paved surface is covered with loose material and in extreme cases is mistaken for an unpaved surface. In that event, use of a paved road emission factor may actually result in a higher estimate than that obtained from the unpaved road emission factor, and the road is better characterized as unpaved in nature rather than paved.

2.2 REVIEW OF PAST AND CURRENT PAVED ROAD EMISSION FACTORS

2.2.1 September 1985 through January 1995.

From September 1985 through January 1995, AP-42 currently contained two sections concerning paved road fugitive emissions. The first, Section 11.2.5, is entitled "Urban Paved Roads" and was first drafted in 1984 using test results from public paved roads. Emission factors are given in the form of the following equation:

$$E = k\,(sL/0.5)^p \qquad (2\text{-}1)$$

where:			
	E	=	particulate emission factor (g/VKT)
	s	=	surface material content silt, defined as particles < 75 µm diameter (%)
	L	=	surface material loading, defined as mass of particles per unit area of the travel surface (g/m^2)
	k	=	base emission factor (g/VKT)
	p	=	exponent (dimensionless)

The factors k and p are given by

Particle size fraction	k (g/VKT)	p
TSP	5.87	0.9
PM_{15}	2.54	0.8
PM_{10}	2.28	0.8
$PM_{2.5}$	1.02	0.6

The form of the emission factor model is reasonably consistent throughout all particle size fractions of interest.

The urban paved road emission factors represented by Equation 2-1 did not change since their inclusion in the 4th Edition (September 1985) and the January 1995 revision. It should be noted that these emission factors were not quality rated "A" through "E." (See Section 3 for an overview of the AP-42 quality rating scheme.)

Section 11.2.6, "Industrial Paved Roads," was first published in 1983 and was slightly modified in Supplement B (1988) to the 4th Edition. Section 11.2.6 contained three distinct sets of emission factor models as described below.

$$E = 0.022\,I \left(\frac{4}{n}\right)\left(\frac{s}{10}\right)\left(\frac{L}{280}\right)\left(\frac{W}{2.7}\right)^{0.7} \qquad (2\text{-}2)$$

For TSP, the following equation is recommended:

where:			
	E	=	emission factor (kg/VKT)
	I	=	industrial augmentation factor (dimensionless)
	n	=	number of traffic lanes (dimensionless)
	s	=	surface material silt content (%)
	L	=	surface material loading across all traffic lanes (kg/km)
	W	=	average vehicle weight (Mg)

The basic form of Equation 2-2 dates from a 1979 report and was originally included in Supplement 14 to AP-42 (May 1983). The version used in AP-42 was slightly revised in that the leading term (i.e., 0.022 in Eq. [2-2]) was reduced by 14%. The industrial road augmentation factor (I) was included to take into account for higher emissions from industrial roads than from urban roads; it varied from 1 to 7. The emission factor equation was rated "B" for cases with I =1 and "D" otherwise.

For smaller particle size ranges, models somewhat similar to those in Eq. (2-1) were recommended:

$$E = k\,(sL/12)^{0.3} \qquad (2\text{-}3)$$

where:
- E = emission factor (kg/VKT)
- k = base emission factor (kg/VKT), see below
- sL = road surface silt loading (g/m2)

The base emission factor (k) above varied with aerodynamic size range as follows:

Particle size fraction	k (g/VKT)
PM_{15}	0.28
PM_{10}	2.22
$PM_{2.5}$	0.081

These models represented by Equation 2-3 were first developed in 1984 from 15 emission tests of uncontrolled paved roads and they were rated "A."

During the development of Eq. (2-3), tests of light-duty traffic on heavily loaded road surfaces were identified as a separate subset, for which separate single-valued emission factors were developed. Section 11.2.6 recommended the following for light-duty (less than 4 tons) vehicles traveling over roads where the surface material was dry and the road was heavily loaded (silt loading greater than 15 g/m^2):

$$E = k \qquad (2\text{-}4)$$

where:
- E = emission factor (kg/VKT)
- k = single-valued factor depending on particle size range of interest (see below)

Particle size fraction	k (g/VKT)
PM_{15}	0.12
PM_{10}	0.093

The single-valued emission factors was quality rated "C."

During the time that AP-42 had four methods for estimating emissions from paved roads (Sections 11.2.5 and 11.2.6, AP-42 Fourth Edition, 1993), users of AP-42 noted difficulty selecting the appropriate emission factor model to use in their applications. For example, inventories of industrial facilities (particularly of iron and steel plants) conducted throughout the 1980s yielded measured silt loading values substantially lower than those in the Section 11.2.6 data base. In extreme cases when the models were used with silt loading values outside the range for which they were developed, estimated PM10 emission factors were larger than the corresponding TSP emission factors.

Furthermore, the distinction between "urban" and "industrial" paved roads was blurred. For the purpose of estimating emissions, it was gradually realized that source emission levels are not a question of ownership but rather a question of surface loading and traffic characteristics. Confirmatory evidence was obtained in a 1989 field program[29] which found that paved roads at an iron and steel facility far more closely resembled "urban" roads rather than "industrial" roads in terms of emission characteristics.

Finally, it was unknown how well the emission factors of that time performed for cases of increased surface loading on public roads, such as after application of antiskid materials or within areas of trackout from unpaved areas.[14] These situations were of considerable interest to several state and local regulatory agencies, most notably in the western United States.

2.2.2 January 1995 through October 2002

The January 1995 update attempted to correct as many of the shortcomings of the previous versions as possible. To that end, the update employed an approach slightly different than that used in the past. In addition to reviewing test data obtained since the September 1988 update[8], the test data used for both of the 1988 sections were also included for reexamination in the final data set. In assembling the data base, no distinction was made between public and industrial roads or between controlled and uncontrolled tests, with the anticipation that the reformulated emission factor will be applicable over a far greater range of source conditions.

The inclusion of controlled tests represented a break with EPA previous guidelines for preparing AP-42 sections[9]. Those guidelines presented a clear preference that only uncontrolled tests be used to develop an emission factor. However, the principal control measures for paved roads seek to reduce the value of an independent variable in the emission factor equation, i.e., the silt loading.

The revised emissions factor equation published in the January 1995 update of the paved road section included silt loading, average vehicle weight and a particle size multiplier as independent variables. The resulting equation was:

$$E = k\,(sL/2)^{0.65}\,(W/3)^{1.5} \qquad (2\text{-}5)$$

where: E = particulate emission factor (having units matching the units of k)
k = particle size multiplier for particle size range and units of interest (see below),
sL = road surface silt loading (grams per square meter) (g/m2), and
W = average weight (tons) of the vehicles traveling the road.

The selection of the value for the independent variable for the particle size multiplier was based upon the units of the emissions factor desired and the size range for the emissions.

Particle Size Multipliers for Paved Road Equation

Size Range	Multiplier k		
	g/VKT	g/VMT	lb/VMT
$PM_{2.5}$	2.1	3.3	0.0073
PM_{10}	4.6	7.3	0.016
PM_{15}	5.5	9.0	0.020
PM_{30}	24	38	0.082

2.2.3 October 2002 through December 2003

Prior to October 2002, the basis of the particle sizing information for paved roads emissions factors was high volume sampler impactors data. While the initial particle sizing was performed by cyclones, subsequent particle sizing was performed by slotted impactors. The impactor data had biases created by particle bounce and reintrainment. As such particle sizing below 10 µm was questioned. In October 2002, a three city paved and unpaved road emissions study was completed that evaluated particle sizing at 10 and 2.5µm and assessed the default values for silt loading. The results of the three city study formed the basis for revising the $PM_{2.5}$ particle size multiplier k from 2.1 g/VKT (3.3 g/VMT or 0.0073 lb/VMT) to 1.1 g/VKT (1.8 g/VMT or 0.0040 lb/VMT). The form of the predictive equation and the exponents for silt loading and average vehicle weight were unchanged. The changes in the October 2002 revision provided recommended default silt loading data for normal and worst case public paved roads based upon the updated silt loading values for public paved roads. The remaining numerical revisions that were made in the emissions factor for paved roads included an adjustment for the normal mitigation effects due to rain events. For long term average conditions, a 25% reduction in the particulate emissions was included for every day that there was measureable rain for that day. A similar adjustment was included that used hourly time intervals rather that a daily time interval.

2.2.4 December 2003 through November 2006

The December 2003 revision of the AP-42 Section for paved roads incorporated a constant in the predictive equation for particulate emissions factors. The AP-42 equations prior to December 2003 estimated PM emissions from re-entrained road dust, and vehicle exhaust, brake wear and tire wear emissions. In the December 2003 revision of the section, the component of emissions due to exhaust, brake wear and tire wear were separated from the composite fugitive dust emission factor equation. The first stated reason for the separation was to eliminate the possibility of double counting emissions. With the introduction of EPA's Mobile6.2 model, estimates of PM emissions from exhaust, brake wear and tire wear were calculated based upon the vehicle mix, vehicle speed and road class. The double counting of emissions was a possibility when both the fugitive dust emission factors from AP-42 and Mobile6.2 were used to estimate emissions from vehicle traffic on paved roads. The second stated reason was to incorporate decreases in particulate matter emissions from the exhaust of newer vehicle models and fuel sources. Since the majority of data supporting the paved road emission factor equation was developed at the time prior to when the vehicles in the fleet incorporated significant reductions of particulate matter emissions. A technical memorandum provided the basis for estimating PM emissions due to exhaust, break wear and tire wear. The technical memorandum used estimated emissions from a 1980's model year vehicle fleet since the emissions tests supporting the emissions factors equation were performed in the early 1980's to early 1990's. It was believed that since 1980, there have been and will continue to be improvements in vehicles and fuel that will result in a decrease in PM emissions from engine exhaust. Depending on the emissions factors units desired, the constant that was included in the emissions factor equation had values of 0.2119 g/VKT, 0.1317 g/VMT or 0.00047 lb/VMT for PM_{30}, PM_{15} and PM_{10} emissions. For $PM_{2.5}$ emissions, depending on the required emissions factors units, the constant used in the equation had values of 0.1617 g/VKT, 0.1005 g/VMT or 0.00036 lb/VMT.

2.2.5 November 2006 through May 2010

In November 2006, the particle size multiplier k was lowered to 0.66 g/VKT, 1.1 g/VMT or 0.0024 depending on the needed units for the emissions factor. The revision was based upon a broad based assessment of the biases associated with the cyclone/impactor method for particulate sizes less than 10 μm in aerodynamic diameter. While the December 2003 update revised the particle size multiplier, the update was based upon limited test data. In addition, the impact of biased emissions factor ratios for $PM_{2.5}$ impacted fugitive sources other than paved roads. The impact was due to particle bounce from the cascade impactor stages to the backup filter potentially inflating $PM_{2.5}$ concentrations. The impact was possible even though steps were taken to minimize particle bounce in the earlier studies. The assessment study was sponsored by the Western Regional Air Partnership and conducted by the Midwest Research Institute (MRI). The testing was conducted at MRI's Aerosol Test Facility (ATF) in Deramus Field Station in Grandview, Missouri using surface dust collected from seven locations in five western states. The tests provided the basis for comparing the average $PM_{2.5}$ concentration and the collocated PM_{10} concentration. The study compared the fine fraction ratios derived from FRM samplers to those derived from the cyclone/impactor method. The cyclone/impactor samplers and operating method used in the study were the same as those that generated the original AP-42 emission factors and associated $PM_{2.5}$ / PM_{10} ratios. The study consisted of 100 test runs covering PM_{10}concentration from approximately 0.3 mg/m^3 to 7 mg/m^3.

2.2.6 May 2010

This update recommends an updated equation for paved roads that is based upon additional test data that was conducted on roads with slow moving traffic and stop and go traffic. The emissions tests were performed for the Corn Refiners Association by Midwest Research Institute (MRI). The testing focused on PM_{10} emissions at four corn processing facilities. Unlike the development of earlier paved road equations, the equation development for this version adjusts the individual test data measured emissions by excluding exhaust emissions, tire wear emissions and brake wear emissions prior to the equation development. As a result, different values are subtracted from the results of each test based upon the average vehicle weights, average vehicle speed, ambient temperature, year of test and estimated mix of light duty and heavy duty vehicles.

SECTION 3

GENERAL DATA REVIEW AND ANALYSIS

To reduce the amount of literature collected to a final group of references from which emission factors could be developed, the following general criteria were used:

1. Emissions data must be from a primary reference:
    a. Source testing must be from a referenced study that does not reiterate information from previous studies.
    b. The document must constitute the original source of test data. For example, a technical paper was not included if the original study was contained in the previous document. If the exact source of the data could not be determined, the document was eliminated.

2. The referenced study must contain test results based on more than one test run.

3. The report must contain sufficient data to evaluate the testing procedures and source operating conditions.

A final set of reference materials was compiled after a thorough review of the pertinent reports, documents, and information according to these criteria.

3.1 LITERATURE SEARCH AND SCREENING

Review of available literature identified three paved road testing programs (presented later as Table 4-1) since the time of the last Section 11.2 update.[8] The individual programs are discussed in detail in the next section. In addition, as discussed at the end of Section 2, earlier controlled industrial road test data were reexamined. The previous update[8] noted that Eq. (2-4) yielded quite good estimates for emissions from vacuum swept and water flushed roads. Furthermore, it became apparent that previous distinctions between "industrial" and "urban" roads had become blurred as interest focused on heavily loaded urban roads (e.g., after snow/ice controls) and on cleaner industrial roads (as the result of plant-wide control programs).

3.2 EMISSION DATA QUALITY RATING SYSTEM

As part of the analysis of the emission data, the quantity and quality of the information contained in the final set of reference documents were evaluated. The following data are to be excluded from consideration:

1. Test series averages reported in units cannot be converted to the selected reporting units.

2. Test series representing incompatible test methods (i.e., comparison of EPA Method 5 front-half with EPA Method 5 front- and back-half).

3. Test series of controlled emissions for which the control device is not specified.

4. Test series in which the source process is not clearly identified and described.

5. Test series in which it is not clear whether the emissions were measured before or after the control device.

Test data sets that were not excluded were assigned a quality rating. The rating system used was that specified by EPA for preparing AP-42 sections.[9] The data were rated as follows:

A Multiple tests that were performed on the same source using sound methodology and reported in enough detail for adequate validation. These tests do not necessarily conform to the methodology specified in EPA reference test methods, although these methods were used as a guide for the methodology actually used.

B Tests that were performed by a generally sound methodology, but lack enough detail for adequate validation.

C Tests that were based on an untested or new methodology or that lacked a significant amount of background data.

D Tests that were based on a generally unacceptable method but may provide an order-of-magnitude value for the source.

The following criteria were used to evaluate source test reports for sound methodology and adequate detail:

1. Source operation. The manner in which the source was operated is well documented in the report. The source was operating within typical parameters during the test.

2. Sampling procedures. The sampling procedures conformed to a generally acceptable methodology. If actual procedures deviated from accepted methods, the deviations are well documented. When this occurred, an evaluation was made of the extent such alternative procedures could influence the test results.

3. Sampling and process data. Adequate sampling and process data are documented in the report, and any variations in the sampling and process operation are noted. If a large spread between test results cannot be explained by information contained in the test report, the data are suspect and were given a lower rating.

4. Analysis and calculations. The test reports contain original raw data sheets. The nomenclature and equations used were compared to those (if any) specified by EPA to establish equivalency. The depth of review of the calculations was

dictated by the reviewer's confidence in the ability and conscientiousness of the tester, which in turn was based on factors such as consistency of results and completeness of other areas of the test report.

3.3 EMISSION FACTOR QUALITY RATING SYSTEM

The quality of the emission factors developed from analysis of the test data was rated utilizing the following general criteria:

A—Excellent: Developed only from A-rated test data taken from many randomly chosen facilities in the industry population. The source category is specific enough so that variability within the source category population may be minimized.

B—Above average: Developed only from A-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industries. The source category is specific enough so that variability within the source category population may be minimized.

C—Average: Developed only from A- and B-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. In addition, the source category is specific enough so that variability within the source category population may be minimized.

D—Below average: The emission factor was developed only from A- and B-rated test data from a small number of facilities, and there is reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of the emission factor are noted in the emission factor table.

E—Poor: The emission factor was developed from C- and D-rated test data, and there is reason to suspect that the facilities tested do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of these factors are always noted.

The use of these criteria is somewhat subjective and depends to an extent on the individual reviewer.

3.4 METHODS OF EMISSION FACTOR DETERMINATION

Fugitive dust emission rates and particle size distributions are difficult to quantify because of the diffuse and variable nature of such sources and the wide range of particle size involved including particles which deposit immediately adjacent to the source. Standard source testing methods, which are designed for application to confined flows under steady state, forced-flow conditions, are not suitable for measurement of fugitive emissions unless the plume can be draw into a forced-flow system. The following presents a brief overview of applicable measurement techniques. More detail can be found in earlier AP-42 updates.[8,10]

3.4.1 Mass Emission Measurements

Because it is usually impractical to enclose open dust sources or to capture the entire emissions plume, only the upwind-downwind and exposure profiling methods are suitable for measurement of particulate emissions from most open dust sources.[10] These two methods are discussed separately below.

The basic procedure of the upwind-downwind method involves the measurement of particulate concentrations both upwind and downwind of the pollutant source. The number of upwind sampling instruments depends on the degree of isolation of the source operation of concern (i.e., the absence of interference from other sources upwind). Increasing the number of downwind instruments improves the reliability in determining the emission rate by providing better plume definition. In order to reasonably define the plume emanating from a point source, instruments need to be located at two downwind distances and three crosswind distances, at a minimum. The same sampling requirements pertain to line sources except that measurement need not be made at multiple crosswind distances.

Net downwind (i.e., downwind minus upwind) concentrations are used as input to dispersion equations (normally of the Gaussian type) to back calculate the particulate emission rate (i.e., source strength) required to generate the pollutant concentration measured. Emission factors are obtained by dividing the calculated emission rate by a source activity rate (e.g., number of vehicles, or weight of material transferred per unit time). A number of meteorological parameters must be concurrently recorded for input to this dispersion equation. At a minimum the wind direction and speed must be recorded on-site.

While the upwind-downwind method is applicable to virtually all types of sources, it has significant limitations with regard to development of source-specific emission factors. The major limitations are as follows:

1. In attempting to quantify a large area source, overlapping of plumes from upwind (background) sources may preclude the determination of the specific contribution of the area source.

2. Because of the impracticality of adjusting the locations of the sampling array for shifts in wind direction during sampling, it cannot be assumed that plume position is fixed in the application of the dispersion model.

3. The usual assumption that an area source is uniformly emitting does not allow for realistic representation of spatial variation in source activity.

4. The typical use of uncalibrated atmospheric dispersion models introduces the possibility of substantial error (a factor of three according to Reference 11) in the calculated emission rate, even if the stringent requirement of unobstructed dispersion from a simplified (e.g., constant emission rate from a single point) source configuration is met.

The other measurement technique, exposure profiling, offers distinct advantages for source-specific quantification of fugitive emissions from open dust sources. The method uses the isokinetic profiling concept that is the basis for conventional (ducted) source testing. The passage of airborne pollutant immediately downwind of the source is measured directly by means of simultaneous multipoint sampling over the effective cross section of the fugitive emissions plume. This technique uses a mass-balance calculation scheme similar to EPA Method 5 stack testing rather than requiring indirect calculation through the application of a generalized atmospheric dispersion model.

For measurement of nonbuoyant fugitive emissions, profiling sampling heads are distributed over a vertical network positioned just downwind (usually about 5 m) from the source. If total particulate emissions are to be measured, sampling intakes are pointed into the wind and sampling velocity is adjusted to match the local mean wind speed, as monitored by anemometers distributed over height above ground level.

The size of the sampling grid needed for exposure profiling of a particular source may be estimated by observation of the visible size of the plume or by calculation of plume dispersion. Grid size adjustments may be required based on the results of preliminary testing. Particulate sampling heads should be symmetrically distributed over the concentrated portion of the plume containing about 90% of the total mass flux (exposure). For example, assuming that the exposure from a point source is normally distributed, the exposure values measured by the samplers at the edge of the grid should be about 25% of the centerline exposure.

To calculate emission rates using the exposure profiling technique, a conservation of mass approach is used. The passage of airborne particulate (i.e., the quantity of emissions per unit of source activity) is obtained by spatial integration of distributed measurements of exposure (mass/area) over the effective cross section of the plume. The exposure is the point value of the flux (mass/area/time) of airborne particulate integrated over the time of measurement.

3.4.2 Emission Factor Derivation

Emissions factors are typically derived from the ratio of the emissions to an activity level. It is assumed that the emissions are linearly proportional to the selected activity level. Usually the final emission factor for a given source operation, is the arithmetic average of the individual emission factors calculated from each test of that source type. In rare instances, the range of individual emission factor values is also presented.

As an improvement over the presentation of a final emission factor as a single-valued arithmetic mean, an emission factor may be presented in the form of a predictive equation derived by regression analysis of test data. The use of a predictive equation with a relatively good correlation coefficient (R^2) provides a means for improving the accuracy of the emissions factor in estimating the actual emissions when the independent variables are known. Such an equation mathematically relates emissions to parameters when characterize source conditions. These parameters may be grouped into three categories:

1. Measures of source activity or energy expended (e.g., the speed and weight of a vehicle traveling on an unpaved road).

2. Properties of the material being disturbed (e.g., the content of suspendable fines

in the surface material on an unpaved road).

3. Climatic parameters (e.g., number of precipitation-free days per year on which emissions tend to be at a maximum).

An emission factor equation is useful if it is successful in "explaining" much of the observed variance in emission factor values on the basis of corresponding variance sin specific source parameters. This enables more reliable estimates of source emissions on a site-specific basis.

A generic emission factor equation is one that is developed for a source operation defined on the basis of a single dust generation mechanism which crosses industry lines. An example would be vehicular traffic on unpaved roads. To establish its applicability, a generic equation should be developed from test data obtained in different industries.

3.5 EMISSION FACTOR QUALITY RATING SCHEME USED IN THIS STUDY

The uncontrolled emission factor quality rating scheme used in this study is somewhat different than was used in earlier updates[8,11] of this section and represents a refinement of the rating system developed by EPA for AP-42 emission factors, as described in Section 3.3. The scheme entails the use of the same rating assessment of source test data quality followed by an initial rating assessment of the emission factor(s) based on the number and quality of the underlying source test data.

Test data that were developed from well documented, sound methodologies were assigned an A rating. Data generated by a methodology that was generally sound but either did not meet a minimum test system requirements or lacked enough detail for adequate validation received a B rating.

In evaluating whether an upwind-downwind sampling strategy qualified as a sound methodology, the following minimum test system requirements were used. At least five particulate measuring devices must be operated during a test, with one device located upwind and the other located at two downwind and three crosswind distances. The requirement of measurements at crosswind distances is waived for the case of line sources. Also wind direction and speed must be monitored concurrently on-site.

The minimum requirements for a sound exposure profiling program were the following. A one-dimensional, vertical grid of at least three samplers is sufficient for measurement of emissions from line or moving point sources while a two-dimensional array of at least five samplers is required for quantification of fixed virtual point source missions. At least one upwind sampler must be operated to measure background concentration, and wind speed must be measured on-site.

Neither the upwind-downwind nor the exposure profiling method can be expected to produce A-rated emissions data when applied to large, poorly defined area sources, or under very light and variable wind flow conditions. In these situations, data ratings based on degree of compliance with minimum test system requirements were reduced one letter.

Following the assignment of the individual source test quality ratings, the factor quality rating of the single-valued emission factor will be evaluated. Recently approximately 20 “A” and “B” rated source test reports have been required to justify a factor quality rating of “A”. Each halving of the number of source test reports results in a one letter grade reduction in the final factor quality rating. Several of the source test reports used as the basis for the emissions factor development include measurements conducted at different locations. To the extent that there are more than two tests at the different locations and that the different locations within a given reference represent differences in source conditions, each of the different source conditions will be counted as an independent test. The development of the paved road emissions factor differs from typical in that it includes the use of stepwise multiple non linear regression. Following the initial factor quality rating, the adjusted correlation coefficient will be used to increase the emissions factor quality rating. Only correlation coefficients above 0.4 will be used to increase the emissions factor quality rating.

SECTION 4

AP-42 SECTION DEVELOPMENT

4.1 REVISIONS TO SECTION NARRATIVE

The AP-42 presented later in this background document is intended to replace the current version of Section 13.2.1 "Paved Roads" in AP-42. The last update of this section is dated November 2006. The general form of the emissions factor equation presented in the paved road section has been consistent since the January 1995 major revision. Since this date revisions have been made addressing the influence of rain events, estimating default silt loading levels for various classes of roads, separating particulate emissions associated with the roads verses those associated with the vehicles and addressing biases in the measurement of $PM_{2.5}$ with devices that use impactors to perform particulate sizing.

4.2 POLLUTANT EMISSION FACTOR DEVELOPMENT

This update to Sections 13.2.1 is planned to address the application of the emissions factor equation addressing only the component associated with paved road surface materials and at speeds lower than 10 miles per hour. In order to achieve this goal, the following general approach was taken

1. Assemble the available test data for paved roads in a single data base, making no distinction between public and industrial roads or between controlled and uncontrolled roads.
2. Develop PM_{10} and $PM_{2.5}$ engine, tire wear and brake ware emissions estimates for each of the available data sets. For each of the available data sets, estimate the emissions associated with the road surface material by subtracting the engine, tire wear and brake wear from the measured PM_{10} emissions.
2. Conduct a series of stepwise linear regression analyses of the revised and adjusted data base to assess the most critical parameters and to develop an emission factor model with:
   - silt loading,
   - mean vehicle weight, and,
   - mean travel speeds

   as potential correction parameters.
3. Conduct an appropriate validation study of the reformulated model.

4.2.1 Review of Specific Data Sets

4.2.1.1 Street Sanding Emissions And Control Study, PEI Associates, Inc., Cincinnati, OH, October 1989. (Reference 15)

This test program was undertaken to characterize PM_{10} emissions from six streets that were periodically sanded for anti-skid control within the Denver area. The primary objective was given as development of a predictive algorithm for clean and sanded streets, with a secondary objective stated as defining the effectiveness of control measures. Summary information is given in Table 4-1.

Sampling employed six to eight 8 PM_{10} samplers equipped with volumetric flow control. Samplers were arranged in two upwind/downwind configurations. The "basic" configuration consisted of six samplers arranged in identical patterns upwind and downwind of the test road, with one sampler and one pair of samplers at nominal distances of 20 and 5 m, respectively, from the road.

The second configuration was used for tests of control measure effectiveness. The road segment was divided into two halves, corresponding to the treated and experimental control (untreated) portions. Identical sampling arrays were again used upwind and downwind on both halves, at nominal distances of 20 and 5 m. Because this array employed all eight samplers available, no collocation was possible for the second configuration.

In addition to the PM_{10} concentration measurements, several other types of samples were collected:

- Wind speed/direction and incoming solar radiation were collected on-site, and the results were combined to estimate atmospheric stability class needed to calculate emission factors.
- Colorado Air Pollution Control Division (APCD) representatives collected traffic data, including traffic counts, travel speeds, and percentage of heavy-duty vehicles.
- Vacuums with disposable paper bags were used to collect the loose material from the road surface. In addition to samples taken from the travel lanes, the field crew took daily samples of material adjacent to curbs and periodic duplicate samples.

The study collected PM_{10} concentration data on 24 different days and calculated a total of 69 different emission rates for baseline, sanded and controlled paved road surfaces. Emission factors were obtained by back-calculation from the CALINE3 dispersion model[12] together with a series of assumptions involving mixing widths and heights and an effective release height. Although data collected at the 20 m distance were used to evaluate results, the test report did not describe any sensitivity analysis to determine how dependent the emission rates were on the underlying assumptions.

TABLE 4-1. SUMMARY INFORMATION FOR REFERENCE 15

					PM_{10} emission factor (g/VKT)	
Operation	Location	State	Test dates	No. of tests	Geom. mean	Range
Vehicle traffic	Colfax	Colorado	3-4/89	17	1.33	0.53-9.01
Vehicle traffic	York St.	Colorado	4/89	1	1.07	1.07
Vehicle traffic	Belleview	Colorado	4/89	4	1.62	1.10-4.77
Vehicle traffic	I-225	Colorado	4/89	9	0.31	0.17-0.51
Vehicle traffic	Evans	Colorado	5-6/89	29	1.06	0.21-7.83
Vehicle traffic	Louisiana	Colorado	6/89	7	0.96	0.42-1.73

The testing program found difficulty in defining "upwind" concentrations for several of the runs, including cases with wind reversals or winds nearly parallel to the roadway orientation. A total of eight of the 69 tests required that either an average concentration from other test days or a downwind concentration be used to define "upwind" conditions. In addition, the test report described another seven runs as invalid for reasons such as wet road surfaces, nearby dust sources or concentrations increasing with downwind distance.

A series of stepwise regression analyses were conducted, with different predictive equations presented for (a) baseline conditions, (b) sanded roads, and (c) roads swept to remove the sand applied, and (d) all conditions combined. In each case, only one independent variable was included in the predictive equation: silt loading, for cases (a) and (d); and time since treatment, for (b) and (c).

In general, Reference 15 is reasonably well documented in terms of describing test conditions, sampling methodology, data reduction and analysis. A chief limitation lies in the fact that neither sampling configuration fully met minimum requirements for the upwind-downwind method presented in Section 3.4. Specifically, only two or three samplers were used downwind rather than the minimum of four.

Furthermore, a later report[6] drawing upon the results from Reference 15 and 17 effectively eliminated 24% of the combined baseline tests because of wind directions. In addition, the later report[6] noted that the baseline data should be considered as "conservatively high" because roughly 70% of the data were calculated assuming the most unstable atmospheric class (which results in the highest back calculated emission factor). Because of these limitations, the emission data have been given an overall rating of "D."

4.2.1.2 RTP Environmental Associates 1990. Street Sanding Emissions and Control Study, prepared for the Colorado Department of Health. July 1990. (Reference 17)

This test program was quite similar to that described in Reference 15 cited in paragraph 4.2.1.1 and used an essentially identical methodology. In fact, the two test reports are very similar in outline, and many passages in the two reports are identical. The primary objective was given as expanding the data base in Reference 15 to further develop predictive algorithms for clean and sanded streets. Summary information is given in Table 4-2.

The test program employed the same two basic PM_{10} sampling arrays as did Reference 15. A third configuration was used for "profile" tests, in which additional samplers were placed at 10 and 20 ft heights. (Analysis of results from elevated samplers is not presented in Reference 17.)

As was the case in Reference 15, additional samples were collected including:

- Wind speed/direction were collected on-site, and the results used in estimating atmospheric stability class needed to calculate emissions factors. (Unlike Reference 15, solar radiation measurements were not collected.)
- Traffic data, including traffic counts, travel speeds, and percentages of heavy-duty vehicles were collected.
- Vacuums with disposable paper bags were used to collect the loose material

from the road surface. The program developed an extensive set of collocated samples of material along the edges of the roadway.

The study collected PM_{10} concentration data on 33 days and calculated a total of 131 different emission rates for baseline, sanded and controlled paved road surfaces. Emission factors were obtained by back-calculation from the CALINE3 dispersion model[12] together with essentially the same assumptions as those in Reference 15. This report also noted the same difficulty as Reference 15 in defining "upwind" concentrations in cases with wind reversals or winds nearly parallel to the roadway orientation. Unlike Reference 15, however, this report does not provide readily available information on how many tests used either an average concentration from other test days or a downwind concentration to define "upwind" conditions. Reference 6 does, however, describe seven tests as invalid because of filter problems or because upwind concentrations were higher than downwind values.

As with the Reference 15 program, a series of stepwise regression analyses were conducted. This test program combined data from Reference 15 and 17 and considered predictive equations for (a) baseline conditions, (b) sanded roads, and (c) roads swept to remove the sand applied, and (d) all conditions combined.

Unlike Reference 15, however, Reference 17 appears to present silt loading values that are based on wet sieving (see page 8 of the test report) rather than the dry sieving technique (as described in Appendix E to AP-42) routinely used in fugitive dust tests. (MRI could not obtain any clarifying information during telephone calls to the testing organization and the laboratory that analyzed the samples.) Wet sieving disaggregates composite particles and results from the two types of sieving are not comparable.

There is additional confusion over the silt loading values given in Reference 17 for cleaning tests. Specifically, the same silt loading value is associated with both the treatment and the experimental control. This point could not be clarified during telephone conversation with the testing organization. Attempts to clarify using test report appendices were unsuccessful. Two appendices appear to interchange silt loading with silt percentage. More importantly, it could not be determined whether the surface sample results reported in Appendix D to Reference 17 pertain to treated or the experimental control segment, and with which emission rate a silt loading should be associated.

TABLE 4-2. SUMMARY INFORMATION FOR REFERENCE 17

Operation	Location	State	Test dates	No. of test	PM_{10} emission factor (g/VKT)	
					Geom. mean	Range
Vehicle traffic	Mexico	Colorado	2/90	3	2.75	1.08-6.45
Vehicle traffic	State Hwy 36	Colorado	1-3/90	13	1.31	0.14-4.18
Vehicle traffic	Colfax	Colorado	2-4/90	41	1.32	0.27-5.04
Vehicle traffic	Park Rd.	Colorado	4/90	11	1.26	0.69-3.33
Vehicle traffic	Evans	Colorado	2-3/90	11	2.10	0.87-7.27
Vehicle traffic	Louisiana	Colorado	1,3/90	9	3.24	1.40-5.66
Vehicle traffic	Jewell	Colorado	1/90	1	6.36	6.36
Vehicle traffic	Bryon	Colorado	4/90	3	8.38	5.53-14.72

Reference 17 contains substantial amounts of information, but is not particularly well documented in terms of describing test conditions, sampling methodology, data reduction and analysis. In addition, the same limitations mentioned in connection with Reference 15 are equally applicable to Reference 17, as follows:

- not meeting the minimum number of samplers.
- numerous tests conducted under variable wind conditions.
- frequent use (70% to 80% of the tests) of the most unstable atmospheric stability class in the CALINE 3 model which will result in the highest calculated emission rate.

Because of these limitations, emission rate data have been given an overall rating of "D." Furthermore, the silt loading data in this report are considered suspect for reasons noted above.

4.2.1.3 T. Cuscino, Jr., et al., *Iron And Steel Plant Open Source Fugitive Emission Control Evaluation,* EPA 600/2 83 110, U. S. Environmental Protection Agency, Cincinnati, OH, October 1983. (Reference 6, ref_06c13s0201_2011.pdf)

This study evaluated paved road control techniques at two different iron and steel plants. (See Tables 9 and 10 in Reference 8.) Data were quality rated as "A," and uncontrolled test results were incorporated into the data base for Section 11.2.6 published in 1983. The only use of the controlled test results, however, was the following addition to Section 11.2.6.4 in 1988:

> "Although there are relatively few quantitative data on emissions from controlled paved roads, those that are available indicate that adequate estimates generally may be obtained by substituting controlled loading values into .. [Equations (2-2) and (2-3)].... The major exception to this is water flushing combined with broom sweeping. In that case, the equations tend to overestimate emissions substantially (by an average factor of 4 or more)."

In the current update, the controlled emission factors have been used as part of the overall data base to develop predictive models. Although PM_{10} emission data are not specifically presented in the report, appropriate values were previously developed by log-normal interpolation of the PM_{15} and $PM_{2.5}$ factors.[8]

4.2.1.4. G. E. Muleski, *Measurement of Fugitive Dust Emissions from Prilled Sulfur Handling, Final Report,* MRI Project No. 7995-L, Prepared for Gardinier, Inc., June 1984 (Reference 45)

This was first report identified to suggest that heavily loaded paved roads may be better considered as unpaved in terms of emission estimates. The program produced three tests of emissions from end-loader travel over paved surfaces. Two of the three tests were conducted on very heavily loaded surface, while the third was on a cleaned paved surface. (See Tables 20 and 21 of the 1987 update.)[8]

No PM_{10} emission factors were reported; results were presented for total particulate (TP) and suspended particulate (SP, or PM_{30}). Data were quality rated "A" in the 1987 report.

Because no PM_{10} data were given, Test Report 5 data were most directly useful as independent data against which the TSP emission factor model (Eq. (2-2)) could be assessed. This comparison showed generally good agreement between predicted and observed with agreement becoming better as source conditions approached those in the underlying data base.

The 1987 update[8] developed PM_{10} emission factors based on information contained in the test report. When compared to the single valued factors (Equation [2-4]), agreement for the first two tests was within a factor of approximately two. The third test — that of the cleaned surface — could not be used to assess the performance of either Eq. (2-1) or Eq. (2-3) because the surface loading value could not be converted to the necessary units with information presented in the report.

4.2.1.5 T. F. Eckle and D. L. Trozzo, *Verification of the Efficiency of a Road-Dust Emission-Reduction Program by Exposure Profile Measurement,* Presented at EPA/AISI Symposium on Iron and Steel Pollution Abatement, Cleveland, Ohio, October 1984. (Reference 46)

This paper discussed the development of an exposure profiling system as well as an evaluation of the effectiveness of a paved road vacuum sweeping program. Because no reference is made to an earlier test report, this paper is considered to be the original source of the test data. Although ten uncontrolled and five controlled tests are mentioned, test data are reported only in terms of averages. (See Tables 24 and 25 in Reference 8.) Only TSP emission factors are presented. Although data were obtained using a sound methodology, data were rated "C" because of inadequate detail in the paper.

Averaged data from Test Report 8 were used in an independent assessment of Eq. (2-2). Although only average emission levels could be compared, the data suggested that TSP emissions could be estimated within very acceptable limits.

4.2.1.6 Roadway Emissions Field Tests at U.S. Steel's Fairless Works, U.S. Steel Corporation, Fairless Hills, PA, USX Purchase Order No. 146-0001191-0068, May 1990. (Reference 31, ref_31c13s0201_2011.pdf).

This 1989 field program used exposure profiling to characterize emissions from paved roads at an integrated iron and steel plant near Philadelphia, Pennsylvania, in November 1989. In many respects, this program arose because of uncertainties with paved road emission factor models used outside their range of applicability. During the preparation of an alternative emission reduction ("bubble") plan for the plant, questions arose about the use of AP-42 equations and other EPA guidance[13] in estimating roadway emissions involved in the emissions trade. This program provided site-specific data to support the bubble plan. This testing program also represented the first exposure profiling data to supplement the AP-42 paved road data base since the 1984 revision. Site "C" was located along the main access route and had a mix of light- and medium-duty vehicles. Site "E" was located near the southwest corner of the plant and the traffic consisted mostly of plant equipment. Table 4-3 provides summary information and Table 4-4 provides detailed information.

The program involved two paved road test sites. The first (site "C") was along the four-lane main access route to the plant. Average daily traffic (ADT) had been estimated as more than 4,000 vehicle passes per day, with most vehicles representative of "foreign" equipment (i.e., cars, pickups, and semi-trailers rather than plant haul trucks and other equipment). Site "E," on the other hand, was located near the iron- and steel-making facilities and had both lower ADT and heavier vehicles than site "C." The plant regularly vacuum swept paved roads, and two cleaning frequencies (two times and five times per week) were considered during the test program.

Eight tests were conducted at Site C-1 and four tests were conducted at Site E-2. The paved road test sites were considered uncontrolled. The road width, moisture content, and mean number of wheels were not reported. The test data are assigned an “A” rating. Table 4-3 presents summary information and Table 4-4 presents detailed test information. Warm wire anemometers at two heights measured wind speed.

Depending on traffic characteristics of the road being tested, a 6 to 7.5 m high profiling array was used to measure downwind mass flux. This array consisted of four or five total particulate sampling heads spaced at 1.5 m heights and was positioned at a nominal 5 m distance downwind from the road. A high-volume sampler with a parallel-slot cascade impactor and a cyclone preseparator (cutpoint of 15 µmA) was employed to measure the downwind particle size distribution, and a standard high-volume sampler was utilized to determine the downwind mass fraction of total suspended particulate matter (TSP). The height for downwind sizing devices (2.2 m) was selected after review of prior test results. It approximated the height in a roadway dust plume at which half the mass emissions pass above and half below. The upwind (background) particle size distribution was determined with a high-volume cyclone/ impactor combination. Warm wire anemometers at two heights measured wind speed.

Additional samples included:

- Average wind speeds at two heights and wind direction at one height were recorded during testing to maintain isokinetic sampling.
- Traffic data, including traffic counts, travel speeds, and vehicle class were recorded manually.
- Vacuums with disposable paper bags were used to collect the loose material from the road surface.

The sampling equipment met the requirements of a sound exposure profiling methodology specified in Section 3.4 so that the emission test data are rated "A." The test report presents emission factors for total particulate (TP), total suspended particulate (TSP) and PM_{10}, for the ten paved road emission tests conducted.

Reference 31 found that the emission factors and silt loadings more closely resembled those in the "urban" rather than the "industrial" data base. That is to say, emissions agreed more closely with factors estimated by the methods of September 1985 AP-42 Section 11.2.5 than by methods in Section 11.2.6. Given the traffic rate of 4000 vehicles per day at Site "C," this finding was not terribly surprising. What was far more surprising was that emissions at Site "E" were also more "urban" than "industrial." Although the TSP and PM_{10} models in Section 11.2.5 showed a slight tendency to underpredict, the Section 11.2.6 PM_{10} model overestimated measured emissions by at least an order of magnitude. The performance of the industrial TSP model, on the other hand, was only slightly poorer than that for the urban TSP model.

4.2.1.7 Midwest Research Institute, Paved Road Particulate Emissions - Source Category Report, for U.S. EPA, July 1984. (Reference 8, ref_08c13s0201_2011.pdf)

This document reports the results of testing of paved roads conducted in 1980 at sites in Kansas City, MO, St. Louis, MO, Tonganoxie, KS, and Granite City, IL. Paved road test sites included commercial/industrial roads, commercial/residential roads, expressways, and a street in a rural town. The expanded measurement program reported in this document was used to develop emission factors for paved roads and focused on the following particle sizes: PM_{15} (inhalable particulate matter [IP]), PM_{10}, and $PM_{2.5}$.

Total airborne PM emissions were characterized using an exposure profiler containing four sampling heads. High-volume samplers with size selective inlets (SSI) having a cutpoint of 15 µmA were used to characterize upwind and downwind PM_{15} concentrations. A high- volume sampler with a SSI and a cascade impactor was also located downwind to characterize particle size distribution within the PM_{15} component. Upwind and downwind standard high- volume samplers measured TSP concentrations. Warm wire anemometers at two heights measured wind speed.

A total of 19 paved road emission tests were conducted in four cities. These included four tests of commercial/industrial paved roads, ten tests of commercial/residential paved roads, four expressway tests, and one test of a street in a rural town. Additionally, as part of this study, 81 dust samples were collected in 12 cities. The mean number of vehicle wheels was not reported. The test data are assigned an A rating. Table 4-5 presents summary test data and Table 4-6 presents detailed test information.

