TECHNICAL REPORT

PARTICULATE MATTER AND TRANSPORTATION PROJECTS, AN ANALYSIS PROTOCOL

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Katherine Nanzetta, Research Assistant (UCD)
Douglas Eisinger, Program Manager (UCD)
Tom Kear, Research Engineer (UCD)
Robert O'Loughlin, Air Quality Specialist (FHWA)
Michael J. Brady, Sr. Env. Engineer (Caltrans)

Dr. Deb Niemeier, Principal Investigator
Dept. of Civil and Env. Engineering
University of California
One Shields Ave.
Davis, CA 95616

Prepared for:

The California Department of Transportation
Environmental Program, MS-32
1120 N Street
Sacramento, CA 94274
(916) 653-0158

The U.S. Federal Highway Administration
Western Resource Center
201 Mission Street
San Francisco, CA 94105
(415) 744-3823

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Request to develop a project-level PM_{10} analysis protocol to satisfy the transportation conformity requirement for hot spot PM_{10} analyses.

ABSTRACT

Transportation conformity regulations require an evaluation of the impact of transportation projects on the concentration of particulate matter less than 10 microns in aerodynamic diameter (PM_{10}). As of early 2005, the U.S. Environmental Protection Agency (EPA) had not released quantitative assessment guidance; thus, the conformity regulations require only qualitative PM_{10} evaluations. In December 2004, EPA published proposed regulations to revise the PM hot spot analysis requirements. The proposed regulations include various PM_{10} and $PM_{2.5}$ analysis requirement options, but do not yet include or reference guidance materials needed to complete such analyses. Absent analysis tools and guidance on how to conduct quantitative analyses, which is largely due to the complexity of the primary and secondary nature of PM_{10} problems, project analysts have struggled to determine project level impacts on localized PM_{10} concentrations. This report describes a new protocol for qualitatively analyzing project-level PM_{10} effects to determine whether a transportation project will create a PM_{10} "hot spot" problem. The protocol was developed by the UC Davis-Caltrans Air Quality Project at the University of California, Davis (U.C. Davis) on behalf of the California Department of Transportation (Caltrans) and the U.S. Federal Highway Administration (FHWA). The protocol includes a four-part methodology to screen projects unlikely to contribute to exceedances of the PM_{10} air quality standards: (1) a "project comparison" approach for maintenance areas that allows users to compare the proposed project to pre-existing facilities, (2) a "project comparison" approach for nonattainment areas, (3) a "threshold screening" analysis that takes advantage of real-world measurements of the contribution of roadways to observed PM_{10} concentrations, and (4) a "relocate and reduce, build vs. no-build" approach that assesses whether a project will spatially reallocate traffic to reduce hot spot problems. Project analysts can use the protocol as a resource to comply with the transportation conformity regulations.

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INTRODUCTION AND MOTIVATION

One of the more vexing air quality problems facing transportation and air quality planners involves meeting transportation conformity emission budget requirements for on-road mobile source primary emissions of particulate matter less than 10 microns in aerodynamic diameter (PM_{10}). Estimated tailpipe emissions of pollutants such as carbon monoxide (CO), volatile organic compounds (VOCs), and oxides of nitrogen (NO_x) have exhibited a downward trend over time as cleaner-operating cars, trucks, and buses enter the vehicle fleet and replace aging and higher-polluting vehicles; reductions have been most pronounced for CO and VOC, although the U.S. Environmental Protection Agency (EPA) documents declining on-road motor vehicle NO_x emissions since 1997 (USEPA, 2002a; Tables A-2, A-4, A-5). In contrast, estimated primary on-road mobile source PM_{10} emissions, which are mostly composed of re-entrained road dust, plus minor contributions from tire wear, brake wear, and tailpipe exhaust, are trending upward over time (e.g., see 1996 through 2000 paved road emission data; USEPA, 2002a; Table A-6).

Primary PM_{10} road dust emissions are estimated as a function of vehicle miles traveled (VMT): the greater the VMT, the higher the estimated primary PM_{10}. The U.S. Environmental Protection Agency (EPA) directly links estimated primary PM_{10} to VMT in its emission estimation methodology by computing an emission factor in grams per VMT, as described in Equation 1 (USEPA 1995).

Equation 1: EPA AP-42 road dust emissions methodology

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

where:

E = particulate emission factors (in g/VMT)
k = base emission factor (in g/VMT) for PM equal or less than a given diameter
sL = road surface silt loading (in g/m^2)
W = average weight of the vehicles traveling the road (in tons)

Equation 1 has important implications for planners responsible for forecasting travel and expected emissions. Inevitably, regional transportation plans (RTPs) forecast VMT increases over time that parallel or exceed expected population growth rates. Metropolitan areas exceeding National Ambient Air Quality Standards (NAAQS) for PM_{10} have to offset increased primary emissions from on-road motor vehicles by reducing other primary PM_{10} sources, or by reducing secondary PM_{10} formation (that is reducing emissions of pollutants such as VOC and NO_x that contribute to atmospheric formation of aerosol particles).

Transportation conformity regulations require planners to demonstrate that proposed transportation projects will not "cause or contribute to any new localized" PM_{10} violations, or "increase the frequency or severity of any existing" PM_{10} violation in PM_{10} nonattainment and maintenance areas (USEPA 1997). Conformity project-level, or hot spot analyses for PM_{10} are currently a qualitative requirement, pending EPA's release of guidance on how to conduct quantitative analyses (USEPA 1997).

In 2001, the Federal Highway Administration (FHWA) released general guidance for preparing transportation project-level PM_{10} conformity analyses (FHWA, 2001). The California Department of Transportation (Caltrans) and FHWA sought to build upon FHWA's 2001 guidance document by providing planners with a step-by-step tool to assist those responsible for documenting transportation project-level, or hot spot, PM_{10} effects. This report presents a step-by-step PM_{10} qualitative analysis protocol prepared to assist Caltrans and FHWA. The protocol allows users to qualitatively screen projects from transportation conformity analyses that are unlikely to create PM_{10} hot spot problems.

Although designed to address the transportation conformity requirements, the protocol may also be used to satisfy National Environmental Policy Act (NEPA) analysis requirements. Protocol users should understand, however, that for NEPA purposes, use of the protocol needs to be supplemented to account appropriately for other PM-related issues such as air toxics or $PM_{2.5}$.

On December 13, 2004, EPA published a Supplemental Notice of Proposed Rule Making (SNPRM) announcing the agency's intention to further revise the transportation conformity PM hot spot analysis requirements (USEPA, 2004). EPA's SNPRM proposes several hot spot analysis requirement options for both PM_{10} and $PM_{2.5}$. The analysis approaches detailed in this document provide project analysts with several tools likely to be of assistance once EPA issues its final PM hot spot regulations. Although this document focuses solely on PM_{10}, the principles upon which this document is based should also provide insights to help address $PM_{2.5}$ hot spot questions. Further research is needed, however, to provide specific analysis guidance regarding $PM_{2.5}$ hot spot assessments.

The underlying foundation for the protocol is the scientific literature describing the relationship between on-road traffic, emissions, and PM_{10} concentrations. Where possible, the protocol takes advantage of peer-reviewed literature documenting real-world observations of on-road contributions to PM_{10}. The protocol also employs analysis techniques based on measured air quality data, EPA and California Air Resources Board (CARB) emission factors, and EPA-approved analysis concepts currently employed to meet the federal transportation conformity requirements for ozone precursors and carbon monoxide. Although the protocol is based, in part, on California data, it may be applied in any PM_{10} nonattainment or maintenance area. The protocol is not required for use, but is available to analysts as a resource when completing PM_{10} hot spot analyses under the transportation conformity regulations.

ELIGIBILITY CHECKLIST

The protocol is not appropriate for all transportation projects. Some transportation projects are exempt from conformity analyses, other projects may not yet be included in conforming transportation improvement programs (TIPs) or RTPs, and others may be quickly screened out without the effort of working through the more detailed protocol steps. **Table 1** includes a checklist of eight questions to help analysts determine whether the protocol applies for their respective project analysis. Background material and discussion of the supporting research used to develop Table 1 are given in Appendix A.

PROTOCOL STEP-BY-STEP PROCEDURES

Assuming the protocol is applicable for a particular project analysis and the project is not immediately screened out, analysts begin by proceeding through four roughly sequential processes. A project that screens out at any point in a process does not continue to a subsequent process. For each of the four analysis processes included in **Figure 1**, the following discussion outlines the underlying conceptual logic for the approach and briefly describes each process.

Table 1. Applicability of the protocol for a specific project. [1]

Eligibility Checklist

The project may be immediately screened out if

1. The project is exempt from conformity.
2. The project is not in a federal PM_{10} nonattainment or maintenance area.
3. The project is not funded or approved by FHWA or the Federal Transit Administration (FTA).
4. The project "build" VMT is less than or equal to the "no-build" VMT.
5. There are no receptors within 100 m of the proposed project location.

The protocol is not appropriate if any of the following conditions are met:

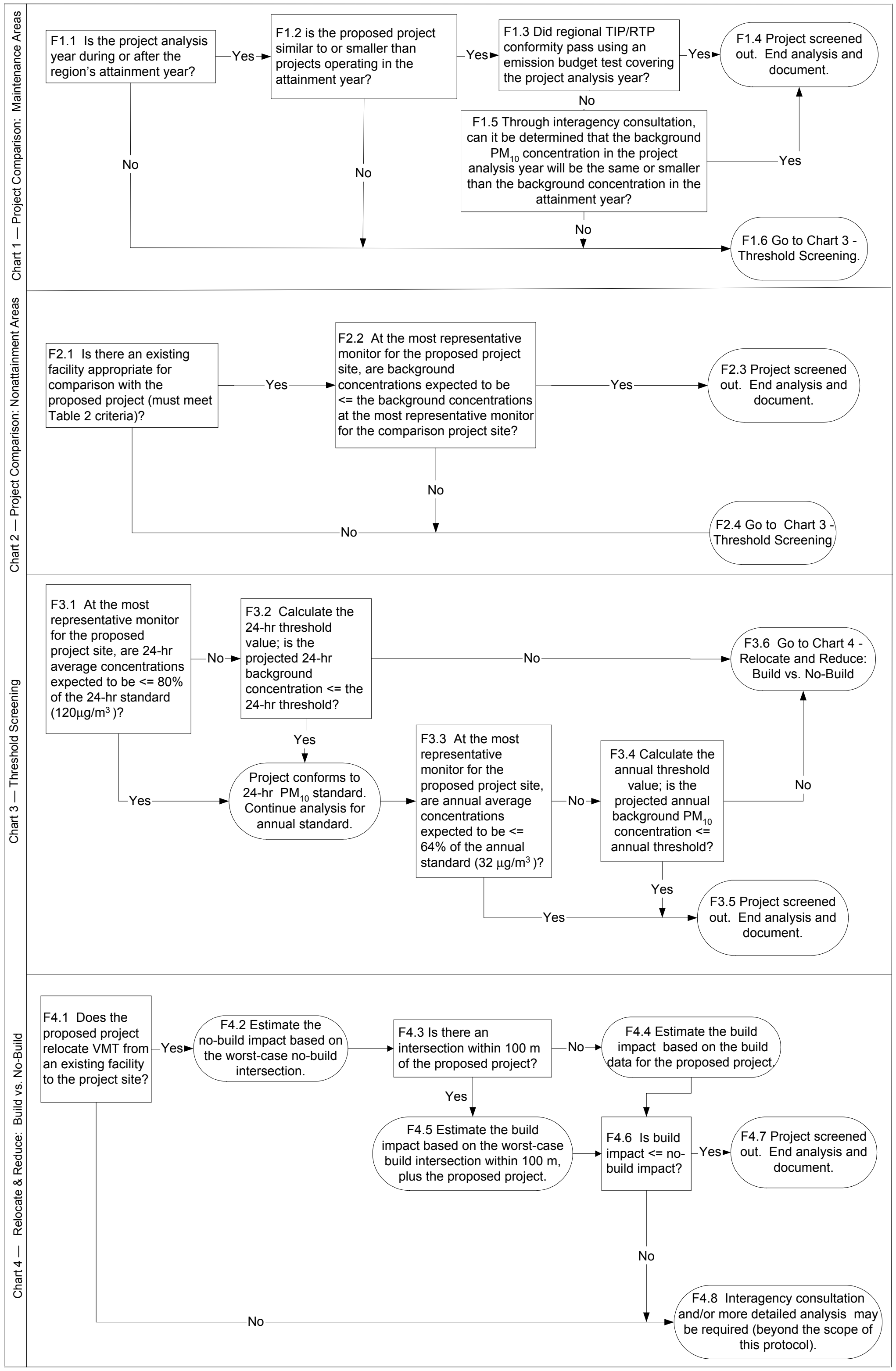
6. The project is not included in a conforming TIP or RTP.[2]
7. PM_{10} concentrations at the project site are dominated by non-vehicular sources.
8. The expected proportion of heavy-duty diesel VMT for the proposed project differs from regional facilities of the same type (e.g., 20% of the vehicles forecasted to use the proposed project are anticipated to be diesel trucks, compared to similar regional facilities where diesel trucks constitute only 5% or 6% of the vehicle fleet).

Explanation of Checklist

- Conditions 1, 2, and 3 relate to specific elements of the transportation conformity requirements; if any of the conditions are true, no further analysis is required.
- Conditions 4 and 5 relate to situations that should not result in a hot spot problem. Current PM_{10} estimation procedures link emissions to VMT (Equation 1); identical or lower VMT effectively means no increased PM_{10}. Field studies indicate that roadway contributions to PM concentrations largely dissipate within 100 m from the road.
- Conditions 6, 7 and 8 relate to situations best addressed through interagency consultation, rather than through use of the protocol.

[1] Appendix A includes a more detailed discussion of the technical material supporting the eligibility checklist.
[2] Projects in rural areas may not be included in a conforming RTP or TIP. Analysts in rural areas should check through interagency consultation to determine whether the protocol may still be used.

Figure 1. Flowchart illustrating the step-by-step qualitative PM_{10} analysis protocol.



Process 1, Project Comparison: Maintenance Areas

Conceptual Logic of Process 1

This step compares the proposed project to other projects in the attainment year. Two elements are important to screening out projects in this step. First, the project cannot have higher average daily traffic volumes than other projects already in existence or projected to exist in the attainment year. Second, analysts need to show that background PM_{10} concentrations in the proposed project's *analysis year* are not expected to be greater than background concentrations in the *attainment year*. The underlying logic for this step is that an area that has achieved the air quality standards is, by definition, not experiencing PM_{10} violations. Thus, by induction, none of the projects from the set of transportation projects in the region at the time of attainment should be hot spot problems. Since a hot spot problem is a function of the incremental PM_{10} contribution from the project plus background PM_{10} concentrations, this analysis requires the analyst to document that, over time, background concentrations will not increase such that the proposed project results in a violation. This is a check to prevent future hot spot violations beyond the attainment year for the area.

Detailed Process

F1.1 begins by determining whether the project analysis year falls on or after the region's attainment date. For the project comparison approach to work in maintenance areas, the region must already have achieved attainment of the PM_{10} standards prior to the analysis year of the proposed project.

F1.2 checks whether there are appropriate comparison projects. To allow comparisons to existing projects, the proposed project cannot have higher average daily traffic volumes than, and must be similar in design concept and scope to, one of the projects included in the RTP or TIP for the attainment year. The attainment year comparison project should be a pre-existing project operating at the time of attainment, not a project that the RTP or TIP included among those planned for future construction.

F1.3 considers whether background PM_{10} concentrations are acceptable. A project's contribution to observed hot spot PM_{10} concentrations is a function of the incremental PM_{10} contribution from the project plus background PM_{10} concentrations. The project comparison approach assumes that for the project *analysis year*, background PM_{10} concentrations have not worsened (i.e., increased) compared to background concentrations assumed for the *attainment year*. Step F1.3 provides a quick check of this assumption by asking analysts to determine whether RTP or TIP conformity findings employed a PM_{10} emission budget test. Regional conformity determinations that meet PM_{10} emission budget tests for future years demonstrate that background PM_{10} concentrations are not problematically high when combined with incremental project contributions for the projects included in the RTP and TIP.

The F1.3 project comparison approach is conservative, meaning it errs on the side of being environmentally protective. An illustration helps explain the principles embedded in the approach. Assume:

1. A regional PM_{10} attainment year of 2006.
2. A proposed intersection (the *proposed project*) with a 2011 analysis year.
3. An existing intersection (the *comparison project*) which, in attainment year 2006, experiences similar traffic volumes and is otherwise comparable in design concept and scope to the proposed project in 2011.
4. An RTP that extends to year 2025 and a regional conformity analysis that met emission budget tests from 2006 through 2025.

Since the RTP met emission budgets from 2006 through 2025, by definition future-year background PM_{10} concentrations are projected to decrease enough to offset any rise in primary PM_{10} emissions due to increased VMT. By 2011, the comparison project will likely have higher VMT than experienced in 2006; however, the comparison project is still acceptable by 2011 since regional conformity was acceptable. Thus, comparing the 2011 proposed project to the comparison project's 2006 operating volumes is conservative because background concentrations will be lower in 2011; we could reasonably assume that the proposed project would be acceptable even if its traffic volumes resembled the year-2011 volumes for the comparison project, rather than the (probably lower) year-2006 traffic volumes used in the analysis.

F1.4 is the analysis end point; protocol users should document the analysis assumptions used to determine that the project will not create a PM_{10} hot spot problem. F.1.5 handles cases where regional conformity determinations are based on build vs. no-build tests, rather than a budget test. Analysts are directed to confirm analysis year background conditions through interagency consultation. Finally, F.1.6 directs users to continue to Process 3, Threshold Screening, in the event the proposed project was not screened out in Process 1.