TABLE 4-3. SUMMARY INFORMATION FOR REFERENCE 31

Operation	Location	State	Test dates	No. of tests	TSP emission factor, lb/VMT		PM_{10} emission factor, lb/VMT	
					Geom. mean	Range	Geom. mean	Range
Vehicle traffic	AU-X (Unpaved road)	PA	11/89	2	0.61	0.39-0.96	0.16	0.14-0.18
Vehicle traffic	Paved road	PA	11/89	6	0.033	0.012-0.12	0.0095	0.0009-0.036
Vehicle traffic	Paved road	PA	11/89	4	0.078	0.033-0.30	0.022	0.0071-0.036

1 lb/VMT = 281.9 g/VKT.

TABLE 4-4. DETAILED INFORMATION FROM PAVED ROAD TESTS FOR REFERENCE 31

Test runs	PM_{10} emission factor, lb/VMT	Duration, min	Meteorology		Vehicle characteristics			Silt loading, g/m^2	Silt, %
			Temperature, °F	Mean wind speed, mph	No. of vehicle passes	Mean vehicle weight, ton	Mean vehicle speed[a]		
AU-C-3	0.00497	103	50	12	836	5.5	(27)	0.42	10
AU-C-4	0.0355	147	63	11	1057	6.0	25	0.52	12
AU-C-5	0.0337	120	62	14	963	3.9	29	0.23	9.7
AU-C-6	0.00816[c]	187	39	14	685	6.2	(27)	0.23[b]	8.6
AU-C-7	0.000887	96	42	12	703	3.0	(27)	0.26[b]	7.7
AU-C-8	0.0174	218	40	15	779	2.0	(27)	0.15[b]	9.9
AU-E-1	0.00709	154	43	12	210	12	15	4.0	17
AU-E-2	0.0234	89	44	13	373	5.1	16	4.0	17
AU-E-3	0.0355	118	41	9.3	330	2.6	(15)	2.2	18
AU-E-4	0.0199	130	41	9.3	364	2.6	(15)	1.3	15

a Value in parentheses is the average speed measured for test road during the field exercise.
b Test conducted on a paved road surface vacuum-swept five times per week.
c Mean TSP/TP or PM_{10}/TP ratio applied.
1 lb/VMT = 281.9 g/VKT.
1 g/m^2 = 1.434 gr/ft^2

TABLE 4-5. SUMMARY INFORMATION FOR REFERENCE 8

Operation	State	Test dates	No. of tests	PM_{15} emission factor, lb/VMT		PM_{10} emission factor, lb/VMT		$PM_{2.5}$ emission factor, lb/VMT	
				Geom. mean	Range	Geom. mean	Range	Geom. mean	Range
Commercial/ Industrial	MO	2/80	4	0.0078	0.0036 - 0.013	0.0068	0.0034 - 0.011	0.0045	0.0030 - 0.0063
Commercial/ Residential	MO, IL	2/80	10	0.0021	0.0006 - 0.012	0.0017	0.0004 - 0.0093	0.0011	0.0002 - 0.0037
Expressway	MO	5/80	4	0.0004	0.0002 - 0.0008	0.0004	0.0002 - 0.0007	0.0002	0.0001 - 0.0003
Rural Town	KS	3/80	1	0.031	0.031	0.025	0.025	0.005	0.005

1 lb/VMT = 281.9 g/VKT.

TABLE 4-6. DETAILED INFORMATION FROM PAVED ROAD TESTS FOR REFERENCE 8

Category	Run test No.	PM_{10} emission factor, lb/VMT	Duration, min.	Temp., °F	Mean wind speed, mph	Road width, ft	No. of vehicle passes	Mean vehicle speed, mph	Mean vehicle weight, tons	Silt loading, g/m^2	Silt (%)
Commercial/Industrial	M-1	0.0110	120	28	7.4	44	2,627	30	5.6	0.46	10.7
Commercial/Industrial	M-2	0.00340	86	27	6.5	44	2,166	30	3.8	0.26	6.2
Commercial/Industrial	M-3	0.00781	120	28	7.8	44	2,144	30	4.5	0.15	3.5
Commercial/Industrial	M-9	0.00712	136	50	7.4	44	3,248	30	4.1	0.29	12.2
Commercial/Residential	M-4	0.000400	240	38	7.8	36	2,763	35	2.1	0.43	18.8
Commercial/Residential	M-5	0.00153	226	53	2.2	36	2,473	35	2.2	1.00	21.4
Commercial/Residential	M-6	0.00304	281	35	5.6	36	3,204	30	2.1	0.68	21.7
Commercial/Residential	M-13	0.000680	194	60	2.7	22	5,190	35	2.7	0.11	13.7
Commercial/Residential	M-14	0.00301	178	55	9.2	22	3,940	35	2.7	0.079	-
Commercial/Residential	M-15	0.00323	135	77	11.4	22	4,040	35	2.7	0.047	8.1
Commercial/Residential	M-17	0.00582	150	75	4.0	40	3,390	30	2.0	0.83	5.7
Commercial/Residential	M-18	0.000800	172	75	5.1	40	3,670	30	2.0	0.73	7.1
Commercial/Residential	M-19	0.000390	488	70	2.7	20	5,800	30	2.4	0.93	8.6
Expressway	M-10	0.000390	182	60	2.9	96	11,148	55	4.5	0.022	-
Expressway	M-11	0.000700	181	56	8.7	96	11,099	55	4.8	0.022	-
Expressway	M-12	0.000190	150	65	4.7	96	9,812	55	3.8	0.022	-
Expressway	M-16	0.000530	254	70	4.0	96	15,430	55	4.3	0.022	-
Rural Town	M-8	0.0247	345	50	4.7	30	1,975	20	2.2	2.50	14.5

1 lb/VMT = 281.9 g/VKT.
1 g/m2 = 1.434 gr/ft2

4.2.1.8 Midwest Research Institute, *Size Specific Particulate Emission Factors for Uncontrolled Industrial and Rural Roads,* for U. S. EPA, January 1983. (Reference 7, ref_07c13s0201_2011.pdf).

This document reports the results of testing conducted in 1981 and 1982 at industrial unpaved and paved roads and at rural unpaved roads. Unpaved industrial roads were tested at a sand and gravel processing facility in Kansas, a copper smelting facility in Arizona, and both a concrete batch and asphalt batch plant in Missouri. The study was conducted to increase the existing data base for size-specific PM emissions. The following particle sizes were of specific interest for the study: PM_{15}, PM_{10}, and $PM_{2.5}$.

Exposure profiling was utilized to characterize total PM emissions. Five sampling heads, located at heights of up to 5 m, were deployed on the profiler. A standard high-volume sampler and a high-volume sampler with an SSI (cutpoint of 15 µmA) were also deployed downwind. In addition, two high-volume cyclone/impactors were operated to measure particle size distribution. A standard high-volume sampler, a high-volume sampler with an SSI, and a high-volume cyclone/impactor were utilized to characterize the upwind TSP and PM_{15} concentrations and the particle size distribution within the PM_{15} fraction. Wind speed was monitored with warm wire anemometers.

A total of 18 paved road tests and 21 unpaved road tests are completed. The test data are assigned an A rating. Industrial paved road tests were conducted as follows: three unpaved road tests at the sand and gravel processing plant, three paved road tests at the copper smelting plant, four paved road tests at the asphalt batch facility, and three paved road tests at the concrete batch facility. The industrial road tests were considered uncontrolled and were conducted with heavy duty vehicles at the sand and gravel processing plant and with medium duty vehicles at the asphalt batch, concrete batch, and copper smelting plants. Table 4-7 presents summary test data and Table 4-8 presents detailed test information.

TABLE 4-7. SUMMARY OF PAVED ROAD EMISSION FACTORS FOR REFERENCE 7

Industrial category	Type	TP, lb/VMT		PM_{15}, lb/VMT		PM_{10}, lb/VMT		$PM_{2.5}$, lb/VMT	
		Geo. mean	Range	Geo. mean	Range	Geo. mean	Range	Geo. mean	Range
Asphalt Batching	Medium duty	1.83	0.750-3.65	0.437	0.124-0.741	0.295	0.0801-0.441	0.130	0.0427-0.214
Concrete Batching	Medium duty	4.74	2.25-7.23	1.66	0.976-2.34	1.17	0.699-1.63	0.381	0.200-0.562
Copper Smelting	Medium duty	11.2	7.07-15.7	4.01	2.02-5.56	2.78	1.35-3.86	0.607	0.260-0.846
Sand and Gravel Processing	Medium Duty	5.50	4.35-6.64	1.02	0.783-1.26	0.633	0.513-0.753	0.203	0.194-0.211

1 lb/VMT = 281.9 g/VKT.

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TABLE 4-8. DETAILED INFORMATION FROM PAVED ROAD TESTS FOR REFERENCE 7

Run No.	Industrial category	Traffic	PM_{10} emission factor, lb/VMT	Duration, min.	Mean wind speed, mph	Road width, ft	No. of vehicle passes	Vehicle characteristics			Moisture content, %	Silt loading, g/m^2	Silt, %
								Mean vehicle weight, tons	No. of wheels	Mean vehicle speed, mph			
Y-1	Asphalt Batching	Medium Duty	0.257	274	5.37	13.8	47	3.6	6	10	0.22	91	2.6
Y-2	Asphalt Batching	Medium Duty	0.401	344	4.70	14.1	76	3.7	7	10	0.51	76	2.7
Y-3	Asphalt Batching	Medium Duty	0.0801	95	6.04	14.1	100	3.8	6.5	10	0.32	193	4.6
Y-4	Asphalt Batching	Medium Duty	0.441	102	5.59	14.1	150	3.7	6	10	0.32	193	4.6
Z-1	Concrete Batching	Medium Duty	0.699	170	6.71	24.3	149	8.0	10	10	a	11.3	6.0
Z-2	Concrete Batching	Medium Duty	1.63	143	9.84	24.9	161	8.0	10	15	a	12.4	5.2
Z-3	Concrete Batching	Medium Duty	4.01	109	9.62	24.9	62	8.0	10	15	a	12.4	5.2
AC-4	Copper Smelting	Medium Duty	3.86	38	8.72	34.8	45	5.7	7.4	10	0.43	287	19.8
AC-5	Copper Smelting	Medium Duty	3.13	36	9.62	34.8	36	7.0	6.2	15	0.43	188	15.4
AC-6	Copper Smelting	Medium Duty	1.35	33	4.92	34.8	42	3.1	4.2	20	0.53	400	21.7
AD-1	Sand and Gravel	Heavy Duty	3.27	110	7.61	12.1	11	42	11	23	a	94.8	6.4
AD-2	Sand and Gravel	Heavy Duty	0.753	69	5.15	12.1	16	39	17	23	a	63.6	7.9
AD-3	Sand and Gravel	Heavy Duty	0.513	76	3.13	12.1	20	40	15	23	a	52.6	7.0

1 lb/VMT = 281.9 g/VKT.

1 g/m^2 = 1.434 gr/ft^2

[a] Not measured

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4.2.1.9. Midwest Research Institute, *Iron and Steel Plant Open Source Fugitive Emission Control Evaluation*, for U. S. EPA, August 1983, (Reference 6, ref_06c13s0201_2011.pdf).

This test report centered on the measurement of the effectiveness of different control techniques for PM emissions from fugitive dust sources in the iron and steel industry. The test program was performed at two integrated iron and steel plants, one located in Houston, Texas, and the other in Middletown, Ohio. Control techniques to reduce emissions from paved roads, unpaved roads, and coal storage piles were evaluated. For paved roads, control techniques included vacuum sweeping, water flushing, and flushing with broom sweeping. Particle emission sizes of interest in this study were total PM, PM_{15}, and $PM_{2.5}$.

The exposure profiling method was used to measure paved road particulate emissions at the Iron and Steel plants. For this study, a profiler with four or five sampling heads located at heights of 1 to 5 m was deployed. Two high-volume cascade impactors with cyclone preseparators (cutpoint of 15 μmA), one at 1 m and the other at 3 m, measured the downwind particle size distribution. A standard high-volume sampler and an additional high-volume sampler fitted with a SSI (cutpoint of 15 μmA) were located downwind at a height 2 m. One standard high-volume sampler and two high-volume samplers with SSIs were located upwind for measurement of background concentrations of TSP and PM_{15}.

Twenty-three paved road tests of controlled and uncontrolled emissions were performed. These included 11 uncontrolled tests, 4 vacuum sweeping tests, 4 water flushing tests, and 4 flushing and broom sweeping tests. For paved roads, this test report does not present vehicle speeds, mean number of wheels, or moisture contents. Because vehicle speeds above 15 MPH and moisture content are not expected to influence the emissions equation, the test data are assigned an A rating. Table 4-9 presents summary test data and Table 4-10 presents detailed test information. The PM_{10} emission factors presented in Table 4-10 were calculated from the PM_{15} and $PM_{2.5}$ data using logarithmic interpolation.

After vacuum sweeping, emissions were reduced slightly more than 50 percent for two test runs and less than 16 percent for two test runs. Water flushing applied at 0.48 gal/yd^2 achieved emission reductions ranging from 30 percent to 70 percent. Flushing at 0.48 gal/yd^2 combined with broom sweeping resulted in emission reductions ranging from 35 percent to 90 percent.

TABLE 4-9. SUMMARY OF PAVED ROAD EMISSION FACTORS FOR REFERENCE 6

Control method	Location	State	Test date	No. of tests	TP, lb/VMT		PM_{15}, lb/VMT		$PM_{2.5}$, lb/VMT	
					Geo mean	Range	Geo mean	Range	Geo mean	Range
None	A,D,F,J	OH	7/80, 10/80, & 11/80	7	1.22	0.29-5.50	0.38	0.13-2.14	0.10	0.04-0.52
Vacuum Sweeping	A	OH	10/80 & 11/80	4	0.87	0.53-1.46	0.45	0.27-0.87	0.14	0.08-0.26
Water Flushing	D,L	TX	6/81	4	1.43	1.30-1.74	0.47	0.32-0.65	0.08	0.08-0.09
Flushing & Broom Sweep	K,L,M	TX	6/81	4	0.96	0.54-2.03	0.20	0.10-0.49	0.07	0.04-0.13
None	L,M	TX	6/81	4	3.12	0.83-5.46	0.92	0.31-1.83	0.26	0.06-0.62

1 lb/VMT = 281.9 g/VKT.

TABLE 4-10. DETAILED INFORMATION FROM PAVED ROAD TESTS FOR REFERENCE 6

Site	Test Run No.	Control method	PM_{10} emission factor, (lb/VMT)	Duration (min.)	Temp., (°F)	Mean wind speed, (mph)	No. of vehicle passes	Mean vehicle weight, (tons)	Silt loading, (g/m^2)	Silt, %
A	F-34	None	0.536	62	90	4.2	79	28	2.79	16
A	F-35	None	0.849	127	90	7.5	130	25	2.03	10.4
A	F-36	VS	0.147	335	50	5.9	263	8.3	0.202	18.3
A	F-37	VS	0.209	241	50	4.8	199	17	0.043	26.4
A	F-38	VS	0.430	127	50	4.5	141	18	0.217	27.9
A	F-39	VS	0.686	215	50	6.4	190	18	0.441	19.6
D	F-61	None	1.35	108	40	11.0	93	40	17.9	21.0
D	F-62	None	0.929	77	45	12.1	94	36	14.4	20.3
D	F-74	WF	1.32	205	50	9.0	67	29	5.59	9.45[a]
F	F-27	None	0.357	91	100	9.5	158	14	17.7	35.7
F	F-45	None	0.608	135	50	4.0	172	16	5.11	28.4
J	F-32	none	0.144	259	90	5.8	301	14	0.117	13.4
K	B-52	FBS	0.0946	60	90	2.9	119	12	7.19	34.3
L	B-50	FBS	0.230	104	90	5.6	123	9.4	13.6	28.2[b]
L	B-51	FBS	0.435	93	90	4.2	127	11	13.6	28.2[b]
L	B-54	WF	0.268	101	90	5.4	118	10	3.77	22.6
L	B-55	WF	0.575	82	90	8.5	98	11	6.29	19.6[a]
L	B-56	WF	0.398	61	90	6.3	118	9.2	2.40	11.2
L	B-58	None	1.08	96	90	6.7	67	18	10.4	17.9
M	B-53	FBS	0.161	81	90	5.3	72	20	--	9.94
M	B-57	0.554	None	101	90	3.6	68	12	2.32	6.45[a]
M	B-59	0.993	None	114	90	6.1	67	11	2.06	14.0[a]
M	B-60	1.18	None	112	90	5.0	50	12	3.19	13.5

[a]Average of 2+ values
[b]Sample used for more than 1 run.
[c] PM_{10} emission factors were calculated from the PM_{15} and $PM_{2.5}$ data using logarithmic interpolation.
VS = Vacuum sweeping; WF = Water flushing; FBS = Water flushing and broom sweeping; 1 lb/VMT = 281.9 g/VKT; 1 g/m^2 = 1.434 gr/ft^2

4.2.1.10. Midwest Research Institute, *Fugitive Particulate Matter Emissions* for U.S. Environmental Protection Agency, Emission Factor and Inventory Group, April 15, 1997. (Reference 30, ref_30c13s0201_2011.pdf).

This reference documents the performance of six field studies characterizing the vehicle emissions from three unpaved roads and three paved roads. Testing of unpaved roads was performed in Kansas City, MO; Raleigh, NC; and Reno, NV. Testing of paved roads was performed in Denver, CO; Raleigh, NC; and Reno, NV. Midwest Research Institute measured the emission rates for PM_{10} and $PM_{2.5}$ at all six locations based upon a plume profiling methodology. The test data are assigned an A rating.

Plume profiling calculates emission rates using a conservation of mass approach. The passage of airborne particulate (i.e., the quantity of emissions per unit of source activity) is obtained by spatial integration of distributed measurements of exposure (mass/area) over the effective cross section of the plume. Exposure is the point value of the flux (mass/area time) of airborne particulate integrated over the time of measurement or, equivalently, the net particulate mass passing through a unit area normal to the mean wind direction during the test. The steps in the calculation procedure are as follows. The concentration of PM_{10} measured by a sampler is compared to the wind speed and corrected to standard conditions. The concentration for each sampler is multiplied by the wind velocity and sampling duration to obtain the exposure for each sampling height. The exposure is integrated over the plume-effective cross section. The quantity obtained represents the total passage of airborne particulate matter (i.e., mass flux) due to the source. The exposure is set to zero at the maximum effective height of the plume where the net concentration equals zero). The maximum effective height of the plume is found by linear extrapolation of the uppermost net concentrations to a value of zero. Although at ground level the wind velocity is zero, for calculation, the exposure value at ground level is set equal to the value at a height of 1 m. The integration is then performed from 1 m to the plume height, H, using Simpson's approximation.

Testing in Denver CO was conducted to characterize emissions from a high speed (55 mph speed limit) limited access interstate road and a medium speed (40 mph speed limit) one lane road (two lanes with a wide median). For this part of the study, a profiler with four or five sampling heads located at heights of 1, 3, 5 and 7 m were deployed. One high-volume cascade impactor with cyclone preseparators (cutpoint of 10 μmA) and two dichotomous samplers were used to measured the downwind particle size distribution. All of the particle sizing samplers were located at 2 m above ground level. A single set of the same sampling equipment was located at 2 m above ground level and upwind for measurement of background concentrations of TSP, PM_{10} and $PM_{2.5}$. To the extent possible, each of the emission tests was performed during periods following snowfall, after the test road surface had dried. In most cases, sand application was ordered, because the relatively light snow conditions characteristic of the 1996 winter did not trigger routine sand application.

This test program also assessed the potential bias associated with particle sizing using the historical impactors that followed the cyclone pre-separator. The use of the dichotomous samplers consistently yielded a lower ratio of $PM_{2.5}$ to PM_{10} ratio than were measured by the cyclone/impactor samplers. The $PM_{2.5}$/ PM_{10} ratios measured by the dichotomous samplers are presented to the right of the PM_{10} emissions factors column in Table 4-11. Where two values are presented in the column, these are the ratios measured at two different heights. The ratios range from 0.26 to 0.37. As a result of this study, the constant in the $PM_{2.5}$ emissions factor equation was revised to 25% of the PM_{10} constant.

4.2.1.11. Paved Road Modifications to AP-42, Background Documentation For Corn Refiners Association, Inc. Washington, DC 20006 MRI Project No. 310842, May 20, 2008. (Reference 32, ref_32c13s0201_2011.pdf).

The Corn Refiners Association (CRA) funded four paved road PM_{10} test programs because site conditions did not match source conditions underlying the AP-42 emission factor equation. The sites enforce speed limits of 5 or 15 mph and employ road sweeping programs to manage the build up of silt on the roadways. In addition, plants experience traffic queues (i.e., stop-and-go traffic) during periods with high corn receipts. The combination of heavy trucks (delivering corn to the facilities) and fairly low silt loading (sL) values on the plant roads was not typical of the AP-42 data base. Given these differences, the member companies undertook testing to develop more representative emission factors. Midwest Research Institute designed and conducted the test programs at all four facilities.

Reference 32 compiles test data and information from references 33, 34, 35 & 36. In addition, reference 32 proposes an expansion of the allowable speed parameters supported in the paved road equation. Lastly, reference 32 proposes a revised equation for paved roads to reflect the expanded test information. The data upon which the proposed equation was based included emissions associated with the trucks (engine exhaust, tire wear and brake wear) and with material deposited on the roadway. Since testing documented in references 7 through 10 were conducted at facilities with very similar operating conditions using test procedures that were nearly identical, the following description provides background for all four test programs.

All four testing programs employed the same exposure profiling method used to develop the test data underlying the emission factor predictive equations for both paved and unpaved roads. In each program, a test plan was submitted to the state agency for comment and review prior to the start of testing. The final test reports and supporting information were also submitted to state agencies. Because low emission levels were expected (due to low sL and slow speeds), several precautions were taken to assure reliable quantification. First, long sampling durations were employed. Samplers were operated up to 5 hours to collect adequate sample mass. Second, to ensure adequate traffic during test periods, the facilities provided "drone" passes by corn semi-trailers. Drone traffic mimicked the actual traffic except those trucks returned to staging areas without emptying corn. In addition, testing applied "lessons learned" throughout the programs. For example, when it became apparent how difficult it could be to separate net PM_{10} concentrations (i.e., due to traffic on the road) from background (upwind) concentrations, changes were made in equipment deployment. The use of identical upwind and downwind vertical sampling arrays permitted better definition of the net contribution of roadway emissions.

TABLE 4-11. DETAILED INFORMATION FROM PAVED ROAD TESTS FOR REFERENCE 30

Site	Test Run No.	Road Speed [1]	PM_{10} emission factor, (g/VKT)	$PM_{2.5}$/ PM_{10} Ratio	Duration, min.	Temp., °F	Mean wind speed, mph	No. of vehicle passes	Mean vehicle weight, tons	Silt loading, g/m^2	Silt, %
CO	BH-1	55	1.08	0.20	163	18	2.7	6,561	2.2	0.184	9.4
CO	BH-2	55	0.102	0.34	360	37	17.0	17,568	2.2	0.0127	41.0
CO	BH-3	55	-	0.16	360	46	17.2	14,616	-	0.0127	41.0
CO	BH-4	55	-		Blank	-	-	-	-	-	-
CO	BH-5	40	-		Blank	-	-	-	-	-	-
CO	BH-6	40	4.68	0.03	240	48	3.1	3,112	2.2	1.47	1.2
NC	BJ-6	45	0.301	0.27/0.34	450	71	8.2	14,670	2.2	0.060	52
NC	BJ-7	45	1.94	0.44/0.44	143	68	9.4	3,748	2.2	0.060	52
NC	BJ-9	45		0.6/0.14	178	71	5.3	4,616	2.2	0.060	52
NC	BJ-10	45		0.44/0.33	288	68	3.7	10,218	2.2	0.060	52
NV	BJ-11	45		0.68/0.47	387	75	5.1	13,216	2.2	0.060	52
NV	BK-7	45	0.57	0.29/0.33	420	89	7.3	7,394	2.2	0.082	3.4
NV	BK-8	45	0.44	0.26/0.34	270	87	6.1	5,747	2.2	0.082	3.4
NV	BK-9	45	-	0.13/0.38	240	90	2.6	4,622	-	0.082	3.4

[1] Road Speed is the posted speed limit for the road segment.

In addition to PM_{10} concentrations, each sampling program samples included:

- Measurement of average wind speeds at two heights and wind direction at one height for 5-minute intervals throughout the test period.
- Manual recording of traffic counts by vehicle type. The host facilities provided information on vehicle weights and corn receipts.
- Collection of road surface material by vacuums with disposable paper bags. The material collected within the bag was sieved to determine the surface silt loading.

Reference 32 states that the four test programs conducted by CRA produced 14 and 8 PM_{10} emission factor values for slowly moving and stop-and-go traffic, respectively. Other observations in this report includes: that in all but one of the 22 cases, the AP-42 emission factor overestimated the measured value; that for some tests, "stop-and-go" emission factors were substantially greater than the "slowly moving" factor (presumably because of the diesel exhaust as trucks moved from a dead stop) but that there was no significant difference between "slowly moving" and "stop-and-go" results on average.

Furthermore, Tables 4-12, 4-13, and 4-15 use bold font to indicate those tests that used identical upwind and downwind vertical sampling arrays. Those tests provided better definition of net PM_{10} mass thus producing more accurate emission factors. Although these test results tended to be lower than the other emission factors, the two sets on average did not differ significantly.

4.2.1.12 Midwest Research Institute, *Emission Tests of Paved Road Traffic at Minnesota Corn Processors Marshall, Minnesota Facility,* McVehil-Monnett Associates, July 6, 2001. (Reference 33, ref_33c13s0201_2011.pdf).

Truck traffic flow at the Minnesota Corn Processor's (MCP's) Marshall, Minnesota facility was characterized as either slowly moving (5 mph enforced speed limit) or stop-and-go in nature. In this testing program, data was collected over 5 days during April of 2001. During this period, three stop-and-go traffic situations and six slowly moving traffic instances were examined. Truck traffic progressing through the test site was held to two lanes for queued traffic. Silt content (sL, measured by MCP), truck weight, and number of passes, along with other pertinent data was recorded for each run. For all runs, a vertical network of samplers was operated downwind. The last test period used a vertical array of samplers upwind to better characterize upwind concentrations and to provide a more accurate calculation of the net PM_{10} emission factor.

The results of this testing program are summarized in Table 4-12. The test data are assigned an A rating. The test report remarked that the emission factors obtained were far below the value (0.453 lb/VMT) used in the plant emission inventory. Use of test-specific silt loading and vehicle weight did not significantly improve the predictive accuracy of the AP-42 factor. The tests found no discernable relationship between emission levels and either silt loading or vehicle weight. Finally, it was noted that the shape of the exposure profile was more likely due to diesel exhaust than re-entrained road dust.

Table 4-12. Summary of Emissions Data from MCP's Marshall, Minnesota Facility (Reference 33)

Run	Test condition	Traffic rate (veh/hr)	Traffic speed (mph)[a]	Mean vehicle weight, W (tons)	Surface silt loading, sL (g/m^2)	Measured PM_{10} emission factor (lb/VMT)
CE-1	Stop-and-go	38	NA	36	1.16	0.059
CE-2	Stop-and-go	32	NA	36	0.86	0.14
CE-11	Slowly moving	35	5	12	1.34	0.34
CE-3	Stop-and-go	47	NA	39	0.86	0.10
CE-13	Slowly moving	48	5	13	1.34	0.051
CE-15	Slowly moving	30	5	40	1.91	0.14
CE-16	Slowly moving	28	5	40	1.41	0.17
CE-17	Slowly moving	29	5	40	2.93	0.091
CE-19	**Slowly moving**	**61**	**5**	**38**	**0.76**	**0.041**

[a] Vehicle speed was maintained at the plant limit of 5 mph. NA = Not applicable.
Bold entries indicate that identical vertical sampling arrays were used to better isolate the source contribution.

4.2.1.12. Midwest Research Institute, *Emission Tests of Paved Road Traffic at Minnesota Corn Processors Columbus, Nebraska Facility*, McVehil-Monnett Associates, July 13, 2001. (Reference 34, ref_34c13s0201_2011.pdf).

Truck traffic flow at MCP's Columbus, Nebraska facility was characterized as either slowly moving (5 mph enforced speed limit) or stop-and-go in nature. Between June 12 and 15, 2001, four tests each of stop-and-go and slowly moving traffic were performed. Trucks entered by the north gate and traveled past a vertical sampling array en route to a staggered queue at which a second vertical sampling array was positioned. In this way, testing evaluated both source conditions (stop-and-go and slowing moving) at once. Building on experience from testing at the MCP Marshall facility, the last two runs, CF-4 and CF-5, used identical upwind and downwind vertical sampling arrays to better characterize background concentrations. In that case, only one condition could be evaluated during a test. The results of the MCP Columbus test program are summarized in Table 4-13. The test data are assigned an "A" rating.

4.2.1.13. Midwest Research Institute, *Emission Tests of Paved Road Traffic at Cargill Sweeteners North America Blair, Nebraska Facility*, McVehil-Monnett Associates, November 27, 2002. (Reference 35, ref_35c13s0201_2011.pdf).

This report describes a testing program conducted at Cargill's Blair, Nebraska facility during August 2002. The plant used a regular sweeping program to reduce surface loadings on paved roads. Testing relied on regular corn truck traffic at the site, although the plant provided a limited amount of "drone" traffic. The test data are assigned an "A" rating.

Eight PM_{10} emission tests were attempted. The test report describes difficulty encountered in isolating net PM_{10} mass due to traffic on the test road. During test plan review, the Nebraska Department of Environmental Quality requested a change in test site to allow two trucks to pass by at the same time. The original site would have permitted upwind monitoring in the immediate vicinity of the tests road, but this was not possible at the second location. Furthermore, steeply sloping ground on the upwind side of the test road prevented use of a vertical background sampling array (as used at the two MCP plants) to better isolate the source contribution.

The results are summarized in Table 4-14. Only two tests (CI-7 and CI-8) had net mass attributed to the source. In the remaining instances, the measured downwind PM_{10} concentrations were lower than upwind values. It was stated that this was believed to be an undesired result from moving the test source. Runs CI-7 and CI-8 showed the measured emission factor to be much lower than that predicted by the AP-42 equation. Comments in the report indicated that exposure profiles showed a maximum more likely due to diesel exhaust than from re-entrained surface road dust.

4.2.1.14. Midwest Research Institute, *Emission Tests of Paved Road Traffic at ADM's Marshall, Minnesota Facility*, McVehil-Monnett Associates, December 5, 2003. (Reference 36, ref_36c13s0201_2011.pdf).

The test program at ADM's Marshall MN facility represented the last test by the Corn Refiners Association. By September 2003, the Marshall facility had implemented a road sweeping program. Three tests of PM_{10} emissions were conducted, one from stop-and-go traffic and two from slowly moving traffic. Because of experience gained from the earlier tests, identical vertical networks of samplers were operated downwind and upwind during each test.

The results of this testing program are summarized in Table 4-15. The test data are assigned an A rating. Measured emission factors were all significantly lower than that predicted by the AP-42 equation. The test report also remarked that the measured emission rates were independent of traffic rate, while the AP-42 factor implies a linear dependency between the emission and traffic rates.

The results are summarized in Table 4-14. Only two tests (CI-7 and CI-8) had net mass attributed to the source. In the remaining instances, the measured downwind PM_{10} concentrations were lower than upwind values. It was stated that this was believed to be an undesired result from moving the test source. Runs CI-7 and CI-8 showed the measured emission factor to be much lower than that predicted by the AP-42 equation. Comments in the report indicated that exposure profiles showed a maximum more likely due to diesel exhaust than from re-entrained surface road dust.

Table 4-13. Summary of Emissions Data from MCP's Columbus, Nebraska Facility (Reference 34)

Run[a]	Test condition	Traffic rate (veh/hr)	Traffic speed (mph)[b]	Mean vehicle weight, W (tons)	Surface silt loading, sL (g/m^2)	Measured PM_{10} emission factor (lb/VMT)
CF-1/N	Low Speed	47	5.0	40	0.97	0.011
CF-1/S	Stop-and-go	47	NA	40	0.97	0.043
CF-2/N	Slowly moving	66	5.3	41	0.81	0.036
CF-2/S	Stop-and-go	66	NA	41	0.81	0.14
CF-3/N	Slowly moving	54	5.1	41	0.63	0.0024
CF-3/S	Stop-and-go	54	NA	41	0.63	0.051
CF-4/N	**Slowly moving**	**86**	**4.7**	**41**	**1.1**	**0.0068**
CF-5/N	**Stop-and-go**	**52**	**NA**	**41**	**1.4**	**0.036**

[a] Suffix indicates whether tests was conducted on the North or South portion of the corn haul road. Trucks were held in a queue toward the south; trucks entering the north gate traveled passed the north sampling array to reach the queue.

[b] Speed of moving trucks determined by accumulating time required to travel a measured distance. NA = not applicable.

Bold entries indicate that identical vertical sampling arrays were used to better isolate the source contribution.

Table 4-14. Summary of Emissions Data from Cargill's Blair, Nebraska Facility (Reference 35)

Run	Test condition	Traffic rate (veh/hr)	Traffic speed (mph) [a]	Mean vehicle weight, W (tons)	Surface silt loading, sL (g/m^2)[b]	Measured PM_{10} emission factor (lb/VMT)[c]
CI-1	Low Speed	45	13.4 / 16.8 12.8 / 16.9	26	0.06	-
CI-2	Low Speed	45		26	0.06	-
CI-3	Slowly moving	60[d]	13.6 / 12.7 13.5 / 15.5	27	0.06	-
CI-4	Low Speed	60[d]		27	0.06	-
CI-7	Slowly moving	47	15.2 / 16.2 13.6 / 16.1	27	0.05	0.0036
CI-8	Low Speed	47		27	0.05	0.0066
CI-11	Low Speed	56	13.5 / 12.7	27	0.025	-
CI-12	Low Speed	56		27	0.25	-

[a] Vehicle speed for inbound (loaded) /outbound (empty) trucks determined by accumulating time required to travel a measured distance.
[b] Surface silt loading sample information provided by Cargill.
[c] "-" indicates that no net mass was attributed to the test road traffic.
[d] Twenty of 238 total passes were by "drone" trucks.

Table 4-15. Summary of Emissions Data from ADM's Marshall, Minnesota Facility (Reference 36)

Run	Test Condition	Traffic rate (veh/hr)	Traffic speed (mph)[a]	Mean vehicle weight, W (tons)	Surface silt loading, sL (g/m^2)	Measured PM_{10} emission factor (lb/VMT)
CM-1	**Slowly moving**	**154**	**NA**	**40**	**0.72**	**0.014**
CM-2	**Stop-and-go**	**42**	**NA**	**40**	**0.72**	**0.14**
CM-4	**Slowly moving**	**156**	**5**	**40**	**0.70**	**0.016**

[a] Vehicles speeds maintained at plant limit of 5 mph. NA = not applicable.
Bold entries indicate that identical vertical sampling arrays were used to better isolate the source contribution.

4.2.1.15. E.H. Pechan & Associates, Inc., *Recommendations for Emission Factor Equations in AP-42 Paved Roads Section: TECHNICAL MEMORANDUM* August 21, 2003. (Reference 28, ref_28c13s0201_2011.pdf).

This technical memorandum documents the procedure that was used to separate the various components of paved road particulate matter emissions into two components. One component includes the emissions from exhaust, brake wear and tire wear. The other component includes the particulate matter reentrained from the road surface. The combined paved road particulate matter emissions were estimated with the empirical equation published in the October 2002 AP-42 Section for Paved Roads. The vehicle exhaust, brakewear and tirewear emission factors were obtained from the MOBILE6.2 model. A typical vehicle fleet and fuel source from 1980 was utilized for the model runs. The assumption included a vehicle fleet for July 1980, a gasoline sulfur content of 300 ppm, a diesel sulfur content of 500 ppm and no use of reformulated gas. The vehicle fleet assumptions used in the analysis are presented in Table 4-16. The model was run to estimate PM_{10} and $PM_{2.5}$ emission factors in g/VMT for each vehicle class at speeds of 25, 30, 35, 40, 45, 50, 55, and 60 mph. Within vehicle classes, the greatest standard deviation was lower than 0.04% of the emissions factor. Based on the low relative standard deviation, it was assumed that the vehicle speed was not a factor in exhaust, brakewear and tirewear PM emissions. Table 4-16 presents the vehicle fleet characteristics used in the model and the calculated average PM_{10} and $PM_{2.5}$ emission factors for exhaust, brakewear and tirewear for each class of vehicle.

Table 4-16: Vehicle Fleet Assumptions Used in 2003 MOBILE6.2 Model

VehicleType	LDGV	LDGT12	LDGT34	LDGT	HDGV	LDDV	LDDT	HDDV	MC
GVWR	3,075	4,105	7,000		35,000	3,705	6,000	70,000	550
VMT Distribution	0.6748	0.1477	0.0758		0.0365	0.0088	0.0118	0.0352	0.0094
PM_{10} Emissions Factor	0.1053	0.1061	0.2746	0.1632	0.3825	0.7206	0.7206	2.1227	0.0922
$PM_{2.5}$ Emissions Factor	0.0686	0.0690	0.1851	0.1084	0.2576	0.6519	0.6521	1.9272	0.0590

The contractor developed "AP-42 Composite" PM_{10} and $PM_{2.5}$ emission factors using the October 2002 AP-42 paved roads emission factor equation with the mean vehicle weight set at 3.74 tons (a value they indicated was typical of the 1980 paved road vehicle fleet. The contractor used silt loadings ranging from 0.02 to 400 g/m^2 for calculating the emissions factors. The contractor also calculated the fleet average PM_{10} and $PM_{2.5}$ emission factors for exhaust, brakewear and tirewear by summing the products of the VMT Distribution ratio and the PM_{10} and $PM_{2.5}$ emission factors for each vehicle class. The calculated fleet average values were 0.2119 for PM_{10} and 0.1617 for $PM_{2.5}$. The contractor then subtracted the fleet average emissions factors for exhaust, brakewear and tirewear from the "AP-42 Composite" emissions factors to produce an emission factor for only the re-entrained road dust component. The contractor noted that the while the stated applicable silt loadings for the October 2002 AP-42 paved road equation ranged from 0.02 to 400 g/m^2 the $PM_{2.5}$ emissions factor became negative at silt loadings less than 0.029 g/m^2. They stated that since negative emissions were not physically possible, the equation they recommended was only valid for silt loading ranging from 0.03 to 400 g/m^2. While no test data are associated with this report, the report does provide estimates of engine exhaust, tire wear and brake wear derived from an EPA emissions model which is based upon emissions testing by a validated test method on multiple vehicles for each type of vehicle. As a result, emissions estimates by vehicle class are assigned an A rating. Because the use of a national average vehicle fleet emissions estimate does not provide emissions that are representative of the mix of vehicle classes measured during the above test reports, the composite emissions estimates are assigned a C rating.

4.2.1.16. E-mail communication between Ron Myers of EPA/OAQPS/SPPD/MPG, RTP, NC and Prashanth Gururaja and Ed Glover of EPA/OTAQ/ASD/HDOC re. Diesel exhaust, tire and brake wear for low speed stop and go traffic; January 2009 through May 2009. (Reference 37, ref_37c13s0201_2011.pdf).

This e-mail communication and spreadsheet file concerns estimates of PM_{10} emissions associated with slow moving and stop and go diesel engine semi-trailer trucks. The purpose of the request was to provide a means to disaggregate the consolidated PM emissions measured of trucks during delivery of product at corn storage and transfer facilities. The request stated that the trucks were 18 wheel semitrailers of about ten years of age, were queued for the delivery of their load to a transfer or processing facility and that the estimated vehicle speed averaged about 1 mph but that they were stopped most of the time. $PM_{2.5}$ emissions were estimated using the MOVES mobile source emissions model. The trucks modeled were approximately ten years old, traveling at an average of 1.5 mph on level pavement. Emissions were estimated at 11.06035 g/hour or 8.789778 g/VMT. PM_{10} emissions were estimated to be approximately 3% greater than $PM_{2.5}$ emissions. While no test data are associated with this report, the report does provide estimates of engine exhaust, tire wear and brake wear derived from an EPA emissions model which is based upon emissions testing by a validated test method on multiple vehicles for the specific type of vehicle measured during the Corn Refiners Association Studies. As a result, emissions estimates for slow moving trucks are assigned an A rating.

4.2.1.17. E-mail communication between Ron Myers of EPA/OAQPS/SPPD/MPG, RTP, NC and Gary Dolce, David Brzezinski and Rudolph Kapichak of EPA/OTAQ/ASD/HDOC re. vehicle exhaust, tire and brake wear for urban unrestricted road-types; October 2010 through December 2010. (Reference 39, ref_39c13s0201_2011.pdf).

This e-mail communication and spreadsheet files concern improved estimates of PM_{10} emissions associated engine exhaust, tire wear and brake wear for free flowing traffic. The purpose of the estimates was to update the emissions estimates produced by E. H. Pechan using the 2003 version of MOBILE6.2. The emissions model used for this updated emissions estimates was the 2010 version of the MOVES model. Like the MOBILE6.2 model, the emissions predicted with the MOVES model provide a means for disaggregating the emissions measured during the paved road field studies that measured emissions due to road surface dust, vehicle exhaust, break wear and tire wear.

It is explained in the documentation that in order to develop an equation for road dust alone, estimates of the particulate emissions from vehicle exhaust, brake wear and tire wear were required. The e-mail documentation states that the MOVES model includes significant new data about PM emissions from both light duty and heavy duty on-road vehicles which allow MOVES to account for the influences of ambient temperature, vehicle speed, and vehicle deterioration on emissions. The documentation further states that none of those factors are accounted for in MOBILE6.2.

Documentation includes information provided to OTAQ on the test date (sometimes month and year, sometimes just year), vehicle speed, ambient temperature, and average vehicle weight for each of the paved road field studies. The documentation states that OTAQ created a MOVES2010a model input file that approximated the information for the paved road field studies as closely as possible. The documentation also states that since MOVES2010a provides output for calendar years 1990 and 1999-2050 alternative scenarios were developed to estimate emissions for years which MOVES2010a is not programmed to provide.

The documentation states that the speed and ambient temperature measured during the field study provided additional independent variables used in the MOBILE2010a model to estimate emissions. The documentation indicates that an emissions estimate was produced for each of the individual tests by allocating all of the vehicle activity to a single MOBILE2010a speed bin which included the vehicle speed observed in the test. To reduce the number of number of total runs needed, temperatures for the individual tests were rounded to the nearest multiple of 5 degrees. In a small number of cases, vehicle speed or temperature data were not available for particular tests. In those cases, a vehicle speed of 25 mph or an ambient temperature of 75 degrees was used. All other inputs to MOVES were national defaults.

All vehicle and fuel type combinations (except for electric vehicles) were included. Emissions were generated only for the urban unrestricted road-type. Emissions were generated for all PM10 pollutants (primary exhaust PM_{10} total, primary PM_{10} brake wear, and primary PM_{10} tire wear. Only running exhaust and crankcase running exhaust processes were included in the exhaust emissions calculations as the test sites did not include any starting or idling activity. Inventory results generated by MOVES source type (vehicle type) were divided by VMT to get emission factors by source type for each speed and temperature bin in the original test data.