Process 2, Project Comparison: Nonattainment Areas

Conceptual Logic of Process 2

In this process, which is analogous to Process 1, the PM_{10} protocol user is instructed to find a similar or larger-scale project that is already built and for which there are no recorded violations of the PM_{10} standards. The existing project must be located in a geographically and meteorologically similar area to the proposed project. Since the existing project has exhibited no violations, the proposed project can be screened from further analysis. The main difference between Process 2 and Process 1 is that Process 2 can be applied in nonattainment regions. Conceptually, this step allows for those unique situations where an entire metropolitan area may be nonattainment, but where some portions of the nonattainment region are either upwind or meteorologically isolated such that localized PM_{10} violations are not occurring in those upwind or isolated areas.

Detailed Process

F2.1 assists the analyst in finding an appropriate existing project to use for comparison purposes. The criteria are more restrictive than those used to identify a comparative project in Process 1 (**Table 2**). Since by definition the region is nonattainment, at least some parts of the region exceed the PM_{10} NAAQS, and, therefore, the set of eligible comparative projects in the region will be smaller.

Table 2. Criteria for identifying projects for comparison (nonattainment regions).

Criteria that Comparison Project Must Meet
1. Located in the same nonattainment area as the proposed project
2. Same facility type/silt loading as proposed project
3. Nearby monitored PM_{10} concentrations below the federal PM_{10} standards
4. Greater or equal traffic volumes as the proposed project's analysis year volumes
5. Similar fleet mix as proposed project, especially regarding heavy-duty diesel vehicles
6. Similar yearly rainfall as proposed project site
7. Similar wind patterns as proposed project site
8. Similar temperature ranges as proposed project site

F2.2 includes a check on background PM_{10} concentrations (analogous to step F1.5). F2.3 is the analysis end point; protocol users should document the analysis assumptions used to determine that the project will not create a PM_{10} hot spot problem. F2.4 directs users to continue to Process 3, Threshold Screening, in the event the proposed project was not screened out in Process 2.

Process 3, Threshold Screening

Conceptual Logic of Process 3

This approach compares a project's contribution (or incremental addition) to the ambient PM_{10} concentration with an allowable threshold. The threshold is defined as the national ambient air quality standard less estimated background concentrations. For example, if the 24-hr background concentration was 120 ug/m^3; the 24-hr allowable threshold would be the 150 ug/m^3 standard less the 120 ug/m^3 background concentration, or an allowable incremental project contribution of no more than 30 ug/m^3.

Field studies at several road sites have measured the difference between upwind and downwind PM_{10} concentrations. The studies document incremental PM_{10} contributions made by the road project (freeway, arterial, intersection) and identify traffic volumes and meteorological conditions associated with the observed PM_{10} concentrations. **Appendix B** includes summary information describing the field study literature used to create the Threshold Screening portion of the Protocol. In this step, protocol users use the literature to determine whether the proposed project is similar enough in nature to be compared to projects identified in the literature. Protocol users also estimate the incremental PM_{10} contribution expected from the proposed project, based on comparisons to the findings in the literature. This process allows the user to document whether the incremental PM_{10} contribution plus the background PM_{10} concentration would be below the PM_{10} air quality standards. The protocol relies on two layers of analysis: first, the proposed project is screened against the 24-hr PM_{10} NAAQS, and second, the project is screened against the annual PM_{10} NAAQS.

Inherent in the Threshold Screening approach is an understanding that regional and microscale PM_{10} concentrations do not exceed the NAAQS in the project analysis year. Projects in areas exceeding the NAAQS must continue to Step 4, Relocate and Reduce.

Note that the literature is limited. Protocol users should compare the proposed project's design concept and scope to the projects found in the literature and assess whether the proposed project may be reasonably compared to the projects documented in the literature. Mitigation components of a proposed project may be incorporated in this protocol step; refer to Appendix E for discussion and examples.

Detailed Process

F3.1 serves to check whether the project passes the 24-hr PM_{10} NAAQS screening test. The approach is conservative in that the protocol selects the highest incremental road contribution (29.6 $\mu g/m^3$) observed in the literature and uses that value to establish an expected 24-hr increment from a proposed project (Ashbaugh et al 1996). **Table 3** includes a summary of the reported incremental PM_{10} contribution from roads. Protocol users should refer to Appendix B, which describes in greater detail the studies used to create Table 3, to determine whether the material in Table 3 may be appropriately compared to the project being analyzed.

Table 3 is based on real-world observations and serves as a useful check to estimate the potential incremental PM_{10} contribution from a specific facility; it is conservatively based on the highest PM_{10} contributions observed in the available literature. In addition to being conservative by selecting the highest observed incremental contribution (see Table 3 values), the protocol also (conservatively) adopts the highest incremental contribution measured *over 3 hours* in the real-world to represent a *24-hr increment*; this likely overstates the actual road increment. Since the 24-hr PM_{10} NAAQS is 150 $\mu g/m^3$, and the highest estimated roadway increment over all project types measured was 29.6 $\mu g/m^3$, proposed projects are considered not to cause a hot spot violation if they will be located in areas where the 24-hr background concentrations are less than 120 $\mu g/m^3$ (150 – 30).

F3.2 provides users with a methodology to refine the proposed project's estimated incremental contribution. Assuming the proposed project failed step F3.1, step F3.2 compares the proposed project to each of the projects observed in the literature. If the protocol user finds an appropriate match between the proposed project and a project documented in the literature, the user may then estimate the proposed project's incremental PM_{10} contribution (Table 3). The difference between step F3.1 and step F3.2 is that F3.1 used the highest incremental value observed in the literature, independent of project design concept and scope. Step F3.2 provides the user an opportunity to substitute a lower 24-hr incremental value by finding an appropriate comparison project in the literature.

Table 3. Threshold table to estimate 24-hr PM_{10} project-level incremental contribution.

Facility Type	Veh/hr	Veh/day	Reported Incremental PM_{10} Concentration Based on Maximum Field Measurements ($\mu g/m^3$)[a,b,c]	Reference
Intersection	4,517		29.6[d]	Ashbaugh et al.1996
		68,000	5.8	Cowherd and Grelinger 1998
Freeway	5,517		5.3	Cahill et al.1994
		>150,000	8.0	Venkatram and Fitz 1998
Arterial	1000		21.0	Venkatram and Fitz 1998
Collector	200		15.9	Venkatram and Fitz 1998
Local	20		10.9	Venkatram and Fitz 1998

[a]The reported field measurements are based on various averaging times of 24 hours or less. To be conservative, the protocol does not adjust the values but uses them as-is to approximate 24-hr incremental contributions. For example, the 29.6 $\mu g/m^3$ value reported by Ashbaugh et al. (1996) was measured over a 3-hr sampling period. Presumably, 24-hr average values would be less than the 3-hr value.

[b]Protocol users should compare their proposed project's design concept and scope to the information in Table 3 and determine whether there is an appropriate comparison available; we recommend applying Table 3 findings in a manner that conservatively represents incremental PM_{10} contributions (i.e., in a way that likely over-estimates, rather than underestimates, the likely PM_{10} contribution from a proposed project). Appendix B includes more details on the field studies cited in Table 2.

[c]Table 3 values represent information available at the time the protocol was developed. Protocol users should substitute more recent information as it becomes available.

[d]The Ashbaugh et al. (1996) 29.6 $\mu g/m^3$ value is the highest reported and was selected to create the screening level referred to in step F3.1 of the protocol (see Figure 1).

F3.3 assumes the project has passed the 24-hr screening test and serves as a check on whether the project passes the annual PM_{10} screening test. Field data were unavailable to directly estimate annual roadway incremental PM_{10} contributions. Consequently, the protocol estimates an annual increment by applying a conversion ratio (CR) to convert 24-hr values into annual values (Equation 2). The approach is conservative because the maximum 24-hr increment discussed in step F3.1 is selected as the initial value in this conversion. To develop a conversion ratio, we calculated the ratio between observed 24-hr and annual average PM_{10} concentrations using monitored 1998-2000 California data (California Air Resources Board 2001). A CR should be estimated for the three most recent years of monitoring data, and the maximum (most conservative) of those three values should be used. Further discussion is given in Appendix C.

Equation 2: Conversion ratio between 24-hr and annual average PM_{10} concentrations.