Emissions estimates for free flowing light duty vehicles and trucks are assigned an B rating since most of the test data were for model years which an alternative emissions scenario (year, vehicle mix and assumed degradion level) was used as the independent variables used in the MOVES model input file. While it is likely that vehicle emissions prior to 1990 had tailpipe emissions very similar to the 1990 model year, this can not be verified. Also, while the emissions for each test are comprised of a large number of vehicles and the emissions factor produced by the MOVES model are based upon a large number of supporting tests, it is unclear that the MOVES model is an accurate and precise indication of the vehicle exhaust, tire wear and brake wear emissions during each test series.

4.2.1.18. Midwest Research Institute; *Analysis of the Fine Fraction of Particulate Matter in Fugitive Dust*; Western Governors' Association - Western Regional Air Partnership (WRAP); October 12, 2005. (Reference 43, ref_43c13s0201_2011.pdf).

This project was conducted by Midwest Research Institute for the Western Regional Air Partnership to provide more accurate $PM_{2.5}$ and PM_{10} fugitive dust emissions inventories for regional haze regulatory purposes to address the significant contribution of fugitive dust to visibility impairment. The results of this project were expected to affect the quantity of dust apportioned to the fine versus coarse size modes. It was stated that the results would be helpful in developing accurate emission inventories for PM nonattainment, maintenance, and action plan areas in the WRAP region. Finally, it was stated that the results may be used to seek modifications to the EPA's AP-42 emission factors to ensure widespread availability of the information developed in the study.

During the first testing phase of the project, $PM_{2.5}$ measurements using the high-volume cascade impactors were compared to simultaneous measurements obtained using EPA reference- method samplers for $PM_{2.5}$. The tests were conducted in a flow-through wind tunnel and exposure chamber, where concentration level and uniformity were controlled. With the same test setup, a second phase of testing was performed with reference method samplers, for the purpose of measuring $PM_{2.5}$ to PM_{10} ratios for fugitive dust from different geologic sources in the West. The testing provided information on the magnitude and variability of $PM_{2.5}$ to PM_{10} ratios for source materials that were recognized as problematic with regard to application of mitigative dust control measures.

Three dust source materials were tested under the first Phase of the study. The three dust source materials included an Owens Dry Lake surface soil, and two Arizona road dust reference standards (one coarse and one fine fraction material). Fixed PM_{10} concentration levels in the range of 1, 2.5, and 5 milligrams per cubic meter (each with its naturally occurring $PM_{2.5}$ level) were tested. It was stated that those PM_{10} concentration levels were selected as representative of dust plume concentrations under which major particle mass contributions to plume samples occur in emission factor development. The ratios of $PM_{2.5}$ to PM_{10} for fugitive dust from different geologic soil types were measured. A total of seven source materials were tested. The materials included Alaska river bed sediment, Arizona alluvial channel, Arizona agricultural soil, New Mexico unpaved landfill road dust, New Mexico grazing soil, California Salton Sea shoreline soil, and Wyoming unpaved road surface material. Test results included the calculation of the average $PM_{2.5}$ concentration and the collocated PM_{10} concentration. It was intended that any variation in $PM_{2.5}$/ PM_{10} ratio be evaluated as a function of the test soil properties (for example, position in soil texture triangle).

A total of 100 individual tests were performed, including 17 blank runs (for quality assurance purposes). The results of the testing are well documented and the documentation is sufficient to assess that the study was well designed and implemented. This was a laboratory study designed to assess those emissions sources that were considered to have the greatest influence in PM_{10} and $PM_{2.5}$ non attainment areas. As a result, the study is assigned a quality rating of B when applied within the bounds of the type of surface material that was available and for dust generation characteristics comparable to those used in the study. The study included no paved road surface material and was weighted toward higher particulate matter concentrations. Since the study was a laboratory study, did not include any paved road surface materials, and was weighted toward higher particulate concentrations, it is assigned a quality rating of "D" when used for paved roads.

The results of the Phase I testing indicated that the $PM_{2.5}$ concentrations measured by the cyclone/impactor system were consistently biased by a factor of about 2 relative the $PM_{2.5}$ concentrations measured by the Partisol samplers. While there was some data separation of different test materials, the second phase testing showed a tendency of the measured $PM_{2.5}$/ PM_{10} ratio to decrease with increasing PM_{10} concentration. At PM_{10} concentrations above 1.0 mg/m3 the $PM_{2.5}$/ PM_{10} ratio was between 0.1 and 0.15. The $PM_{2.5}$/ PM_{10} ratio increased to about 0.35 as the PM_{10} concentration approached about 0.5 mg/m3.

4.2.1.19. Midwest Research Institute; *Background Document for Revisions to Fine Fraction Ratios Used for AP-42 Fugitive Dust Emission Factors*; Western Governors' Association - Western Regional Air Partnership (WRAP); November 1, 2006. (Reference 44, http://www.epa.gov/ttn/chief/ap42/ch13/bgdocs/b13s02.pdf).

This report summarizes the results of the October 2005 WRAP study which evaluated the $PM_{2.5}$/ PM_{10} ratio measured by the cyclone/impactor system and measured by the Partisol samplers. While no additional analyses of the laboratory study were performed, suggested $PM_{2.5}$/ PM_{10} ratios were made for use in revising existing AP-42 emissions factor parameters for $PM_{2.5}$ dust emissions factor equations in Sections 13.2.1 (paved roads), 13.2.2 (unpaved roads), 13.2.3 (material transfer and storage piles), 13.2.4 (windblown dust) and 13.2.5 (industrial wind erosion). A revised $PM_{2.5}$/PM_{10} ratio of 0.15 was recommended for the paved roads emissions factor.

4.2.1.20. Technical Memorandum from William B. Kuykendal to File, Subject: *Decisions on Final AP-42 Section 13.2.1 "Paved Roads"*, October 10, 2002. (Reference 38, ref_38c13s0201_2011.pdf).

This technical memorandum to the files summarizes and responds to comments on an October 2001, EPA proposed revision of Section 13.2.1 "Paved Roads" for AP-42 and request for comments. The memorandum also presents EPA's decisions and rational supporting these decisions for the final changes leading to the final section. The proposed revisions to the section included an adjustment for rain events (comparable to the adjustment in the unpaved road section) which in essence "zeroed" the emissions on days that more than 0.01 inch of rain was recorded. In addition, the proposed revisions included the separation of vehicle engine exhaust, breakwear and tirewear as recommended in the E. H. Pechan Technical Memorandum of August 21, 2003. The memorandum includes attachments with the detailed comments that lead to the final revision of the emissions factor equation. The final changes to the emissions factor equation included:

- the subtraction of 0.2119 g/VMT for engine exhaust, brakewear and tirewear,
- an adjustment of (1- (P/4N)) for rain events (P = number of rain days and N = number of days in period), and
- an adjustment of (1- (1.2P/N)) for rain events (P = number of rain hours and N =

number of hours in period).

4.2.1.21. ***Clark County (Nevada) Paved Road Dust Emission Studies in Support of Mobile Monitoring Technologies*****; R. Langston, R.S. Merle Jr, V. Etyemezian, H. Kuhns, J. Gillies, D. Zhu, D. Fitz, K. Bumiller, D.E. James and H. Teng; Clark County Department of Air Quality and Environmental Management, Desert Research Institute, University of California, Riverside, University of Nevada, Las Vegas; December 22, 2008.**
(Reference 42, http://www.epa.gov/ttn/chief/ap42/ch13/related/Final_Test_Report.pdf).

This report documents the fourth phase of a study by Clark County to investigate alternative ways of estimating PM_{10} emissions of surface dust entrained from paved roads. A new vehicle-mounted mobile sampling technology was tested in comparison with the traditional AP-42 method and its associated road surface sampling. In addition, the plume flux profiling method, was used to calibrate the mobile monitoring technology.

Two versions of the mobile monitoring technology were tested—TRAKER and SCAMPER. Both technologies involve on-board sampling of the dust plume generated by a test vehicle. Both use continuous optical based PM_{10} particle monitors in conjunction with GPS systems, so that dust plume concentrations can be mapped on to the road system traveled by the test vehicle. The SCAMPER samples the plume in the wake of the test vehicle. The TRAKER I and II test vehicles sample the plumes from the front wheel wells of the respective vehicles. TRAKER II has a dilution system to provide for use on unpaved roads. All three units have samplers that monitor the PM10 concentration in front of the vehicle so that "background" PM_{10} can be subtracted.

The referenced study evaluated mobile monitoring technologies in comparison with the traditional AP-42 methodology, but in a controlled measurement environment that included restricted vehicle movement, controlled vehicle speeds and controlled road surface material loadings. This was accomplished by dedicating half of a divided roadway as the test course for the 5-day field study. The stated specific study objectives were as follows:

- Comparison of SCAMPER and TRAKER system measurements with emission measurements using a downwind flux tower.
- Determination of the relationship between roadway silt loading and SCAMPER and TRAKER measurements at several standard vehicle speeds (25, 35 and 45 mph).
- Comparison of SCAMPER and TRAKER measurements to AP-42 emission estimates.
- Characterization of road surface silt depletion rate as a function of the number of vehicle passes.
- Characterization of quantified emissions vs. quantified silt loading mass.
- Data assessment and review for recommendations on performance specifications for vehicle-mounted mobile sampling systems.

Particle concentration measurements formed the basis for the mobile monitoring technologies as well as the roadside emission flux measurements. A continuously recording optical light scattering particle monitor (DustTrak Model 8520, TSI Inc., Shoreview MN) was the basic instrument used for PM_{10} readings. A collocated mass-based reference monitor was used to correct the DustTrak readings to equivalent PM_{10} mass-based concentrations, using a plume profiling tower with various reference, reference equivalent and DustTrak monitors at different heights. Canister vacuum cleaners with hard-floor inlets were used to recover applied soil from the roadway sites into pre-tared vacuum bags. Three soil recovery techniques were used during the study. Road dust emission factors were then calculated for the silt loadings using the 2006 AP-42 emission factor equation. A weight of 2.88 tons, based on the arithmetic average of the reported weights of the three mobile source vehicles was used to calculate the AP-42 emission factors from the silt loadings.

Thirteen different experimental test conditions were performed. Most consisted of approximately 30 vehicle passes, with each pass identified by the mobile sampling technology. Each run consisted of three passes by each mobile sampling technology. Cross-comparisons were performed to determine the ratio between the DustTrak reading and the PM_{10} mass-based concentration measured by a collocated reference sampler. The correlation between the DustTrak and TEOM showed that DustTrak values would have to be multiplied by a factor of 2.8 ± 0.6 to obtain mass-equivalent PM_{10}. A controlled laboratory tests was also used to obtain a relationship between the DustTrak measurements and mass-based measurements. These tests generated a DustTrak correction multiplier of 2.4, which was chosen for use in this program.

Two conclusions were made from the test results obtained in the study, when comparing mobile monitoring technologies with the AP-42 methodology:

- The calibrated mobile methods measured emission factors that were about 1.5 times higher than found with the AP-42 methodology when higher silt loadings were applied to the test road.
- The mobile methods tracked each other quite well under most conditions.

It was concluded that a different silt mobilization process occurred as a result of silt being distributed on top the embedded road surface aggregates and hence being more easily entrained by vehicle mechanical and aerodynamic shear. It was also stated that aged silt found on most roads is more likely to be embedded between the road surface aggregates. Another conclusion identified in the field study was that implementation of mobile monitoring technologies provide for much easier representation of spatially distributed roadway emission characteristics, while eliminating the need to divert traffic.

4.2.1.22. *Technical Support Document for Mobile Monitoring Technologies*; Prepared For Clark County Department of Air Quality and Environmental Management; Chatten Cowherd; Midwest Research Institute; January 9, 2009. (Reference 41, http://www.epa.gov/ttn/chief/ap42/ch13/related/Mobile_Monitoring_TSD_010909.pdf).

This report states that it documents a peer review process conducted to determine whether the mobile monitoring method is a suitable alternative to the traditional AP-42 method for developing road dust emission factors. The report identifies seven individuals which were requested to review the series of Clark County test reports and to judge the value of mobile monitoring technologies in relation to the traditional approach for determining paved road dust emission factors.

The items addressed in this document include:

- A summary of road dust entrainment dynamics,
- A brief discussion of the basis of the current road dust emissions estimating method. Also described were the methods used to characterize the road surface silt loadings, the statistical methods used in developing the AP-42 emission factor equations and the use of roadside plume exposure profiling to quantify mass emissions rates.
- A brief discussion of the methods used to estimate independent variables required for the AP-42 emissions factor equations, associated restrictions and the resulting limitations and a subjective assessment of the uncertainties.
- A more in depth discussion of the two mobile monitoring technologies (the Desert Research Institute (DRI) and the CE-CERT version) is provided. The report identifies the presence of high background dust concentration and high wind speeds as two restrictions for the use of mobile monitoring. The report discusses the subjectively established calibration requirements for mobile monitoring. Calibration requirements identified include determining the relationship between concentrations measured by the instrument used for mobile monitoring and the Federal Register Measurement Method, the relationship between the concentrations measured at different vehicle speeds, different road dust characteristics and different vehicle weight during mobile monitoring and mass emissions measured by plume profiling.
- The report provides a discussion comparing of the implementation of the traditional application of the emissions factor and the use of mobile monitoring to develop emissions inventories.
- Lastly, the report provides the charge provided to the reviewers, an overview of comments by the reviewers and an indication of what changes will be made to address the reviewers concerns in a Specification for Mobile Monitoring document.

While this document states that the purpose is to demonstrate that mobile monitoring is equivalent or superior to the traditional AP-42 methodology, it provides only subjective opinions of the author and the selected reviewers. While there were no quantitative indicators to compare the precision or accuracy of the mobile monitoring technologies over the normal range of road conditions (silt loadings, mix of vehicle weights, vehicle speed) and resultant emissions produced, the author and the majority of the reviewers concluded that the method was more accurate and precise than the traditions measurement and monitoring methods. The review does reveal that there is an understanding that there is a lack of precision and understanding of independent variables other than silt loading, weight and speed which influence road dust emissions. Several reviewers highlight the potential of mobile monitoring methods to replace or supplement the resource intensive and dangerous collection of representative silt loading information. Several reviewers also highlight the need for further development and standardization of mobile monitoring such that the method could be used for managing the road dust emissions where required.

4.2.1.23. Mobile Monitoring Method Specifications; Prepared For Clark County Department of Air Quality and Environmental Management; Chatten Cowherd; Midwest Research Institute; February 6, 2009. (Reference 40, http://www.epa.gov/ttn/chief/ap42/ch13/related/MM_Method_Specifications_020609.pdf).

This document provides instructions for performing a standardized methodology for the construction of a mobile sampling platform, specifications for instrumentation used with

Federal Register Methods for PM10 or PM2.5, calibrations required to correlate the combined sampling platform and instrumentation with standardized plume profiling testing used to quantify mass emissions from roads and procedures for collecting information for use in road surface characteristics or emissions.

4.2.2. EMISSIONS FACTOR DEVELOPMENT.

A total of 103 individual tests are available. All tests quantified PM_{10} emissions. Lastly, plume profiling was the test method. Of these, 81 emissions tests included mean vehicle weight, road silt loading, and vehicle speed. The remaining tests included all of these parameters except vehicle speed. These emissions tests measured PM_{10} emissions associated with engine exhaust, tire wear, brake wear and material deposited on the road surface. Policy decisions within EPA make it necessary to separate particulate matter emissions associated with the operation of the vehicles (engine exhaust, tire wear and brake wear) and those associated with the road surface characteristics. These policy decisions are based in part on the recent and future efforts to control engine exhaust emissions. Many of the emissions tests performed to quantify particulate matter emissions from paved roads were conducted in the mid 1980's to middle 1990's. Several of the emissions studies have experienced comparable upwind and downwind concentrations with downwind particulate that appears to consist of a large percentage of organic or carbonaceous material. The first separation of vehicle associated emissions and pavement associated emissions was in the 2003 update. This update used the national VMT weighted fleet average PM_{10} emissions factor of 0.2119 g/VMT to subtract from the existing emissions factor equation as a means of separating the emissions from engine exhaust, tire wear and brake wear from the composite paved road emissions factor. A fleet average vehicle weight of 3.75 tons is associated with this emissions factor. Since the average vehicle weight used in the development of the paved road emissions factor equation was about 10 tons, the PM_{10} emissions factor for engine exhaust, tire wear and brake wear probably underestimated these emissions. In addition, because of the range and variation in mean vehicle weight, the use of an average for adjustment value introduces excessive error in the estimated road dust emissions estimates. Improved test specific adjustments for vehicle exhaust, tire wear and brake wear can be made since (1) average vehicle weights are available for each test series, (2) PM_{10} emissions factors estimates for each vehicle class are available using the MOVES model and (3) PM_{10} emissions estimates for slowly moving and stop and go truck traffic are available. By subtracting the estimated test specific vehicle emissions from the measured emissions prior to performing the stepwise multiple regression, emissions associated with the road surface material will be isolated.

4.2.2.1. Compilation and Adjustment of Final Data Base.

In keeping with the results from the data set review, a final data base was compiled by combining the following sets:

1. The January 1983 EPA data base,
2. the August 1983 EPA data base,
3. the July 1984 EPA data base,
4. the May 1990 USX data base,

5. the April 1997 EPA data base, and
6. the May 2008 CRA data base.

While several of the test reports include detailed information on the number of light duty vehicles, moderate weight trucks and heavy weight trucks, none provide detailed information on vehicle class as used to estimate emissions of vehicle exhaust, tire wear and break wear. For this assessment the vehicle classes will be separated into two vehicle classes. One group of vehicle class will include the six classes of light duty vehicles/trucks and motorcycles. The other group of vehicle class includes gas and diesel heavy duty trucks. Other assumptions used to estimate vehicle associated emissions include:

- The test fleet includes a mixture of light duty vehicles, heavy duty gas trucks and heavy duty diesel trucks when the average vehicle weight is less than 23 tons.
- The test fleet includes a mixture of light duty vehicles and heavy duty diesel trucks when the average vehicle weight is between 23 tons and 35 tons.
- The test fleet includes only heavy duty diesel trucks when the average vehicle weight is more than 35 tons.

First, the average vehicle weight and emissions are determined for the two classes of vehicles used to estimate the adjustment for the measured emissions. The vehicle weights and VMT distribution presented in Table 4-16 are used to calculate the average vehicle weight. The VMT adjusted gross vehicle weight is calculated for each class of vehicle by multiplying the VMT distribution by the average gross vehicle weight for the class. The individual vehicle class VMT adjusted gross vehicle weights are summed to arrive at the two VMT adjusted gross vehicle weights used in this assessment. For light duty vehicles, the VMT adjusted gross vehicle weight is 3320 pounds. For heavy duty trucks, the VMT adjusted gross vehicle weight is 3742 pounds. The sums of the VMT distributions for these two classes of vehicles are obtained by summing the individual VMT distributions for the two classes of vehicles used in this assessment. For light duty vehicles, the VMT distribution is 0.928. For heavy duty trucks, the VMT distribution is 0.0717. Dividing the VMT adjusted gross vehicle weights by the VMT distributions and converting to tons yields the average vehicle weights for the two classes of vehicles. For light duty vehicles, the average gross vehicle weight is 1.79 tons. For the combination of heavy duty gas and diesel trucks, the average gross vehicle weight is 26.09 tons.

Next, an algorithm is developed to provide test run specific ratios of light duty vehicles and heavy duty trucks. The algorithm is developed by solving the following two equations.

$$W_t = (R_{LD} \text{ x } W_{LD}) + (R_{HD} \text{ x } R_{HD})$$

$$1.00 = R_{LD} + R_{HD}$$

where: W_t = Test report average vehicle weight

W_{LD} = Average Light Duty Vehicle Weight (1.78848 tons)

R_{HD} = Average Heavy Duty Truck Weight (26.09135 tons)

R_{LD} = Light duty vehicle ratio

R_{HD} = Heavy duty truck ratio

For test runs where the average vehicle weight is less than 23 tons, the resulting algorithm to estimate the ratio of heavy duty gas/diesel trucks in each test series is:

$$R_{HD} = (W_t - 1.78848) / (26.09135 - 1.78848)$$

For tests where the average vehicle weight is more than 23 tons, the resulting algorithm to estimate the ratio of heavy duty diesel trucks in each test series is:

$$R_{HD} = (W_t - 1.78848) / (35 - 1.78848)$$

Run specific emissions estimates for vehicle exhaust, brake wear and tire wear are estimated using the EPA Office of Transportation and Air Quality MOVES (MOtor Vehicle Emission Simulator) 2010 model[29]. For all tests with vehicle speed greater than 10 mph only emissions for freely moving traffic is calculated. Emissions for a representative mix of light duty vehicles and for a representative mix of heavy duty trucks are calculated. For each test series, information on the date of the test, the location of the test program, ambient temperature during the test, average vehicle speed, and other general information required to generate a valid PM_{10} emissions calculation with the MOVES model. While the MOVES model has the ability to generate start up emissions, all test conditions are assumed to include only vehicles which have achieved normal operating temperatures. For all test series with average vehicle speeds greater than 10 mph, the MOVES model calculated only running exhaust, tire wear and brake wear emissions. For heavy duty vehicles, the running emissions ranged from 0.645 g/VMT to 4.896 g/VMT. For light duty vehicles, the running emissions ranged from 0.0196 g/VMT to 0.1324 g/VMT. For test series with average vehicle speeds below 9.9 mph, in addition to running exhaust, tire wear and brake wear emissions; exhaust emissions during acceleration and idling are included. A separate MOVES model run estimated the average emissions for the non steady state emissions at 11.06 g/hour. The emissions factor for this driving condition was calculated by dividing the hourly emissions by the average vehicle speed. Summing the product of emissions factors from heavy duty trucks and light duty vehicles and the ratio of heavy duty vehicles and light duty vehicles provides an estimate of the total engine exhaust; tire wear and brake wear emissions for the test run.

The test run specific emissions factor estimate for engine exhaust, tire wear and brake wear is subtracted from the test run measured emissions factor to produce the test run specific emissions factor due to road surface material. To allow log transformation of the data, values of zero or less were set to 0.01 g/VMT. Table 4-17 presents the final dependent and independent variables for all of the useable test series that were assembled for developing the paved road emissions factor equation. There were 10 test runs of the 103 available data where downwind emissions were not measureable. Six of the data were associated with low speed traffic at corn refining facilities and four of the data were high or moderate speed urban traffic. None of these ten data were included in the data analyzed to estimate the predictive emissions factor equation. There were 3 out of the 103 available data sets where the estimated emissions from engine exhaust, tire wear and break wear were equal to or comparable to the measured emissions. Two of the three test runs were on roads where the average vehicle speed was 55 mph. Emissions of two additional test runs with vehicle speeds of 55 mph had engine exhaust, tire wear and break wear emissions greater than 160% of the road emissions. The silt level for one of the 55 mph test runs was greater than all other 55 mph data sets and was performed to characterize emissions from a road that had been sanded for traction control. For slightly slower moving traffic (40 – 45 mph), three of the five test runs had significant percentage of engine exhaust; tire wear and brake wear emissions. One of the remaining two runs had silt levels greater than 60% of the entire data set and the test was performed to characterize emissions from a road that had been sanded for traction control.

Graphical presentations of the final PM_{10} data base are shown in Figures 4-1 through 4-5. Because of the large range of silt loadings and estimated emissions factors, the data are plotted on a logarithmic scale for the first three figures. Figure 4-1 presents the data base by silt loading with five ranges of average vehicle weight depicted with different shape and color data points. The figure shows that with increasing silt loading there is an increase in the PM_{10} emissions factor. Figure 4-2 presents the data base by average vehicle weight with seven ranges of silt loading depicted with different shape and color data points. Although there is a significant overlap of the different vehicle weight data, there appears to be some relationship between average vehicle weight and the PM_{10} emissions factor. As with silt loading, it appears that the PM_{10} emissions factor increases with increasing vehicle weight. The wider spread of the data around the center line of the data makes the relationship more difficult to discern. Figure 4-3 presents the relationship between silt loading and average vehicle weight with eight ranges of emissions factors depicted with different shape and color data points. Although very poor, there appears to be a weak relationship between silt loading and vehicle weight. The cause of this relationship is probably due to the selection of the test location and parameters than any physical force that would cause this relationship. Figure 4-4 presents the relationship between average vehicle speed and the PM_{10} emissions factor. It appears that between 10 and 55 mph, the emissions factor decreases with increasing speed. Below 10 mph there does not appear to be a speed relationship. Figure 4-5 presents the relationship between silt loading and vehicle speed with five ranges of PM_{10} emissions factors. The silt loading appears to decrease with increasing speed above 10 mph. In addition, there seems to be a clear increase in PM_{10} emissions factor as silt loading increases and speed decreases. Figure 4-6 presents a three dimensional view of the silt loading, vehicle weight and PM_{10} emissions factors. One data point seems to be very uncharacteristic of the general trend of the data. Figure 4-7 provides a two dimensional view of the data with the data identifier in the label. For three data points, the PM_{10} emissions factor is also included in the label. The point which has the uncharacteristic emissions is point Z-3 with a PM_{10} emissions factor of 1819 g/VMT. While this value is the highest emissions factor of all of the 92 test data, both the vehicle weight and silt loading for this run are near other data which are under 100 g/VMT. As a result, this data was flagged as a potential outlier. This data was reassessed following log transformation and the variation was determined to be comparable with other data and was included in the final data set used to estimate the predictive equation. Figure 4-8 presents the three dimensional view of the test data with silt loading, vehicle weight and PM_{10} emissions factor with test run Z-3 removed. With point Z-3 removed, there appears to be two regimes of the data. Most of the data had silt loadings below 20 g/m^2 with few gaps down to 0.013 g/m^2. There are ten data with silt loadings spread out from 50 g/m^2 to almost 400 g/m^2 with no data between these two regimes. There appears to be one incline associated with the lower silt loading data and a significantly greater incline for the higher silt loading data. This greater incline is the result of a small number of data collected prior to 1983. These data have higher silt loadings that the default silt loading for the peak additive contribution value for roads with average daily traffic volume counts of less than 500. While there may be a very small number of streets that reach this silt loading level, these are believed to be unrepresentative of typical well managed urban or rural roads during any season. As a result, these data are flagged as extreme values and were not included in the final data set used to estimate the predictive equation.

Table 4-17. Final Paved Roads Emissions Factor Data Set

Reference	Run ID	Silt loading (g/m2)	Speed (mph)	Weight (tons)	Downwind Concentration mg/m^3	Measured PM_{10} Emission factor (g/VMT)	Estimated Fraction Heavy Duty Vehicles	Estimated Engine, brake, tire emission factor (g/VMT)	Estimated PM_{10} Road Dust Emission factor (g/VMT)
USX 5/1990	AUC3	0.42	27	5.5	0.011	2.25	0.153	0.3298	1.920
	AUC4	0.52	25	6	0.04	16.1	0.173	0.3537	15.746
	AUC5	0.23	29	3.9	0.07	15.3	0.087	0.1941	15.106
	AUC6	0.23	27	6.2	0.03	3.7	0.182	0.3961	3.304
	AUC7	0.26	27	3	0.01	0.402	0.050	0.1653	0.237
	AUC8	0.15	27	2	0.03	7.88	0.009	0.0936	7.786
	AUE1	4	15	12	0.01	3.22	0.420	0.9337	2.286
	AUE2	4	16	5.1	0.6	10.6	0.136	0.3709	10.229
	AUE3	2.2	15	2.6	0.08	16.1	0.033	0.1804	15.920
	AUE4	1.3	15	2.6	0.06	9.01	0.033	0.1804	8.830
EPA 7/1984	M-1	0.46	30	5.6	0.124	4.99	0.157	0.3610	4.629
	M-2	0.26	30	3.8	0.033	1.55	0.083	0.2486	1.301
	M-3	0.147	30	4.5	0.070	3.54	0.112	0.2845	3.256
	M-4	0.432	35	2.1	0.030	0.177	0.013	0.0927	0.084
	M-5	1.01	35	2.2	0.090	0.692	0.017	0.0749	0.617
	M-6	0.716	30	2.1	0.063	1.38	0.013	0.1043	1.276
	M-7	0.59	35	2.3	0.130	4.22	0.021	0.1146	4.105
	M-8	2.48	20	2.2	0.120	11.2	0.017	0.1063	11.094
	M-9	0.293	30	4.1	0.130	3.24	0.095	0.2190	3.021
	M-10	0.022	55	4.5	0.104	0.177	0.112	0.1798	0.010
	M-11	0.022	55	4.8	0.080	0.322	0.124	0.2009	0.121
	M-12	0.022	55	3.8	0.080	0.084	0.083	0.1403	0.010
	M-13	0.11	35	2.7	0.065	0.306	0.038	0.0988	0.207
	M-14	0.079	35	2.7	0.030	1.37	0.038	0.1044	1.266
	M-15	0.049	35	2.7	0.090	1.47	0.038	0.0886	1.381
	M-16	0.022	55	4.3	0.060	0.241	0.103	0.1581	0.083
	M-17	0.809	30	2	0.056	2.64	0.009	0.0501	2.590
	M-18	0.731	30	2	0.080	0.37	0.009	0.0501	0.320
	M-19	0.929	30	2.4	0.050	0.177	0.025	0.0791	0.098

Table 4-17. (Continued)

Reference	Run ID	Silt loading (g/m2)	Speed (mph)	Weight (tons)	Downwind Concentration mg/m^3	Measured PM_{10} Emission factor (g/VMT)	Estimated Fraction Heavy Duty Vehicles	Estimated Engine, brake, tire emission factor (g/VMT)	Estimated PM_{10} Road Dust Emission factor (g/VMT)
EPA 1/1983	Y1	90.7	10	3.6		117	0.075	0.2274	116.773
	Y2	76.1	10	3.7		182	0.079	0.2359	181.764
	Y3	193	10	3.8		36.3	0.083	0.2443	36.056
	Y4	193	10	3.7		200	0.079	0.2359	199.764
	Z1	11.3	10	8		317	0.256	0.6096	316.390
	Z2	12.4	15	8		740	0.256	0.5697	739.430
	Z3	12.4	15	8		1820	0.256	0.5697	1819.430
	AC4	287	10	5.7		1750	0.161	0.4090	1749.591
	AC5	188	15	7		1420	0.214	0.4852	1419.515
	AC6	399	20	3.1		613	0.054	0.1466	612.853
	AD1	94.8	23	42		1480	1.000	1.8114	1478.189
	AD2	63.6	23	39		342	1.000	1.8114	340.189
	AD3	52.9	23	40		233	1.000	1.8114	231.189
EPA 8/1983	F34	2.78	NR	28	0.552	188	0.789	1.4388	186.561
	F35	2.03	NR	25	0.057	298	0.699	1.2790	296.721
	F36	0.201	NR	8.3	0.134	54.7	0.268	0.5320	54.168
	F37	0.417	NR	17	0.163	77.2	0.626	1.1617	76.038
	F38	0.218	NR	18	0.301	167	0.667	1.2339	165.766
	F39	0.441	NR	18	0.177	253	0.667	1.2339	251.766
	F27	14.8	NR	14	0.531	130	0.502	0.9292	129.071
	F32	0.117	NR	14	0.138	53.1	0.502	0.9292	52.171
	F61	17.9	NR	40	0.327	463	1.000	1.8261	461.174
	F45	5.11	NR	16	0.744	212	0.585	1.0896	210.910
	F62	14.4	NR	36	0.294	317	1.000	1.8226	315.177
	F74	5.59	NR	29	0.114	545	0.819	1.5012	543.499

Table 4-17. (Continued)

Reference	Run ID	Silt loading (g/m2)	Speed (mph)	Weight (tons)	Downwind Concentration mg/m^3	Measured PM_{10} Emission factor (g/VMT)	Estimated Fraction Heavy Duty Vehicles	Estimated Engine, brake, tire emission factor (g/VMT)	Estimated PM_{10} Road Dust Emission factor (g/VMT)
EPA 8/1983	B50	13.6	NR	9.4	0.225	82.1	0.313	0.5936	81.506
	B51	13.6	NR	11	0.410	140	0.379	0.7108	139.289
	B52	7.19	NR	12	0.102	35.4	0.420	0.7836	34.616
	B54	3.77	NR	10	0.187	93.3	0.338	0.6379	92.662
	B55	6.3	NR	11	0.295	183	0.379	0.7108	182.289
	B56	2.4	NR	9.2	0.229	126	0.305	0.5794	125.421
	B58	10.4	NR	18	0.190	368	0.667	1.2221	366.778
	B57	2.32	NR	12	0.358	195	0.420	0.7836	194.216
	B59	2.06	NR	11	0.149	348	0.379	0.7108	347.289
	B60	3.19	NR	12	0.339	439	0.420	0.7836	438.216
EPA 4/1997	BH1	0.184	55	2.2	0.233	1.08	0.017	0.0306	1.049
	BH2	0.0127	55	2.2	0.030	0.102	0.017	0.0306	0.071
	BH3	0.0127	55	2.2		0	0.017	0.0305	
	BH6	1.47	40	2.2	0.300	4.68	0.017	0.0343	4.646
	BJ6	0.06	45	2.2	0.045	0.301	0.017	0.0336	0.267
	BJ7	0.06	45	2.2	0.130	1.94	0.017	0.0336	1.906
	BJ9	0.06	45	2.2		0	0.017	0.0305	
	BJ10	0.06	45	2.2		0	0.017	0.0305	
	BJ11	0.06	45	2.2		0	0.017	0.0305	
	BK7	0.082	45	2.2	0.033	0.57	0.017	0.0336	0.536
	BK8	0.082	45	2.2	0.033	0.44	0.017	0.0336	0.406
CRA 5/2008	CE-1	1.16	1	36	0.050	27	1.000	11.06	15.940
	CE-2	0.86	1	36	0.075	64	1.000	11.06	52.940
	CE-11	1.34	5	12	0.200	154	0.420	2.212	151.788
	CE-3	0.86	1	39	0.070	45	1.000	11.06	33.940
	CE-15	1.91	5	40	0.065	63.5	1.000	2.212	61.288
	CE-16	1.41	5	40	0.050	77.1	1.000	2.212	74.888
	CE-17	2.93	5	40	0.040	41.3	1.000	2.212	39.088
	CE-19	0.76	5	38	0.040	18.6	1.000	2.212	16.388

Table 4-17. (Continued)

Reference	Run ID	Silt loading (g/m2)	Speed (mph)	Weight (tons)	Downwind Concentration mg/m^3	Measured PM_{10} Emission factor (g/VMT)	Estimated Fraction Heavy Duty Vehicles	Estimated Engine, brake, tire emission factor (g/VMT)	Estimated PM_{10} Road Dust Emission factor (g/VMT)
CRA 5/2008	CE-12	1.34	5	13	0.085	23.1	0.461	2.212	20.888
	CF-1N	0.97	5	40	0.035	4.99	1.000	2.212	2.778
	CF-1/South	0.97	1	40	0.040	19.5	1.000	11.06	8.440
	CF-2N	0.81	5.3	41	0.044	16.3	1.000	2.0868	14.213
	CF-2/South	0.81	1	41	0.080	63.5	1.000	11.06	52.440
	CF-3N	0.63	5.1	41	0.015	1.09	1.000	2.1686	0.010
	CF-3/South	0.63	1	41	0.025	23.1	1.000	11.06	12.040
	CF-4N	1.1	4.7	41	0.019	3.08	1.000	2.3532	0.727
	CF-5	1.4	1	41	0.030	16.3	1.000	11.06	5.240
	CI-1	0.06	15.1	26		0	0.729	1.0008	
	CI-2	0.06	14.85	26		0	0.729	1.0008	
	CI-3	0.06	13.15	27		0	0.759	1.0410	
	CI-4	0.06	14.5	27		0	0.759	1.0410	
	CI-7	0.05	15.3	27	0.030	1.63	0.759	1.0409	0.589
	CI-8	0.05	15.3	27	0.030	2.99	0.759	1.0409	1.949
	CI-11	0.025	13.1	27		0	0.759	1.0410	
	CI-12	0.25	13.1	27		0	0.759	1.0410	
	CM-1	0.72	5	39.8	0.035	6.35	1.000	2.212	4.138
	CM-2	0.72	1	39.6	0.050	63.5	1.000	11.06	52.440
	CM-4	0.7	5	39.5	0.035	7.26	1.000	2.212	5.048

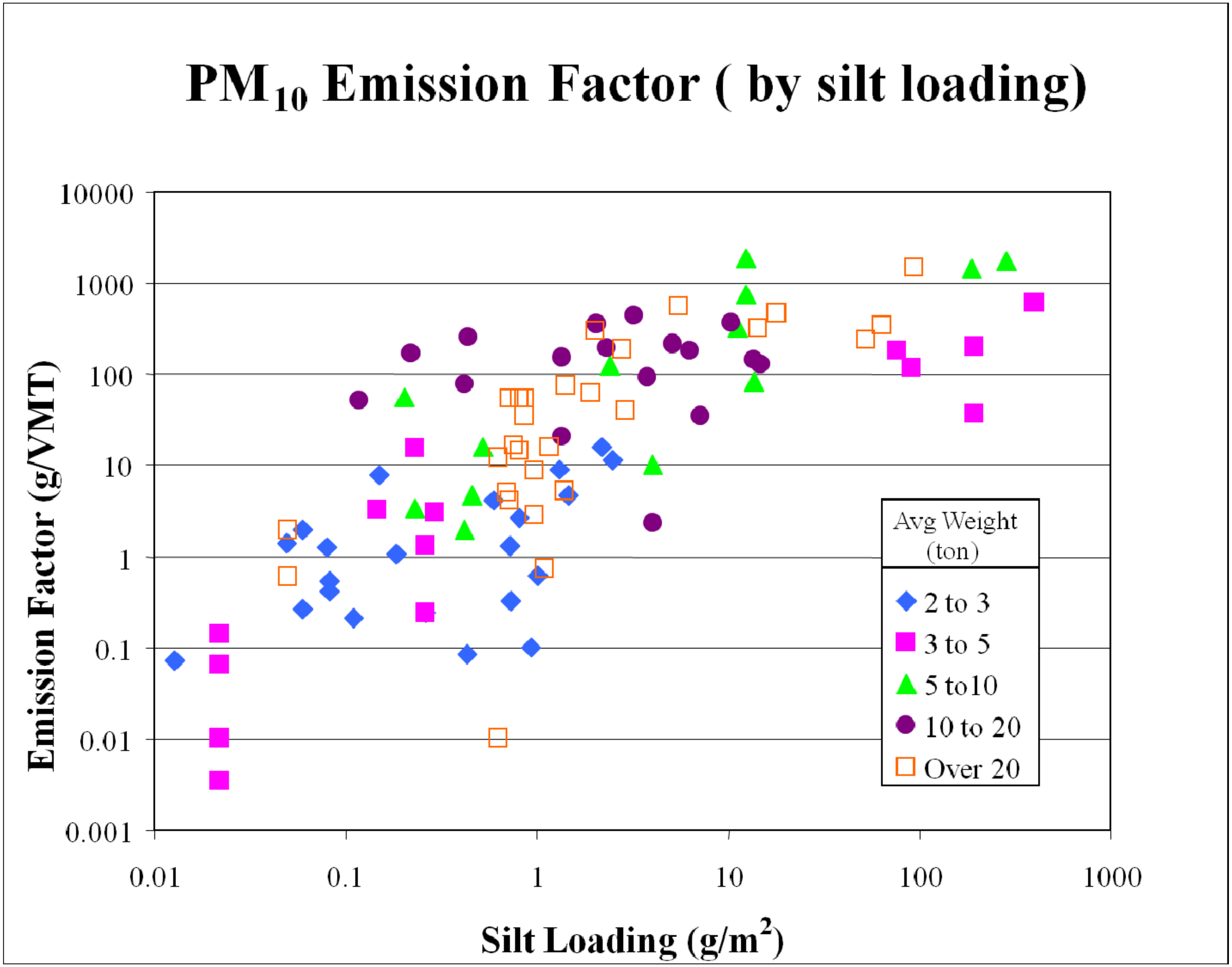

Figure 4-1. PM_{10} Emissions Factor Data Base by Silt Loading (93 test runs).

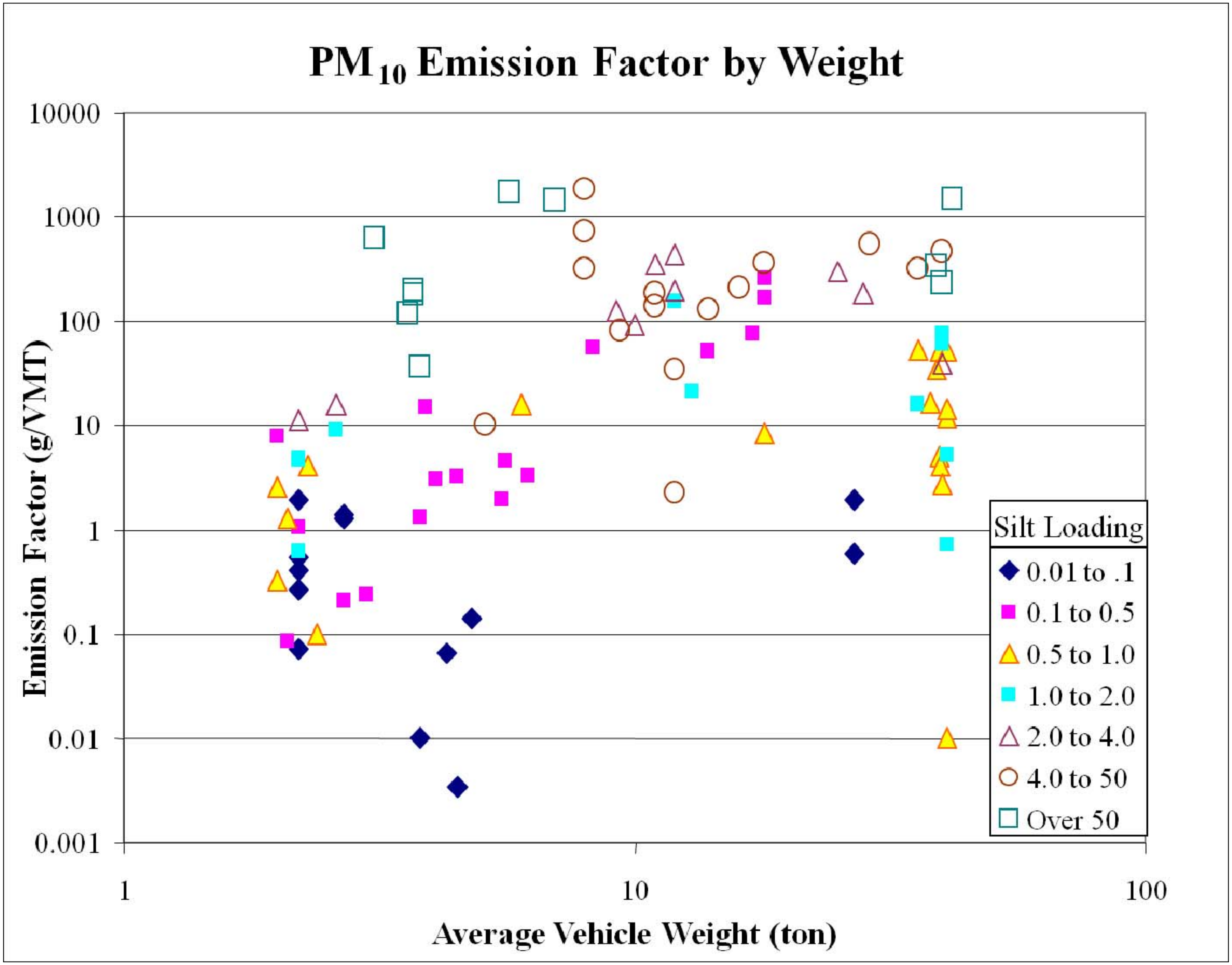

Figure 4-2. PM_{10} Emissions Factor Data Base by Average Vehicle Weight (93 test runs).

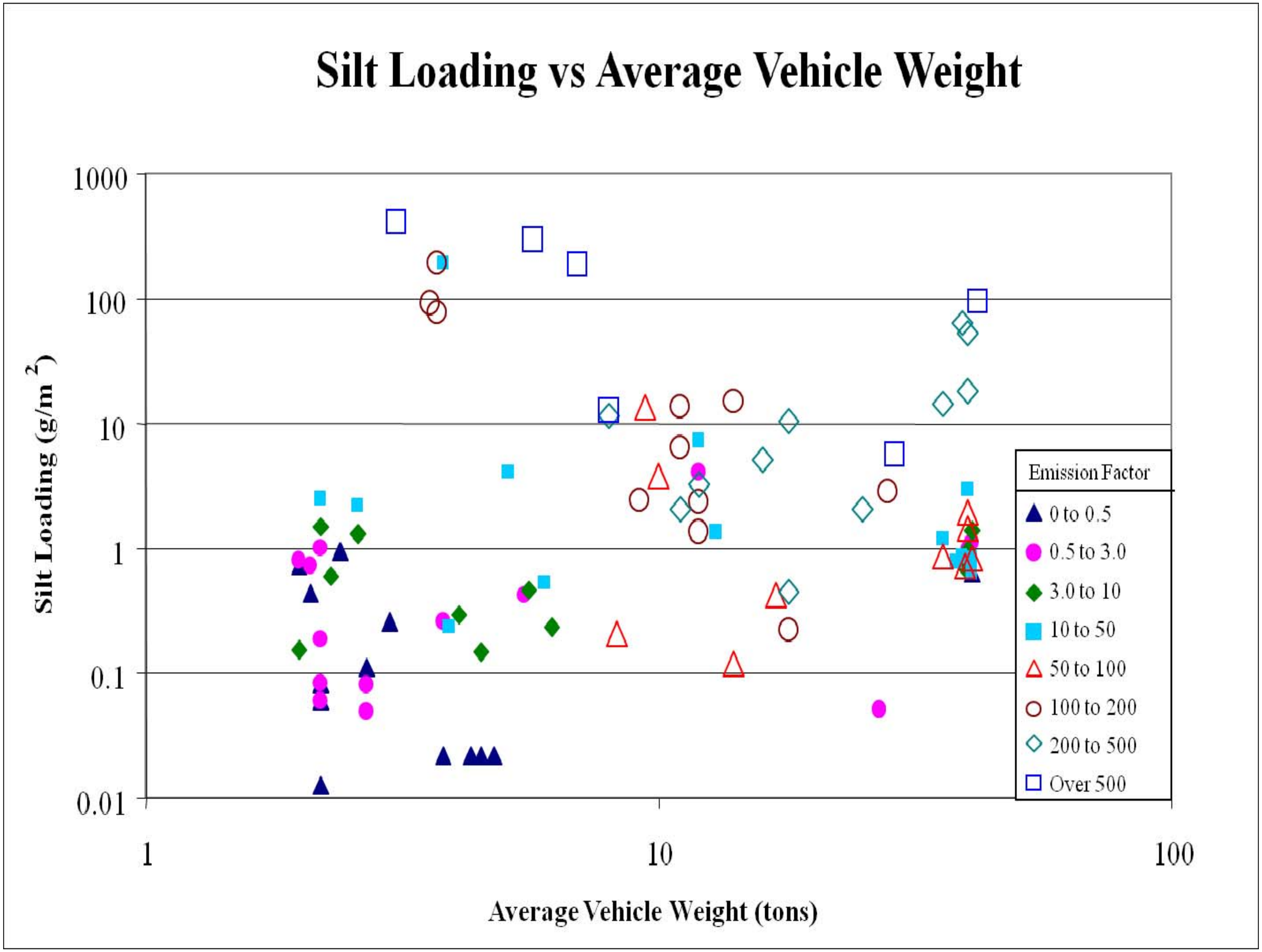

Figure 4-3. Silt Loading vs. Average Vehicle Weight (93 Test Runs).

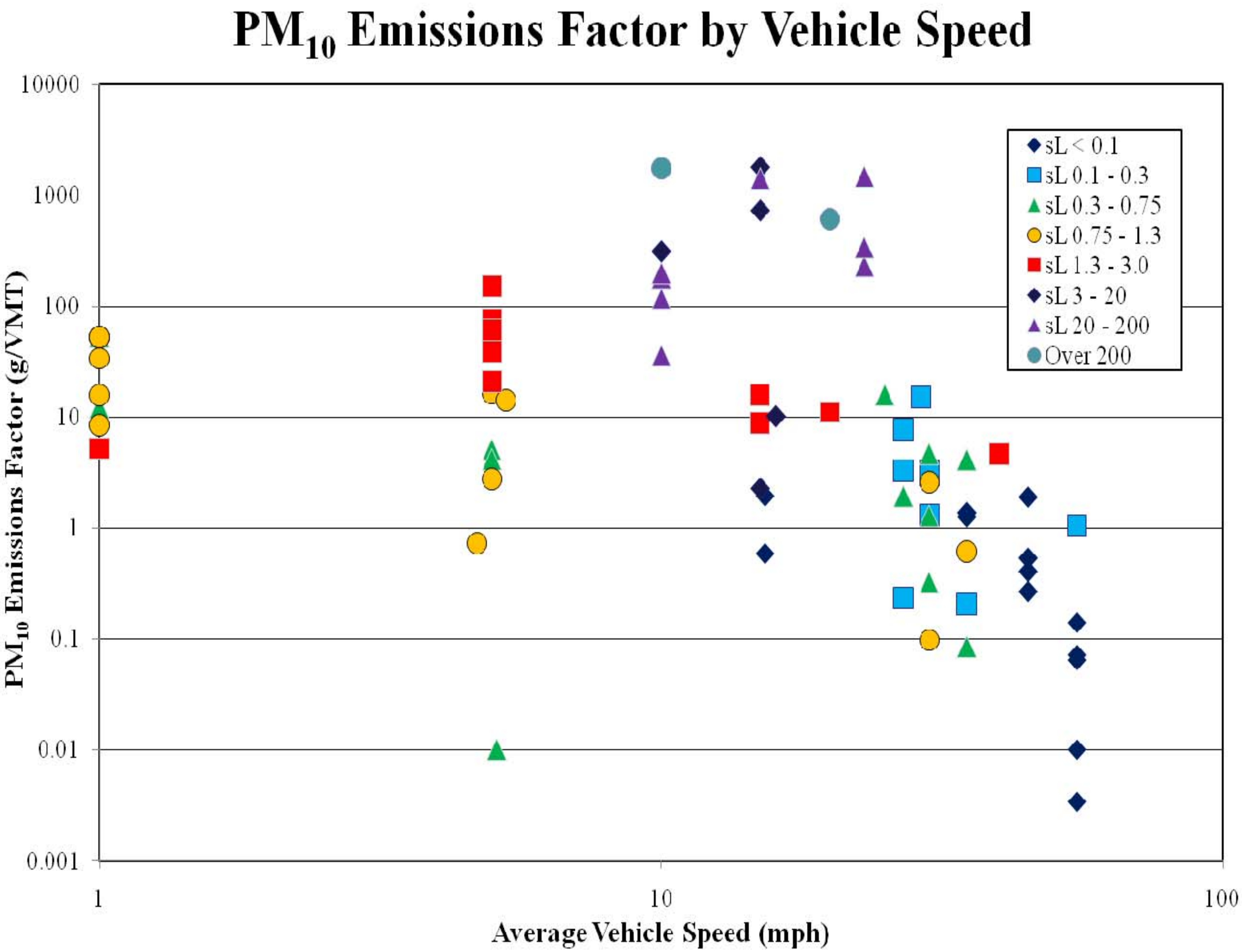

Figure 4-4. PM_{10} Emissions Factors by Vehicle Speed.

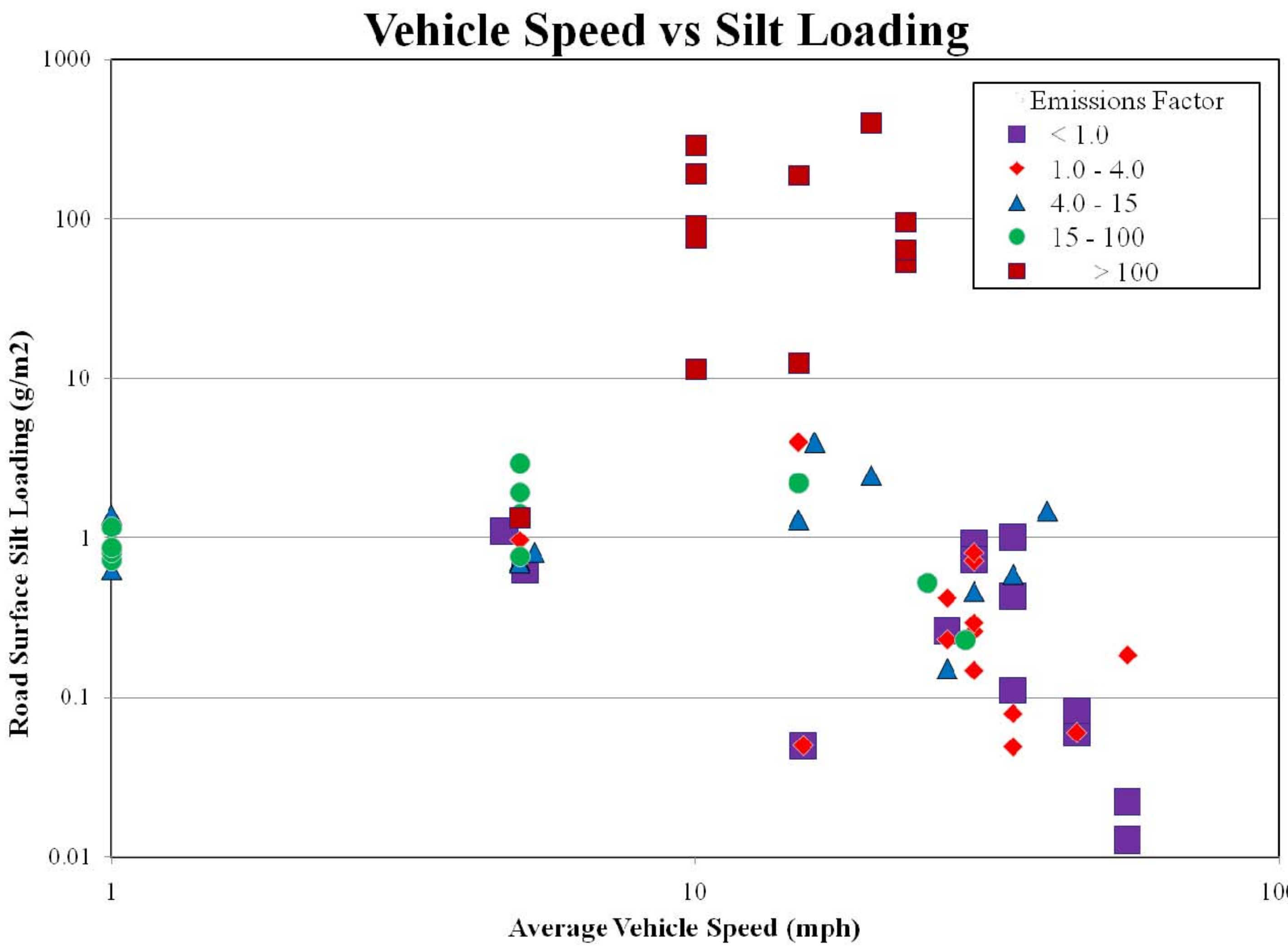

Figure 4-5. Vehicle Speed vs Silt Loading.

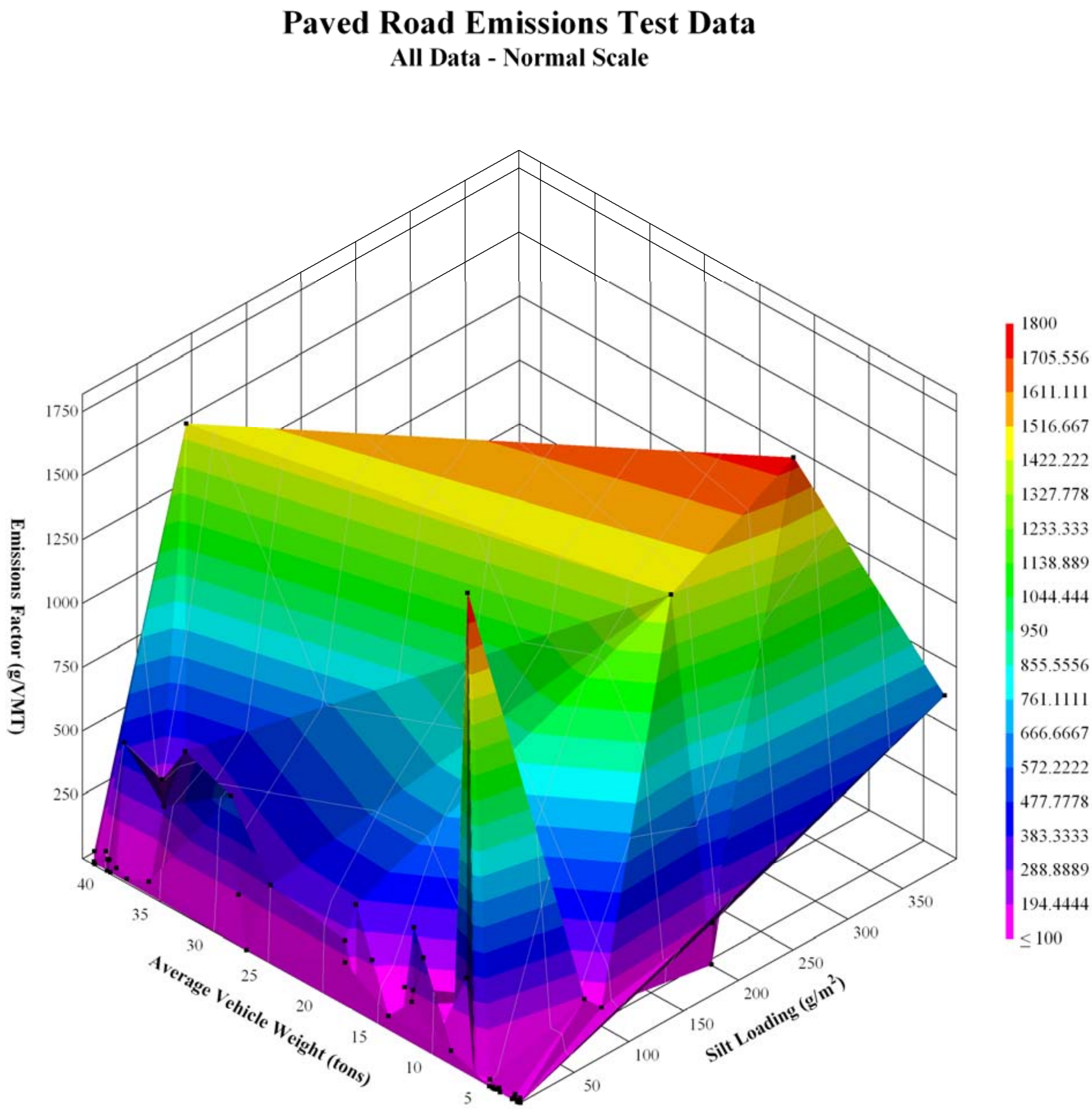

Figure 4-6. Paved Road Dust Emissions Factors, All Data.

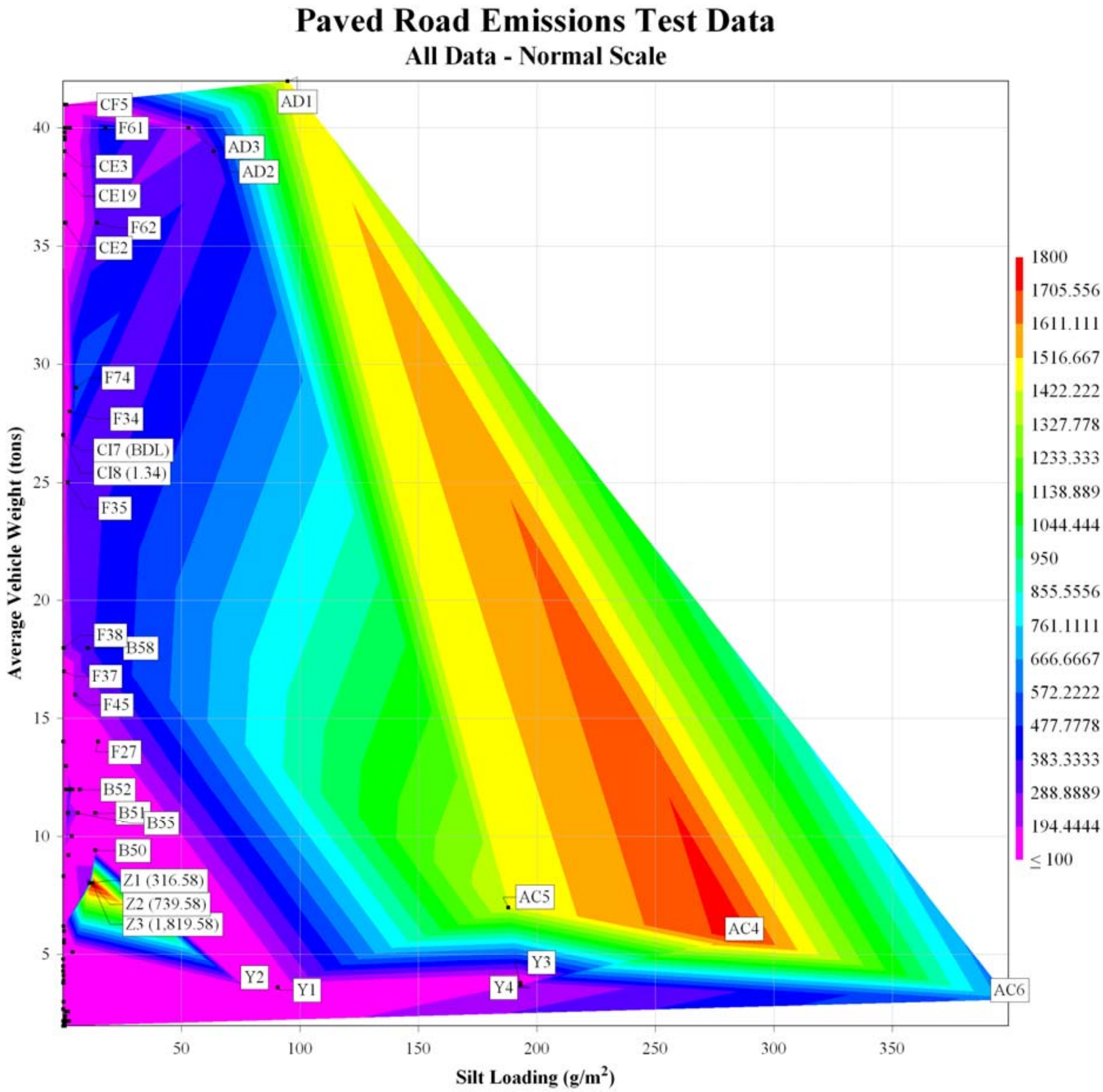

Figure 4-7. All Paved Road Data, Silt Loading by Vehicle Weight with EF.

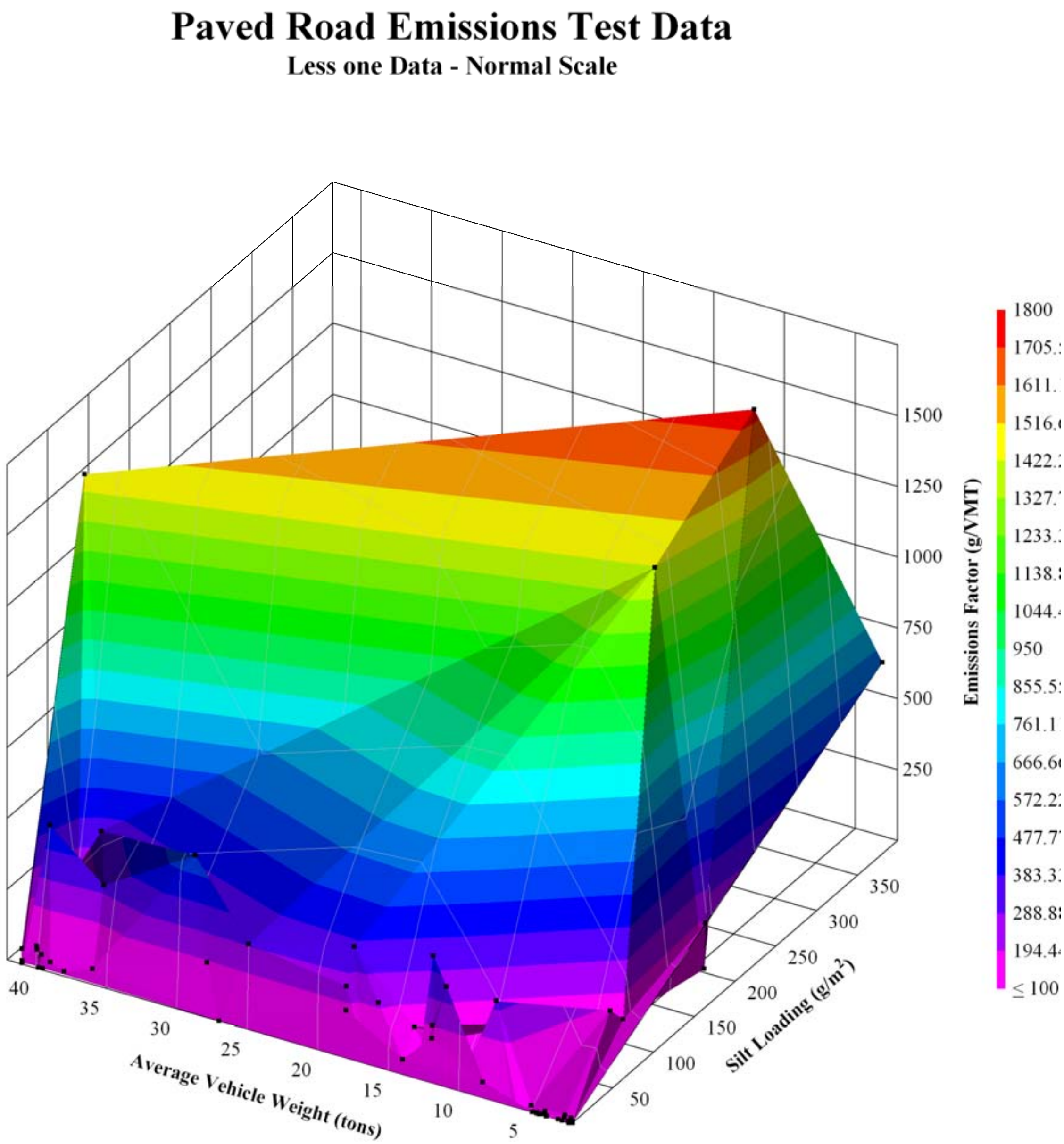

Figure 4-8. Paved Road Dust Emissions Factor Data Excluding Z-3.

4.2.2.2. Emission Factor Development.

Stepwise multiple linear regression was used to develop a predictive model with the final data set. The potential correction factors included:

- silt loading, sL
- mean vehicle weight, W
- mean vehicle speed, S

All variables were log-transformed in order to obtain a multiplicative model as in the past. Table 4-18 presents the correlation matrix of the log-transformed independent and dependent variables. The most notable feature of the correlation matrix is the high degree of correlation between silt loading and emissions factors. The correlation between emissions factor, weight and speed is much lower than with silt loading. The high correlation between weight and speed is believed to be the result of the large data collected by the corn refiners association to characterize emissions at terminals. This suggests that obtaining accurate silt loading information is the most important independent variable to obtain for accurately estimating emissions factors.

Table 4-18 Correlation Matrix for log-transformed PM_{10} data.

	PM_{10} Emission factor (g/VMT)	Silt loading (g/m^2)	Weight (tons)	Speed (mph)
PM_{10} Emission factor (g/VMT)	1			
Silt loading (g/m^2)	0.8010	1		
Weight (tons)	0.3280	-0.1841	1	
Speed (mph)	-0.4066	-0.2785	-0.7784	1

Initially several regression analysis were performed using the Data Analysis tools in MS Excel to evaluate a range of independent variables. The independent variables included silt loading, average vehicle weight, the product of silt loading and vehicle weight, the square of silt loading (after log transformation) and the square of the vehicle weight (after log transformation). In addition, the influence of including and excluding flagged test runs were explored. The primary criteria for selecting the most appropriate form and supporting data set was the predictive performance of the equation using the combination of the correlation coefficient, the P-value and the relative percent difference from the actual emissions factor for the test series with silt loadings and vehicle weights in the range of default values used in the national inventory. The stepwise regression was first performed using the “Regression” function in the “Analysis Tool” of Excel. It was determined that the use of the speed term either produced equations with P-values greater than 0.1 or produced equations with independent parameter relationships that were illogical (i.e. increased emissions with decreased weight). It was also determined that the inclusion of data with silt loadings greater than 20 g/m^2 produced equations which uniformly overestimated test data with lower silt loadings without a significant improvement in estimating the high silt loading data. Also, the exclusion of the ten data with high silt loadings did not significantly change the predictive accuracy of the equation for the ten high silt loading test runs. The 93 test data with positive measured emissions were provided to a statistician for subsequent analysis with SAS.

Several additional assessments were performed to determine an equation that provided a high correlation coefficient, a low average percent error for test series with targeted independent variables and which provided a reasonable level of predictive accuracy for test series where the independent variables were outside the targeted range. The equation which produced the highest correlation coefficient was one which forced the intercept to zero. This equation performed well and was consistent with engineering assessments of the physical influences on emissions. This equation used only silt loading and average vehicle weight as the independent variables. It was decided that the traditional scaling factors of 2 for silt loading and 3 for average vehicle weight were no longer required and resulted in simpler calculation of paved roads emissions factors. The resulting equation for PM_{10} is:

$$EF = 1.0\,(sL)^{0.912}(W)^{1.021}$$

Table 4-19 shows the statistical output. The predicted exponents for silt and weight are 0.912 and 1.021 respectively and have a coefficient of determination (R^2) of 0.72. The standard error associated with the silt and weight terms are 0.12 and 0.08 respectively. As a result, it is expected that 95% of future data would fall within equations with exponents of 0.677 and 1.14 for the silt term and 0.852 and 1.19 for the weight term.

The range of conditions which existed at the test sites used in developing the equation was as follows:

Silt loading:	0.03 - 400 g/m2
	0.01 - 570 grains/square foot (ft2)
Mean vehicle weight:	1.8 - 38 megagrams (Mg)
	2.0 - 42 tons
Mean vehicle speed:	1 - 88 kilometers per hour (kph)
	1 - 55 miles per hour (mph)

Table 4-19. Regression Analysis using Silt Loading and Weight.

SUMMARY OUTPUT   All positive test data, sL < 20 force 0, sL W

Regression Statistics	
Multiple R	0.848347765
R Square	0.71969393
Adjusted R Square	0.703887682
Standard Error	1.921751464
Observations	83

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	768.0593789	384.0296894	103.9849195	5.61978E-23
Residual	81	299.1434238	3.693128689		
Total	83	1067.202803			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A
Weight (tons)	1.0212836	0.084774552	12.04705393	9.58964E-20	0.852608836	1.189958364
Silt loading (g/m2)	0.911843675	0.117787966	7.741399277	2.42283E-11	0.677482574	1.146204776

An assessment of the performance of the predictive equation is difficult since the range of silt loadings and the associated emissions factors spans five orders of magnitude. This is further complicated by the focus of many of the field tests. Approximately half of the field test locations were selected either due to concerns that these sources were major contributors to air quality impacts, or were selected because of elevated road silt levels to allow the measurement of a difference from background concentrations of particulate matter. Another complication is that PM emissions of the vehicle exhaust were not measured during the tests and a modeled average emission factor or rate was subtracted to arrive at the road dust emissions.

One can assess the performance of the predictive equation by calculating the average predicted to actual ratio and producing the cumulative distribution of these ratios. For the two parameter equation, the average predicted to actual ratio is 49. This is significantly lower than the average predicted to actual ratio of 315 for the previous equation when applied to the existing data. When limited to silt loading levels of 20 g/m2, the new equation produces average predicted vs actual ration of 38 compared to the previous equations ration of 221. It should be noted that the previous equation subtracted 0.2119 g/VMT (the estimated national average engine exhaust, brake wear and tire wear emissions factor) from the previous equation which was based upon measured emissions. The new equation subtracts the estimated engine; brake wear and tire wear emissions estimated for each test run. These emissions average 1.565 g/VMT and range from 0.031 to 11.06 g/VMT depending on meteorological conditions, vehicle speed and vehicle weight determined during the test. Figure 4-9 depicts the cumulative distribution of the predicted to actual ratios for both the previous equation and the new equation. Figure 4-10 presents this same information but with ranges of silt loading depicted through the use of different shapes and colors for the markers of the data. Figure 4-11 is this same information but with ranges of vehicle weights depicted with different markers. It is difficult to discern any differences below the ratio of 1.0. Above the ratio of 1.0 the increased range of the predicted vs actual ratio of the older equation is evident. The new equation appears to demonstrate an improved performance compared to the previous equation.

Another means of assessing the performance of the regression equations is to compare the calculated results of the equations to the actual value measured. With a large range of measured emissions factors, comparing the relative percent difference between the results of the equation and the measured value places the differences in the smallest measured value and the largest measured value on comparable terms. Two comparisons were made to assess the relative predictive performance of the existing equation to the previous equation. As shown with the average percent error for the entire population in Table 4-23, the new equation provides an order of magnitude improvement in estimating the actual measured emissions over the previous equation. Associated with the reduction in the percent difference from actual emissions is a 47 percent reduction in the emissions factor. When the performance of the equation is evaluated within classes of the independent variables of silt loading, average vehicle weight and speed; the new equation shows comparable or improved performance in all groups of the variables except two.

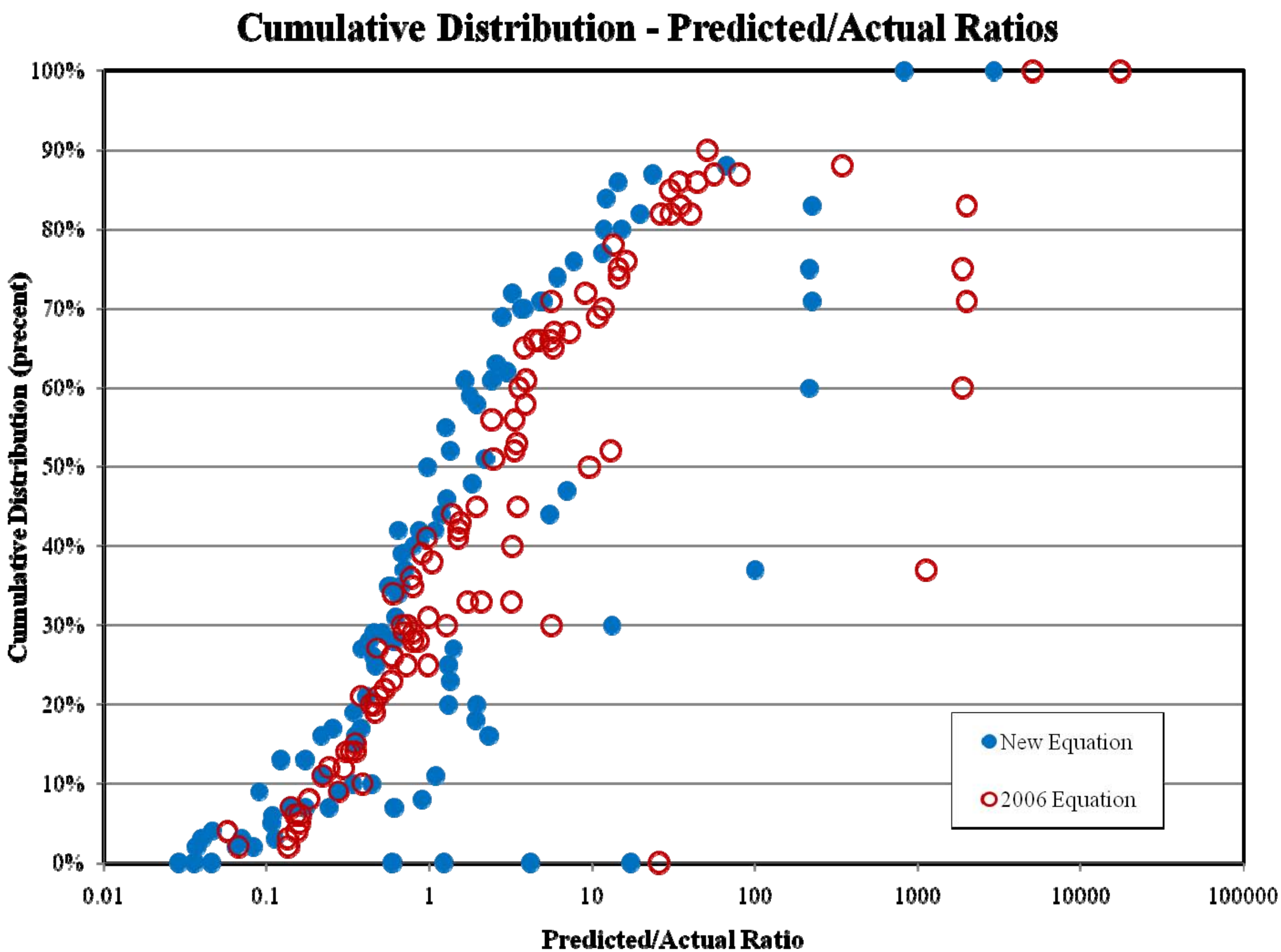

Figure 4-9. Cumulative Distribution of Predicted/Actual Ratios.

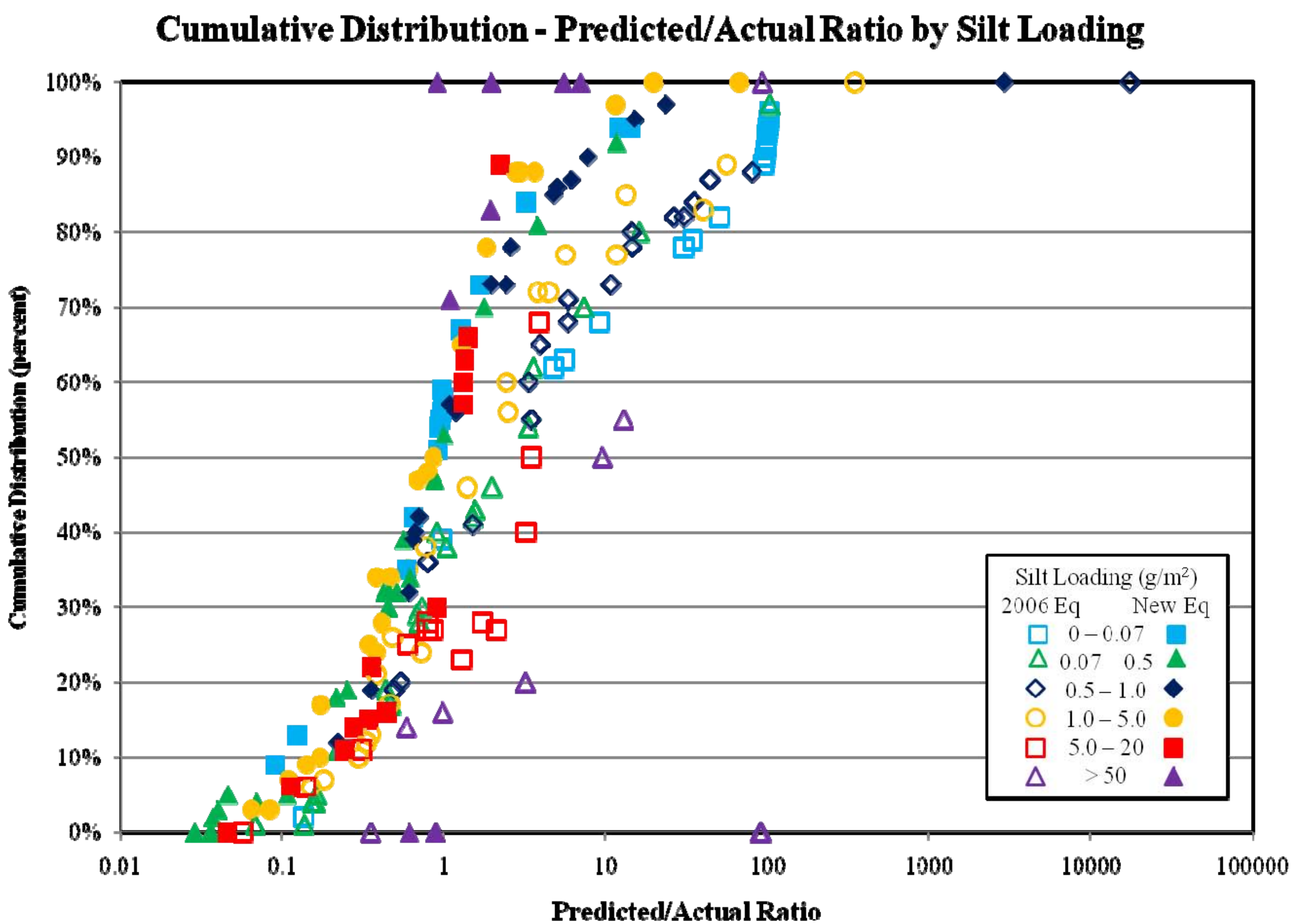

Figure 4-10. Cumulative Distribution – Predicted/Actual by Silt Loading.

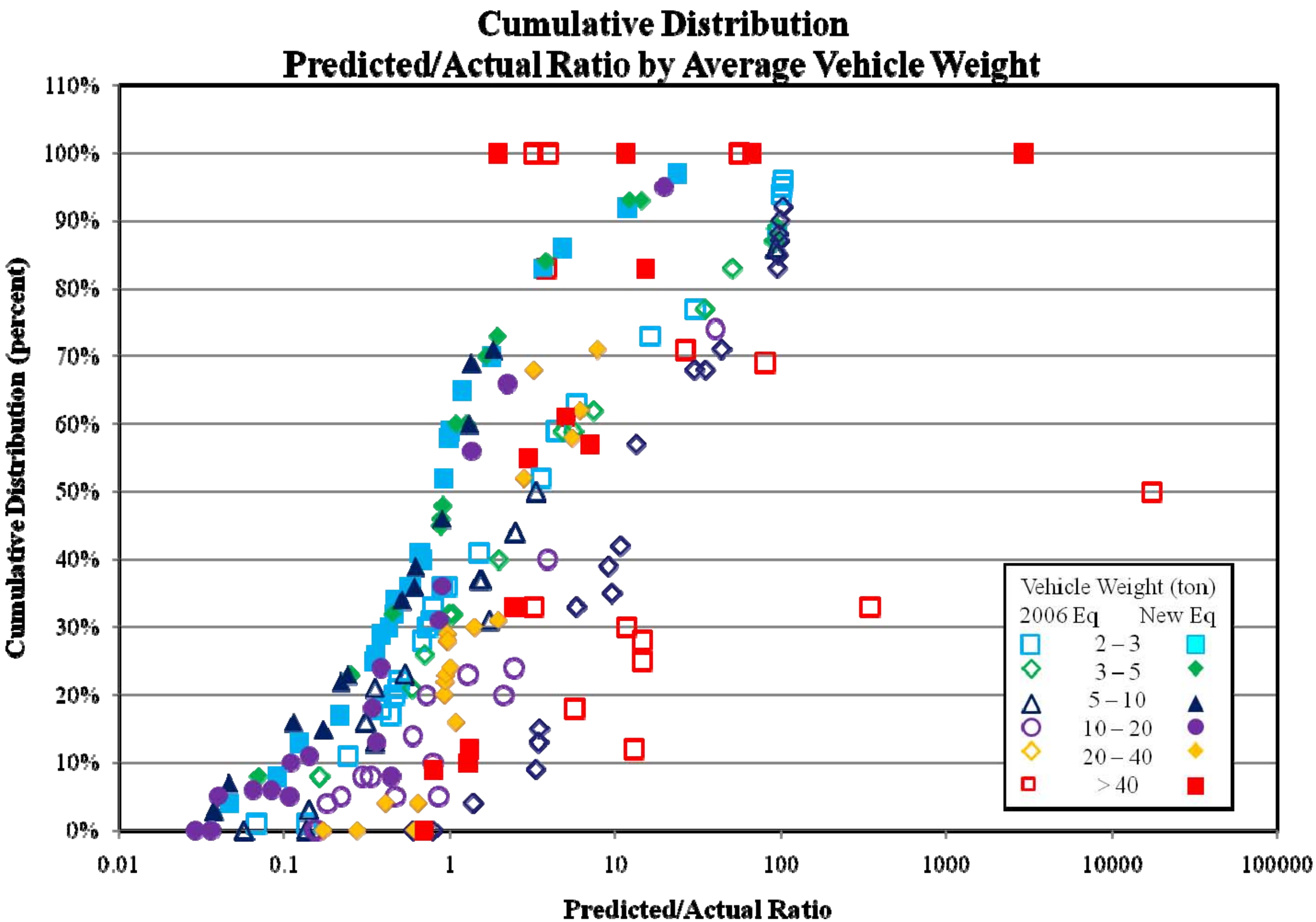

Figure 4-11. Cumulative Distribution – Predicted/Actual by Average Vehicle Weight.