$CR = PM_{Ann} / PM_{24\text{-}hr}$

where for a specific monitor,

CR	=	conversion ratio to adjust 24-hr values to represent annual values
PM_{Ann}	=	average of all quarterly mean PM_{10} concentrations
$PM_{24\text{-}hr}$	=	maximum monitored 24-hr concentrations

For each county in California, we selected the monitor that yielded the highest CR value within that county. For protocol screening purposes, we then selected the highest CR value from among all the counties and used that value to represent the relationship between 24-hr and annual average PM_{10} values. In California, the highest CR value was 0.60, although values will differ by area of the country (in California, CR ranged from 0.08 to 0.60; see Table C-1). Applying the 0.60 CR value to the maximum observed 24-hr increment, we estimated a maximum annual roadway PM_{10} increment of 17.8 $\mu g/m^3$ (29.6×0.60). Step F3.3 establishes whether annual average background PM_{10} concentrations are expected to be less than or equal to 32 $\mu g/m^3$ (the annual standard of 50 $\mu g/m^3$, minus the maximum annual road increment of 17.8 $\mu g/m^3$). If annual background PM_{10} concentrations are sufficiently low, the project passes the annual screening test.

F3.4 provides users with a methodology to refine the estimated annual incremental contribution from a project if the project fails step F3.3. The protocol suggests two steps to develop a project-specific annual PM_{10} increment. First, the protocol directs analysts to select a 24-hr increment value that best represents the proposed project (analogous to step F3.2, which directs users to Table 3). Second, the protocol suggests that analysts use a CR that is appropriate for the region in the vicinity of the proposed project. Screening step F3.3 used the most conservative CR for California; projects proposed for other parts of California should use the CR that is specific to the project location. **Table 4** includes example data used to estimate the CR for California counties; Appendix C includes CR values for all California counties. To use the protocol outside of California, analysts can compute a CR or select a surrogate from the California list.

Table 4. Example 24-hr toannual average PM_{10} conversion ratios (CR) for California counties.

Location	Year	Annual Average PM_{10} / Max 24-hr ($\mu g/m^3$) = CR	Max CR
Lowest Estimated CR for all California Counties			
San Francisco Bay Air Basin, Solano County	1998	17.19 / 71.3 = 0.241	0.28
	1999	19.34 / 83.7 = 0.231	
	2000	14.96 / 53.0 = 0.282	
Highest Estimated CR for all California Counties			
Mountain Counties Air Basin, Sierra County	1998	22.61 / 60.0 = 0.377	0.60
	1999	25.01 / 68.0 = 0.368	
	2000	23.43 / 39.0 = 0.601	

Source: California Air Resources Board (2001). See Appendix C for more information and CR values for all California counties, excluding values for Inyo, Mono, and Imperial counties which are dominated by wind blown dust.

F3.5 is the analysis end point; protocol users should document the analysis assumptions used to determine that the project will not create a PM_{10} hot spot problem. F3.6 directs users to continue to Process 4, Relocate and Reduce: Build vs. No-Build, in the event the proposed project was not screened out in Process 3.

Process 4, Relocate and Reduce: Build vs. No-Build

Conceptual Logic of Process 4

Projects that are not screened out under the previous processes will undertake the final protocol analysis process. In Process 4, the purpose is to estimate whether the proposed project would result in relocating existing traffic and whether, in the process of relocating that traffic, reduce the expected worst-case PM_{10} concentrations in the project area. The regulatory premise for this process was expressed by EPA in the preamble to its 1993 transportation conformity rule, where EPA discussed approaches for conducting PM_{10} project-level hot spot analyses:

> EPA continues to believe that a seemingly new violation may be considered to be a relocation and reduction of an existing violation only if it were in the area substantially affected by the project and if the predicted design value for the "new" site would be less than the design value at the "old" site without the project—that is, if there would be a net air quality benefit (EPA, 1993; p. 62213a).

This process allows protocol users to estimate whether a net air quality benefit occurs within the area substantially affected by the project. Conceptually, the approach is best suited for projects that move existing traffic from roads with higher silt loads, such as local streets or arterials, to roads with lower silt loads such as freeways. For example, the proposed project may alleviate congestion on an existing facility by moving traffic from local streets and intersections onto a less congested major arterial or a highway. Studies indicate that on a per-vehicle basis, PM_{10} concentrations contributed by freeways can be up to an order of magnitude lower than intersection or arterial contributions of PM_{10} (U.S. Environmental Protection Agency 2002; California Air Resources Board 1997). The approach is suitable for either PM_{10} nonattainment or maintenance areas.

The main analytical technique employed by the "relocate and reduce" approach is to convert build and no-build traffic volumes to common "freeway-equivalent" units. EPA and California Air Resources Board (CARB) document default silt loads by road type, with freeways having the lowest silt loads, and arterials and local streets having the highest silt loads (U.S. Environmental Protection Agency 2002; California Air Resources Board 1997). The protocol uses CARB default values for road-specific silt loads to derive "freeway-equivalent" road miles for each road type. For example, using CARB averaged silt load values, assuming similar vehicle weights on each road type, and using Equation 1, an estimate showing that local roads produce six times more PM_{10} on a g/mi basis than freeways was computed. **Table 5** provides a summary of the freeway equivalents for the types of roads that can be estimated using this method. Converting build and no-build traffic volumes into common freeway-equivalent travel units facilitates quick comparisons to determine whether the proposed project improves or worsens worst-case PM_{10} conditions.

Note that the approach is conservative, meaning it errs on the side of protecting the environment, in that it does not take credit for the potential beneficial impact improved traffic flow has on exhaust PM emissions. If traffic is relocated from surface streets to a freeway, the relocated traffic will likely encounter stop-and-go driving conditions less frequently than it would have on surface streets. Primary PM emissions from diesel exhaust are relatively high during stop and go driving, and are reduced during more free-flow conditions (Clark et al., 2002). Thus, relocating traffic should reduce tailpipe exhaust PM. The Relocate and Reduce methodology is conservative since it focuses solely on the beneficial aspects of relocating traffic to roads with reduced silt loads, and thus reducing road dust emissions.

Table 5. Estimated PM_{10} "road equivalents" among different facilities.

These Types of Travel Can be Approximated as Equivalent
1 local road vehicle-mile is equivalent to: 6 freeway vehicle-miles
1 local road vehicle-mile is equivalent to: 4.2 major street/highway or collector vehicle-miles
1 major street/highway or collector vehicle-mile is equivalent to: 1.4 freeway vehicle-miles

Source: CARB (1997) default silt load values, and Equation 1.

Mitigation components of a proposed project may be incorporated in this protocol step, refer to Appendix E for discussion and examples.

Detailed Process

F4.1 determines whether the proposed project relocates VMT from existing facilities to the proposed facility. Protocol users are asked to compare anticipated build and no-build traffic volumes in the vicinity of the proposed project and to determine whether the build scenario results in reallocation of volumes from existing roads to the proposed facility.

F4.2 directs users to approximate no-build PM_{10} conditions. The methodology includes two steps. First, users select the worst-case no-build intersection in the vicinity of the proposed project and forecast analysis year traffic volumes for that intersection. By using the worst-case intersection, a conservative estimate of the worst-case PM_{10} conditions can be approximated for the no-build scenario. Second, the user converts the intersection traffic volumes into freeway-equivalent miles. The end product is an estimate of freeway-equivalent miles of travel at the worst-case no-build intersection for the project analysis year.

F4.3 asks analysts to consider whether an intersection exists within 100 m of the proposed facility. The purpose of this step is to insure that in constructing a conservative screening analysis, the worst-case build conditions reflect the possibility that PM_{10} concentrations will be a function of both the project and other facilities within 100 m of the project. The literature (see Table 1) suggests that road impacts are most pronounced within 100 m of a facility. If there is no intersection within 100 m of the proposed facility, the user is directed to step F4.4. If there is an intersection, users proceed to step F4.5.

F4.4 instructs users to estimate the build impact of the project. The analyst uses projected build traffic volumes for the analysis year and converts those volumes to freeway-equivalent miles.

F4.5 covers situations where intersections are located within 100 m of the proposed facility. The user must forecast traffic volumes for the proposed facility's analysis year and convert those volumes into freeway-equivalent miles. Users then estimate analysis year traffic volumes for the worst-case (highest volume) intersection within 100 m of the proposed project and convert those miles to freeway-equivalents. The sum of the project under analysis and the worst-case intersection freeway-equivalent miles can then be computed.

F4.6 is a test to determine whether the number of freeway-equivalent miles is greater in the build or no-build case. F4.7 is the analysis end point; protocol users should document the analysis assumptions used to determine that the project will not create a PM_{10} hot spot problem. F4.8 directs projects that fail the process to conduct more detailed analyses or work through interagency consultation to determine whether PM_{10} will be a problem.

EXAMPLE APPLICATIONS

"Threshold screening" Analysis for an Intersection Project (Process 3)

Hypothetical Project Facts

Assume a project is proposed for Sacramento, California that is an intersection improvement expected to result in "build" traffic volumes of 30,000 vehicles per day (VPD). Worst-case background 24-hr average PM_{10} concentrations are currently 130 $\mu g/m^3$, and annual average concentrations are 42 $\mu g/m^3$ at the proposed project site. Based on discussions with the local air quality management district, the protocol user estimates that the proposed project site is expected to experience steady or declining background PM_{10} concentrations in future years. Abbreviated text from the Figure 1 flowchart descriptions is reproduced here in italics, with example results following.

Qualitative Analysis with Flowchart Process 3 - Threshold Screening

F3.1. Are 24-hr background PM_{10} concentrations near the proposed project site below 120 $\mu g/m^3$?

> Concentrations are not below 120 $\mu g/m^3$, the screening threshold based on observed worst-case conditions. Background concentrations are estimated to be 130 $\mu g/m^3$; the project continues on to Step F3.2.

F3.2. Is the 24-hr incremental PM_{10} contribution from the project less than the allowable threshold?

Yes, the project increment is less than the allowable threshold. The protocol user reaches this conclusion by estimating the project's incremental 24-hr PM_{10} contribution from data in Table 3. In this example, the Table 3 entry for 68,000 VPD is the closest selection and is conservative since the anticipated traffic volumes are less than 68,000 VPD. Based on the Table 3 data, the incremental concentration assumed for the 24-hr PM_{10} analysis is 5.8 µg/m^3. The analyst then estimates an allowable 24-hr threshold value for the intersection project by subtracting the expected 24-hr background concentration from the PM_{10} 24-hr NAAQS (150 µg/m^3– 130 µg/m^3). The estimated project increment of 5.8 µg/m^3 is less than the allowable threshold of 20 µg/m^3. From this, it can be qualitatively concluded that a PM_{10} hot spot violation of the 24-hr standard will not occur as a result of this project. The analyst continues through the flowchart to check the annual standard.

F3.3 and F3.4. Is the proposed project's estimated annual PM_{10} incremental contribution below the acceptable threshold?

The project fails the general annual screening test but passes the more specific annual threshold test (steps F3.3 and F3.4 respectively). Since expected annual average background concentrations are 42 µg/m^3, the project does not screen out with step F3.3 (42 µg/m^3 exceeds the allowable 32 µg/m^3). The threshold for the annual check must then be computed and compared against the annual project increment (F3.4). To conduct this comparison, first, the analyst determines the 24-hr project increment and then, using Equation 3, converts the 24-hr increment (Table 3) to an annual increment by applying the CR (Table C-1 in the Appendix includes the CR for Sacramento County).

Equation 3. Conversion of 24-hr increment to annual increment.

$$\text{Increment}_{\text{Ann}} = \text{Increment}_{\text{Proj}} \times \text{CR}$$

where

$\text{Increment}_{\text{Ann}}$	=	Project's annual incremental PM_{10} concentration
$\text{Increment}_{\text{Proj}}$	=	Project's 24-hr incremental contribution (from Table 3)
CR	=	Conversion ratio (from Table C-1 or local data)

In this example, the project's estimated 24-hr PM_{10} increment is 5.8 µg/m^3 (F3.2), the CR is 0.31 (from Table C-1), and the resulting estimated annual project increment is 1.8 µg/m^3 (Equation 4).

Equation 4. Estimating an annual increment of 1.8 µg/m^3.

$$\text{Increment}_{\text{Ann}} = 5.8\,\mu\text{g/m}^3 \times 0.31 = 1.8\,\mu\text{g/m}^3$$

Next, the analyst computes the allowable annual threshold based on the specific project location using Equation 5.

Equation 5. Estimating an allowable annual threshold.

$$Thresh_{Ann} = NAAQS_{Ann} - Background_{Ann}$$

where

$Thresh_{Ann}$	=	Allowable annual project increment ($\mu g/m^3$)
$NAAQS_{Ann}$	=	Annual PM_{10} NAAQS (50 $\mu g/m^3$)
$Background_{Ann}$	=	Annual background concentration ($\mu g/m^3$)

In this example, the estimated background PM_{10} concentration was 42 $\mu g/m^3$; by subtracting the background concentration from the annual NAAQS of 50 $\mu g/m^3$, the analyst estimates an allowable annual project increment of 8 $\mu g/m^3$. In the final step, the estimated project increment is compared to the allowable threshold. The forecasted project increment is 1.8 $\mu g/m^3$; the allowable increment is 8 $\mu g/m^3$. It can be qualitatively concluded that a PM_{10} hot spot violation of the annual standard will not occur as a result of this project.

F3.5. Project screens out; end analysis and document findings.

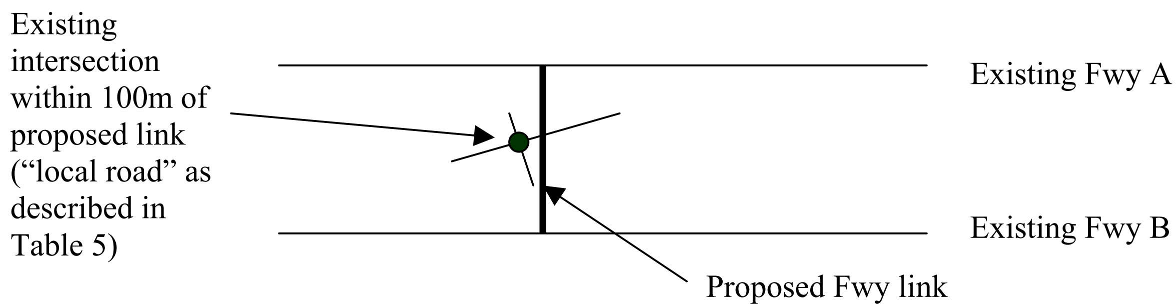
The proposed project has passed the conformity hot spot test. The protocol user should document the assumptions used during the analysis to support a project-level conformity determination.

Relocate and Reduce Analysis, Build vs. No-Build Approach (Process 4)

Hypothetical Project Facts

The proposed project will connect two existing freeways with a new, elevated freeway segment and associated ramps (Figure 2). The project will be built within 100 m of an existing intersection with 9,000 VPD prior to the project's construction. Projections show that the new freeway segment will relocate 6,250 VPD from the existing intersection onto the new freeway segment. In addition, it is estimated that the new freeway segment will add 43,750 more VPD to the traffic that passes through the area. Total expected volumes on the new freeway will be 50,000 VPD (6,250 VPD relocated from the existing intersection, plus 43,750 new VPD).

Figure 2. New freeway link and existing intersection within 100 m.



Background concentrations are very high near the project site, and the project has failed the other qualitative analysis steps. Table 6 shows the anticipated build and no-build traffic volumes.

Table 6. Build vs. no-build conditions for hypothetical "relocate and reduce" example.

Facility	No-Build Volumes (VPD)	Build Volumes (VPD)
Freeway	0	50,000
Intersection (road type)	9,000 (local road)	2,750 (local road)

Qualitative Analysis with Flowchart Step 4 – Relocate and Reduce

F4.1. Does the proposed project relocate vehicles from an existing site to the project site?

Yes, the identified intersection will have reduced volumes in the build case.

F4.2. Estimate the no-build PM_{10} impacts (in freeway-equivalent units per day) based on the worst-case (highest VPD) no-build intersection.

The worst-case no-build intersection is projected to carry 9,000 VPD. The no-build road type is "local road" for the intersection. For qualitative analysis purposes, we assume that intersection VPD estimates are proportional to vehicle miles per day. We make this assumption based on the AP-42 PM_{10} estimation methodology, which is VMT based (see Equation 1). In addition, neither EPA nor CARB define silt loads for intersections. Thus, to facilitate converting all road use into freeway-equivalents, we assume intersections are equivalent to the road type associated with the approaches to the intersection, which for this project are "local roads." From Table 5, 1.0 local-road miles is equivalent to 6.0 freeway-miles. Therefore, traffic at the no-build intersection is equivalent to 54,000 freeway-miles (6.0 freeway-miles/1.0 local road-miles multiplied by 9,000 local-road miles).

F4.3. Is there an intersection within 100 m of the proposed project facility?

Yes, as shown in Figure 2, there is an intersection within 100 m of the freeway.

F4.5. Estimate the build impact based on the worst-case build intersection within 100 m, plus the proposed project facility.

The intersection illustrated in Figure 2 is the only intersection within 100 m of the freeway, and, in this simplified example, it is therefore also the worst-case build intersection. The build road type is "local road" for the intersection, meaning the intersection has not been improved as part of the new freeway project. Given expected build traffic volumes of 2,750 VPD, the build scenario results in 16,500 freeway-mile equivalents (6.0 freeway-miles/1.0 local road-miles multiplied by 2,750 local road miles; from Table 5). The new freeway produces 50,000 freeway-miles. The total project build impact is, thus, 66,500 freeway-equivalent miles (50,000 from the freeway, plus 16,500 from the intersection).

F4.6. Is build impact less than the no-build impact?

No, the build impact is not less than the no-build impact (66,500 is greater than 54,000).

F4.8. Interagency consultation or more detailed analysis is needed.