Figure 4-12 through Figure 4-9 provide graphical indications of the performance of the updated equation to estimate the actual emissions. The first figure shows the relationship of emissions to the road surface silt loading. Included in this figure is information on the average vehicle weight through the use of a different shape and color for different ranges of vehicle weight. While not shown, the previous equation had a greater spread than the new equations estimates. Figure 4-13 shows the influence of vehicle weight on the emissions factors. For all weight ranges, the spread of the data is much greater than is demonstrated in the figures with silt as the ordinate. Included in this figure is information on the silt loading associated with the test. One can see a general increase in emissions with silt loading. This is probably due to the greater correlation between silt loading and PM_{10} emissions factors than between average vehicle weight and PM_{10} emissions factors. Figure 4-9 shows the influence of speed on the emissions factors. As with vehicle weight, there is a greater spread of the emissions factor than when silt is the primary dependent variable graphed. One can also see a weak relationship between silt loading and average vehicle speed.

Table 4-20. Comparison of Previous and New Equations for Estimating Paved Road Dust Emissions.

	Predictive Performance of Paved Road Dust Emissions Equations					
	Average Relative Percent Difference [1]			Relative Standard Deviation		
	Old Equation vs Actual	New Equation vs Actual	Old Equation vs New Equation	Old Equation vs Actual	New Equation vs Actual	Old Equation vs New Equation
Population Average	31,378	3,142	-47	5.77	5.84	-1.2
By Classes of Silt Loading (g/m^2)						
≤ 0.2	33,601	3,858	-71	2.12	1.38	-0.62
0.2 – 0.75	102,647	17,049	-62	3.71	11.54	-0.35
0.75 – 1.5	3,236	669	-61	2.48	0.41	-0.46
1.5 – 50	221	47	-45	3.57	0.11	-0.46
≥ 50	248	253	73	1.81	0.27	1.20
By Classes of Average Weight (ton)						
2 - 3	467	333	40	2.09	0.43	-1.62
3 – 5	718	289	350	1.71	0.72	9.91
5 – 10	-2	-41	53	-394.3	0.37	-0.74
10 – 40	38,248	4,906	74,840	3.06	24.73	-0.18
≥ 40	128,217	21,549	68,550	4.27	112.84	-0.22
By Classes of Average Speed (mph)						
< 10	90,216	15,112	-79	4.30	20.67	-0.07
10 – 25	54,063	7,034	-6	2.17	4.94	-15.11
25 – 45	293	170	-41	2.41	0.139	-0.45
45	1,041	662	-34	1.28	0.198	-0.05
55	1,404	467	-114	1.57	0.114	-0.60

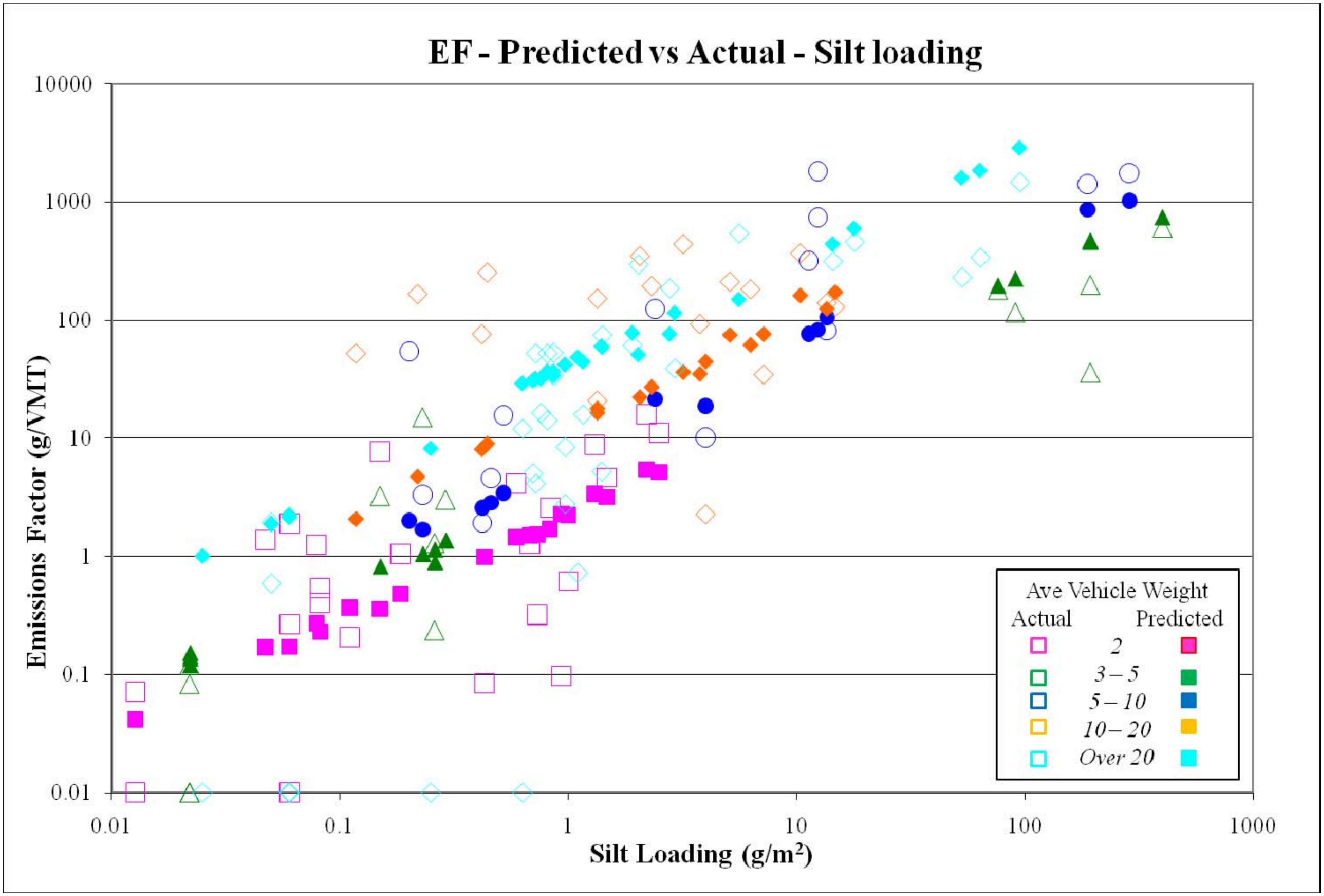

Figure 4-12. Predicted vs Actual PM_{10} Emissions Factor by Silt Loading.

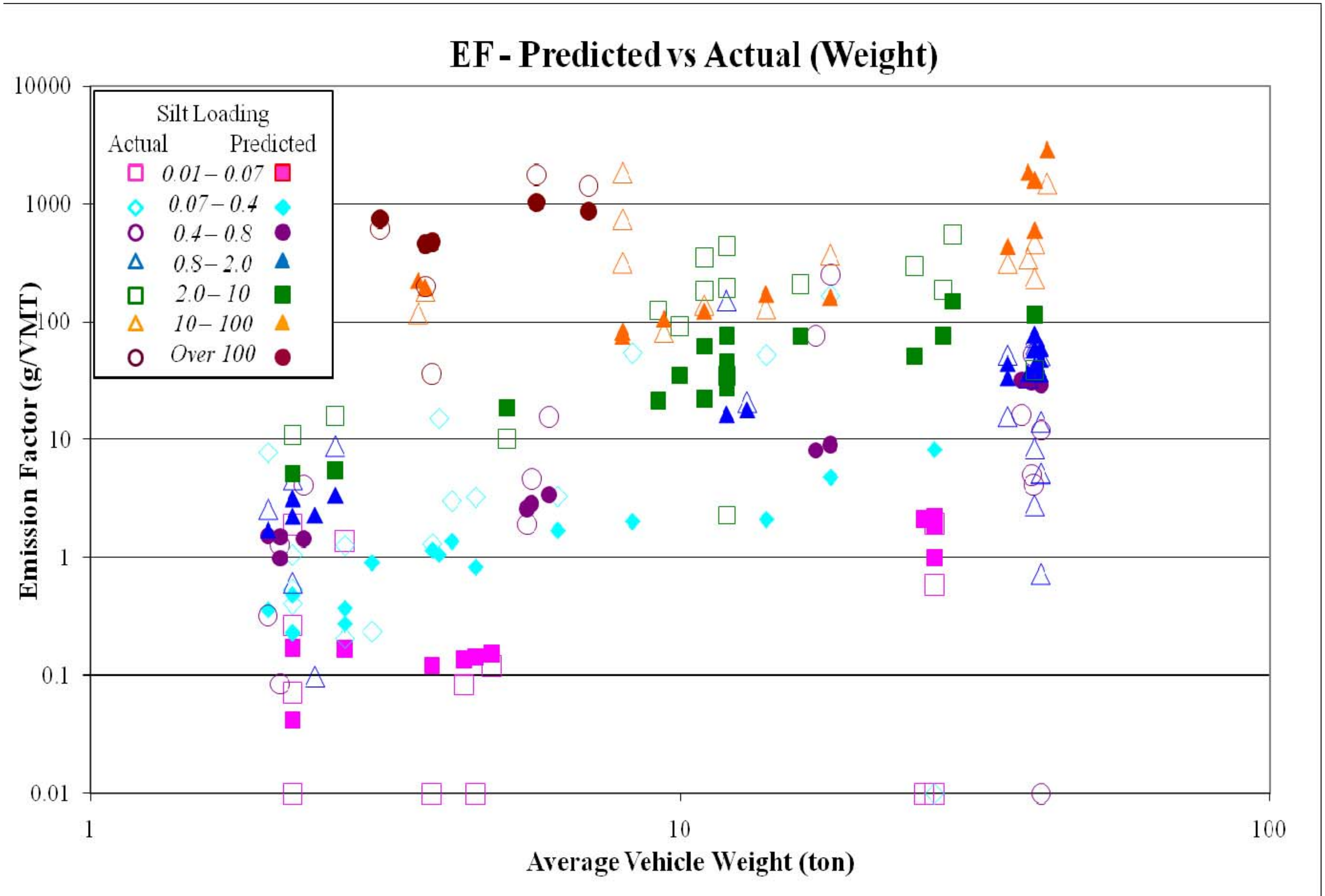

Figure 4-13. Predicted vs Actual PM_{10} Emissions Factor by Average Vehicle Weight.

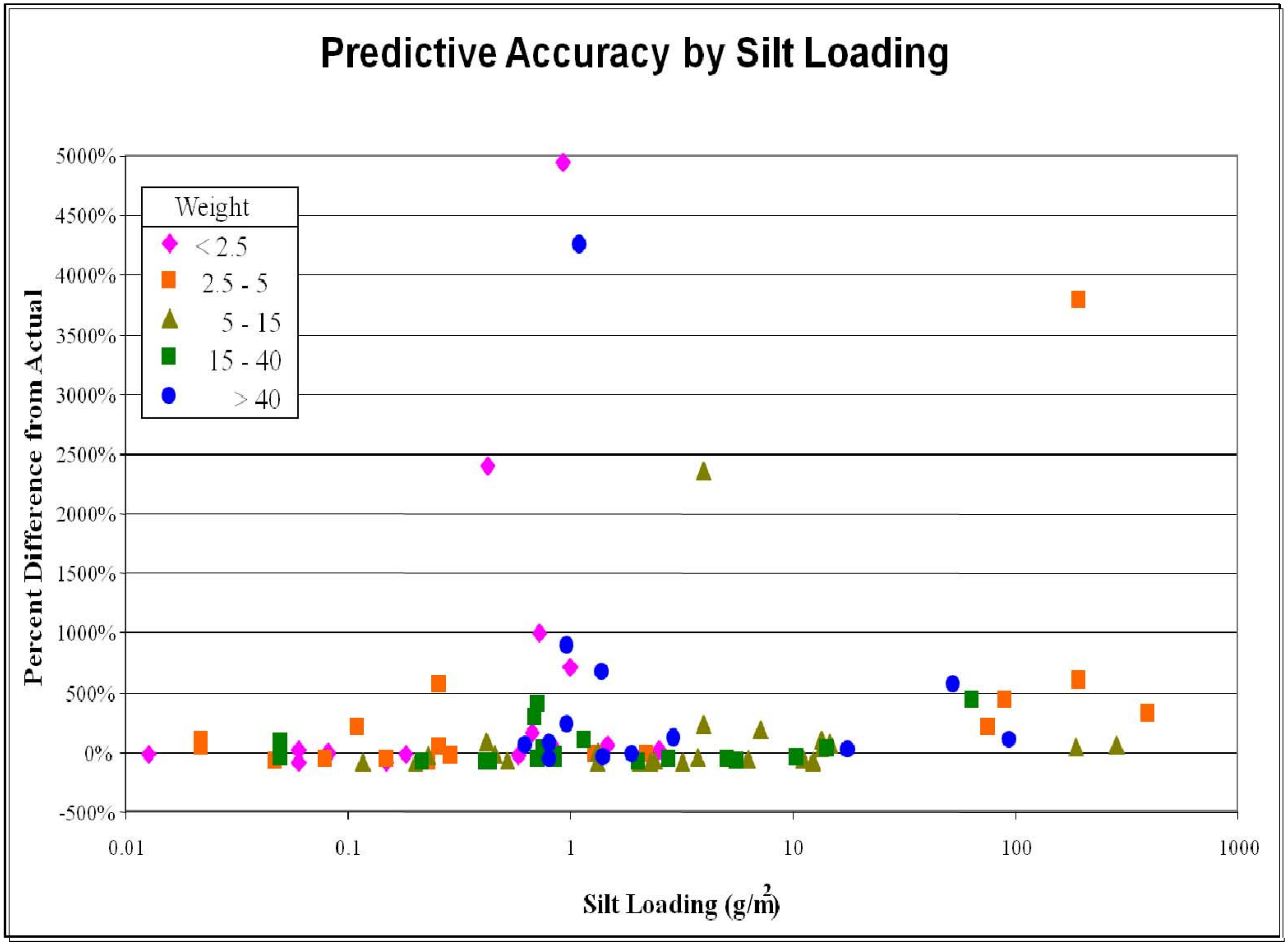

Figure 4-14. Predictive Accuracy by Silt Loading (unrestricted range).

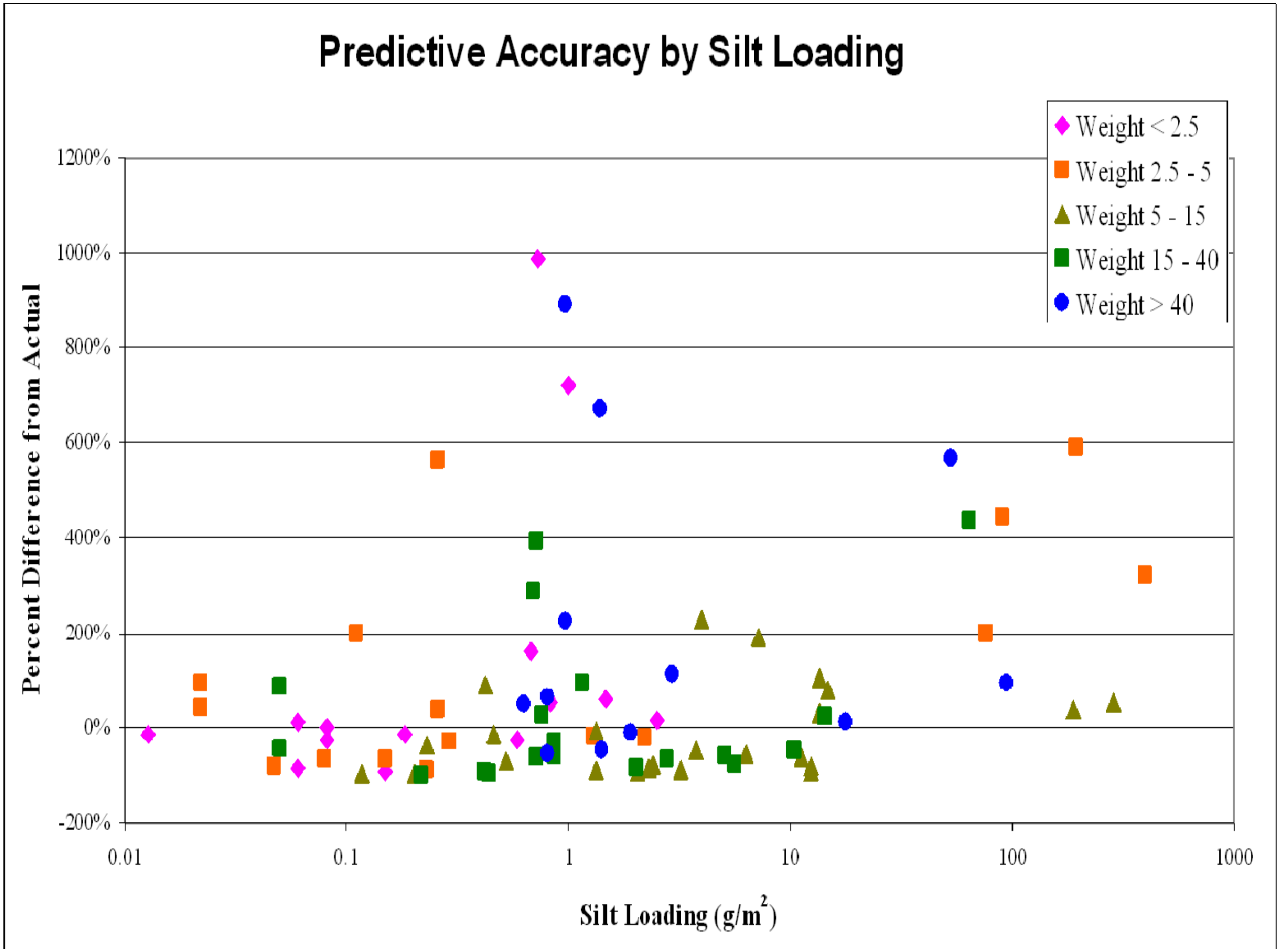

Figure 4-15. Predictive Accuracy by Silt Loading (restricted range).

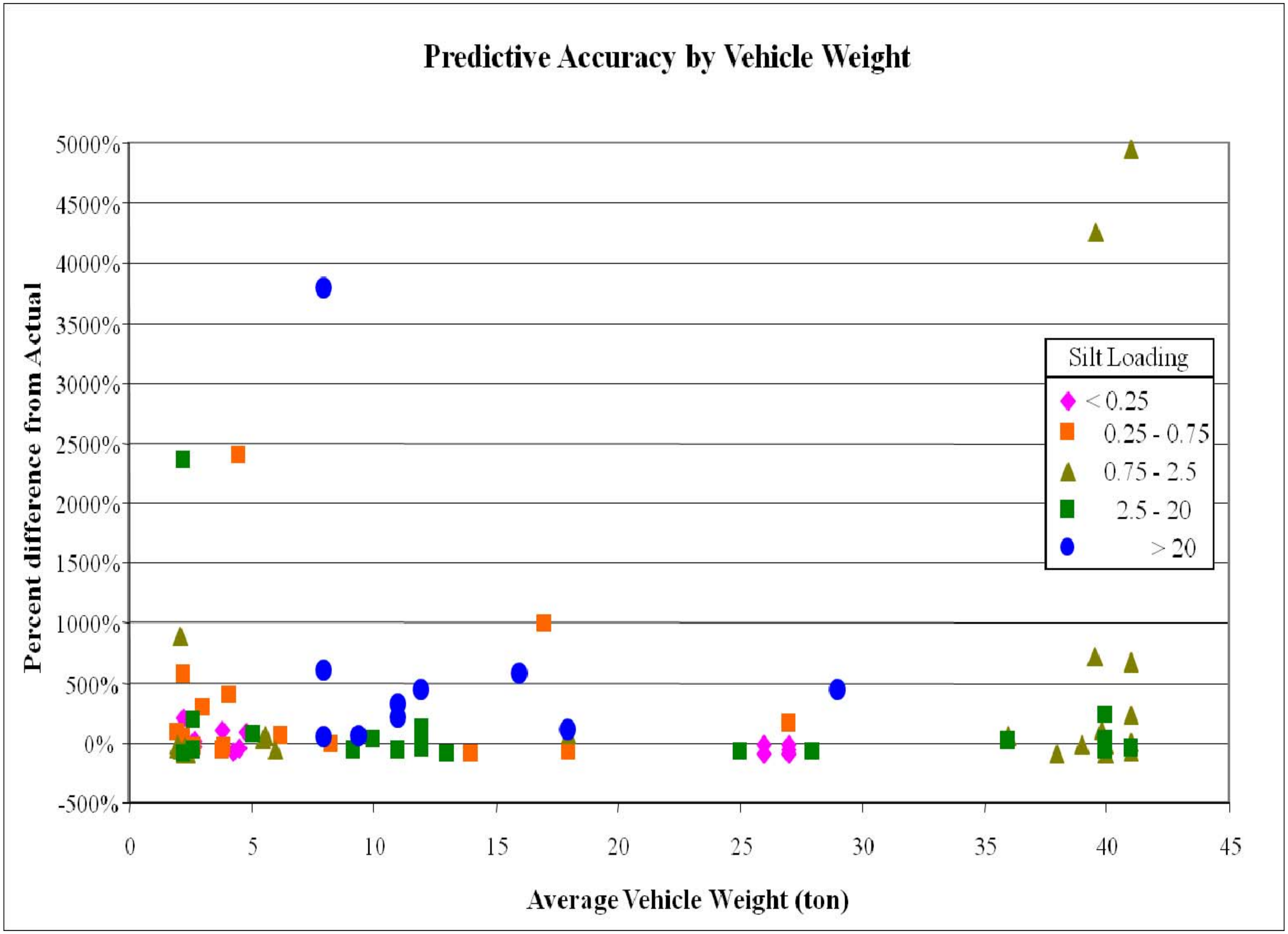

Figure 4-16. Predictive Accuracy by Average Vehicle Weight (unrestricted range).

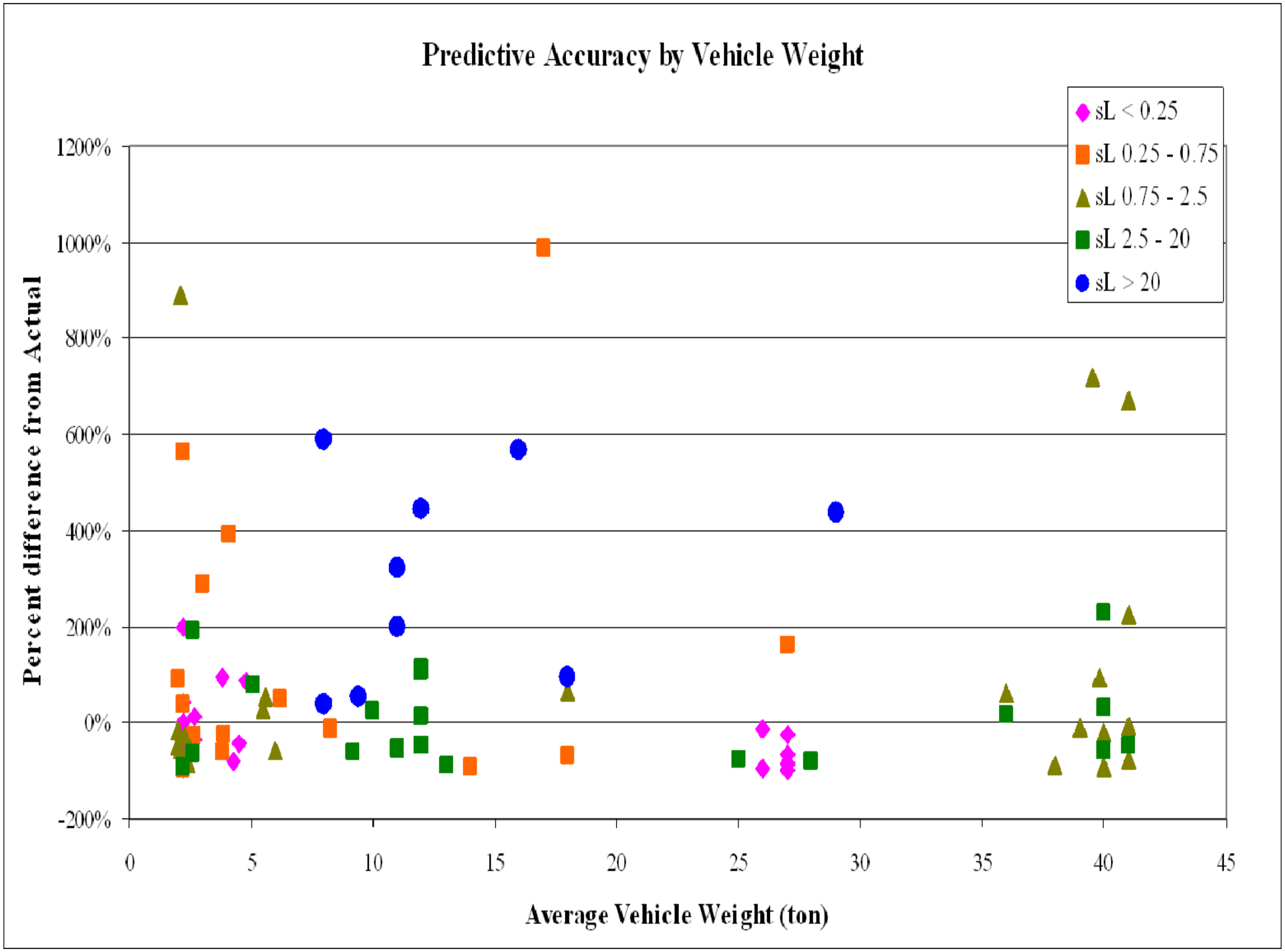

Figure 4-17. Predictive Accuracy by Average Vehicle Weight (restricted range).

4.2.2.3 Emissions Factor Quality Rating Assessment.

All of the source test data used to develop the emissions factor equation were rated A since the test procedures used were profiling tests and were all well documented. While only six reports are available that provide documentation of emissions factors for paved roads, these test reports contain the results of 17 different road conditions. The reports and the number of test conditions documented in the report are:

- USX 5/1990 - 2 tests (sL ~.3 & sL > 2),
- EPA 7/1984 - 2 tests (30 mph & 55 mph),
- EPA 1/1983 - 4 tests (<15 mph, >20 mph, W < 3 tons, W 5-8 tons, W > 30 tons),
- EPA 8/1983 - 2 tests for two parameter equation,
- EPA 4/97 - 3 tests (speed 55, 45), 3 locations, and
- CRA 5/2008 - 4 tests (4 locations, 2 speeds,)

However, since the EPA 8/1983 report does not contain information on the average speed of the vehicles in the study, none of the tests documented in that report is usable for further data set groupings. The remaining five reports contain the results of 15 different road conditions. While all of the tests were performed on paved roads, the ranges of conditions (silt loading, vehicle speed and vehicle weight) were diverse. An assessment of the variation associated with the data and the impact of that variation on a single value emissions factor. The average of all the adjusted emissions factors is 140 g/VMT and the standard deviation is 387. A relative standard deviation of 3 is greater than many other factors. As a result, the number of tests needed to achieve the predictive accuracy of the mean is greater. The availability of 15 A or B rated test reports would normally justify an initial assignment of a factor rating of B. However, the greater variability of the underlying data justifies a single value factor rating of C.

The stepwise regression of the available data indicated that a large portion of the variation of the emissions factor was due to the large range of the road silt loading that existed at the test locations. The preliminary regressions produced equations with varying constants and exponents with correlation coefficient below 60%. By excluding the high silt loading data and forcing a zero intercept, the correlation coefficient (R2) for the final equation is 72%. This indicates that approximately 72% of the variations in the emissions factors are due to the silt level and average vehicle weight. As a result of the improved ability of the equation to estimate the measured values over the single value emissions factor, a quality rating of B is assigned to the equation.

4.2.2.4 Assignment of equation parameters for PM_{30} and $PM_{2.5}$.

While several of the reports include measurements of $PM_{2.5}$, the WRAP studies suggest that many of these measurements are in error due to particle bounce issues with the impactor stages. The results of the WRAP study indicated that the $PM_{2.5}$ concentrations measured by the cyclone/impactor system were consistently biased by a factor of about 2 relative the $PM_{2.5}$ concentrations measured by the Partisol samplers. The second phase of the WRAP showed a tendency of the measured $PM_{2.5}$/ PM_{10} ratio to decrease with increasing

PM_{10} concentration. At PM_{10} concentrations above 1.0 mg/m3 the $PM_{2.5}$/ PM_{10} ratio was between 0.1 and 0.15. The $PM_{2.5}$/ PM_{10} ratio increased to about 0.35 as the PM_{10} concentration approached about 0.5 mg/m3. While some of the paved road test data encountered concentrations above 1.0 mg/m3 much of the test data consisted of measured concentrations below 0.5 mg/m3. The paved road emissions factor for $PM_{2.5}$ was revised to 15% of the calculated PM_{10} emissions factor in 2008. It is not clear whether the WRAP study assessed the PM_{10} concentrations measured during the paved roads testing prior to their recommendations for revising the $PM_{2.5}$ emissions factors. As shown in Table 4-17 the PM_{10} concentrations associated with 58 of the 71 test runs used to develop the three parameter emissions factor equation. Many of these test runs involve traffic volumes that would produce fairly constant particulate concentrations. Also, of these 58 test runs, only three runs were the highest PM_{10} concentrations greater than 0.5 mg/m3. An earlier report (Reference 5) measured $PM_{2.5}$/ PM_{10} ratios during field tests. The range of $PM_{2.5}$/ PM_{10} ratios was from 0.25 to 0.37. Since essentially all of the measured PM_{10} concentrations used for the stepwise regression were below 0.5 mg/m^3 and the ratios measured during field sampling of paved road emissions were between 0.25 and 0.37, the recommended $PM_{2.5}$ emissions factor is 25% of the PM_{10} emissions factor. Since there is little measured $PM_{2.5}$ data, an emissions factor quality rating of "D" is assigned.

While a stepwise regression could be performed to estimate the PM_{30} emissions factor equation, it is believed that the number of available data would be significantly less and a comparable confidence in the resulting equation could not be achieved. The ratio of PM_{30} to PM_{10} presented in the present AP-42 section is 5.2 and is proposed for the revised equation.

4.2.2.5. Assignment of a precipitation correction factor.

As is presented in Reference 38, a correction parameter for precipitation events was included in the revision of the AP-42 section in October 2002. As recommended in the Technical Memorandum to the files, the correction parameters are retained in this version of the AP-42 section.

4.3 DEVELOPMENT OF OTHER MATERIAL IN AP-42 SECTION

Concurrent with the development of the revised AP-42 section for paved roads, a separate effort was conducted to assemble a silt loading data base for nonindustrial roads. Over the past 10 years, numerous organizations have collected silt loading samples from public paved roads. Unfortunately, uniformity—in sampling and analysis methodology as well as roadway classification schemes—has been sorely lacking in these studies.

Silt loading data were compiled in the following manner. Persons knowledgeable about PM_{10} at each EPA regional office were asked to identify sL data for public roads. In many instances, the EPA representatives identified state/local air regulatory personnel who were then asked to supply the data. Given that the relative importance of PM_{10} emissions from public sources is greater in the western United States, it is not surprising that most of the data are from that area of the country. What is surprising, perhaps, is that Montana has collected roughly two- thirds of all data. Furthermore, only Montana had data collected from the same road over extended periods of time, thus permitting examination of temporal variation.

The assembled data set did not yield any readily identifiable, coherent relationship between silt loading and road class, average daily traffic (ADT), etc. Much of the difficulty is probably due to the fact that not all variables were reported by each organization. Further complicating the analysis is the fact that, in many parts of the country, paved road silt loading varies greatly over the course of the year. Recall that repeated sampling at Montana municipalities indicated a very noticeable annual cycle. Nevertheless, it is questionable whether the seasonal variation noted in the Montana data base could successfully predict variations for many other sites. While one could possibly expect similar variations for, say, Idaho or Wyoming roads, there is far less reason to suspect a similar cycle in, say, Maine or Michigan, in the absence of additional information.

Because no meaningful relationship could be established between sL and an independent variable, the decision was made to directly employ the nonindustrial data base in the AP-42 section. The draft AP-42 section presents the cumulative frequency distribution for the sL data base, with subdivisions into (a) low-ADT (< 5000 vehicles/day) and high-ADT roads and (b) first and second halves of the year. Suggested default values are based on the 50th and 90th percentile values.

The second use of the assembled data set recognizes that the end users of AP-42 are the most capable in identifying which roads in the data base are similar to roads of interest to them. The draft AP-42 section presents the paved road surface loading values together with the city, state, road name, collection date (samples collected from the same road during the same month are averaged), road ADT if reported, classification of the roadway, etc. Readers of AP-42 are invited to review the data base and to select values that they deem appropriate for the roads and seasons of interest.

4.4 References for Section 4

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Appendix A

Response to Comments

Comments and responses on 2010 proposed revision of Section 13.2.1 Paved Roads.

Commenter .... Page

Chatten Cowherd of Midwest Research Institute on behalf of the Center for the Study of Open Source Emissions (CSOSE) 1

Rebecca Kies and Courtney Bokenkroger Senior Statistician of Midwest Research Institute, Kansas City, MO. 5

Greg Muleski of Midwest Research Institute 7

Camille Sears for the Sierra Club 9

David E. James, PhD PE; Associate Vice Provost for Academic Programs; UNLV, Las Vegas, NV. 14

Steve Zemba of Cambridge Environmental Inc for the National Asphalt Pavement Association. 16

Catharine Fitzsimmons, Chief, Air Quality Bureau and Lori Hanson Iowa Department of Natural Resources. 16

Pat Davis of MARAMA for the States of New Jersey, Delaware, Maryland and Massachusetts. 17

Julie McDill (MARAMA), David Fees (Delaware), Julie Rand (New Jersey). 18

Gary Garman of McVehil-Monnett. 19

Comments and Responses on June 2010 Draft Revision of AP-42 Section 13.2.1 for Paved Roads.

Chatten Cowherd of Midwest Research Institute on behalf of the Center for the Study of Open Source Emissions (CSOSE)

Comment: The general consensus among the Center for the Study of Open Source Emissions (CSOSE) participants who have worked in this field is that the proposed equation does not offer improved predictive capability but introduces additional data requirements to the paved road emission inventory process.

Response: We disagree that the proposed equation does not offer improved predictive capability. The predictive equation published in November 2006 produced negative PM_{10} emissions at very low silt loadings and negative $PM_{2.5}$ emissions estimates whenever a silt loading of less than 0.06 and average vehicle weight of 3.75 tons (or silt loading of 0.1 and vehicle weight of 3 tons). As presented in Table 4-23 of the draft background report, the 2006 equation had an average relative percent error of over 27,000 compared to the proposed equation with a relative percent error of 1,200. Part of the error imbedded in the 2006 equation is due to the use of the estimated 1980's fleet average vehicle emissions (average vehicle weight of 3.75 tons) for adjustment of the equation presented in the 2003 revision of the AP-42 section. This average underestimated the vehicle emissions of the fleets measured in almost 2/3 of the paved road emissions test (58 of the 93 tests had average vehicle weights over 5 tons). Since the proposed revision provided a correction to each test series based upon the average vehicle weight presented in the test report and the correction used in the final revision includes variations in speed, ambient temperature, year of vehicle fleet; this error has been reduced. Combining the reduction in error of the test data with the use of a more traditional revised stepwise regression of the paved road emissions data, we believe the revised equation will provide a superior basis than the 2006 equation.

Comment: There is also the broader issue of adopting mobile monitoring as the basis for more realistic emission inventorying of paved roads.

Response: EPA agrees that the adoption of mobile monitoring to estimate either the silt loading of the road system or the emissions factor provides a significant advance in characterizing the system wide emissions and the variation that exists with different roads. The use of mobile monitoring offers the ability to characterize road classes which have been problematic in the past due to resource constraints and safety issues. The ability of mobile monitoring to provide a temporally and spatially resolved emissions estimates and to characterize significantly more miles of roadways than were possible by the traditional vacuuming, screening and weighing techniques is a distinct advantage. In addition, the mobile monitoring method provides an excellent means for tracking system wide management controls instituted to provide emissions reductions from roadway emissions.

In the final version of the AP-42 section we describe the mobile monitoring technique along with a brief assessment that mobile monitoring provides significant improvements in the estimation of road dust emissions caused by vehicle traffic.

Comment: The proposed equation has a significant new data input requirement (vehicle speed) that increases the difficulty of generating paved road emission inventories.

Response: We disagree; access to the average vehicle speed of road segments is an existing requirement for the accurate estimation of vehicle exhaust emissions in the MOVES model. While the incorporation of the vehicle speed for every road segment may increase the complexity of emissions inventory development, for most road systems emissions estimates can be assembled by grouping of road segments into a limited number of groups.

The assessment of the influence of the speed term on the predictive accuracy of the resulting equation is a better criterion to determine whether this term should be used in the equation. Limited improvement (or degradation) in the predictive accuracy of the equation provides a more compelling rationale to exclude the speed term in the final equation than the alleged difficulty of generating the emissions inventory. The reassessment of the form of the emissions factor equation included the assessment of the influence of speed on the predictive accuracy of the equation, the improvement of the equation to address the variance which may be due to the independent parameters, and the statistical significance of each variable in predicting the dependent variable.

Comment: Based on our discussions of the proposed equation and the technical analyses presented by EPA, we find the scientific foundation for the revision unconvincing.

Response: The foundation upon which EPA proposed a revision of the paved road equation was a proposal by the Corn Refiners Association (CRA) to perform emissions tests to support the extension of the applicable source conditions. The Corn Refiners retained the services of Midwest Research Institute (MRI) in Kansas City to perform the emissions testing at lower average vehicle speeds to support the extension of the applicable source conditions. Twenty two usable profiling tests were performed. In addition to designing and conducting the emissions tests, MRI provided EPA with three options for incorporating the new data into the paved roads section. The Agency decided that returning to multiple estimation methods would recreate the problems that existed prior to 1995 when there was two AP-42 sections for paved roads and multiple methods within these two sections.

When MRI drafted the AP-42 section that included the CRA data, it was highlighted by the Office of Transportation and Air Quality (OTAQ) that the proposal and adoption of a revised equation had conformity implications that needed to be addressed. Several issues associated with conformity were raised. These included the situation that areas containing low volume rural roads were predicted to have greater emissions of PM_{10} than the previous equation predicted. Another situation was that the revised equation may result in greater predicted emissions of $PM_{2.5}$ under some conditions. The greater predicted emissions were the result of the existing equation generating negative emissions for high volume roads. In an assessment to understand the extent and significance of these issues, it was revealed that the vehicle exhaust, tire wear and break wear emissions components were not addressed properly. The estimates of vehicle exhaust, tire wear and break wear used in the 2003 revision did not account for the significant differences in these emissions during the available tests and in addition significantly mis characterized for the additional data provided by the corn refiners. For the historical data, the proposed revision incorporated test specific emissions estimates as calculated by MOBIL 6.2 and based upon the average vehicle weight reported for each test. For the CRA data, the proposed revision incorporated test specific emissions estimates as calculated by the MOVES model and based upon the average vehicle weight, vehicle speed and estimated acceleration rates. For consistency and for improved accuracy in predicting vehicle exhaust emissions, MOVES model estimates were calculated for the historical data. While the incorporation of the data provided by the Corn Refiners Association extended the capabilities of the equation to 1 mph, the Corn Refiners Association data highlighted the variable significance of exhaust emissions and the need to address these emission on a test by test basis. An additional advantage of determining road emissions prior to developing the road emissions equation is that the equation never predicted negative PM_{10} or $PM_{2.5}$ emissions.

Comment: Besides the problems stated above, we find difficulty in understanding the scientific basis for replacing the existing $PM_{2.5}/PM_{10}$ ratio published in 2006 with the ratio that was previously used by EPA. The ratio in the existing equation was accepted by EPA as an outcome of an experimental program supported by the Western Regional Air Partnership (WRAP).

Response: In evaluating the data underlying the equation proposed in this revision, all of the data were assessed to understand the basis and representativeness of the data. The WRAP laboratory study was evaluated and was found to focus primarily on categories of emissions that would generate very large concentrations of dust emissions and focused primarily on western sources of these emissions. These types of emissions sources have a high probability of overloading air sampling devices that depend on impaction to collect particles of differing sizes. These sources are also predominately dominated by sources where the emissions may have large variations over time depending on the repetition rate of the activity which generates the emissions. Paved roads, especially those with high traffic volumes and those that have neared their normal aged equilibrium state generate dust emissions of greater consistency in concentration and particle size characteristics. Not only are these emissions more consistent, the emissions concentrations are much lower except when the roads silt loading is very high. These high silt loadings are not typical of public roads except for periods where sand is applied as anti skid material, natural forces exacerbate the normal soil loading on the road or in areas where there is a large track out of dirt from an adjacent unpaved area.

The WRAP study included the collection of seven soil samples. The samples included sediment from Alaska, Alluvial Channel from Phoenix AZ, Agricultural Soil from Phoenix AZ, Road Dust from the Las Cruces Landfill in New Mexico, Grazing Soil from Radium Springs in New Mexico, Shoreline Soils from the Salton Sea in California and a Barrow Pit from Thunder Basin Mine in Wyoming. In addition, three additional samples which were used in the first Phase of the study were also used in the second Phase of the study. These three samples included a Standard fine Arizona Test dust, a Standard coarse Arizona Test dust and Lakebed Soil from Owens Dry Lake in California. For each of these samples, the WRAP study states that two five gallon containers of soil were collected. To collect this volume of sample from paved roads which are in equilibrium would require sweeping or vacuuming of multiple miles of roadway. Additionally, none of these samples are representative of aged material deposited on paved roads except for paved roads which have had anti-skid abrasives (such as sand) applied during winter or where significant windblown dust or track out dirt is deposited on paved roads.

Most of the laboratory tests performed to assess the revised $PM_{10}/PM_{2.5}$ ratio to assign to historical data was conducted at PM_{10} concentrations above 2.5 mg/m^3. The greatest downwind concentration measured in tests used to support the paved road equation development was 0.74 mg/m^3 in run ID F45. Of the tests conducted in the wind tunnel laboratory, only 15 percent of the samples were performed at concentrations below 0.74 mg/m^3. The lowest PM_{10} concentration measured during the laboratory study was 0.381 mg/m^3. Of the 80 profiling tests used to support the paved road emissions factor equation and where the downwind concentrations were available, only five had concentrations greater than 0.358 mg/m^3. In addition, over 80% of the profiling tests had downwind concentrations less than 0.2 mg/m^3 and 60% had downwind concentrations less than 0.1 mg/m^3. In the wind tunnel laboratory studies, the only particulate used to challenge the sampling devices was the material collected for the studies. The emissions measured during the paved road profiling tests was a combination of emissions from the road surface, engine exhaust, break wear and tire wear emissions. As presented in Table 4-17 of the draft background document, vehicle emissions can be a significant component of the emissions measured by the profiling samplers. In three cases, the estimated exhaust, break wear and tire wear emissions exceed the measured emissions and were assigned an emissions factor of 0.01 g/VMT (see test runs M10, M12 and CF-3N). In an additional 10% of the profiling tests, about half of the measured emissions were estimated to be exhaust break wear and tire wear emissions. And in approximately 35% of the profiling tests, the measured emissions were more than 10% exhaust; break wear and tire wear emissions.

Based upon a more careful and thorough examination of the experimental design of the WRAP study and the profile measurements conducted to characterize paved road emissions it is concluded that EPA mistakenly accepted the conclusion that the $PM_{2.5}$ to PM_{10} ratio for paved roads should be estimated at 15%. While the WRAP study provides a reasonable indicator that past measurements of the particle size distributions below 10 µm are unreliable due to particle bounce and re-entrainment associated with impactors, it does not discredit $PM_{2.5}$ to PM_{10} ratios established by field studies which used FRM or equivalent monitors for measuring $PM_{2.5}$ to PM_{10} concentrations. While there were only twelve test runs conducted during the profiling tests documented in the April 15, 1997 report by MRI for EPA, the $PM_{2.5}$ to PM_{10} ratios determined at these three locations provide a superior estimate of a national ratio for estimating $PM_{2.5}$ emissions than an extrapolation from the WRAP laboratory study.

Rebecca Kies and Courtney Bokenkroger Senior Statistician of Midwest Research Institute, Kansas City, MO.

Comment: The approach used by EPA to calculate the proposed paved road equation differs from standard least-squares regression procedures. MRI recommends that ordinary least squares regression procedures be used.

Response: EPA used the non standard approach in an attempt to provide an improved predictor of emissions than the exponential form traditionally used for this section. In the traditional form of regressing the equation, the log transformed data would be regressed and include an intercept. Then when returned to normal space, the inverse log of the intercept constant would be the multiplier for the silt and weight terms. The regression terms for silt and weight would then be the exponents for those terms in the final equation. More sophisticated statistical software and individuals with more thorough knowledge in the application of stepwise non linear regression were not available at the time but were used in the equation development for the published final section. EPA used SAS which is more robust statistical software than Excel for developing the equation used in the final AP-42 section. With guidance from the statistician, EPA used Excel to explore limited alternative forms of the equation that could potentially provide an equation with better predictive accuracy. EPA assessed the influence of test data that potentially would adversely influence the resulting equation and assessed the use of composite factors in an attempt to alleviate the additional problems identified by MRI's statisticians. These assessments led EPA to exclude ten test data where the silt loadings were greater than 20 g/m^2 and to exclude test data where field measurements could not quantify emissions due to traffic on the road. Additional regression methods available in

SAS were evaluated following the exploratory assessment within Excel. The equation which had the best predictive accuracy was based upon the traditional least squares regression of the log transformed data with the intercept forced to zero.

Comment: Additional concerns about gaps in the range of data surfaced during our statistical analysis. Notice the major holes highlighted by the circles in the speed-silt loading and speed-weight boxes. The dataset is missing low silt loading, low speed; low silt loading, high speed data; and low weight, low speed data. Ideally, the boxes relating silt loading, weight, and speed should be completely filled with data points in order to cover all ranges of possible occurrences and consider them to be independent factors in the model.

Response: It is recognized that there are gaps in the data. In most cases, the contractor performing the study (MRI in all cases) and the studies sponsor (EPA, industry) was interested only in un-managed road systems at the test location. In some of these instances, the condition highlighted would not be expected due to the physical forces influencing the independent variables. For example, low silt loading would not be a normal condition when the average vehicle speeds are low since the aerodynamic energy imparted on the road surface would not be great enough to move the silt to the road shoulder. This situation of low silt loading and low average speed may be a possibility should there be active management of the silt loading on the road. Either the active management of the road silt loading lacks the frequency to achieve lower silt loadings or there was not a need to achieve these lower silt loadings. In other cases, the data may be missing due to safety concerns associated with the collection of one or more pieces of information. For example, the collection of data at roads with high speed and low silt loading requires extensive time to collect sufficient material to quantify the low silt loading. Should resources become available in the future improving the emissions factor for paved roads, the collection of test data to fill in these data gaps will be suggested. In addition, mobile monitoring methods may be a viable alternative to the vacuuming of roads to estimate the silt loading of roads where there are safety concerns.

Comment: It is recommended that different modeling options be explored to find the best fit and set of predictors for the data provided. Two such options are:

- Look at low speed and high speed models separately, potentially excluding vehicle speeds under 5 mph from equation development.
- Use a composite factor of weight and speed together with either weight or speed as independent variables in the regression. This helps alleviate the problems due to multicollinearity between weight and speed seen in these data.

Response: EPA assessed different modeling options to find a best fit. A return to multiple sets of equations or values as predictors which introduce multiple results for similar independent variables has been shown to create confusion, "results in shopping for a fortuitous estimate" and adversarial debates. Any set of predictors should have nearly identical results for comparable independent parameters where there multiple predictors could be used.

EPA evaluated the exclusion of atypical independent parameter conditions such as the very low speed conditions. Other conditions that were evaluated were very high silt loading conditions. It was decided to exclude emissions tests with silt loading levels over 20 g/m^2 due to the potential complexity of an equation needed to incorporate the different characteristics that these few data present. While these high silt loadings may have been representative of conditions which would be tolerated by the sources (or regulatory authorities) in the mid to early 1980's, they are unusual conditions and may not be reasonable to use in developing or assessing the best predictor for the more representative and dominant situations. It is believed that management practices would be implemented by sources and regulatory authorities to address extended durations of high silt loading conditions. Additionally, an assessment of the final equations ability to estimate the emissions of the ten tests with high silt loading. While there were changes in the percent difference from actual emissions for individual test runs, the average percent difference from actual emissions was almost the same as the 2006 equation.

Greg Muleski of Midwest Research Institute

Comment: The measured emission factor for CM-2 should be "63.5" rather than "6.35" so the independent variable in Table 4-17 should have been about 52 g/vmt (rather than the default value of 0.02 g/vmt).

Response: The measured PM_{10} emissions factor in Table 4-15 was checked against the value reported in the test report. The value of 0.14 lb/VMT in the table was consistent with the value in the submitted test report. As indicated in the comment, there was an error in transcribing or units conversion to transfer the value from Table 4-15 to Table 4-17. The emissions factor for the Corn Refiners Association test numbered CM-2 was revised from 6.35 grams/VMT to 63.5 grams/VMT in Table 4-17. As a result, the subtraction of the estimated vehicle exhaust, tire wear and break wear resulted in Road Dust Emissions of 52.44 grams/VMT rather than 0.02 grams/VMT.

Comment: The two-step regression process described in Section 4.2.2.2 differs from standard stepwise multiple regression used in the past AP-42 updates. It is not clear how R-squared values at each step can be combined to obtain a meaningful value.

Response: As indicated by several comments from individuals at MRI, the multi-step regression used by EPA does not conform to traditional stepwise multiple regression techniques. More traditional techniques were used in the development of the equation used in the final section and SAS (which is more robust software for statistical analysis) was employed to assess the predictive accuracy of the final equation.

Comment: The high degree of correlation between speed and weight precludes both being included as independent terms in the emission factor equation.

Response: It was believed that the large number of tests where the road surface silt loading was artificially changed through either the addition of sand or through removal with mechanical means altered the normal correlation between the vehicle speed and the road silt loading. With the use of more robust statistical software, the presence of inter correlation between speed and silt loading was re assessed. In addition, the more robust software allows a better determination of the potential improvement of an equation which includes speed to predict road dust emissions. This assessment revealed that the use of the speed term was contraindicated and the final equation contains only silt loading and average vehicle weight as independent variables.

Comment: The goal should be to develop a predictive tool for situations without measured emissions rather than trying to get the best fit for the set of measured emissions.

Response: The use of Excel to generate the predictive equation made an evaluation of the capability for the equation to predict data that was not part of the existing data set difficult and labor intensive. The use of SAS allows for a more reliable assessment of the equations predictive capabilities.

Comment: The geometric mean is the better choice than the arithmetic average when working with the predicted/observed ratios.

Response: It is assumed that the use of the geometric mean is a metric to evaluate the predictive accuracy of the equation through the use of the average predicted to observed values. With the use of SAS, several indicators of the predictive capabilities of the resulting equation were evaluated.

Comment: The document would have benefitted from a thorough review/edit prior to being posted on the CHIEF web site.

Response: Prior to posting the final background report, the AP-42 Section and background report was reviewed and edited more thoroughly and the Table of contents was updated to provide an accurate indication of the contents of the chapters.

Comments and Responses on June 2010 Draft Revision of AP-42 Section 13.2.1 for Paved Roads.

Camille Sears for the Sierra Club

Comment: I have a few concerns regarding USEPA's proposed revision to AP-42 Section 13.2.1:

- USEPA's multiple regression analysis incorporating vehicle speed excludes a valuable data set for assessing paved road PM emissions from industrial facilities.
- USEPA's proposed revision to AP-42 Section 13.2.1 results in a very significant reduction in PM_{10} and $PM_{2.5}$ emission factors from paved roads in industrial settings.
- It is unclear whether USEPA's proposed revision to AP-42 Section 13.2.1 improves upon predictive performance of the existing 2006 emission factor.

Response: The performance of the multiple stepwise regression of the data recognized that incorporation of the speed term involved the exclusion of 22 test runs. EPA recognized that the exclusion of these data could affect the resulting equation and decided to include the speed term since the correlation coefficient showed a modest improvement. Another commenter indicated that there are better software and process available than were used by EPA to develop the equation. EPA employed software more suited for stepwise multiple nonlinear regression than Microsoft Excel in the final equation development. EPA used this improved software for a more rigorous assessment of the influence of incorporating the speed term in the equation in this reassessment. (In EPA's reassessment, it was revealed that the speed term provided no improvement in the predictive accuracy of the resulting equation. As a result, the equation published in the final AP-42 section includes only silt loading and average vehicle weight).

While EPA is cognizant of potential impact of any changes that may result in revising the emissions factors in AP-42, the primary goal of emissions factors development is to provide factors that provide as accurate of a prediction of the target population as possible. The underlying data has considerable variation even when several of the independent parameters are nearly identical. With the increased number of independent parameters, it is possible that some situations where emissions will be greater than the previous equation and some where emissions will be less.

While there may be some situations where the predictive performance of the proposed equation performed poorer at predicting the underlying data, there were others where the predictive performance was improved. Several measures were used to assess the predictive performance of the revised equation and the final equation performs better than the previous equation.

Comment: USEPA excluded 22 tests performed at two integrated iron and steel plants due to lack of vehicular speed data. These iron and steel plant source tests are crucial for calculating fugitive dust emissions from industrial facilities, and excluding these data has a very significant impact on predicted paved road emission rates. As discussed in the following section, USEPA's proposed revision to the paved road emission factor will reduce particulate emission calculations at typical industrial sites by roughly an order of magnitude. This large, and perhaps unrealistic, reduction in calculated industrial paved road emissions is an artifact of trying to develop an emission factor based on tests that must include vehicle speed data.

Response: The exclusion of the 22 tests performed at iron and steel facilities did not significantly bias the equation. An evaluation of the predictive precision of the equation in the November 2006 version of the AP-42 Section for Paved Roads reveals that on average the equation over predicted the 92 individual data by over 11,000%. While approximately 50% of the predicted estimates underestimated the measured emissions and 50% overestimated emissions, overestimates were significantly greater than the underestimates. The 25 percentile value underestimated actual emissions by 54% while the 75 percentile value overestimated actual emissions by 713%. The equation using only silt loading and average vehicle weight which was rejected for the equation that included speed overestimates actual emissions by 1,429%. The equation that was proposed and includes the speed term overestimates actual emissions by only 890%. For both the previously published equation and the proposed equation, the majority of the overestimation appears to be associated with the lowest speeds, silt loading in the middle third of the data and in the highest average vehicle weights. In these categories, it appears that the previously published equation overestimates emissions more than the proposed equation. With respect to roads with greater average vehicle weights such as may be present at industrial facilities, the equation in the November 2006 AP-42 section tended to overestimate emissions more than the proposed equation. Table 1 below presents the independent parameter variables, estimated measured emissions, predicted emissions by the 2006 AP-42 equation, the equation considered in the proposal that includes only silt loading and average vehicle weight and the equation proposed that includes silt loading, average vehicle weight and speed (with an average speed of 35 mph assigned for unrecorded speeds). For those test conditions where average vehicle weight was greater than 8 tons, the 2006 AP-42 equation tended to overestimate actual emissions factors by about 350%. The equation that considered only silt loading and average vehicle weight tended to overestimate actual emissions factors by about 3%. The equation that considered silt loading, average vehicle weight and speed tended to underestimate actual emissions factors by about 12%. A comparison between the equation proposed for use and the equation that was considered but did not include the speed term shows that the exclusion of the 22 test data that were missing the average speed did not adversely affect the average predictive capabilities of the equation. As stated elsewhere, a more rigorous and capable statistical software package was used to develop the final equation used in the AP-42 section.

For the equation published in the 2011 final AP-42 section, the predictive accuracy is slightly improved over the equation proposed in the draft AP-42 section. As presented in Table 2, the equation published in the final section provides a moderately better or worse predictor of actual emissions for a few tests, but does not provide a significantly different accuracy that the equation in the draft AP-42 section. While the equation presented in the AP-42 section published in 2006 overestimates actual emissions factors by 350%, the equation presented in the final 2011 section overestimates actual emissions by an average of 77%.

Table 1. Performance of 2006 AP-42 equation and equations considered for 2010 draft section revision.

					Predicted Emissions (g/VMT)			Percent difference from Measured		
ID #	Silt Loading	Average Speed	Average Weight	Measured EF (g/VMT)	Old AP-42 (sL, W)	Rejected Proposal (sL, W)	Proposed (sL, W, s)	Old AP-42 (sL, W)	Rejected Proposal (sL, W)	Proposed (sL, W, s)
AD1	94.8	23	42	1478.189	4696.25	1575.71	1156.43	218%	7%	-22%
F61	17.9	NR	40	461.174	1476.91	325.20	235.28	220%	-29%	-49%
AD3	52.9	23	40	231.189	2987.29	881.27	636.21	1192%	281%	175%
AD2	63.6	23	39	340.807	3241.81	1020.25	751.93	853%	200%	121%
F62	14.4	NR	36	315.177	1094.65	241.87	179.78	247%	-23%	-43%
F74	5.59	NR	29	543.498	427.73	83.19	63.42	-21%	-85%	-88%
F34	2.78	NR	28	186.561	257.62	42.37	31.39	38%	-77%	-83%
CI-7	0.05	15.3	27	0.589	17.71	1.02	0.53	2907%	73%	-11%
CI-8	0.05	15.3	27	1.949	17.71	1.02	0.53	809%	-48%	-73%
F35	2.03	NR	25	296.721	177.11	28.62	21.73	-40%	-90%	-93%
F38	0.218	NR	18	165.766	25.19	2.73	2.05	-85%	-98%	-99%
F39	0.441	NR	18	251.766	39.95	5.21	4.09	-84%	-98%	-98%
B58	10.4	NR	18	366.778	313.08	95.42	90.51	-15%	-74%	-75%
F37	0.417	NR	17	76.038	35.33	4.70	3.76	-54%	-94%	-95%
F45	5.11	NR	16	210.911	165.22	44.58	42.38	-22%	-79%	-80%
F32	0.117	NR	14	52.170	11.42	1.22	0.98	-78%	-98%	-98%
F27	14.8	NR	14	129.070	270.08	105.02	111.94	109%	-19%	-13%
B57	2.32	NR	12	194.216	64.10	16.59	16.78	-67%	-91%	-91%
B60	3.19	NR	12	438.216	78.89	22.24	22.93	-82%	-95%	-95%
B52	7.19	NR	12	34.616	133.95	46.98	50.85	287%	36%	47%
AUE1	4	15	12	2.286	91.43	27.39	24.99	3900%	1098%	993%
B59	2.06	NR	11	347.289	52.04	13.74	14.26	-85%	-96%	-96%
B55	6.3	NR	11	182.289	107.84	38.43	42.66	-41%	-79%	-77%
B51	13.6	NR	11	139.289	177.97	78.02	90.68	28%	-44%	-35%
B54	3.77	NR	10	92.662	66.87	21.97	24.52	-28%	-76%	-74%
B50	13.6	NR	9.4	81.506	140.54	67.62	83.43	72%	-17%	2%
B56	2.4	NR	9.2	125.421	43.92	13.44	15.07	-65%	-89%	-88%
F36	0.201	NR	8.3	54.168	7.33	1.25	1.26	-86%	-98%	-98%
							Average	358%	3%	-12%

Table 2. Performance of 2006 AP-42 equation, equation proposed in 2010 draft section and Final 2010 section.

					Predicted Emissions (g/VMT)			Percent difference from Measured		
ID #	Silt Loading	Average Speed	Average Weight	Measured EF (g/VMT)	Old AP-42 (sL, W)	Proposed (sL, W, s)	Final (sL, W)	Old AP-42 (sL, W)	Proposed (sL, W. s)	Final (sL, W)
AD1	94.8	23	42	1478.189	4696.25	1156.43	2886.277	218%	-22%	95%
F61	17.9	NR	40	461.174	1476.91	235.28	600.570	220%	-49%	30%
AD3	52.9	23	40	231.189	2987.29	636.21	1613.169	1192%	175%	598%
AD2	63.6	23	39	340.807	3241.81	751.93	1859.513	853%	121%	447%
F62	14.4	NR	36	315.177	1094.65	179.78	442.254	247%	-43%	40%
F74	5.59	NR	29	543.498	427.73	63.42	149.639	-21%	-88%	-72%
F34	2.78	NR	28	186.561	257.62	31.39	76.359	38%	-83%	-59%
CI-7	0.05	15.3	27	0.589	17.71	0.53	1.886	2907%	-11%	220%
CI-8	0.05	15.3	27	1.949	17.71	0.53	1.886	809%	-73%	-3%
F35	2.03	NR	25	296.721	177.11	21.73	51.060	-40%	-93%	-83%
F38	0.218	NR	18	165.766	25.19	2.05	4.773	-85%	-99%	-97%
F39	0.441	NR	18	251.766	39.95	4.09	9.073	-84%	-98%	-96%
B58	10.4	NR	18	366.778	313.08	90.51	161.994	-15%	-75%	-56%
F37	0.417	NR	17	76.038	35.33	3.76	8.133	-54%	-95%	-89%
F45	5.11	NR	16	210.911	165.22	42.38	75.113	-22%	-80%	-64%
F32	0.117	NR	14	52.170	11.42	0.98	2.093	-78%	-98%	-96%
F27	14.8	NR	14	129.070	270.08	111.94	172.829	109%	-13%	34%
B57	2.32	NR	12	194.216	64.10	16.78	27.253	-67%	-91%	-86%
B60	3.19	NR	12	438.216	78.89	22.93	36.436	-82%	-95%	-92%
B52	7.19	NR	12	34.616	133.95	50.85	76.446	287%	47%	121%
AUE1	4	15	12	2.286	91.43	24.99	44.785	3900%	993%	1859%
B59	2.06	NR	11	347.289	52.04	14.26	22.375	-85%	-96%	-94%
B55	6.3	NR	11	182.289	107.84	42.66	62.006	-41%	-77%	-66%
B51	13.6	NR	11	139.289	177.97	90.68	125.074	28%	-35%	-10%
B54	3.77	NR	10	92.662	66.87	24.52	35.222	-28%	-74%	-62%
B50	13.6	NR	9.4	81.506	140.54	83.43	106.525	72%	2%	31%
B56	2.4	NR	9.2	125.421	43.92	15.07	21.429	-65%	-88%	-83%
F36	0.201	NR	8.3	54.168	7.33	1.26	2.010	-86%	-98%	-96%
							Average	358%	-12%	77%

Comment: USEPA prepared a consequence analysis of the National Emission Inventory ("NEI") resulting from their proposed revision.8 USEPA found that their revised paved road emission factor will significantly reduce PM_{10} emissions in the NEI (up to 200% reduction), while $PM_{2.5}$ emissions are only slightly affected (some NEI calculations increase, some decrease). USEPA, however, did not examine the affect of their draft revised paved road equation on fugitive dust emissions from industrial sources.

Response: The estimated impact on State Emissions Inventories and the NEI was performed as a tool for decisions which may need to be made to address conformity requirements. The Agency may provide States with extensions of times for adopting revised emissions estimates in their SIP and Transportation plans. These estimates were also produced to assist State and local agencies understand the potential impact that the revised emissions factors may have on their PM_{10} and $PM_{2.5}$ inventories which are being prepared to address non attainment conditions and required SIP plan development. The emissions inventory impact estimates were not produced as a decision criteria for revision of the emissions factor equation. The only criteria used in assessing the proper equation to publish are the representativeness of the underlying test data and the comparison of the equation to the actual measured emissions. Although not presented in the background report, the performance of the equation was made by ordering the available test data by silt loading, average vehicle weight and by speed to evaluate whether there was any systematic bias which was driven by one or more outlying data. Table 4-23 of the background report for the proposed revision did include the average percent error for the 2006 equation and the proposed equation. When arranged by weight, the 2006 equation produced errors of about 70,000 percent for vehicle weights of over 10 tons while the proposed equation produced errors of about 2,500 percent. The equation published in the final section produces errors of 5,000 percent for vehicle weights between 10 and 40 tons and errors of about 20,00 percent for vehicle weights over 40 tons. Although when limited to these high weight classes the performance appears to be worse, for lower weight classes the new equation demonstrates superior performance to both the previous published equation and the proposed equation.

David E. James, PhD PE; Associate Vice Provost for Academic Programs; UNLV, Las Vegas, NV.

Comment: In many parts of the country where there is significant rain or a rainy season, rain days may considerably effect estimated PM_{10} emissions in the inventory. However, for Las Vegas and other places like it in arid places, I tend to use a 'pessimistic' approach that doesn't include the rain days, since rain occurs sporadically, and what rain does fall is often very light. For the desert southwest, I think that it is best to look at the data without rain adjustments.

Response: It is recognized that the mitigation adjustment for rain events in AP-42 is imperfect. It is recognized that with very light rain events, the silt loading on paved roads may increase due to the removal of soil on the under carriage of vehicles. For most areas of the US, these very light rain events are offset with heavier rain events. Over a month to a year, these enrichment and mitigation events balance out. It should also be noted that the mitigation level is not based upon any measured data and is an "engineering or expert elicitation" estimate.

The emissions factors and the adjustment factors in AP-42 are educated estimates of the national average value and do not include variations that may occur due to local and regional influences. While some variation in the emissions factors for paved road has been reduced through the incorporation of the independent variables silt loading, vehicle weight and number of rain events, the remaining variation is still substantial. EPA does not prohibit the use of alternative emissions factors or adjustments when accompanied by a scientifically credible rationale and supporting data.

Comment: With locally derived data, we obtain results that are different from those that might be predicted using default silt loading data. The actual impact on total estimated PM_{10} emissions in an inventory or SIP would depend on how much VMT was assigned to each roadway category.

Response: It is recognized that the default silt loading information presented in AP-42 does not provide the precision and accuracy that may be needed to properly represent the influence of emissions from paved or unpaved roads. It is also recognized that the resources required collecting representative silt loadings for large numbers of roads is substantial. However, where roads are believed to be significant contributors to the levels of ambient air particulate matter, obtaining this information is valuable to accurately estimate emissions. To address the needs to obtain this information in a cost effective manner, we have included a discussion of the potential advantages of mobile monitoring to develop temporally and spatially resolved silt loading (or emissions) information.

Comment: I also ran a hypothetical sensitivity analysis comparing arbitrary combinations of vehicle weight and silt loading, to see what the impacts of the new PM_{10} equation might be.

Response: It is recognized that different road classes may have different silt loadings and the vehicles using these roads may have different average vehicle weights. These variables will have differing influences on the predicted emissions from these roads. As a result, the use of locally derived silt loading information is strongly encouraged.

Steve Zemba of Cambridge Environmental Inc for the National Asphalt Pavement Association.

Comment: The recommended default values for silt loading in draft Table 13.2.1-3, and particularly that for asphalt batching, may be too high for typical current applications. The recommended value is 120 g/m2, but, as you know, in EPA's 2000 Emission Assessment Report for Hot Mix Asphalt Plants, a silt-loading value 3 g/m2 is suggested for paved roads at typical hot-mix asphalt production facilities. Also, site-specific measurements at a hot mix asphalt facility in Alexandria, Virginia in 2005 (using the sampling and analytical methods described in AP42 Appendix C) found a silt loading level of 0.5 g/m2. This facility, which we analyzed in detail for the City of Alexandria, employs aggressive dust suppression techniques.

Response: Values presented in Table 13.2.1-3 are based upon road dust samples collected in the mid to late 1970's through the mid to late 1980's. It is unclear whether any management practices were used at these facilities to control the silt loading of the roads where these samples were collected. It is possible that current normal maintenance practices would achieve lower silt loadings than are presented in the table. Statements in the documentation included in the reports by the Corn Refiners Association and several other test programs used in the equation development indicate that there was active management of the road surface dust levels. As a result, the silt loading data collected during those test programs are lower than they would be otherwise. While there is no requirement to use the silt loading values provided in the tables of AP-42 updated silt loading data can be collected by any individual as long as they follow the procedures presented in the AP-42 appendices. It is recommended that in addition to documenting the sampling and analyses, the documentation include normal housekeeping practices and special monitoring and maintenance practices at the collection sites. While we cannot guarantee rapid incorporation of new silt loading data into the table, any reports submitted will be posted for use by subsequent users.

Catharine Fitzsimmons, Chief, Air Quality Bureau and Lori Hanson Iowa Department of Natural Resources.

Comment: The DNR supports the revision of this section to incorporate new data from corn wet mills and to account for mean vehicle speeds below 10 miles per hour.

Response: Thanks for your support.

Comment: The proposed form of the equation requires that a mobile source emissions model be run in order to determine a paved road emission factor. Obtaining the emissions factor for vehicle emissions in this manner will be problematic as the DNR does not have the resources to generate specific emissions factors for vehicle emissions by running MOVES20I0 for every construction permitting project that includes a paved haul road. The DNR suggests that either the empirical equation be developed to include vehicle emissions from engine exhaust, tire and brake wear, or that a table of default values be included in the section to account for vehicle emissions as an alternative to running a mobile source emission model.

Response: While vehicle exhaust emissions may have been relatively stable for the last twenty or thirty years, several regulatory programs which cover mobile source emissions are expected to produce decreasing exhaust emissions over the next five to ten years. In addition, engine exhaust like road dust emissions is highly dependent on the road characteristics, meteorological conditions, vehicle speed, vehicle class and other environmental conditions. As a result, a default engine exhaust equation will result in unknown errors and may lead to incorrect decisions on different programs. While decisions for many programs may not require the accuracy that would occur with individual selection of the requisite parameters needed for the most accurate emissions estimates, this would be a decision that should be made for each application. While State agencies (Department of Transportation or Air Quality) may not have the resources or time to generate a project specific emissions estimate for every project, individual States are in a better position to develop default parameters (engine exhaust, silt and average vehicle weight) which is appropriate for use for projects with different sensitivities.

Pat Davis of MARAMA for the States of New Jersey, Delaware, Maryland and Massachusetts.

Comment: We have been examining the ERTAC/PECHAN emission factors for Road Dust and Maryland noticed that the $PM_{2.5}$ emission factors were zeroed out for the following road types:

- Urban Collector
- Urban Minor Arterial
- Urban Other Principal Arterial
- Urban Other Freeways and Expressways
- Urban Interstate

Emission factors for PM_{10} were found and there was no mention in the documentation of why the $PM_{2.5}$ emission factors were zeroed out, so we are bit confused.

Response: As a result of a revision of the ratio of the $PM_{2.5}$ to PM_{10} recommended by the Western States Air Resources Council (WESTAR) from 25% to 15%, the multiplier k in the predictive equation for $PM_{2.5}$ was revised from 1.8 (for grams/VMT) to 1.1 (for grams/VMT) in the 2006 revision of the paved roads AP-42 Section. With a constant emissions factor of

0.1617 subtracted for the vehicle exhaust break wear and tire wear emissions, these emissions result in a negative calculated road dust emission when one enters an average vehicle weight of 4 tons or less and a silt loading of 0.2 grams/square meter or less. While the k value used in the previous version of the equation resulted in negative emissions whenever the silt loading was less than 0.03 grams/square meter, this affected only Freeways, Expressways and Interstates and was believed to be rational since roadways with average speeds of 55 mph (and the normal level of silt for that speed) had a high number of tests with low measured emissions and were considered to be composed primarily of exhaust emissions.

In the equation presented in the final version of this update, the estimated exhaust component was subtracted from each source test prior to the stepwise regressions of the test data to develop the predictive equation. As a result of the absence of vehicle exhaust, tire wear and break wear in the predictive equation, there are no conditions that will result in negative emissions for the road dust emissions.

Julie McDill (MARAMA), David Fees (Delaware), Julie Rand (New Jersey).

Comment: Here is Delaware's paved road dust spreadsheet for 2007, using the new equation. We got very detailed with this category; estimating emissions by month. Regarding the new equation, PM_{10} was reduced by 58% from the emissions submitted to MACTEC; while $PM_{2.5}$ increased by 48%. I believe the $PM_{2.5}$ increase is caused by two factors-first, the $PM_{2.5}$/ PM_{10} ratio was increased to 25% (previously 15%). The second reason is that under the old equation, one had to apply a correction factor, C, to remove the exhaust, brake, and tire wear from the front part of the equation. By subtracting C at the end of the equation, the resulting $PM_{2.5}$ value went negative for several roadway types. Of course we zeroed these out, but with the new method there is never a situation where the emission factor value can go negative. Having negative emission factors result from the use of the old equation was obviously a flaw in the method, so I expect the new equation is more accurate. I look forward to NJ's results when they apply the new equation, to see if they get changes similar to mine.

New Jersey has similar results, but even more drastic for $PM_{2.5}$. An increase in $PM_{2.5}$ of 350% and a decrease in PM_{10} of 46% I think one big cause is the difference in k factor, among other changes. The k factor for $PM_{2.5}$ went down from the 2003 AP-42 to the 2006 AP-42, and back up again in this new draft. We guessed at the new vehicle speed requirement, but a slight variation in speeds will not make that much of a difference.

Response: It is correct that the k value and the C value both influence the predictive value for the emissions factor. In addition, the exponents associated with the silt loading and the average vehicle weight also influence the emissions estimates. It is also correct that the updated equation will not generate a negative emissions factor since the vehicle emissions, tire wear and break wear will not be included in the equation development. Based upon an assessment of the predicted to actual emissions factor for each of the available emissions tests, the updated equation provides an improved estimate of the emissions compared to the previous equation. It is also believed that the return to the $PM_{2.5}$ to PM_{10} ratio of 25% is a better indicator of the $PM_{2.5}$ than the 15% ratio that was based upon laboratory assessment conducted for WESTAR.

Gary Garman of McVehil-Monnett.

Comment: It's good to see the paved road section is being revised. Thanks. It has been a challenge in the past explaining to industrial clients that paving a road would actually result in higher predicted emissions than if the road is left unpaved. I think we'll see more paving and actual emission reductions as a result of the new equation. A few editorial comments on the draft paved road section:

Page 13.2.1-1, third paragraph, first sentence..change to "The particulate emission factors presented in a previous version.."

Page 13.2.1-5, third paragraph, last sentence..change "Table 13.2.1-3" to "Table 13.2.1-2"

Page 13.2.1-8, fifth paragraph, first sentence..change "Table 13.2.1-3" to "Table 13.2.1-2"

Page 13.2.1-9, second paragraph, second sentence..remove hyphen between "not" and "suggest"

Table 13.2.1-3...the page number this table is on should be changed to 13.2.1.10. Also, total loading range for iron and steel should be 0.006-4.77, not 43.0-64.0.

Page 13.2.1-11, first paragraph, fourth sentence..remove hyphen between "any" and "of"

Thanks again. I look forward to this draft being finalized.

Response: An assessment of the paved verses unpaved road equation performance will be conducted. A statement will be added to the paved road section explaining that under some high silt loading conditions the equation may predict higher emissions than for an unpaved road and that for these conditions the unpaved road equation should be used. The typographical errors will be corrected in the final version.

Comments on Proposed Paved Road Equation
Cowherd, Chatten to: Ron Myers 08/31/2010 03:00 PM
Cc: "Kies, Rebecca", "Muleski, Greg"
History: This message has been forwarded.

Hello Ron,

Thank you for the opportunity to comment on the proposed revision to the paved road dust equation in AP-42 section 13.2.1. The attached letter presents comments developed on behalf of the Center for the Study of Open Source Emissions (CSOSE).

As you know, the revised equation (proposed by EPA as a replacement for the existing equation) and its technical foundation were topics of discussion during the August 18 teleconference hosted by the CSOSE. During this teleconference and in related information exchanges, the general consensus among CSOSE participants who have worked in this field is that the proposed equation does not offer improved predictive capability but introduces additional data requirements to the paved road emission inventory process.

There is also the broader issue of adopting mobile monitoring as the basis for more realistic emission inventorying of paved roads. In previous conversations, I believe that you have acknowledged the clear advantages of mobile monitoring over the traditional AP-42 method for determining paved road dust emissions with its reliance on limited and difficult measurements of silt loading.

We believe that the CSOSE constitutes a substantial resource in resolving these issues and in assisting EPA with the goal of developing improved emission factors such as those applicable to paved road dust emissions.

Please contact me with any questions or comments.

Sincerely,

Chat Cowherd

Chatten Cowherd, Jr., Ph.D.
Midwest Research Institute
425 Volker Boulevard
Kansas City, MO 64110
(816) 753-7600 ext. 1586
(816) 360-5346 direct dial

Center for Study of Open Source Emissions

Chatten Cowherd, Jr., Ph.D.
Director
ccowherd@mriresearch.org
(816) 360-5346

August 31, 2010

Mr. Ron Myers
U.S. Environmental Protection Agency
Research Triangle Park NC 27711

RE: **Proposed Revision to AP-42 Emission Factor Equation for Paved Road Dust**

Dear Mr. Myers:

The **Center for Study of Open Source Emissions (CSOSE)** is pleased with the opportunity to submit comments in response to EPA's proposed revision of the emission factor equation in AP-42 Section 13.2.1. It should be noted that these comments were prepared by the undersigned as Director of CSOSE, taking into account verbal and written communications from interested members of the Center, including those provided during a presentation and discussion of this topic in the August 18 teleconference hosted by the Center. However, this letter was not circulated to CSOSE participants for review prior to submission.

One of the goals of CSOSE is to promote transparency and collaboration in the documentation of test results and in the use of those results to derive effective tools for compliance with air quality standards. We believe that this goal is consistent with EPA's stated goal ***to develop a self-sustaining emissions factors program that produces high quality, timely emissions factors, better indicates the precision and accuracy of emissions factors, encourages the appropriate use of emissions factors, and ultimately improves emissions quantification*** (see EPA's Advance Notice of Proposed Rulemaking on "Emission Factors Program Improvements," Oct. 14, 2009).

We acknowledge the concerns of various parties related to the scientific foundation for the proposed equation as well as the increased effort required in developing vehicle speed data to include in paved road emission inventories. CSOSE participants have presented analyses demonstrating that the proposed equation does not provide an improved predictive capability above that provided by the current equation. In addition the proposed equation has a significant new data input requirement (vehicle speed) that increases the difficulty of generating paved road emission inventories and that has possible implications on projected effectiveness of current SIP-mandated control strategies.

Based on our discussions of the proposed equation and the technical analyses presented by EPA, we find the scientific foundation for the revision unconvincing. This leads us to question the process used in advancing this proposed equation. Our understanding of the rationale for revision of the existing equation might be clarified if there were evidence of an internal review process within EPA that raised issues and resolved them appropriately.

Besides the problems stated above, we find difficulty in understanding the scientific basis for replacing the existing PM-2.5/PM-10 ratio published in 2006 with the ratio that was previously used by EPA. The ratio in the existing equation was accepted by EPA as an outcome of an experimental program supported by the Western Regional Air Partnership (WRAP). That experimental program included regular progress updates in WRAP teleconferences with participation from EPA representatives. To our knowledge, WRAP was never directly informed in advance that the stated conclusions of their study are now being discounted.

We have encouraged others to present comments on the proposed equation that are supportive of the goal of providing improved emission factors. At the time of this writing, we are aware that separate comments are being submitted by Midwest Research Institute (Ms. Courtney Bokenkroger and Dr. Greg Muleski), by the Clark County Department of Air Quality and Environmental Management (Mr. Rodney Langston) and by the University of Nevada at Las Vegas (Dr. David James).

We trust that EPA will publish all comments as well as the responses to each comment. This will be of great assistance to all in moving toward the best possible use of the test data in supporting a meaningful and appropriate emission factor equation for entrained dust from paved roads.

In summary, we conclude that there is no compelling scientific justification for adopting the proposed emission factor equation as a replacement for the existing equation. This problem is compounded by the requirement for additional input data and the potential impact on current and future emission inventories as tools for compliance determination. We conclude that an internal EPA review may not have been performed prior to posting the proposed equation for public comment. Finally we emphasize the importance of publishing all comments submitted to EPA along with EPA's responses to each comment.

If you have questions about these comments submitted on behalf of CSOSE, please contact the undersigned by email (*ccowherd@mriresearch.org*) or by telephone (816) 360-5346. We look forward to your responses to these comments. We believe that CSOSE constitutes a substantial resource in resolving the above issues and in assisting EPA with the goal of developing improved emission factors for open sources. Thank you again for the opportunity to submit comments on the proposed revision to the current AP-42 equation for paved road dust emissions.

Sincerely yours,

CENTER FOR STUDY OF OPEN SOURCE EMISSIONS

Chatten Cowherd, Jr.

Chatten Cowherd, Jr., Ph.D.
Director

From: "Kies
To: Ron Myers/RTP/USEPA/US@EPA

Date: Tuesday, August 31, 2010 11:17AM
Subject: Statistical Comments on Draft AP-42 Section 13.2.1
History: This message has been forwarded.

Ron,

Thank you for the opportunity to comment on the proposed AP-42 paved roads section 13.2.1. Attached to this email are MRI's comments resulting from statistical analysis of the proposed changes to the paved road equation by MRI Senior Statistician, Courtney Bokenkroger. These comments have been reviewed by myself, Chat Cowherd, and Greg Muleski.

Please feel free to respond with any questions or comments.

Sincerely,

Becky Kies

Rebecca Kies

Assistant Scientist

Midwest Research Institute

425 Volker Blvd. KCMO 64110

(816) 360-3825 (direct)

(816) 753-7600 x1818

rkies@mriresearch.org

Attachments:

Comments in Response to EPA Proposed Section 13.2.1 Paved Road Equation.pdf

MIDWEST RESEARCH INSTITUTE
425 Volker Boulevard • Kansas City, Missouri 64110

Courtney Bokenkroger
Senior Statistician
816-360-5303

August 31, 2010

Mr. Ron Myers
U.S. Environmental Protection Agency
Research Triangle Park NC 27711

RE: **Draft AP-42 Section 13.2.1 Paved Roads**

Dear Mr. Myers:

Midwest Research Institute (MRI) is pleased with the opportunity to submit comments in response to EPA's proposed draft revisions to AP-42 Section 13.2.1 Paved Roads and corresponding background documents. We applaud EPA's effort to improve the quality of the emission factor model for paved roads and appreciate your consideration of external comments.

MRI has a productive history of work in air pollutant source testing, process characterization, and development of emission factors for EPA's Emission Factor Handbook (AP-42). Besides serving for more than 25 years as an EPA contractor in the testing of ducted sources and in associated methods development, we have made unique contributions to the development and application of test methods for open (non-ducted) sources. The open sources that we have tested over the past 35 years include agricultural operations, paved and unpaved roads, construction activities, surface mining activities, military training operations, and open area wind erosion. Because of the large natural variability of these sources, MRI pioneered the concept of predictive emission factor equations rather than relying on simple averaging of test results for fugitive dust sources. This approach reduced the uncertainty of emission factor estimates for unpaved roads--as the largest contributor to the national PM-10 emission total--by up to two orders of magnitude.

Our comments on the draft AP-42 Section 13.2.1 Paved Roads focus on a statistical analysis of the data set and procedure used to calculate the proposed new paved road emission factor equation and can be summarized as follows:

- The approach used by EPA to calculate the proposed paved road equation differs from standard least-squares regression procedures. MRI recommends that ordinary least-squares regression procedures be used.
- In using ordinary least squares regression to compare models for only the field measurements that included vehicle speed, we find that inclusion of speed in the model takes away from the explanation of variance of the model (R^2) and that vehicle speed does not have a statistically significant relation to emission factor.
- It is recommended that different modeling options be explored to find the best predictive equation from the data provided. Two such options are:
  - Look at low speed and high speed models separately, potentially excluding vehicle speeds under 5 mph from equation development.

- Use a composite factor of weight and speed together with either weight or speed as independent variables in the regression. This helps alleviate the problem of the multicollinearity of weight and speed seen in these data.

Model Comparison

The data set used by EPA to develop the proposed paved road equation included emission factor, silt loading, weight, and speed. Out of 93 total observations, 71 included speed data. The 71 observations that included speed data were the ones used by MRI for model comparison.

It is not reasonable to compare the proposed model with other possible models for the data using the approach taken by EPA to calculate the proposed model. The double-regression approach used renders two different R-square values (one for each regression), neither of which accurately represent the proportion of variability explained by the final resulting model.

The resulting equations obtained from running least-squares regression on the log transformed, normalized values with and without inclusion of speed on the set of 71 data points appear below.

Regression without speed: $EF = 6.51 * (\text{silt loading}/2)^{0.97} * (\text{weight}/3)^{0.36}$

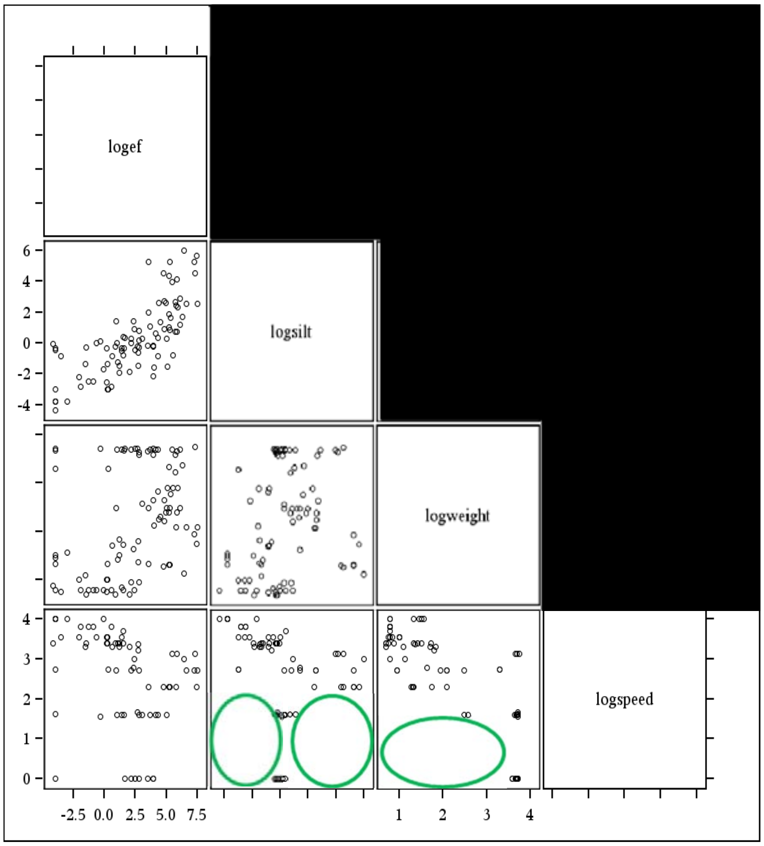
Regression including speed: $EF = 6.41 * (\text{silt loading}/2)^{0.97} * (\text{weight}/3)^{0.27} * (\text{speed}/30)^{-0.12}$

	Variance Explained by Model	Variable	p-value	"Proportion of Variance Explained"
Regression without speed	$R^2 = 0.6335$	Silt loading	< 0.0001	0.62673
		Weight	0.0739	0.04621
Regression including speed	$R^2 = 0.6288$	Silt loading	< 0.0001	0.62673
		Weight	0.3892	0.04621
		Speed	0.7140	0.00202

The R-square value from a standard least-squares regression represents the proportion of variability explained by the model. When speed is included in the regression, the R-square is slightly lower than when speed is not included. This means that the model explains less of the variance seen in emission factor when speed is included than when it is not.