The proposed project has not passed the conformity hot spot test and further analysis or consultation is necessary. Note, however, that a minor change to this example illustrates how potential mitigation strategies can offset PM_{10} problems. If the intersection is improved in the build scenario, the project passes the screening test. Assume, for example, that the intersection in Figure 2 was, as part of the freeway project, improved so that its approaches became "major streets." Also assume that the traffic volumes in the build scenario remained the same as projected in Table 6; in other words, the new freeway segment would reduce the intersection traffic volumes to 2,750 VPD in the build scenario. The improved intersection would be assumed to have 3,850 freeway-equivalent miles, rather than 16,500 freeway-equivalent miles (silt loadings would reflect major-street conditions, rather than local-road conditions; see Table 5). Total build freeway-equivalent miles would equal 53,850 (50,000 from the freeway plus 3,850 from the intersection). Since the no-build scenario is equivalent to 54,000 freeway-equivalent miles, the build scenario represents a 150-mile reduction from the no-build forecast. Given the analysis results, planners might be motivated to modify the proposed project to incorporate intersection improvements that reduce silt loads and PM_{10}; such a modification would allow the project to pass the qualitative PM test. Refer to Appendix E for more detailed discussion of integrating mitigation into the Protocol.

CONCLUSIONS

The qualitative PM_{10} analysis protocol is a new method for conducting a step-by-step screening to identify projects unlikely to contribute to violations of the PM_{10} NAAQS. The protocol was designed to be conservative and serves as a resource for transportation analysts responsible for preparing project-level transportation conformity PM_{10} hot spot analyses. Although some of the underlying data used to create the protocol is California-specific, methods detailed in the protocol have wide applicability, and users have the ability to substitute local data more appropriate to the proposed project.

REVIEW PROCESS AND RESPONSE TO COMMENTS

During the development of the PM_{10} protocol, the study team solicited and received comments from various reviewers. A summary paper describing the protocol was accepted by the Air & Waste Management Association (AWMA) for presentation at the Association's June 2003 annual conference (Eisinger et al., 2003). The paper went through an AWMA peer-review prior to acceptance. In addition, staff from FHWA and the California Air Resources Board provided comments. Appendix F includes a summary of the major comments received on the protocol, as well as responses to those comments.

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APPENDIX A: SUPPORTING MATERIAL FOR ELIGIBILITY CHECKLIST AND RELATED BACKGROUND INFORMATION FOR PROTOCOL STEPS

Characteristics of Projects and PM_{10} hot-spots

The potential impacts of transportation projects depend on a number of factors, however projects that have the following characteristics are not expected to worsen or create a PM_{10} hot-spot.

1. Some proposed projects will produce incremental emissions that are below the amount needed to exceed the PM_{10} standard in the area where the project is located. In other words, conceptually, in a given area that does not otherwise exceed the PM_{10} NAAQS, there is an amount of VMT that may be accommodated within the limits of the PM_{10} standards such that the area may be able to sustain certain levels of traffic without creating or worsening a PM_{10} hot-spot. However, areas that have ambient PM_{10} concentrations already near or above the PM_{10} NAAQS may not be able to accommodate additional PM_{10} emissions without contributing to an existing hot-spot or creating a new hot-spot. These concepts are the basis for the Threshold Screening Approach, detailed in Process 3.

2. Projects that result in the relocation of VMT from a facility with a high silt loading (such as an intersection or arterial) to a facility with lower silt loadings (such as a freeway) may improve air quality near the facility that experiences a reduction in build volumes. This is because the emission factor for paved road emissions due to re-entrained road dust is directly proportional to silt loading (refer to Equation 1). This is the basis for the Relocate and Reduce Approach, detailed in Process 4.

3. Freeway projects and improvements to the level of service (LOS) of existing freeways are not likely to cause a violation of the PM_{10} standard, unless the location is already very close to the standard (Cowherd and Grelinger 1998; Cahill et al 1994; Venkatram and Fitz 1998; Etyemezian et al. 2003). Freeway locations with free-flow traffic were found to not significantly increase downwind PM_{10} concentrations in California (Cahill et al.1994; Venkatram and Fitz 1998). Further, a marginal increase of volumes on an existing high volume, high-speed facility such as a freeway is not expected to substantively alter PM_{10} concentrations, especially in California (Cahill et al 1994; Gaffney and Shimp 1997; Etyemezian et al 2003).
4. The project may not impact sensitive receptors such as schools, homes, and businesses, if the project location is further than 100 m away. Research has shown that roadway-related PM10 concentrations are highest within approximately 100m of the roadway, and are much harder to observe outside the 100 m envelope (Ashbaugh et al 1996; Watson and Chow 1996, Zhu et al 2002a, 2002b). This finding was the basis for Item 5 in the Eligibility Checklist detailed in Table 1.

5. Inclusion of mitigation techniques for example, paving previously unpaved shoulders and street sweeping, may reduce re-entrained road dust (Moosmuller et al1998; Fitz et al 1998). Street sweeping may be most effective on local streets rather than high-traffic roadways (Fitz et al 1998). Although studies have shown that silt loadings are lowered from street sweeping activities, one study reported higher PM10 concentrations after sweeping than before (Fitz et al 1998). However, this study also presented the results of a statistical test that indicated that

there was no difference between the before and after PM10 concentrations with 95% confidence (using a Wilcoxan two tailed ranked sum test) (Fitz et al 1998). Mitigation may be integrated into the PM10 hot spot analysis if the proposed project contains mitigation elements and the analyst chooses to apply the benefits to the PM10 analysis, refer to Appendix E.

Background Information Concerning Situations Where PM_{10} Concentrations are Dominated by Non-Vehicular Sources

Table 1 (item 7.) in the text, states the protocol is not appropriate in situations where PM_{10} concentrations are dominated by sources other than on-road motor vehicles. This appendix discussion provides background information to assist protocol users in understanding how to interpret whether a particular site is dominated by non-vehicular sources.

In brief, there is no explicit threshold amount that establishes an insignificant or de-minimus on-road contribution to PM_{10} emissions. Protocol users should, when in doubt as to whether a situation qualifies as being dominated by non-vehicular sources, use the interagency consultation process to seek clarification. Provided below are (a) excerpts from EPA federal register notices that provide further guidance, and (b) an example California situation where EPA approved a PM_{10} SIP analysis concluding that on-road mobile sources were insignificant PM_{10} contributors.

Federal Register Excerpts

1. During the regulatory process to establish the 1997 transportation conformity regulations, EPA provided guidance to help states determine whether on-road mobile source PM_{10} contributions were significant. In the notice of proposed rulemaking (NPRM) for the transportation conformity regulations (61 FR 36118; July 9, 1996), EPA noted: "The SIP would have to demonstrate that it would be unreasonable to expect that such an area would experience enough motor vehicle growth for a violation to occur. Such a demonstration would have to be based on a number of factors, including the percentage of the inventory comprised by motor vehicle-related emissions currently and in the future, how close the monitoring data is to the standard, the absence of SIP motor vehicle control measures, historical trends in growth of motor vehicle emissions and VMT, and projections of motor vehicle emissions and VMT."

2. Also, in EPA's November 5, 2003 conformity NPRM, "Proposed rule - Transportation Conformity Rule Amendments for the New 8-hour Ozone and $PM_{2.5}$ National Ambient Air Quality Standards and Miscellaneous Revisions for Existing Areas," there are provisions to eliminate PM_{10} hot spot analysis requirements in areas where EPA has made a formal determination that the PM_{10} SIP finds hot-spot emissions to be insignificant (68 FR 62716; November 5, 2003).

Example Situation Where On-Road Mobile Sources Are Insignificant Contributors to PM_{10}

The Owens Valley in California is an example PM_{10} nonattainment area where EPA has determined that on-road mobile sources are insignificant PM_{10} contributors. EPA proposed to approve the Owens Valley PM_{10} SIP on June 25, 1999, and published a final SIP approval on

August 18, 1999. EPA's June 25, 1999 NPRM includes a detailed discussion about PM_{10} sources:

> "The peak 24-hour PM-10 inventory includes 8,346 tons per day (tpd) from wind erosion on the exposed Owens dry lake bed; 516 tpd from off-lake sources of lake bed dust; and 42 tpd from prescribed burning. The Owens Valley inventory has insignificant emissions from major source categories in typical PM-10 nonattainment areas, including reentrained dust from motor vehicles (0.15 tpd unpaved roads, 0.19 paved roads), residential wood burning (0.24 tpd), and industrial facilities (0.23 tpd, plus a proposed soda ash project projected to emit 0.51 tpd). Secondary aerosols are also insignificant PM-10 sources in Owens Valley, and so the inventories are for primary particulate only" (64 FR 34176; June 25, 1999; the SIP is available at: http://www.epa.gov/fedrgstr/EPA-AIR/1999/June/Day-25/a16227.htm).

Using Table 1 from the qualitative PM_{10} protocol, an analyst would determine that proposed Owens Valley transportation projects would be insignificant contributors to PM_{10}. Thus, Owens Valley transportation projects could qualitatively pass the PM_{10} hot spot test without having to complete any of the analyses included in the qualitative PM_{10} protocol.