The column labeled p-value represents the statistical significance of the factor in the prediction of the dependent variable (the lower the p-value, the greater the significance). In order to be considered statistically significant for inclusion in the model, generally p-values are less than or equal to 0.15. Note that the p-values for the equation that includes speed indicate that speed and weight are both statistically insignificant (this is because there is likely a relationship between weight and speed). When speed is not included, weight is statistically significant.

The column labeled "proportion of variance explained" is the proportion of R-square that is explained by each individual variable. Speed contributes almost no additional "explanation of variance" to the model (i.e. speed doesn't add much to the predictive power of the model).



Gaps in the Data

Additional concerns about gaps in the range of data surfaced during our statistical analysis. Notice the major holes highlighted by the circles in the speed-silt loading and speed-weight boxes. The dataset is missing low silt loading, low speed; low silt loading, high speed data; and low weight, low speed data. Ideally, the boxes relating silt loading, weight, and speed should be completely filled with data points in order to cover all ranges of possible occurrences and consider them to be independent factors in the model.

Conclusions and Recommendations

The proposed approach used by EPA to calculate the proposed paved road equation differs from standard regression procedures. The two-regression approach used results in two different R-square values, neither of which accurately represent the proportion of variability explained by the final resulting model. Additionally, different data sets were used to develop the two models.

In using ordinary least-squares regression to compare data models for the same data, inclusion of speed in the model does not significantly add to the explanation of variance in emission factor. Also, speed does not have a statistically significant relationship with emission factor.

The low-speed data ($\leq$ 5 mph) have an un-proportionally large effect on the fit of the model. This is of concern because there are not enough low speed data to represent all ranges of weight and silt loading.

Because the correlation between the log-transformed, normalized weight and speed in the model is approximately -0.78, inclusion of both factors introduces issues related to multicollinearity. The problem with having highly correlated variables in a model is that the coefficients are easily influenced by the dataset used in estimation and may not be meaningfully interpreted because they are not independent.

It is recommended that different modeling options be explored to find the best fit and set of predictors for the data provided. Two such options are:

- Look at low speed and high speed models separately, potentially excluding vehicle speeds under 5 mph from equation development.
- Use a composite factor of weight and speed together with either weight or speed as independent variables in the regression. This helps alleviate the problems due to multicollinearity between weight and speed seen in these data.

If you have questions or comments about this evaluation of the proposed paved road equation in EPA AP-42 Section 13.2.1, please contact the undersigned by email (cbokenkroger@mriresearch.org) or telephone (816- 360-5303). We look forward to your response on this matter.

Sincerely yours,
MIDWEST RESEARCH INSTITUTE

Courtney Bokenkroger

Courtney Bokenkroger
Senior Statistician

Comments on Section 13.2.1 draft
Muleski, Greg to: Ron Myers 08/30/2010 02:58 PM

History: This message has been forwarded.

Ron

Thank you for the opportunity to comment on the draft paved road emission factor. Based on my analysis for the Corn Refiner Association member companies, I know that the revision moves the power on the "mean vehicle weight term" in the right direction.

My specific comments are as follows:

1. The measured emission factor for CM-2 should be "63.5" rather than "6.35" so the independent variable in Table 4-17 should have been about 52 g/vmt (rather than the default value of 0.02 g/vmt).

2. The two-step regression process described in Section 4.2.2.2 differs from standard stepwise multiple regression used in the past AP-42 updates. It is not clear how R-squared values at each step can be combined to obtain a meaningful value.

3. The high degree of correlation between speed and weight precludes both being included as independent terms in the emission factor equation. Furthermore, it is not clear what inclusion of speed does for the model. The goal should be to develop a predictive tool for situations without measured emissions rather than trying to get the best fit for the set of measured emissions.

4. The geometric mean is the better choice than the arithmetic average when working with the predicted/observed ratios.

5. The draft background document is in rough shape. It would have been better to have posted only Section 4 to avoid confusion arising from the table of contents, references, etc. The document would have benefitted from a thorough review/edit prior to being posted on the CHIEF web site.

Please feel free to contact me with any questions or comments.

Greg Muleski

FW: Message from KMBT_421
Muleski, Greg to: Ron Myers 08/26/2010 09:52 AM

History: This message has been replied to and forwarded.

Ron

Sorry I missed your phone call. I've attached 2 annotated pages from your draft background document that show the problem.

-----Original Message-----
From: copier211h@mriresearch.org [mailto:copier211h@mriresearch.org]
Sent: Thursday, August 26, 2010 8:50 AM
To: Muleski, Greg
Subject: Message from KMBT_421

Table 1-14. Summary of Emissions Data from Cargill's Blair, Nebraska Facility (Test Report 3)

Run	Test condition	Traffic rate (veh/hr)	Traffic speed (mph)[a]	Mean vehicle weight, W (tons)	Surface silt loading, sL (g/m^2)[b]	Measured PM_{10} emission factor (lb/VMT)[c]
CI-1	Low Speed	45	13.4 / 16.8	26	0.06	-
CI-2	Low Speed	45	12.8 / 16.9	26	0.06	-
CI-3	Slowly moving	60[d]	13.6 / 12.7 13.5 / 15.5	27	0.06	-
CI-4	Low Speed	60[d]		27	0.06	-
CI-7	Slowly moving	47	15.2 / 16.2 13.6 / 16.1	27	0.05	0.0036
CI-8	Low Speed	47		27	0.05	0.0066
CI-11	Low Speed	56	13.5 / 12.7	27	0.025	-
CI-12	Low Speed	56		27	0.25	-

[a] Vehicle speed for inbound (loaded) /outbound (empty) trucks determined by accumulating time required to travel a measured distance.

[b] Surface silt loading sample information provided by Cargill.

[c] "-" indicates that no net mass was attributed to the test road traffic.

[d] Twenty of 238 total passes were by "drone" trucks.

Table 4-15. Summary of Emissions Data from ADM's Marshall, Minnesota Facility (Test Report 4)

Run	Test Condition	Traffic rate (veh/hr)	Traffic speed (mph)[a]	Mean vehicle weight, W (tons)	Surface silt loading, sL (g/m^2)	Measured PM_{10} emission factor (lb/VMT)
CM-1	**Slowly moving**	**154**	**NA**	**40**	**0.72**	**0.014**
CM-2	**Stop-and-go**	**42**	**NA**	**40**	**0.72**	**0.14**
CM-4	**Slowly moving**	**156**	**5**	**40**	**0.70**	**0.016**

[a] Vehicles speeds maintained at plant limit of 5 mph. NA = not applicable.

Bold entries indicate that identical vertical sampling arrays were used to better isolate the source contribution.

①

This is OK; converts to 63.5 g/VMT

NOTE: I checked the value against Table 4-4 in our 12/5/03 report (next page)

Table 4-4. Measurement-Based PM-10 Emission Rates/Factors

Run	Traffic rate[a] (veh/hr)	Mean vehicle[a] weight (tons)	Silt loading (g/m^2)	Measured line source emission rate (g/mile-s)	Measured per vehicle emission factor (lb/vmt)	AP-42 predicted emission[a] factor (lb/vmt)
CM-1 (low speed)	154	39.8	0.72	0.27[b]	0.014	0.40
CM-2 (stop/go)	41.9	39.6	0.72	0.76[b]	0.14	0.40
CM-4 (low speed)	156	39.5	0.70	0.31[b]	0.016	0.39

[a] Vehicle weights based on the following values (lbs) in MCP's Title V application:

	Empty	Loaded
Straight Truck	10,000	26,000
Tandem	19,000	45,000
Semi	27,000	80,000

All trucks were inbound and full (including "drone" passes). AP-42 factor based on value of 40 tons.

[b] Based on 2 lines of queued traffic.

4.2 Discussion and Recommendation

The PM-10 emission factors developed in the 2003 testing program provide further evidence that Equation 1-1 produces highly overestimated predictions for PM-10 emissions from paved road traffic at the Marshall facility. At least two features of the AP-42 modeling approach fail to describe the emissions observed at Marshall.

First, re-entrained surface road dust is not nearly as dominant in the emissions measured at Marshall as compared to the AP-42 emission factor database. This was first noted in the 2001 test report [3]. The 2003 program provides no evidence that measured emissions exhibit a dependency on silt loading even remotely similar to that found in Equation 1-1.

Just as importantly, the 2003 test results point up a second shortcoming of AP-42 in modeling emissions at the Marshall plant. The predicted emission rate using AP-42 is found by multiplying Equation 1-1 by the traffic volume. In other words, the emission rate varies linearly with traffic rate. For example, if twice as many vehicles pass during one hour compared to the next, then the first hour's emission rate should be twice that of the second.

However, measured emission rates are remarkably constant over the range of traffic rates considered during the two test programs. Figure 4-1 presents the line source emission rate measured in both 2001 and 2003 for the inbound corn haul route. The emission rate is plotted against the traffic rate. Also included for comparison are the predicted values using AP-42. Measured emission rates show no significant relationship with traffic rate.

Emission Tests of Paved Road Traffic at ADM's Marshall, Minnesota Facility

Test Report

For
McVehil-Monnett Associates

MRI Project No. 310479.1.001

December 5, 2003

Reference	Run ID	Silt loading (g/m2)	Speed (mph)	Weight (tons)	Downwind Concentration mg/m^3	Measured PM-10 Emission factor (g/VMT)	Estimated Fraction Heavy Duty Vehicles	Estimated Engine, brake, tire emission factor (g/VMT)	Estimated PM-10 Road Dust Emission factor (g/VMT)
	CF-2/South	0.81	1	41	0.080	63.5	1.000	11.06	52.440
	CF-3N	0.63	5.1	41	0.015	1.09	1.000	2.1686	0.020
	CF-3/South	0.63	1	41	0.025	23.1	1.000	11.06	12.040
	CF-4N	1.1	4.7	41	0.019	3.08	1.000	2.3532	0.727
	CF-5	1.4	1	41	0.030	16.3	1.000	11.06	5.240
	CI-7	0.05	15.3	27	0.030	1.63	0.759	1.6434	0.020
	CI-8	0.05	15.3	27	0.030	2.99	0.759	1.6434	1.347
	CM-1	0.72	5	39.8	0.035	6.35	1.000	2.212	4.138
	CM-2	0.72	1	39.6	0.050	6.35	1.000	11.06	0.020
	CM-4	0.7	5	39.5	0.035	7.26	1.000	2.212	5.048

(2) should be 63.5

(3) and this should be 63.5 - 11.06 ≈ 52 g/VMT

From: "Camille Sears" <camille.marie@sbcglobal.net>
To: Ron Myers/RTP/USEPA/US@EPA

Date: Monday, August 30, 2010 11:53PM
Subject: Re: AP-42 13.2.1
History: This message has been forwarded.

Hi Ron,

Attached are our comments. Please let me know if you have questions.

Your help is greatly appreciated!

Best wishes,
Camille

Attachments:
SC-13.2.1.comments.pdf

Camille Sears 502 W. Lomita Ave., Ojai, CA 93023

Tel: (805) 646-2588 e-mail: camille.marie@sbcglobal.net

August 30, 2010

Mr. Ron Myers
U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711

Subject: Proposed Revision to AP-42 Section 13.2.1 – Paved Roads

Dear Mr. Myers,

Thank you for the opportunity to provide comments on the proposed revision to AP-42 Section 13.2.1. I have reviewed the proposed AP-42 revisions and associated reference documents and on behalf of Sierra Club offer the following brief comments.

1. Introduction

The existing USEPA air pollution emission factor for fugitive dust from vehicle traffic on paved roads is as follows:[1]

$$E = k(S_L/2)^{0.65} * (W/3)^{1.5} - C$$

Where: E = annual or other long-term average emission factor in the same units as k

k = particle size multiplier (from Table 13.2.1-1, k = 0.0024 lb/vehicle mile traveled (VMT) for $PM_{2.5}$ and 0.016 lb/VMT for PM_{10})

S_L = road surface silt loading (g/m^2)

W = average weight of vehicles (tons)

C = emission factor for 1980s vehicle fleet exhaust, brake wear, and tire wear (from Table 13.2.1-2, C = 0.00036 lb/VMT for $PM_{2.5}$ and 0.00047 lb/VMT for PM_{10})

The existing version of AP-42 Section 13.2.1 appears to be based on 64 source tests performed prior to 1995, the date when the paved road emission factor first takes its current form.

In July 2008, the Corn Refiners Association ("CRA") proposed a revision to AP-42 Section 13.2.1. CRA's proposed revision is based on 22 additional source tests performed at ethanol plants in 2001

[1] USEPA, Office of Air Quality Planning and Standards, AP-42, Section 13.2.1, Paved Roads, November 2006, p. 13.2.1-4.

through 2003.[2] CRA recalculated a paved road emission factor including the 64 source tests used by USEPA as the bases for the existing emission factor, plus the 22 additional CRA source tests (for a total of 86 tests). Based on their regression analyses, CRA proposed a revised paved road emission factor with the following form:[3]

$$E = k(S_L/2)^{0.8} * (W/3)^{0.8} - C$$

CRA also proposed a revised particle size multiplier (k), where k = 0.0034 lb/VMT for $PM_{2.5}$ and 0.023 lb/VMT for PM_{10})

The additional 22 tests performed by the CRA include:

- Nine tests performed on roads at the Minnesota Corn Processors facility, Marshall, Minnesota, during April 2001;
- Eight tests performed on roads at the Minnesota Corn Processors facility, Columbus, Nebraska, during June 2001;
- Two tests performed on roads at the Cargill Sweeteners North America facility, Blair, Nebraska, during August 2002;
- Three tests performed on roads at ADM's facility, Marshall, Minnesota, during September 2003 (this is the same facility as the April 2001 tests).

In May 2010, USEPA developed and proposed a revision to AP-42 Section 13.2.1, "Paved Roads." From USEPA:

> This update recommends an updated equation for paved roads that is based upon additional test data that was conducted on roads with slow moving traffic and stop and go traffic. The emissions tests were performed for the Corn Refiners Association by Midwest Research Institute (MRI). The testing focused on PM10 emissions at four corn processing facilities.[4]

USEPA's update to AP-42 Section 13.2.1, however, incorporates other data than that collected by the Corn Refiners Association, and, more importantly, USEPA's update excludes important data that have been used in developing the existing paved road emission factor. In summary, USEPA's 2010 update to AP-42 Section 13.2.1 incorporates the following data base changes:

- Including the 22 CRA tests performed in 2001 through 2003;
- Including three tests performed on public roads in Denver, Colorado, during March 1996;

[2] Corn Refiners Association, Paved Road Modifications at AP-42, Background Documentation, MRI Project No. 310842, July 18, 2008, p. 4.
[3] Id., p. 20.
[4] USEPA, Emission factor Documentation for AP-42, Section 13.2.1, Paved Roads, Draft, June 2010, p. 2-9.

- Including two tests performed on public roads in Raleigh, North Carolina, during April 1996;
- Including two tests performed on public roads in Reno, Nevada, during June 1996;
- Excluding 22 tests performed at two integrated iron and steel plants – one located in Houston, Texas, and the other in Middletown, Ohio (during 1980 and 1981).[5]

USEPA developed a proposed multiple regression equation based on paved road silt loading, mean vehicle weight, and vehicle speed. The existing version of AP-42 Section 13.2.1 is based on regression analyses of silt loading and mean vehicle weight. Since vehicle speed was not measured at the 22 tests from the two integrated iron and steel plants (Houston, Texas and Middletown, Ohio during 1980 and 1981), these tests were excluded from the data set.

USEPA's proposed revision to AP-42 Section 13.2.1, which is based on 71 individual source tests, takes the form:[6]

$$E = k(S_L/2)^{0.98} * (W/3)^{0.53} * (S/30)^{0.16}$$

Where: E = annual or other long-term average emission factor in the same units as k

k = particle size multiplier; k = 0.0037 lb/VMT for $PM_{2.5}$ and 0.015 lb/VMT for PM_{10}

S_L = road surface silt loading (g/m^2)

W = average weight of vehicles (tons)

S = average vehicle speed (miles per hour)

This equation does not incorporate emissions from engine exhaust and brake and tire wear, which will need to be estimated and added using USEPA's MOBILE6.2 or MOVES2010 models.

I have a few concerns regarding USEPA's proposed revision to AP-42 Section 13.2.1:

- USEPA's multiple regression analysis incorporating vehicle speed excludes a valuable data set for assessing paved road PM emissions from industrial facilities.
- USEPA's proposed revision to AP-42 Section 13.2.1 results in a very significant reduction in PM_{10} and $PM_{2.5}$ emission factors from paved roads in industrial settings.
- It is unclear whether USEPA's proposed revision to AP-42 Section 13.2.1 improves upon predictive performance of the existing 2006 emission factor.

[5] Id., p. 4-18.
[6] USEPA, Office of Air Quality Planning and Standards, AP-42, Draft Section 13.2.1, Paved Roads, p. 13.2.1-4.

2. Key Industrial Source Tests are Excluded from USEPA's Revised Factor

USEPA's proposed revision to the paved road emission factor includes a third variable, mean vehicle speed. Vehicle speed, however, does not appear to be an important predictive aid to the overall emission factor equation. This is evidenced by vehicle speed having a small (0.16) exponential term in USEPA's proposed paved road emission factor. Furthermore, the CRA, in their analyses of the source test data, state:

> Taken together, these observations indicate that (a) silt loading and vehicle weight may be used as independent variables and that (b) inclusion of speed would add very little to the predictive capability of the model.[7]

I understand that USEPA has been asked to include vehicle speed in the revised paved road emission factor. Doing so, however, excludes valuable source tests that were performed without measuring vehicle speed. In particular, USEPA is excluding 22 tests performed at two integrated iron and steel plants due to lack of vehicular speed data. These iron and steel plant source tests are crucial for calculating fugitive dust emissions from industrial facilities, and excluding these data has a very significant impact on predicted paved road emission rates. As discussed in the following section, USEPA's proposed revision to the paved road emission factor will reduce particulate emission calculations at typical industrial sites by roughly an order of magnitude. This large, and perhaps unrealistic, reduction in calculated industrial paved road emissions is an artifact of trying to develop an emission factor based on tests that must include vehicle speed data.

3. USEPA's Proposed Update will Result in a Roughly Order of Magnitude Emission Reduction at Industrial Sites

In addition to developing an updated paved road emission factor, USEPA prepared a consequence analysis of the National Emission Inventory ("NEI") resulting from their proposed revision.[8] USEPA found that their revised paved road emission factor will significantly reduce PM_{10} emissions in the NEI (up to 200% reduction), while $PM_{2.5}$ emissions are only slightly affected (some NEI calculations increase, some decrease). USEPA, however, did not examine the affect of their draft revised paved road equation on fugitive dust emissions from industrial sources.

I prepared two tables that compare the existing paved road emission factor with USEPA's proposed revision – one for PM_{10} (Table 1A), and one for $PM_{2.5}$ (Table 1B). These tables include a range of silt loading, vehicle weight, and vehicle speed conditions. For each set of silt loading, weight, and speed, I calculated the emission factor using both the existing and proposed paved road emission factor. As can be seen, the reduction in calculated emissions for industrial sites using the revised factor is very large – about an order of magnitude lower for PM_{10} and somewhat less for $PM_{2.5}$.

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[7] Corn Refiners Association, Paved Road Modifications at AP-42, Background Documentation, MRI Project No. 310842, July 18, 2008, p. 15.
[8] See Excel spreadsheet: Impact_of_revised_paved_roads_pm_emission_factors_on_NEI.xls.

USEPA's choice to go ahead with their proposed paved road emission factor would have serious ramifications for NAAQS and PSD increment compliance. This is particularly true for proposed major sources of PM_{10} and $PM_{2.5}$ which have paved haul road emission sources. Using USEPA's proposed revision, sources that are currently being scrutinized for PM_{10} PSD increment and $PM_{2.5}$ NAAQS compliance would most likely be well below any regulatory design concentrations, even with significantly relaxed control measures. Again, USEPA's proposed revision is largely due to excluding a significant portion of the existing industrial source test data base, and is not due to any tests that contradict the excluded data. In effect, USEPA's revision would be "sweeping under the rug" what is perhaps the greatest impact caused by many industrial sources.

In terms of the modeling analyses for NAAQS and PSD increment compliance, the 24-hour PM_{10} PSD increment, which is 30 micrograms per cubic meter "$\mu g/m^3$," is almost always the most problematic regulatory design concentration. Proposed industrial sources, such as coal-fired power plants, pig iron facilities, coal-to-liquid operations, coal-to-synthetic gas plants, and lime production facilities, often cause air impacts that are quite close to exceeding the 24-hour PM_{10} PSD increment. It is common to see proposed PSD permit application modeled impacts consuming some 80 to 99% of the allowable 24-hour PM_{10} PSD increment. The majority of this modeled impact is caused by low-level open source fugitive emissions, including paved haul roads.

There is no basis to assume that the existing paved road emission factor overpredicts fugitive dust emissions from these major sources. And as we discussed earlier, it is common for major sources of emissions to be permitted without any PSD pre-construction or post-construction ambient air monitoring, even when such requirements are triggered by PM_{10} significant monitoring concentrations identified in 40 CFR 52.21(i). Thus, there is no current way to verify whether source PM_{10} impacts at the fenceline are realistically handled by the applied fugitive dust emission factor and subsequent air dispersion modeling.

I have also prepared two tables that compare the existing paved road emission factor with the CRA's proposed revision – one for PM_{10} (Table 2A), and one for $PM_{2.5}$ (Table 2B). While CRA's proposed revision results in lower industrial source PM_{10} and $PM_{2.5}$ emission factors, they are not nearly as severe as the changes proposed by USEPA.

The CRA source tests, however, include an apparent contradiction. CRA's source tests were designed for low vehicular speeds and stop-and-go conditions.[9] But CRA also acknowledges that "inclusion of speed would add very little to the predictive capability of the model."[10] So, the basis for including CRA's source tests in AP-42 Section 13.2.1 seems unnecessary.

Revising AP-42 Section 13.2.1, using either CRA's or USEPA's proposed revisions, will greatly reduce calculated fugitive dust emissions at most industrial facilities. This would make it easier for applicants to meet regulatory design concentration compliance, and to do so with fewer emission controls. These revisions, however, are based on data that are not representative of the majority of

[9] Corn Refiners Association, Paved Road Modifications at AP-42, Background Documentation, MRI Project No. 310842, July 18, 2008, p. 4.
[10] Id., p. 15.

major emission sources. For example, the CRA source tests are for ethanol plants with low to very low silt loading levels. These conditions are not representative of the scores of proposed coal-fired power projects that have recently submitted permit applications to State agencies. And USEPA's modification of the source test data base, to add public road source tests and to eliminate the integrated steel plant tests, probably makes things even worse. The silt loading levels (and associated emission factors) measured at the integrated steel plant sites are representative of many industrial facilities.[11] Excluding these data will weigh the equation in a manner that reduces predictive performance for most industrial plants.

4. USEPA's Proposed Update may not Improve Predictive Performance

As part of the proposed revision to AP-42 Section 13.2.1, it would be helpful if USEPA presented performance analyses of both the existing and proposed paved road emission factors. Furthermore, it would be helpful if USEPA presented performance criteria for sub-categories of emission sources, such as public roads, industrial roads with low silt loading levels, and perhaps industrial roads with higher silt loading levels. From this analysis, USEPA and the reviewing public could get a better idea of whether the proposed changes will provide better predictive capability than does the existing method. And just as important, would be information on predictive performance for each sub-category of emission sources. In other words, we could tell whether improving performance for one source category, ethanol plants for example, would have a detrimental effect on emission prediction for other industrial sources with higher silt loadings.

Likewise, focusing on performance of public roads, with vehicle speed included, greatly affects industrial source emission rates. But what effect does it have on the predictive performance of industrial sources? As we discussed earlier, the coefficient of determination (r^2) is not particularly great for the proposed revision (all data sets included). It would be useful to examine the predictive performance on various subsets of the existing data base, with both the existing and proposed emission factors.

5. Other Factors Affecting USEPA's Paved Road Emission Factor

Following are a few observations that will affect the predictive emission factor equation when used on industrial sources. I believe USEPA should address these concerns prior to revising their existing paved road emission factor.

- The paved road emission factor should consider whether the road shoulder is paved and whether there is a source of dust fallout present. For example, facilities with dust-generating storage piles, and truck traffic moving between these piles, are likely to have high particulate emission rates. This is particularly true for facilities with unpaved road shoulders.

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[11] USEPA, Emission factor Documentation for AP-42, Section 13.2.1, Paved Roads, Draft, June 2010, pp. 4-42 to 4-45.

- Some vehicles have exhaust pipes pointing skyward, others are parallel to the ground, and still others pointing down to the ground. Downward-pointing exhaust can exacerbate resuspension of dust, as I have often observed with forklifts and delivery vehicles with such an exhaust configuration. It is unclear whether industrial vehicles with downward-pointing exhaust are accounted for in the paved road emission factor.
- In developing the revised emission factor, USEPA subtracted a "C" term from the CRA source tests. This results in very small or even negative emission rates for certain tests.[12] Given the plume rise of exhaust from the slow-moving CRA test vehicles, it is possible that most, if not all, of the exhaust plume passed above the downwind air samplers. In other words, the "C" term used by USEPA may be too large for the CRA (and other) source tests. USEPA should reevaluate to what extent, if any, exhaust, and brake and tire wear impact the downwind profile measurements.

6. Concluding Remarks

USEPA's proposed revision to AP-42 Section 13.2.1 excludes a valuable industrial source paved road data base simply because vehicle speed was not included in the study. USEPA's revised emission factor will result in a roughly order of magnitude emission reduction in industrial source paved road emissions. This very significant change may not be appropriate given that a key data set was excluded from the regression analyses.

USEPA may be trying to fit too many source categories into a one-size-fits-all emission factor. Under the umbrella of "paved roads" fits urban freeways, local street traffic, industrial sites with a wide-range of truck sizes and weights, parking lots, and all shapes and sizes of vehicles using these paved surfaces. I understand that USEPA has a very difficult task in developing a paved road emission factor that meets the needs of all affected sources. It is likely that "clean" roads are downward-biasing the emission factor for high-emitting facilities. And the opposite is also true – industrial roads with high silt loading are likely upward-biasing the emission factor for cleaner roads with lighter vehicles.

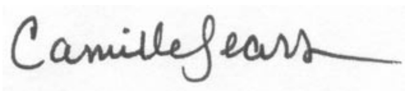
I offer the suggestion that USEPA should consider developing separate paved road emission factors for public and industrial roads. It may not be too far-fetched to examine separate emission factors for sub-categories of industrial source paved road emissions as well. Also, USEPA may want to focus on silt loading and vehicle weight, as variability in vehicle speed seems to have a less significant impact on predicted emission performance.

Until USEPA has addressed whether the severe reduction in industrial source paved road emission calculations is warranted, I believe that the existing AP-42 paved road emission factor should continue to be used.

[12] Id.

I greatly appreciate your help in reviewing and commenting on the proposed revisions to AP-42 Section 13.2.1. Please contact me if you have any questions or require additional information.

Sincerely,



Camille Sears

Table 1A
AP-42 Section 13.2.1: Paved Roads
Comparison of Existing and Draft Paved Road PM10 Emission Factors
(Silt loading resuspension only)

Setting	sL (g/m^2)	W (tons)	S (mph)	Draft E (lb/VMT)	Existing E (lb/VMT)	Draft E / Existing E
Public	0.2	3.75	25	0.0017	0.0045	0.38
Public	0.2	3.75	35	0.0018	0.0045	0.40
Public	0.2	3.75	45	0.0019	0.0045	0.42
Public	0.6	3.75	25	0.0050	0.0098	0.52
Public	0.6	3.75	35	0.0053	0.0098	0.55
Public	0.6	3.75	45	0.0055	0.0098	0.57
Industrial	0.6	10	5	0.0066	0.0441	0.15
Industrial	0.6	10	15	0.0078	0.0441	0.18
Industrial	0.6	10	25	0.0085	0.0441	0.19
Industrial	0.6	20	5	0.0095	0.1255	0.08
Industrial	0.6	20	15	0.0113	0.1255	0.09
Industrial	0.6	20	25	0.0122	0.1255	0.10
Industrial	0.6	30	5	0.0117	0.2309	0.05
Industrial	0.6	30	15	0.0140	0.2309	0.06
Industrial	0.6	30	25	0.0152	0.2309	0.07
Industrial	2.0	10	5	0.0213	0.0969	0.22
Industrial	2.0	10	15	0.0254	0.0969	0.26
Industrial	2.0	10	25	0.0276	0.0969	0.28
Industrial	2.0	20	5	0.0308	0.2749	0.11
Industrial	2.0	20	15	0.0367	0.2749	0.13
Industrial	2.0	20	25	0.0398	0.2749	0.14
Industrial	2.0	30	5	0.0382	0.5055	0.08
Industrial	2.0	30	15	0.0455	0.5055	0.09
Industrial	2.0	30	25	0.0494	0.5055	0.10
Industrial	5.0	10	5	0.0523	0.1762	0.30
Industrial	5.0	10	15	0.0624	0.1762	0.35
Industrial	5.0	10	25	0.0677	0.1762	0.38
Industrial	5.0	20	5	0.0756	0.4992	0.15
Industrial	5.0	20	15	0.0901	0.4992	0.18
Industrial	5.0	20	25	0.0977	0.4992	0.20
Industrial	5.0	30	5	0.0937	0.9174	0.10
Industrial	5.0	30	15	0.1117	0.9174	0.12
Industrial	5.0	30	25	0.1212	0.9174	0.13
Industrial	10.0	10	5	0.1032	0.2767	0.37
Industrial	10.0	10	15	0.1230	0.2767	0.44
Industrial	10.0	10	25	0.1335	0.2767	0.48
Industrial	10.0	20	5	0.1490	0.7835	0.19
Industrial	10.0	20	15	0.1777	0.7835	0.23
Industrial	10.0	20	25	0.1928	0.7835	0.25
Industrial	10.0	30	5	0.1847	1.4398	0.13
Industrial	10.0	30	15	0.2203	1.4398	0.15
Industrial	10.0	30	25	0.2390	1.4398	0.17

Notes:
E = resuspension emission factor; calculations exclude vehicle exhaust, brake wear, and tire wear emissions
sL = silt loading; W = mean vehicle weight; S = mean vehicle speed
For comparison purposes, no rain adjustments or control efficiencies applied

Table 1B
AP-42 Section 13.2.1: Paved Roads
Comparison of Existing and Draft Paved Road PM2.5 Emission Factors
(Silt loading resuspension only)

Setting	sL (g/m^2)	W (tons)	S (mph)	Draft E (lb/VMT)	Existing E (lb/VMT)	Draft E / Existing E
Public	0.2	3.75	25	0.0004	0.0004	1.08
Public	0.2	3.75	35	0.0004	0.0004	1.14
Public	0.2	3.75	45	0.0005	0.0004	1.19
Public	0.6	3.75	25	0.0012	0.0012	1.06
Public	0.6	3.75	35	0.0013	0.0012	1.12
Public	0.6	3.75	45	0.0014	0.0012	1.16
Industrial	0.6	10	5	0.0016	0.0063	0.26
Industrial	0.6	10	15	0.0019	0.0063	0.30
Industrial	0.6	10	25	0.0021	0.0063	0.33
Industrial	0.6	20	5	0.0023	0.0185	0.13
Industrial	0.6	20	15	0.0028	0.0185	0.15
Industrial	0.6	20	25	0.0030	0.0185	0.16
Industrial	0.6	30	5	0.0029	0.0343	0.08
Industrial	0.6	30	15	0.0034	0.0343	0.10
Industrial	0.6	30	25	0.0037	0.0343	0.11
Industrial	2.0	10	5	0.0053	0.0142	0.37
Industrial	2.0	10	15	0.0063	0.0142	0.44
Industrial	2.0	10	25	0.0068	0.0142	0.48
Industrial	2.0	20	5	0.0076	0.0410	0.19
Industrial	2.0	20	15	0.0091	0.0410	0.22
Industrial	2.0	20	25	0.0098	0.0410	0.24
Industrial	2.0	30	5	0.0094	0.0755	0.12
Industrial	2.0	30	15	0.0112	0.0755	0.15
Industrial	2.0	30	25	0.0122	0.0755	0.16
Industrial	5.0	10	5	0.0129	0.0261	0.49
Industrial	5.0	10	15	0.0154	0.0261	0.59
Industrial	5.0	10	25	0.0167	0.0261	0.64
Industrial	5.0	20	5	0.0186	0.0746	0.25
Industrial	5.0	20	15	0.0222	0.0746	0.30
Industrial	5.0	20	25	0.0241	0.0746	0.32
Industrial	5.0	30	5	0.0231	0.1373	0.17
Industrial	5.0	30	15	0.0275	0.1373	0.20
Industrial	5.0	30	25	0.0299	0.1373	0.22
Industrial	10.0	10	5	0.0255	0.0412	0.62
Industrial	10.0	10	15	0.0303	0.0412	0.74
Industrial	10.0	10	25	0.0329	0.0412	0.80
Industrial	10.0	20	5	0.0368	0.1172	0.31
Industrial	10.0	20	15	0.0438	0.1172	0.37
Industrial	10.0	20	25	0.0476	0.1172	0.41
Industrial	10.0	30	5	0.0456	0.2157	0.21
Industrial	10.0	30	15	0.0543	0.2157	0.25
Industrial	10.0	30	25	0.0590	0.2157	0.27

Notes:
E = resuspension emission factor; calculations exclude vehicle exhaust, brake wear, and tire wear emissions
sL = silt loading; W = mean vehicle weight; S = mean vehicle speed
For comparison purposes, no rain adjustments or control efficiencies applied

Table 2A
AP-42 Section 13.2.1: Paved Roads
Comparison of Existing and CRA-Proposed Paved Road PM10 Emission Factors
(Silt loading resuspension only)

Setting	sL (g/m^2)	W (tons)	S (mph)	CRA E (lb/VMT)	Existing E (lb/VMT)	CRA E / Existing E
Public	0.2	3.75	25	0.0039	0.0045	0.86
Public	0.2	3.75	35	0.0039	0.0045	0.86
Public	0.2	3.75	45	0.0039	0.0045	0.86
Public	0.6	3.75	25	0.0100	0.0098	1.03
Public	0.6	3.75	35	0.0100	0.0098	1.03
Public	0.6	3.75	45	0.0100	0.0098	1.03
Industrial	0.6	10	5	0.0225	0.0441	0.51
Industrial	0.6	10	15	0.0225	0.0441	0.51
Industrial	0.6	10	25	0.0225	0.0441	0.51
Industrial	0.6	20	5	0.0396	0.1255	0.32
Industrial	0.6	20	15	0.0396	0.1255	0.32
Industrial	0.6	20	25	0.0396	0.1255	0.32
Industrial	0.6	30	5	0.0549	0.2309	0.24
Industrial	0.6	30	15	0.0549	0.2309	0.24
Industrial	0.6	30	25	0.0549	0.2309	0.24
Industrial	2.0	10	5	0.0598	0.0969	0.62
Industrial	2.0	10	15	0.0598	0.0969	0.62
Industrial	2.0	10	25	0.0598	0.0969	0.62
Industrial	2.0	20	5	0.1044	0.2749	0.38
Industrial	2.0	20	15	0.1044	0.2749	0.38
Industrial	2.0	20	25	0.1044	0.2749	0.38
Industrial	2.0	30	5	0.1447	0.5055	0.29
Industrial	2.0	30	15	0.1447	0.5055	0.29
Industrial	2.0	30	25	0.1447	0.5055	0.29
Industrial	5.0	10	5	0.1250	0.1762	0.71
Industrial	5.0	10	15	0.1250	0.1762	0.71
Industrial	5.0	10	25	0.1250	0.1762	0.71
Industrial	5.0	20	5	0.2179	0.4992	0.44
Industrial	5.0	20	15	0.2179	0.4992	0.44
Industrial	5.0	20	25	0.2179	0.4992	0.44
Industrial	5.0	30	5	0.3016	0.9174	0.33
Industrial	5.0	30	15	0.3016	0.9174	0.33
Industrial	5.0	30	25	0.3016	0.9174	0.33
Industrial	10.0	10	5	0.2179	0.2767	0.79
Industrial	10.0	10	15	0.2179	0.2767	0.79
Industrial	10.0	10	25	0.2179	0.2767	0.79
Industrial	10.0	20	5	0.3797	0.7835	0.48
Industrial	10.0	20	15	0.3797	0.7835	0.48
Industrial	10.0	20	25	0.3797	0.7835	0.48
Industrial	10.0	30	5	0.5254	1.4398	0.36
Industrial	10.0	30	15	0.5254	1.4398	0.36
Industrial	10.0	30	25	0.5254	1.4398	0.36

Notes:

E = resuspension emission factor; calculations exclude vehicle exhaust, brake wear, and tire wear emissions

sL = silt loading; W = mean vehicle weight; S = mean vehicle speed

CRA = Corn Refiners Association

For comparison purposes, no rain adjustments or control efficiencies applied

Table 2B
AP-42 Section 13.2.1: Paved Roads
Comparison of Existing and CRA-Proposed Paved Road PM2.5 Emission Factors
(Silt loading resuspension only)

Setting	sL (g/m^2)	W (tons)	S (mph)	CRA E (lb/VMT)	Existing E (lb/VMT)	CRA E / Existing E
Public	0.2	3.75	25	0.0003	0.0004	0.73
Public	0.2	3.75	35	0.0003	0.0004	0.73
Public	0.2	3.75	45	0.0003	0.0004	0.73
Public	0.6	3.75	25	0.0012	0.0012	1.02
Public	0.6	3.75	35	0.0012	0.0012	1.02
Public	0.6	3.75	45	0.0012	0.0012	1.02
Industrial	0.6	10	5	0.0030	0.0063	0.48
Industrial	0.6	10	15	0.0030	0.0063	0.48
Industrial	0.6	10	25	0.0030	0.0063	0.48
Industrial	0.6	20	5	0.0056	0.0185	0.30
Industrial	0.6	20	15	0.0056	0.0185	0.30
Industrial	0.6	20	25	0.0056	0.0185	0.30
Industrial	0.6	30	5	0.0078	0.0343	0.23
Industrial	0.6	30	15	0.0078	0.0343	0.23
Industrial	0.6	30	25	0.0078	0.0343	0.23
Industrial	2.0	10	5	0.0085	0.0142	0.60
Industrial	2.0	10	15	0.0085	0.0142	0.60
Industrial	2.0	10	25	0.0085	0.0142	0.60
Industrial	2.0	20	5	0.0151	0.0410	0.37
Industrial	2.0	20	15	0.0151	0.0410	0.37
Industrial	2.0	20	25	0.0151	0.0410	0.37
Industrial	2.0	30	5	0.0211	0.0755	0.28
Industrial	2.0	30	15	0.0211	0.0755	0.28
Industrial	2.0	30	25	0.0211	0.0755	0.28
Industrial	5.0	10	5	0.0182	0.0261	0.70
Industrial	5.0	10	15	0.0182	0.0261	0.70
Industrial	5.0	10	25	0.0182	0.0261	0.70
Industrial	5.0	20	5	0.0319	0.0746	0.43
Industrial	5.0	20	15	0.0319	0.0746	0.43
Industrial	5.0	20	25	0.0319	0.0746	0.43
Industrial	5.0	30	5	0.0443	0.1373	0.32
Industrial	5.0	30	15	0.0443	0.1373	0.32
Industrial	5.0	30	25	0.0443	0.1373	0.32
Industrial	10.0	10	5	0.0319	0.0412	0.77
Industrial	10.0	10	15	0.0319	0.0412	0.77
Industrial	10.0	10	25	0.0319	0.0412	0.77
Industrial	10.0	20	5	0.0558	0.1172	0.48
Industrial	10.0	20	15	0.0558	0.1172	0.48
Industrial	10.0	20	25	0.0558	0.1172	0.48
Industrial	10.0	30	5	0.0774	0.2157	0.36
Industrial	10.0	30	15	0.0774	0.2157	0.36
Industrial	10.0	30	25	0.0774	0.2157	0.36

Notes:
E = resuspension emission factor; calculations exclude vehicle exhaust, brake wear, and tire wear emissions
sL = silt loading; W = mean vehicle weight; S = mean vehicle speed
CRA = Corn Refiners Association
For comparison purposes, no rain adjustments or control efficiencies applied

Fw: Dave's comments on the Excel workbook - do not need to be mentioned on the call
dave.james to: Ron Myers 08/18/2010 03:07 PM

Dear Ron,

Please find attached some comments on the proposed new AP42 paved road equation

A) I think that, on tab PM10 Paved Roads EF's, column Z, the
column labeled "Percent Total Emissions Factor Increase" uses the formula (column x - column s) / column x
to calculate percent changes. I think this should be, instead (column x - column s) / column s, so that the percent change is calculated relative to the 2006 emissions factor equation instead of the proposed new 2010 emissions factor equation
Column AD is the recalculated percent reduction for the rain corrected EF's based on this suggested equation revision

B) For the desert southwest, I think that it is best to look at the data without rain adjustments

C) In my edited tab "PM10 Paved Roads EF's" I have added several columns, AB, AC, and AD
(1) Column AB is the calculated raw reduction of 2010 dry EF's compared to 2006 dry EF's. (column u - column o)
(2) Column AC is the calculated percent reduction of 2010 dry EF's compared to 2006 dry EF's using the equation (column u - column o)/column o

D) based on the 7,632 row data set in the tab PM10 Paved Roads EF's

(1) The new 2010 dry EF's are *much lower overall* than the 2006 dry EF's. see the chart in the new tab labeled "compareNewOLDPM10EF's"

(2) The *reductions* of dry 2010 EF's compared to dry 2006 EF's linearly increase in magnitude with the magnitude of the original 2006 emissions factor (see the chart in the new tab labeled "reductions" - calculated in column AB)

(3) When I plot the *percentage changes* of the dry 2010 PM 10 EF's calculated) above against 2006 emissions factors, they are all around 70-80% (see the chart new tab labeled "percent reductions")

E) Athough national data might show reductions, since the new equation
1) raises the influence of silt loading (new exponent 0.98, old exponent 0.65)
2) lowers the influence of vehicle weight (new exponent 0.53, old exponent 1.5)
3) adds in an influence of vehicle speed,
4) eliminates the influence of the correction factor for exhaust brake and tire wear,
I would recommend that any assessment of the impact of the proposed new equation be based on locally sampled data and not use the national data.