APPENDIX B: SUPPORTING MATERIAL FOR THE THRESHOLD SCREENING

Overview Discussion of Screening Concepts and Values Reported in the Literature

Threshold values are used in the threshold screening for the qualitative analyses. Data for the thresholds was based on data from field studies that have measured PM_{10} concentrations upwind and downwind of a variety of facility types. Project increment values were tabulated and categorized based on facility type and vehicle volume; these values represent the contribution of PM_{10} by a specific project. Project screening values were based on the worst-case (highest concentration) values measured in the field studies (the screening values are used as a first step in the Protocol flowchart; see steps F3.1 and F3.3). For both the screening and the threshold checks, the sum of the project increment and the background concentration is compared to the federal standard. If the sum is less than the standard, the project is screened out.

Threshold screening is done first for the 24-hour standard, then for the annual standard. If the project does not screen out using the worst-case thresholds, a project-specific increment is computed based on proposed facility type and expected vehicle volumes. The project-specific increment is found from Table 3. Tables B-1 through B-3 provide information on the individual studies summarized in Table 3. Table B-4 provides a more detailed description of the site characteristics, roadway characteristics, and travel volumes observed across each of the studies used to prepare Table 3. The selection of the appropriate incremental value from Table 3 must be done by the analyst; Table B-4 provides further details to assist in that selection.

Each study included in Tables 3 and B-1 through B-4 measured PM_{10} mass upwind and downwind of the road facility under investigation; however the facility types, traffic volumes, silt loadings, weather conditions, and the horizontal and vertical location of the sampler relative to the road differ among the studies. Another factor that greatly affects the increment reported for a given study is the averaging time of the sample in the published study. Publications reported PM_{10} concentrations for various sampling periods (e.g., 3 hours, 24 hours), or the publications reported PM_{10} concentrations representing an average of multiple sampling efforts. For example, one might compare the results of the 24-hr averaged intersection increment reported in Cowherd and Grelinger (1998), i.e., 5.8 $\mu g/m^3$, with the 3-hr intersection values reported in Ashbaugh et al. (1996), i.e., 29.6 $\mu g/m^3$ (see Table B-4). These differing results can be explained at least in part due to each study's different sampling periods: 24-hrs vs. a 3-hr peak period. If off-peak concentration data are averaged with peak period data, as in Cowherd and Grelinger (1998), the averaged value is lower than the peak concentrations.

Characteristics of the proposed project site that may guide the analyst in choosing the appropriate incremental value include the facility type, traffic volumes, number of lanes, and silt loadings. Protocol users should match their proposed project to the most comparable facility study reported in Table B-4. For some analyses, the proposed traffic volumes will be greater than the largest volumes listed in the threshold table (Table 3). The user may elect to linearly increase the incremental concentration value based on the volumes cited in the experiment and the volumes of the proposed project. This approximation is not expected to under-represent re-entrained road dust contributions to PM_{10}. As stated above, a marginal increase of volumes on an existing high volume, high-speed facility such as a freeway is not expected to substantively alter PM_{10}

concentrations, especially in California (Cahill et al 1994; Gaffney and Shimp 1997). In other words, studies show that there is a "plateau" effect where, beyond a certain base amount of VMT, additional traffic volumes contribute only marginally to road dust emissions. Thus, if a user were to linearly extrapolate the estimated road dust contributions included in Table 3 (e.g., extrapolating for intersection volumes beyond 68,000 vehicles per day), their extrapolation would likely be conservative, since it is likely that at some point the increased volumes contribute less than a linear amount of road dust emissions. In one study, emissions potential has been found to be independent of vehicle volumes, meaning that silt loadings may be in a state of quasi-equilibrium for paved roads at all travel speeds regardless of volumes (Etyemezian et al 2003).

Screening Against the 24-hr PM_{10} NAAQS

The first screening step in Chart 3 employs 24-hr and annual thresholds set based on the worst-case values estimated from the literature, including the highest reported incremental project contribution and the highest conversion ratio (the conversion ratio is an approach used to estimate annual concentrations based on observed 24-hr values; it is discussed in Appendix C).

The initial 24-hr threshold screening value was computed as follows.

$Threshold_{24hr} = 150 - I = \underline{120 \mu g/m^3}$

Where I is the worst case increment for the 24-hr standard. This value is 29.6 $\mu g/m^3$, found in Table 3 for facility type "intersection" and a traffic volume of 4517 veh/hr. Since this was the highest increment reported in the literature, this value was used for the initial screening step. Whereas the initial screening is based on the worst-case values, the project-specific tests in Chart 3 calculate project increments based on more closely matching the proposed project to the various project types studied in the literature.

Screening Against the Annual PM_{10} NAAQS

The annual standard is checked separately in Chart 3 (see Figure 1). The 24-hr data are used to estimate the annual impact of a project using a conversion ratio (described in Appendix C). For the initial screen approach, as long as the maximum annual average background concentration at the project site is 32 $\mu g/m^3$ or less, a hot-spot is assumed not to occur. The 32 $\mu g/m^3$ threshold was computed as follows:

$$Initial\_Screen\_Threshold_{annual} = 50 - (I_{is} * CR_{max}) = \underline{32.24 \mu g/m^3}$$

Where:

50 = the annual PM_{10} NAAQS (in $\mu g/m^3$)
I = Maximum incremental 24-hr PM_{10} contribution from a road = 29.6 $\mu g/m^3$
CR_{max} = Maximum Annual-to-24-hr Conversion Ratio for California = 0.60

CR_{max} was established as 0.60, since this was the greatest conversion ratio calculated for all California counties (see Appendix C). This worst-case value was used to make the annual initial screen threshold check as conservative as possible. The conversion ratio method is described in APPENDIX C: Supporting Material for Conversion ratio method for annualizing 24-hr concentrations.

Published Field Study Findings Used to Estimate Project Increments

The field studies used for the incremental threshold values were all the downwind/upwind type and all but one were done in California. Measurements beside freeways, intersections, arterials, collectors and local roads were done and values reported in the literature were used here. Table B-1 details the concentration measurements used for the threshold values. The incremental concentration for the 24-hr threshold was determined by finding the maximum measurement reported for each facility in the referenced studies, regardless of averaging period for the reported value. For example, the maximum value used for the 24-hour threshold value was measured in an intersection study by Ashbaugh et al (1996) even though the measurement duration for this value was 3 hrs (Table B-1). Since the measurement was taken during peak periods, the approach of using the results of these shorter-time-scale sampling efforts yields a high estimate for PM_{10} concentrations, thus making the protocol conservative.

Ashbaugh et al (1996) Sacramento California Intersection Study

Ashbaugh et al (1996) measured concentrations upwind and downwind of intersections at multiple heights simultaneously. The authors used the field data to compute a concentration difference across the intersection as input to a modeling study to estimate emission factors. Ashbaugh et al (1996) used their field data to calculate concentration difference by subtracting the average of the upwind concentration data measured at 3m and 9m high from the average of the downwind concentration data measured at 1m and 3m high (Equation B-1.)

Equation B-1:
Average(downwind@1mhigh), downwind@3mhigh)) - average(upwind@3m high, upwind@9m high)

This study also used the Ashbaugh et al (1996) data to compute the concentration difference across the intersection using Equation B-2.

Equation B-2:
(Downwind@3mhigh) – average(upwind@3m high, upwind@1m high)

The results from both equations are given in Table B-1. Alternately, a simple difference between concentration data measured at 3m high upwind and downwind could be used (Equation B-3). For illustration and discussion, concentration differences at 3m high are also given in Table B-1.

Equation B-3:
Downwind@3mhigh – upwind@3mhigh

Table B-1: Incremental concentration data based on field data from Ashbaugh et al (1996), measured at a Sacramento, CA intersection. Concentration differences given for the three equations described in the appendix text.

	Veh/hr through intersection	Equation B-1	Equation B-2	Equation B-3
maximum	**4517**	23.55	**29.6**	29
	3973	14.55	11.6	10.3
	3897	18.4	12.35	12.7
	3838	10.75	4.75	3.3
	3699	10.7	8.75	8.7
	2417	20.45	22.2	22.4
	2221	21.65	16.35	16.1
	1536	7.85	8.1	7.9
	1463	9.6	4.7	4.4
	1294	4.65	1.85	1.3
	1064	7.3	7.05	7.8

Note that the maximum value shown here is the value reported in Table 3 of the text.

Cahill et al (1994) Sacramento California Freeway Study

Cahill et al (1994) measured PM_{10} concentrations upwind and downwind of the I-80 freeway in Sacramento, California, two miles west of Highway 113. Upwind data were collected 35m south of the road, from a tower set up in a farm field that had been disked one week earlier to eliminate weeds. Upwind data were collected from the tower at 2m, 4m, and 8m above ground.