Thank you for the opportunity to comment.

Sincerely,

Dave

David E. James, PhD PE
Associate Vice Provost for Academic Programs
Office of the Vice Provost for Academic Affairs
Box 451099
4505 South Maryland Parkway
Las Vegas, NV 89154-1099
Direct Line (702) 895-5804 Main Office (702) 895-1267
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email: dave.james@unlv.edu
http://provost.unlv.edu/acadaffairs.html

Re: Fw: Dave's comments on the EPA Excel workbook - some additional follow up thoughts

dave.james to: Ron Myers 09/15/2010 02:44 PM

Cc: Rodney Langston, Russell Merle

Hi Ron,

Thank you for your good email below and for the additional information.

I apologize for taking so long to get back to you with my thoughts and responses. Here they are:

A) Understood about the zeros being problematic

B) In many parts of the country where there is significant rain or a rainy season, rain days may considerably effect estimated PM10 emissions in the inventory. However, for Las Vegas and other places like it in arid places,
I tend to use a 'pessimistic' approach that doesn't include the rain days, since rain occurs sporadically, and what rain does fall is often very light.

C) I'm glad that my extra columns in your Excel workbook are helpful

D) Yes, from the default data it looks like many of the estimated EF's would go down with the new proposed equation

E) Since we last corresponded,
1) I ran some calculations for Clark County's AP42 measured 2003-2006 silt loading data set using their locally derived fleet weights. Please see the attached file "comparison20062010_AP42 road dust EFs2003_2006.pdf"
If you examine the bottom-most table on the page, where percentage EF changes are computed, that the net impact of the new proposed equation on Clark County's estimated paved road dust PM-10 emissions would be to
a) increase estimated PM10 emissions as grams/VMT 23% on local roads,
b) decrease them by 3% on collector roads (probably not significant), and
c) increase them by 1% on minor arterials (also probably not significant).

With locally derived data, we obtain results that are different from those that might be predicted using default silt loading data. The actual impact on total estimated PM10 emissions in an inventory or SIP would depend on how much VMT was assigned to each roadway category.

2) I also ran a hypothetical sensitivity analysis comparing arbitrary combinations of vehicle weight and silt loading, to see what the impacts of the new PM10 equation might be. Please see the attached file "new2010EFsensitivityanalysis.pdf"
Table 1 shows the 2006 equation predicted PM10 emissions
Table 2 shows the proposed 2010 equation predicted PM10 emissions
Table 3 shows the changes in predicted emissions (2010 EF - 2006 EF)
and
Table 4 shows the Percentage changes, (2010 EF - 2006 EF)/2006 EF

Table 4 shows that the net effect of using the new proposed 2010 equation is that predicted

PM10 emissions
a) increase for lower silt loadings at all fleet average vehicle weights, and
b) decrease for higher silt loadings, espeically at lower fleet average vehicle weights

I hope that these preliminary calculations are helpful. I have also sent them as PDF and as the original Excel files to
my research sponsors, Clark County Dept of Air Quality and Environmental Management.

Sincerely,
Dave

David E. James, PhD PE
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email: dave.james@unlv.edu
http://provost.unlv.edu/acadaffairs.html

From: Myers.Ron@epamail.epa.gov
To: dave.james@unlv.edu
Date: 08/18/2010 06:34 PM
Subject: Re: Fw: Dave's comments on the Excel workbook - do not need to be mentioned on the call

---

Dave:
Thanks for looking at the proposed revisions of the paved road equation.

First, I was trying to replicate the emissions estimates that are being made for the 2008 NEI, any rain adjustments or other mitigation that I included in the spreadsheet are the same as I estimated were used in the NEI emissions estimates. As with you I would not have included as much mitigation for rain and "Street Sweeping" and other silt management as there is is used in the NEI estimates.

A. You are correct. I should have divided by the estimated 2008 emissions as calculated with the existing AP-42. I think this was a hold over from when I was just looking at the road dust emissions estimates. When looking only at road dust emissions, all the zero emissions estimates is problematic since dividing by zero only generates errors in Excel. I added in the vehicle emissions when I saw how many 2008 NEI estimates were zero.

B. I would tend to agree with you as there are not many rain days. As I stated above, I don't know what mitigation is included in the "adjusted" emissions data in the NEI. Frankly to documentation of the NEI emissions estimates doesn't help me much to recreate their emissions estimates (see paved_roads_2294000000_documentation.doc which is attached).

C. Thanks for the calculations. I did these calculation only because a few internal EPA people suggested that I provide State/local agencies with some information to provide an indication of how this change might affect their inventories.

D. My original assessment also showed that the revised equation generates much lower PM10 estimates than the previous equation. From a combined emisions inventory perspective and use in the modeling for SIP development this should get support from inventory developers, modelers and Air Quality Assessors as it has always been difficult to explain how fugitive dust emissions are the majority of the emissions in the inventory but comprise less than 10% of the emissions on PM monitors. This will not get the inventory there but it goes in the right direction. I agree that for best emissions estimates, locally derived silt loadings are needed. However, no one wants to develop these and would rather complain that EPA's default values aren't good enough and they want better defaults. There is so much variation in silt levels on roads no single number is good enough for every road.

Ron Myers
U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Sector Policy and Programs Division
Monitoring Policy Group, D243-05
RTP NC 27711
Tel. 919.541.5407
Fax 919.541.1039
E-mail myers.ron@epa.gov

dave.james---08/18/2010 03:10:06 PM---Dear Ron, This is a resend, using a compressed version of the Excel file to reduce

From:

dave.james@unlv.edu

To:

Ron Myers/RTP/USEPA/US@EPA

Date:

08/18/2010 03:10 PM

Subject:

Fw: Dave's comments on the Excel workbook - do not need to be mentioned on the call

Dear Ron,

This is a resend, using a compressed version of the Excel file to reduce the file size,
in case my earlier send was rejected.

Please find attached some comments on the proposed new AP42 paved road equation

A) I think that, on tab PM10 Paved Roads EF's, column Z, the
column labeled "Percent Total Emissions Factor Increase" uses the formula
(column x - column s) / column x
to calculate percent changes. I think this should be, instead (column x - column s) / column s, so that
the percent change is calculated relative to the 2006 emissions factor equation instead
of the proposed new 2010 emissions factor equation
Column AD is the recalculated percent reduction for the rain corrected EF's based on this suggested equation revision

B) For the desert southwest, I think that it is best to look at the data without rain adjustments

C) In my edited tab "PM10 Paved Roads EF's" I have added several columns, AB, AC, and AD
(1) Column AB is the calculated raw reduction of 2010 dry EF's compared to 2006 dry EF's. (column u - column o)
(2) Column AC is the calculated percent reduction of 2010 dry EF's compared to 2006 dry EF's using
the equation (column u - column o)/column o

D) based on the 7,632 row data set in the tab PM10 Paved Roads EF's

(1) The new 2010 dry EF's are much lower overal l than the 2006 dry EF's. see the chart in the new tab labeled "compareNewOLDPM10EF's"

(2) The reductions of dry 2010 EF's compared to dry 2006 EF's linearly increase in magnitude with the magnitude of the original 2006 emissions factor (see the chart in the new tab labeled "reductions" - calculated in column AB)

(3) When I plot the percentage changes of the dry 2010 PM 10 EF's calculated) above against 2006 emissions factors, they are all around 70-80% (see the chart new tab labeled "percent reductions")

E) Athough national data might show reductions, since the new equation
1) raises the influence of silt loading (new exponent 0.98, old exponent 0.65)

2) lowers the influence of vehicle weight (new exponent 0.53, old exponent 1.5)
3) adds in an influence of vehicle speed,
4) eliminates the influence of the correction factor for exhaust brake and tire wear,
I would recommend that any assessment of the impact of the proposed new equation be
based on locally sampled data and not use the national data.

Thank you for the opportunity to comment.
Sincerely,
Dave

David E. James, PhD PE
Associate Vice Provost for Academic Programs
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http://provost.unlv.edu/acadaffairs.html

From: Steve Zemba <zemba@cambridgeenvironmental.com>
To: Ron Myers/RTP/USEPA/US@EPA
cc: gfore@hotmix.org, Mike <ames@cambridgeenvironmental.com>, Laura Green <green@cambridgeenvironmental.com>, HMarks@hotmix.org

Date: Tuesday, August 31, 2010 02:32PM
Subject: Comment on AP42 Paved Roads Draft Section 13.2.1
History: This message has been replied to and forwarded.

Dear Ron,

I write to provide the attached comment on the draft AP42 section on Paved Road dust emissions. As described in the comment, NAPA (who sponsored the review) is potentially interested in collecting data to provide more representative parameters for applications to the asphalt pavement industry. We would appreciate your advice on how best to gather these data so that they could be submitted for consideration in the AP42 section.

Thanks for your help and consideration,

Steve

--
Stephen G. Zemba, Ph.D., P.E.
Senior Engineer

Cambridge Environmental Inc

58 Charles Street
Cambridge, MA 02141

Office: 617-225-0810 x34 M-W 518-306-4603 Th-F
Cell: 339-223-9328
Fax: 617-225-0813
http://www.CambridgeEnvironmental.com

_AP42PavedRoadsSectionComment083110.pdf	**Type:** application/pdf **Name:** AP42PavedRoadsSectionComment(

Cambridge Environmental Inc

58 Charles Street Cambridge, Massachusetts 02141
617-225-0810 www.CambridgeEnvironmental.com

August 31, 2010

Ronald Myers
U.S. Environmental Protection Agency
109 T.W. Alexander Drive
Mail Code: D243-05
Research Triangle Park, NC 27709

Dear Ron,

It was a pleasure speaking with you again recently – thank you for the background information on the draft update to the AP42 section on Paved Road emissions (Section 13.2.1).

I have reviewed the draft update on behalf of the National Asphalt Pavement Association (NAPA), and write to comment on a specific aspect of interest. I believe that the recommended default values for silt-loading in draft Table 13.2.1-3, and particularly that for asphalt batching, may be too high for typical current applications. The recommended value is 120 g/m^2, but, as you know, in EPA's 2000 Emission Assessment Report for Hot Mix Asphalt Plants, a silt-loading value 3 g/m^2 is suggested for paved roads at typical hot-mix asphalt production facilities. Also, site-specific measurements at a hot mix asphalt facility in Alexandria, Virginia in 2005 (using the sampling and analytical methods described in AP42 Appendix C) found a silt loading level of 0.5 g/m^2. This facility, which we analyzed in detail for the City of Alexandria, employs aggressive dust suppression techniques.

More generally, as you know, best management practices (BMPs) such as water spraying and road sweeping can effectively control dust emissions; by the same token, the absence of these practices can indeed result in dusty roads. Perhaps the value of 120 g/m^2, which appears to be based on older data, derives from testing at one or more facilities that failed to employ BMPs. If so, then perhaps 120 g/m^2 could be considered to be a default value in the absence of BMPs, whereas the value of 3 g/m^2, as used in EPA's Emission Assessment Report, could be a default value in the presence of typical BMPs.

Of course, more data are always better. In that regard, we have spoken with representatives from NAPA , and they have expressed potential willingness to coordinate a study to provide updated values for silt loading and other emission factor parameters that reflect current practices in the hot-mix asphalt industry. At your convenience, might we schedule a call to discuss whether this would be of interest to you and your colleagues at the Agency?

Thank you for your consideration, and best regards.

Sincerely,

Stephen G. Zemba

Stephen G. Zemba, Ph.D., P.E.
Senior Engineer

IDNR comment on proposed AP 42 Section 13.2.1 Paved Roads

Hanson, Lori [DNR] to: Ron Myers 08/20/2010 10:45 AM

Cc: "McGraw, Jim [DNR]"

History: This message has been forwarded.

Mr. Myers,

I have attached the Iowa Department of Natural Resources comments on the proposed revision toAP42 section 13.2.1 on paved roads. Thank you for the opportunity to provide comments, Lori Hanson

Fields of Opportunities

STATE OF IOWA

CHESTER J. CULVER, GOVERNOR
PATTY JUDGE, LT. GOVERNOR

DEPARTMENT OF NATURAL RESOURCES
RICHARD A. LEOPOLD, DIRECTOR

August 20, 2010

U.S. Environmental Protection Agency (EPA)
Measurement Policy Group

Attn: Proposed Revisions to AP42 section13.2.1 Paved Roads

The Iowa Department of Natural Resources (IDNR) is providing comment on the proposed revision of AP-42 Section 13.2.1 for paved roads. The DNR supports the revision of this section to incorporate new data from corn wet mills and to account for mean vehicle speeds below 10 miles per hour.

The current AP-42 emission factor (November 2006) includes vehicle emissions (engine exhaust, tire wear and brake wear) in the empirical equation. Additionally there is a vehicle emission constant "C" that is subtracted from the equation. This "C" constant accounts for 1980's vehicle fleet exhaust, brake wear and tire wear and is subtracted from the equation to eliminate the possibility of double counting emissions and to account for the decrease in particulate emissions from improvements related to newer model trucks and cleaner fuels since the empirical equation was derived. A table of default values for "C" that varied with particle aerodynamic size range is included in the section.

The proposed empirical equation was developed by linear regression analysis after subtracting the engine, tire and brake wear estimated using EPA's MOBILE6.2 and MOVES2010 models from the measured impacts to estimate emissions solely from vehicle travel on the paved roads. To determine the total paved road emission factor, the emission factor from vehicle emissions generated by running either EPA's MOBILE6.2 or MOVES2010 models must be added to the emission factor from the empirical equation. This methodology requires that a mobile source emissions model be run in order to determine a paved road emission factor.

Obtaining the emissions factor for vehicle emissions in this manner will be problematic as the DNR does not have the resources to generate specific emissions factors for vehicle emissions by running MOVES2010 for every construction permitting project that includes a paved haul road. The DNR suggests that either the empirical equation be developed to include vehicle emissions from engine exhaust, tire and brake wear, or that a table of default values be included in the section to account for vehicle emissions as an alternative to running a mobile source emission model.

Thank you for the opportunity to comment on the proposed revision of AP-42 Section 13.2.1 for paved roads.

Sincerely,

for

Catharine Fitzsimmons, Chief
Air Quality Bureau

RE: PECHAN/ERTAC Road Dust Emissions

Pat Davis to: Roy Huntley, Ron Myers 07/26/2010 01:22 PM

History: This message has been replied to.

Hi Ron,

Have you had a chance to look into this issue?

To refresh your memory we noticed that a number of the PM2.5 emission factors
were zeroed out for a number of road types. Can you please tell us why the
road types listed below were zeroed out?

Urban Collector
Urban Minor Arterial
Urban Other Principal Arterial
Urban Other Freeways and Expressways
Urban Interstate

Thanks,
Pat Davis

-----Original Message-----
From: Huntley.Roy@epamail.epa.gov [mailto:Huntley.Roy@epamail.epa.gov]
Sent: Tuesday, July 13, 2010 1:38 PM
To: Myers.Ron@epamail.epa.gov
Cc: Pat Davis
Subject: Fw: PECHAN/ERTAC Road Dust Emissions

Ron, could you answer Pat question?

Roy Huntley
Environmental Engineer
Emission Inventory and Analysis Group
Mail Drop (C339-02)
Environmental Protection Agency
RTP, NC 27711
Voice - 919 541-1060
Fax - 919 541-0684
Office C341H
----- Forwarded by Roy Huntley/RTP/USEPA/US on 07/13/2010 01:24 PM -----
|>
| From: Pat Davis <pdavis@marama.org>
|
|>
| To: Roy Huntley/RTP/USEPA/US@EPA
|
>
|>
| Cc:
Judy Rand <Judy.Rand@dep.state.nj.us>, Julie McDill <jmcdill@marama.org>,
Pat Davis <pdavis@marama.org>, "Fees David F. (DNREC)"<David.Fees@state.de.us>,|
"WRBARNARD@mactec.com" <WRBARNARD@mactec.com>, Walter Simms <wsimms@mde.state.md.us>,
"kenneth.santlal@state.ma.us"<kenneth.santlal@state.ma.us |

|------------>
| Date: 07/13/2010 12:02 PM
|
|
| Subject: PECHAN/ERTAC Road Dust Emissions
|

>Hi Roy,

We have been examining the ERTAC/PECHAN emission factors for Road Dust and Maryland noticed that the PM2.5 emission factors were zeroed out for the following road types:

Urban Collector
Urban Minor Arterial
Urban Other Principal Arterial
Urban Other Freeways and Expressways
Urban Interstate

Emission factors for PM10 were found and there was no mention in the documentation of why the PM2.5 emission factors were zeroed out, so we are bit confused.

We were hoping that you might have answer for us, or be able to point us in the direction of someone who might know why the PM2.5 emission factors are zeroed out.

Thanks, and I hope you are well!
Pat Davis

FW: [chief] Proposed revisions to AP 42 section 13.2.1 Paved Roads
Julie McDill to: Ron Myers 06/23/2010 03:29 PM

History: This message has been replied to.

Hello Ron,

I called and left a message about possibly getting on a call with the MARAMA states in the next couple of weeks to discuss proposed changes to the Paved Road PM emissions estimation method.

Please respond to let me know if and when that might be possible. I can set up a conference call and distribute a slide set. It would be best sometime between July 7 and 16th. What follows (and the attachment) are some emails that give you a flavor of the changes that states are finding as a result of the new calculations. As you probably know, the PM emission from paved roads has always posed problems in modeling. In general, modelers take our inventories and reduced the paved road emissions by about 90% before running the model.

Thanks for your help.

Julie McDill
MARAMA

From: Judy Rand [Judy.Rand@dep.state.nj.us]
Sent: Wednesday, June 16, 2010 4:43 PM
To: Julie McDill; Pat Davis; rthunell@mde.state.md.us; David.Fees@state.de.us
Cc: Nicholle Worland; WRBARNARD@mactec.com; kenneth.santlal@state.ma.us
Subject: RE: [chief] Proposed revisions to AP42 section 13.2.1 Paved Roads

Thanks Dave. We have come up with similar results, but even more drastic for PM2.5. An increase in PM2.5 of 350% and a decrease in PM10 of 46% I think one big cause is the difference in k factor, among other changes. The k factor for PM2.5 went down from the 2003 AP-42 to the 2006 AP-42, and back up again in this new draft. We guessed at the new vehicle speed requirement, but a slight variation in speeds will not make that much of a difference.

See NJ's attached calcs and compare spreadsheet. I won't be in til Monday. If you want to have a call either Nicholle can cover it tomorrow, or we are in on Monday.

Judy

>>> "Fees David F. (DNREC)" <David.Fees@state.de.us> 6/16/2010 2:02 PM >>>
Roger,
Here is Delaware's paved road dust spreadsheet for 2007, using the new equation. We got very detailed with this category; estimating emissions by month.
Regarding the new equation, PM10 was reduced by 58% from the emissions submitted to MACTEC; while PM2.5 increased by 48%. I believe the PM2.5 increase is caused by two factors-first, the PM2.5/PM10 ratio was increased to 25% (previously 15%). The second reason is that under the old equation, one had to apply a correction factor, C, to remove the exhaust, brake, and tire wear from the front part of the equation. By subtracting C at the end of the equation, the resulting PM2.5 value went negative for several roadway types. Of course we zeroed these out, but with the new method there is never a

situation where the emission factor value can go negative. Having negative emission factors result from the use of the old equation was obviously a flaw in the method, so I expect the new equation is more accurate.
I look forward to NJ's results when they apply the new equation, to see if they get changes similar to mine.
If you have any questions about the calculations within the spreadsheet, just give a call.
Regards,
Dave
David F. Fees, P.E.
Managing Engineer
Emission Inventory Development Program
Air Quality Management Section, DNREC
tel. (302) 739-9402, fax (302) 739-3106
e-mail: david.fees@state.de.us<mailto:david.fees@state.de.us>

Blue Skies Delaware; Clean Air for Life

From: Roger Thunell [mailto:rthunell@mde.state.md.us]
Sent: Monday, June 14, 2010 3:00 PM
To: Judy Rand; Julie McDill; Pat Davis
Cc: WRBARNARD@mactec.com; Fees David F. (DNREC); kenneth.santlal@state.ma.us
Subject: RE: [chief] Proposed revisions to AP42 section 13.2.1 Paved Roads

Judy/Dave/Kenneth:
Could any of you send me a spreadsheet calculating emissions in this manner?
I am not sure if we are using the latest methods or not.

Thanks
Roger

>>> Pat Davis <pdavis@marama.org> 6/14/2010 12:54 PM >>>
Thanks a lot for sending this along, Judy. Please let us know what you find when you look at the changes in emissions.

Pat

-----Original Message-----
From: Judy Rand [mailto:Judy.Rand@dep.state.nj.us]
Sent: Monday, June 14, 2010 9:16 AM
To: Julie McDill; Pat Davis
Cc: WRBARNARD@mactec.com; rthunell@mde.state.md.us; David.Fees@state.de.us; kenneth.santlal@state.ma.us
Subject: Fwd: [chief] Proposed revisions to AP42 section 13.2.1 Paved Roads

Pat and Julie,
We are going to look at this to see how it affects emissions. In the past, each change to this category has changed emission calculations.
Thanks,
Judy

Judy Rand, PE
Environmental Engineer
NJDEP Air Quality Planning
(609) 984-1950
jrand@dep.state.nj.us

FW: Proposed revisions to AP 42 section 13.2.1 Paved Roads
Julie McDill to: Ron Myers 06/30/2010 04:25 PM

Hi Ron,
Here is the announcement for our call next week. Can you send me a slide set by noon next Tuesday and I will distribute it to the group and post it on our ftp.
Thanks,
Julie

From: Julie McDill
Sent: Tuesday, June 29, 2010 3:21 PM
To: Paul.Bodner@ct.gov; mark.prettyman@state.de.us; David.Fees@state.de.us; jessica.daniels@dc.gov; melanie.loyzim@maine.gov; rthunell@mde.state.md.us; kenneth.santlal@state.ma.us; david.healy@des.nh.gov; judy.rand@dep.state.nj.us; Nicholle.Worland@dep.state.nj.us; jdbarnes@gw.dec.state.ny.us; rwstanna@gw.dec.state.ny.us; sbogart@state.pa.us; karen.slattery@dem.ri.gov; jeff.merrell@state.vt.us; Thomas.Foster@deq.virginia.gov; laura.boothe@ncdenr.gov; Robert.J.Betterton@wv.gov; mcconnell.robert@epamail.epa.gov; Forde.Raymond@epamail.epa.gov; kremer.janet@epamail.epa.gov; huntley.roy@epa.gov; Susan Wierman
Cc: cooke.donald@epamail.epa.gov; burkhart.richard@epamail.epa.gov; Garcia.Ariel@epamail.epa.gov; Kelly.Bob@epamail.epa.gov; Salomone.Jenna@epamail.epa.gov; Wieber.Kirk@epamail.epa.gov; Moltzen.Michael@epamail.epa.gov; Laurita.Matthew@epamail.epa.gov; Feingersh.Henry@epamail.epa.gov; Kremer.Janet@epamail.epa.gov; Ellsworth.Todd@epamail.epa.gov; Leon-Guerrero.Tim@epamail.epa.gov; Cripps.Christopher@epamail.epa.gov; Rehn.Brian@epamail.epa.gov; Kotsch.Martin@epamail.epa.gov; Dolce.Gary@epamail.epa.gov; Kapichak.Rudolph@epamail.epa.gov; Houyoux.Marc@epamail.epa.gov; Timin.Brian@epamail.epa.gov; Stackhouse.Butch@epamail.epa.gov; Broadwell.Valerie@epamail.epa.gov; Ling.Michael@epamail.epa.gov; Fox.Tyler@epamail.epa.gov; Cook.Leila@epamail.epa.gov; Spink.Marcia@epamail.epa.gov; Wayland.Richard@epamail.epa.gov; Hemby.James@epamail.epa.gov; Wilkie.Walter@epamail.epa.gov; Fernandez.Cristina@epamail.epa.gov; Ruvo.Richard@epamail.epa.gov; Werner.Raymond@epamail.epa.gov; arnold.anne@epamail.epa.gov; Baker.William@epamail.epa.gov; Arnold.David@epamail.epa.gov; Conroy.Dave@epamail.epa.gov
Subject: FW: Proposed revisions to AP42 section 13.2.1 Paved Roads

Hello all,

This email is to announce a teleconference on July 7 at 2:30 PM Eastern concerning the proposed change to the equation used to estimate PM 10 and 2.5 emissions from paved roads. Ron Myers of OAQPS will provide a presentation on the development of the new equation and will answer your questions. Modellers and planners from MANE-VU state agencies along with some USEPA regional staff have been invited. Call in information is as follows:

Number: 866-202-1783
Code: *5743656* - Make sure you press * before and after the number.
Date: July 7
Time: 2:30 - 4:00 P.M. Eastern

BACKGROUND FOR THE CALL
This equation is used to calculate emissions for the area source modeling inventory. Delaware and New Jersey have already done some preliminary calculations and find the new equation results in very different values than the old equation. I attach their spreadsheets for your review. Toward the bottom of this email are texts of emails discussing the differences. In addition is the text distributed by NACAA which provides links to materials

for your formal comment to USEPA.

As you are no doubt aware, modellers have applied a transport fraction reduction to fugitive road dust emissions in the past to bring the calculated impact on ambient PM in line with measured concentrations. The new equation may require a revision to the transport fraction calculation. I have invited our NY modellers to join the call to hear the discussion so that they can consider any impact on the transport fraction calculation.

The new equation is proposed, so we can decide to use the old calculation method for our modeling inventory. That is what is in our current draft area source inventory files. However, States will then face a disconnect with the model for future emission calculations. At any rate, it seems to me that all states should use the same methodology so that the inventory is consistant accross our region.

Julie McDill
MARAMA

Relevant Email texts

From: Judy Rand [Judy.Rand@dep.state.nj.us]
Sent: Wednesday, June 16, 2010 4:43 PM

Thanks Dave. We have come up with similar results, but even more drastic for PM2.5. An increase in PM2.5 of 350% and a decrease in PM10 of 46% I think one big cause is the difference in k factor, among other changes. The k factor for PM2.5 went down from the 2003 AP-42 to the 2006 AP-42, and back up again in this new draft. We guessed at the new vehicle speed requirement, but a slight variation in speeds will not make that much of a difference.

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Roger,
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I look forward to NJ's results when they apply the new equation, to see if they get changes similar to mine.
If you have any questions about the calculations within the spreadsheet, just give a call.
Regards,
Dave

TO: NACAA EMISSIONS & MODELING COMMITTEE
Please information below regarding a proposed revision of the AP-42 paved roads section. The proposed draft can be found here - http://www.epa.gov/ttn/chief/ap42/ch13/index.html; scroll down to section 13.2.1, paved roads. EPA will take comments on the draft until July 30, 2010. For more information, please contact Ron Myers at myers.ron@epa.gov.

Emissions Comparison

		2002	2007 (Existing)	2007(new)	% Change
Annual	**pm-10 tpy**	37,606.28	38,210.45	20,532.18	-46%
	pm-2.5 tpy	3,788.42	1,142.03	5,110.37	347%
Summer	**pm-10 tpd**	115.11	105.70	56.75	-46%
	pm-2.5 tpd	11.56	3.13	14.12	351%
Winter	**pm-10 tpd**	95.87	101.69	54.74	-46%
	pm-2.5 tpd	9.69	3.13	13.63	336%
Spring	**pm-10 tpd**	99.94	105.08	56.41	-46%
	pm-2.5 tpd	10.07	3.11	14.04	351%
Fall	**pm-10 tpd**	101.03	106.23	57.08	-46%
	pm-2.5 tpd	10.18	3.15	14.21	352%

AP-42 k factors (g/mile)

	2003	2006	2010
PM-10	7.3000	7.3000	6.79
PM-2.5	1.8000	1.1000	1.69

2007 CAP Emissions Calculations

	PM10-FIL (TPY)			PM2.5-FIL (TPY)		
	Kent	New Castle	Sussex	Kent	New Castle	Sussex
Rural Oth. Princ. Art.						
January	3.0368	3.8504	5.6417	0.7558	0.9584	1.4042
February	2.8324	3.6256	5.2929	0.7050	0.9024	1.3174
March	3.3463	4.3680	6.3490	0.8329	1.0872	1.5802
April	3.4705	4.4744	6.6084	0.8638	1.1137	1.6448
May	4.3379	5.4584	8.1201	1.0797	1.3586	2.0210
June	4.4049	5.1675	8.5339	1.0964	1.2862	2.1240
July	5.1486	5.3205	10.4483	1.2815	1.3243	2.6005
August	4.8552	5.4994	10.3512	1.2084	1.3688	2.5764
September	4.2558	5.1069	7.7932	1.0592	1.2711	1.9397
October	3.6182	4.6311	6.9531	0.9006	1.1527	1.7306
November	3.2676	4.3388	6.2977	0.8133	1.0799	1.5675
December	2.9585	4.0132	5.7959	0.7364	0.9989	1.4426
	45.5327	**55.8543**	**88.1854**	**11.3329**	**13.9019**	**21.9489**
Rural Minor Arterial						
January	19.7917	0.9224	2.9397	4.9261	0.2296	0.7317
February	19.4746	0.9004	2.7698	4.8472	0.2241	0.6894
March	7.3003	1.0547	1.7424	1.8170	0.2625	0.4337
April	6.7427	1.0176	1.8092	1.6782	0.2533	0.4503
May	7.5361	1.1867	2.1881	1.8757	0.2954	0.5446
June	6.8577	1.0829	2.5017	1.7069	0.2695	0.6226
July	7.5020	1.1643	1.5249	1.8672	0.2898	0.3795
August	7.2545	1.1817	2.8365	1.8056	0.2941	0.7060
September	7.2050	1.1851	2.0514	1.7933	0.2950	0.5106
October	7.0923	1.1383	1.7639	1.7652	0.2833	0.4390
November	6.6536	1.0271	1.5527	1.6561	0.2556	0.3865
December	6.7191	0.9796	1.4285	1.6723	0.2438	0.3556
	110.1298	**12.8408**	**25.1086**	**27.4108**	**3.1960**	**6.2494**
Rural Major Collector						
January	17.4130	10.8453	81.4407	4.3340	2.6993	20.2702
February	15.2798	9.2386	74.5901	3.8031	2.2994	18.5651
March	6.6067	4.1449	31.0497	1.6444	1.0317	7.7281
April	6.3955	4.2942	30.7597	1.5918	1.0688	7.6560
May	8.4396	5.6208	36.4193	2.1006	1.3990	9.0646
June	8.9101	5.3072	11.1730	2.2177	1.3209	2.7809
July	8.7305	6.1122	13.2889	2.1730	1.5213	3.3075
August	7.9809	5.1746	12.3685	1.9864	1.2879	3.0785
September	9.0665	5.4730	33.1489	2.2566	1.3622	8.2506
October	8.0543	4.6414	30.6447	2.0047	1.1552	7.6273
November	6.8855	3.8170	28.0237	1.7138	0.9500	6.9750
December	5.8669	3.4370	27.2418	1.4602	0.8555	6.7804
	109.6292	**68.1062**	**410.1489**	**27.2862**	**16.9513**	**102.0842**
Rural Minor Collector						

2007 CAP Emissions Calculations

	PM10-FIL (TPY)			PM2.5-FIL (TPY)		
	Kent	New Castle	Sussex	Kent	New Castle	Sussex
January	7.5825	3.1843	9.1770	1.8872	0.7926	2.2841
February	6.6536	2.7126	8.4051	1.6561	0.6751	2.0920
March	2.8769	1.2170	3.4988	0.7160	0.3029	0.8708
April	2.7849	1.2609	3.4661	0.6931	0.3138	0.8627
May	3.6750	1.6504	4.1039	0.9147	0.4108	1.0214
June	3.8799	1.5583	4.0969	0.9657	0.3878	1.0197
July	3.8017	1.7946	4.8727	0.9462	0.4467	1.2128
August	3.4753	1.5194	4.5352	0.8650	0.3782	1.1288
September	3.9480	1.6069	3.7353	0.9826	0.4000	0.9297
October	3.5072	1.3628	3.4532	0.8729	0.3392	0.8595
November	2.9983	1.1207	3.1578	0.7463	0.2789	0.7860
December	2.5547	1.0092	3.0697	0.6359	0.2512	0.7640
	47.7380	**19.9970**	**55.5718**	**11.8818**	**4.9772**	**13.8316**
Rural Local						
January	72.2816	14.2450	182.5225	17.9906	3.5455	45.4290
February	63.4268	13.0827	167.1691	15.7866	3.2562	41.6076
March	20.6871	5.3708	17.8860	5.1489	1.3368	4.4517
April	20.0256	4.9021	17.7190	4.9843	1.2201	4.4102
May	26.4262	6.0689	20.9791	6.5774	1.5105	5.2216
June	9.5065	4.9294	20.9434	2.3661	1.2269	5.2127
July	27.3372	5.0483	24.9096	6.8041	1.2565	6.1999
August	24.9900	5.2372	23.1843	6.2199	1.3035	5.7705
September	9.6733	6.0687	19.0953	2.4076	1.5105	4.7527
October	25.2198	5.8458	17.6527	6.2771	1.4550	4.3937
November	21.5599	5.2538	47.3761	5.3662	1.3077	11.7917
December	18.3704	5.0929	46.0544	4.5723	1.2676	11.4627
	339.5044	**81.1457**	**605.4913**	**84.5011**	**20.1968**	**150.7040**
Urban Interstate						
January	0.0000	11.7187	0.0000	0.0000	2.9167	0.0000
February	0.0000	12.5883	0.0000	0.0000	3.1332	0.0000
March	0.0000	13.3265	0.0000	0.0000	3.3169	0.0000
April	0.0000	14.0185	0.0000	0.0000	3.4891	0.0000
May	0.0000	15.5068	0.0000	0.0000	3.8596	0.0000
June	0.0000	14.5005	0.0000	0.0000	3.6091	0.0000
July	0.0000	15.7325	0.0000	0.0000	3.9158	0.0000
August	0.0000	16.9323	0.0000	0.0000	4.2144	0.0000
September	0.0000	14.9430	0.0000	0.0000	3.7192	0.0000
October	0.0000	13.8368	0.0000	0.0000	3.4439	0.0000
November	0.0000	13.6508	0.0000	0.0000	3.3976	0.0000
December	0.0000	12.6716	0.0000	0.0000	3.1539	0.0000
	0.0000	**169.4261**	**0.0000**	**0.0000**	**42.1694**	**0.0000**
Urban Oth. Freeway						
January	2.2724	2.2051	0.0000	0.5656	0.5488	0.0000

2007 CAP Emissions Calculations

	PM10-FIL (TPY)			PM2.5-FIL (TPY)		
	Kent	New Castle	Sussex	Kent	New Castle	Sussex
February	2.1240	2.3687	0.0000	0.5287	0.5896	0.0000
March	2.6382	2.5076	0.0000	0.6566	0.6241	0.0000
April	2.6584	2.6378	0.0000	0.6617	0.6565	0.0000
May	3.3363	2.9179	0.0000	0.8304	0.7262	0.0000
June	3.5141	2.7285	0.0000	0.8747	0.6791	0.0000
July	4.2085	2.9604	0.0000	1.0475	0.7368	0.0000
August	4.1031	3.1861	0.0000	1.0213	0.7930	0.0000
September	3.2980	2.8118	0.0000	0.8209	0.6998	0.0000
October	2.6345	2.6036	0.0000	0.6557	0.6480	0.0000
November	2.3741	2.5686	0.0000	0.5909	0.6393	0.0000
December	2.1895	2.3844	0.0000	0.5450	0.5935	0.0000
	35.3512	**31.8807**	**0.0000**	**8.7988**	**7.9349**	**0.0000**
Urban Oth. Princ. Art.						
January	1.3373	13.5266	3.0648	0.3328	3.3667	0.7628
February	1.2472	13.0598	2.8754	0.3104	3.2505	0.7157
March	1.4735	14.9285	3.4491	0.3668	3.7156	0.8585
April	1.5282	14.5413	3.5900	0.3804	3.6193	0.8935
May	1.9102	16.7660	4.4112	0.4754	4.1730	1.0979
June	1.9397	15.0529	4.6360	0.4828	3.7466	1.1539
July	2.2672	15.1950	5.6760	0.5643	3.7820	1.4127
August	2.1380	15.2299	5.6233	0.5321	3.7906	1.3996
September	1.8740	15.1373	4.2336	0.4664	3.7676	1.0537
October	1.5933	14.6302	3.7772	0.3966	3.6414	0.9401
November	1.4389	13.7450	3.4212	0.3581	3.4211	0.8515
December	1.3028	13.7174	3.1486	0.3243	3.4142	0.7837
	20.0502	**175.5298**	**47.9065**	**4.9904**	**43.6886**	**11.9237**
Urban Minor Arterial						
January	4.3310	4.8764	2.4339	1.0780	1.2137	0.6058
February	4.2617	4.8104	2.2835	1.0607	1.1973	0.5683
March	4.6884	5.7734	1.3887	1.1669	1.4370	0.3456
April	4.3304	5.8589	0.7328	1.0778	1.4582	0.1824
May	4.8399	7.1419	0.9004	1.2046	1.7776	0.2241
June	4.4042	6.2220	0.9463	1.0962	1.5486	0.2355
July	4.8180	6.2667	1.1586	1.1992	1.5597	0.2884
August	4.6591	6.1525	1.1478	1.1596	1.5313	0.2857
September	4.6273	6.2988	0.8642	1.1517	1.5677	0.2151
October	4.5549	5.6747	0.7710	1.1337	1.4124	0.1919
November	4.2731	4.7114	0.6983	1.0636	1.1727	0.1738
December	4.3152	4.3381	1.2677	1.0740	1.0797	0.3155
	54.1031	**68.1252**	**14.5932**	**13.4660**	**16.9561**	**3.6322**
Urban Collector						
January	31.7118	16.1893	32.0745	7.8929	4.0294	7.9832
February	30.9520	0.0378	29.3765	7.7038	3.4325	7.3117

2007 CAP Emissions Calculations

	PM10-FIL (TPY)			PM2.5-FIL (TPY)			STATEWIDE	
	Kent	New Castle	Sussex	Kent	New Castle	Sussex	PM10-PRI	PM2.5-PRI
March	3.7702	9.2060	3.7580	0.9384	2.2913	0.9353		
April	3.4498	9.5377	3.7229	0.8586	2.3739	0.9266		
May	3.8650	12.4840	4.4079	0.9620	3.1072	1.0971		
June	3.5323	11.7876	4.4004	0.8792	2.9339	1.0952		
July	3.6517	13.5754	5.2337	0.9089	3.3789	1.3026		
August	11.2659	11.4931	4.8712	2.8040	2.8606	1.2124		
September	3.5772	12.1557	4.0121	0.8903	3.0255	0.9986		
October	3.5078	10.3087	3.7090	0.8731	2.5658	0.9231		
November	10.2321	8.4777	11.0368	2.5467	2.1101	2.7470		
December	10.0602	7.6337	10.7289	2.5039	1.9000	2.6704		
	119.5761	**122.8866**	**117.3317**	**29.7620**	**34.0090**	**29.2033**		
Urban Local								
January	43.1321	149.3299	23.6401	10.7354	37.1675	5.8839		
February	42.0987	137.1463	21.6515	10.4782	34.1351	5.3890		
March	16.6866	56.3019	9.0129	4.1532	14.0133	2.2433		
April	15.2685	51.3884	8.9287	3.8003	12.7903	2.2223		
May	17.1063	63.6201	10.5715	4.2577	15.8347	2.6312		
June	15.6337	51.6748	10.5535	3.8912	12.8616	2.6267		
July	16.1621	52.9218	12.5521	4.0227	13.1720	3.1242		
August	15.3230	54.9018	11.6827	3.8138	13.6648	2.9078		
September	15.8323	63.6183	9.6223	3.9406	15.8343	2.3949		
October	15.5252	61.2816	8.8953	3.8641	15.2527	2.2140		
November	13.9169	55.0759	8.1345	3.4639	13.7081	2.0246		
December	13.6832	53.3890	7.9076	3.4057	13.2883	1.9682		
	240.3684	**850.6498**	**143.1529**	**59.8266**	**211.7228**	**35.6301**		
All Roadway Types								
January	202.8901	230.8934	342.9350	50.4984	57.4683	85.3550	776.7185	193.3217
February	188.3509	199.5712	314.4139	46.8797	53.0954	78.2562	702.3359	178.2313
March	70.0744	118.1994	78.1346	17.4412	29.4193	19.4473	266.4084	66.3078
April	66.6544	113.9317	77.3368	16.5900	28.3571	19.2488	257.9230	64.1958
May	81.4724	138.4216	92.1014	20.2781	34.4525	22.9236	311.9955	77.6543
June	62.5833	120.0116	67.7849	15.5767	29.8703	16.8714	250.3798	62.3184
July	83.6273	126.0918	79.6648	20.8145	31.3837	19.8282	289.3839	72.0263
August	86.0449	126.5080	76.6007	21.4162	31.4873	19.0656	289.1537	71.9690
September	63.3575	134.4055	84.5562	15.7694	33.4529	21.0457	282.3192	70.2680
October	75.3075	125.9550	77.6201	18.7437	31.3496	19.3193	278.8826	69.4126
November	73.6000	113.7869	109.6988	18.3187	28.3210	27.3035	297.0857	73.9433
December	68.0204	108.6660	106.6430	16.9300	27.0465	26.5430	283.3294	70.5194
	1121.9831	**1656.4422**	**1507.4902**	**279.2565**	**415.7040**	**375.2074**	**4285.9155**	**1070.1679**

comments to draft AP-42 paved road section

Gary Garman to: Ron Myers 06/24/2010 12:58 PM

Please respond to ggarman

History: This message has been replied to and forwarded.

Ron,

It's good to see the paved road section is being revised. Thanks. It has been a challenge in the past explaining to industrial clients that paving a road would actually result in higher predicted emissions than if the road is left unpaved. I think we'll see more paving and actual emission reductions as a result of the new equation. A few editorial comments on the draft paved road section:

Page 13.2.1-1, third paragraph, first sentence..change to "The particulate emission factors presented in a previous version.."
Page 13.2.1-5, third paragraph, last sentence..change "Table 13.2.1-3" to "Table 13.2.1-2"
Page 13.2.1-8, fifth paragraph, first sentence..change "Table 13.2.1-3" to "Table 13.2.1-2"
Page 13.2.1-9, second paragraph, second sentence..remove hyphen between "not" and "suggest"
Table 13.2.1-3...the page number this table is on should be changed to 13.2.1.10. Also, total loading range for iron and steel should be 0.006-4.77, not 43.0-64.0.
Page 13.2.1-11, first paragraph, fourth sentence..remove hyphen between "any" and "of"

Thanks again. I look forward to this draft being finalized.

Gary
--
Gary Garman
Environmental Scientist

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