Cahill et al (1994) measured PM_{10} concentrations at three locations downwind of the freeway, which they termed near-downwind, downwind, and far-downwind, and which were located 17m, 35m, and 70m from the road edge. The 17m (near-downwind) site was a single monitor located 2m above ground, at the fence bounding the freeway. The 35m (downwind) site measured PM_{10} from monitors placed on a single tower at 2m, 4m, and 8m above ground. The 35m downwind site was located where a test well had been drilled into the ground two weeks earlier; Cahill et al (1994) reported observing some fugitive dust north of the tower, but none was observed between the tower and the road. The 70m downwind site collected data at a point 2m above ground. The site was downwind of some potential dust sources, but the authors said they did not sample when winds were strong enough to blow dust from the ground surface.

The data in **Table B-2** represent the average PM_{10} concentration data as reported by Cahill et al (1994; Table 5). Table 3 of the text reports an incremental PM_{10} contribution for freeways, with vehicle volumes of 5,517 veh/hr, of 5.30 $\mu g/m^3$. Cahill et al (1994) reported this value as the difference between the average of selected upwind measurements subtracted from selected downwind measurements. For the downwind measurements, Cahill et al (1994) averaged the 'near downwind' (2m above ground) data with the downwind data collected at 2m and 4m above ground; this value is 53.0 ug/m^3 (see data in Table B-2). For the upwind measurements, Cahill et al (1994) averaged the upwind measurements taken at 2m and 4m above ground; this value is 47.7 ug/m^3 (see data in Table B-2). The downwind minus upwind values equal the estimated incremental PM_{10} contribution from the freeway (53.0 – 47.7 = 5.3).

Table B-2. PM_{10} concentrations measured upwind and downwind of I-80 (Cahill et al 1994), sampling period, and observed travel data.

Horizontal location (distance from I-80 freeway)	Vertical location (distance above ground)	Average observed PM_{10} concentration (µg/m^3)
35m	upwind 2m	49.7
	upwind 4m	45.6
	upwind 8m	49.6
17m	near downwind (2m)	50.1
35m	downwind 2m	59.8
	downwind 4m	49
	downwind 8m	47.6
70m	far downwind	47.7
	TRAFFIC COUNT AVERAGES	
	Westbound = 37,222	Total Sample time = 13.5 hours
	Eastbound = 37,259	
	Total = 74,481	overall: 5,517 veh/hr

Note: as described in the appendix text, Cahill et al used this data to estimate a 5.3 ug/m^3 incremental PM_{10} contribution from freeways.

Venkatram et al (1998) Southern California Paved Road PM_{10} Measurement Study

Venkatram et al. (1998) measured PM_{10} upwind and downwind of different roadway types in Southern California. Six roads were selected and PM_{10} was measured during times when the wind direction was perpendicular to the road. Overall, the uncertainty of the measurements was estimated to be 8 µg/m^3. The values in Table B-3, column "Avg conc difference" were taken from the Venkatram et al (1998) report and are equal to the average of the downwind sampler concentrations minus the average of the upwind sampler concentrations. Multiple PM_{10} samplers were utilized at each site upwind and downwind. The specific sampling approach for each reported site is repeated below. Table B-3 also includes columns with the average concentration difference for each site and for each road type as well as the maximum concentration difference for each facility type (highway, arterial, collector and local). These values are based on the positive concentration difference data; negative values were not included in computing those averages. Notice that the average values for each facility type for all but the collector facility type (which has only one data point) are from 42% to 70% lower than the maximum values.

Venkatram et al (1998) defined facility types as follows:

- Local: <500 cars/day (2 lanes)
- Collector: 500-10,000 cars/day (2 lanes)
- Arterials: 10,000-150,000 cars/day (3-4 lanes)
- Freeway: More than 150,000 cars/day (>4 lanes)

At the highway location, three upwind samplers were 50m from the roadway curb and six downwind samplers were 15m from the curb. One upwind sampler was at 1m height and two were at a 3m height. Downwind samplers were at 1, 2, and 3m high. Sampling times ranged from 10 to 32 hours for this location. Six sets of samples were collected on 15 days.

Three sampling locations were categorized into the arterial category by Venkatram et al (1998). At Iowa Ave, three upwind samplers were utilized, located 20m from the curb horizontally and 1, 3, and 5m vertically. Downwind samplers at the Iowa Ave location were 1m horizontally and 1, 3, and 5m high (2 samplers at each height). They sampled for four days at this location.

Thirteen sets of samples over sixteen days of sampling were done at the Riverside Dr. location with two different sampling setups. Samplers were 1, 3, and 5m high with upwind samplers located 10m from the curb and downwind samplers 5.5m from the curb for the majority of sampling days. For two sampling days the setup for upwind samplers included two samplers at 10.5m from the curb (1m and 3m high) and 3 samplers (2 at 3m high, one at 1m high) at 30m from the curb. For those two days four downwind samplers were 1m and 24m from the curb (1m and 3m high).

The third arterial location was at Canyon Crest Drive. Seven sets of samples over 10 days of sampling were collected at this site; the resulting average concentration differences were repeated in Table B-3. Upwind samplers were 10m from the curb with 2 samplers at each height of 1, 3, and 5m. There were three downwind samplers located 10m from the curb horizontally and 1, 3, and 5m vertically.

Atlanta Ave was the Collector road type sampled for the experiment. One sample day and one set of samples were collected at this location. Upwind samplers were vertically 1, 3, and 5m and 11m horizontally from the roadway curb. Downwind samplers were 1m from the curb at 1, 3, and 5m high with two samplers located at each height.

The local road measured in this study was Fogg St. Four days of sampling were done and four sets of samples were collected at this location. Upwind samplers were 1m from the curb and located at 3m high. Downwind samplers were collocated at 1 and 2m high and 1m horizontally from the curb.

Table B-3: Field data from Venkatram et al (1998).

Road type	Veh/hr	Veh/day	Street name (number of lanes)	Avg conc difference down-up (ug/m^3)	Avg per road (ug/m^3)	Avg per facility type (ug/m^3)	Max (ug/m^3)
Highway		>150,000	Hwy 60&I-215 (6)	-3	5.63	5.63	**8**
				-1			
				-3.6			
				1.9			
				8			
				7			
Arterial	1000		Iowa Ave (4)	15.8	11.40	9.99	**21**
				10.5			
				7.9			
				-5.5			
	1000		Riverside Dr (4)	14.2	11.38		
				17.2			
				2.2			
				5.1			
				4.2			
				21.0			
				12.5			
				8.4			
				15.9			
				-5.1			
				21.0			
				4.6			
				10.2			
				0			
	1000		Canyon Crest Dr (4)	2.7	4.78		
				5.7			
				5.1			
				-5			
				-4			
				5.6			
Collector (2-lane)	200		Atlanta Ave (2)	**15.9**	15.90	15.90	**15.9**
Local (2-lane)	20		Fogg St (4)	1.7	4.60	4.60	**10.9**
				10.9			

Values included in Table 3 to represent incremental PM_{10} concentrations are highlighted in bold; note that in each case, the maximum observed value was used to identify the increment for Table 3. Only positive concentration differences were used to compute the average concentration per road, per facility and the maximum concentration difference included in the last 3 columns

Table B-4: Guidance table for selecting threshold entry (page one of two).

Authors, study location	**Concentration increase downwind-upwind of facility (µg/m³)**	**Silt Loading (g/m²)**	**Estimated EF (mg/VKT)[1]**	**Study focus, and sample site information**	**Sampler location relative to roadway**	**Averaging Time**	**Meteorology**	**Traffic volume and mix**
Ashbaugh et al. (1996), Sacramento, CA	Table B-1 summarizes 11 tests with different traffic volumes through intersection.	13.6 to 33.2	188 +/- 80	Urban/suburban intersection. Two roads intersect, each road had 5 lanes. Concentrations round to drop to background levels less than 100m downwind of intersection	Vertical: downwind 1, 3, 9m upwind 3, 9m Horizontal: downwind 9m. upwind 49m	3 hr of sampling	Wind speed varied diurnally from 2m/s in morning to 5m/s during the day.	Max of 5000 veh/hr (refer to Table B-1)
Cahill et al. (1994) Davis, CA	Table B-2 summarizes study results	Not measured	20	High speed 8 lane freeway, surrounded by agricultural land.	Vertical: downwind 2, 4, 8m upwind 2, 4, 8m Horizontal: downwind 17, 35, 70m. upwind 35m	From 2 to 4 hours	Mean wind speed over sample periods ranged from 1.8 to 2.2m/s	5,517 veh/hr (refer to Table B-2)

Table B-4: Guidance table for selecting threshold entry (page two of two).

Authors, study location	**Concentration <u>increase</u> downwind-upwind of facility ($\mu g/m^3$)**	**Silt Loading (g/m^2)**	**Estimated EF (mg/VKT)[1]**	**Study focus, and sample site information**	**Sampler location relative to roadway**	**Averaging Time**	**Meteorology**	**Traffic volume and mix**
Venkatram, *et al.* (1998), Riverside CA	Ranged from 1.7 to 15.9	0.0013 to 556.65	100 to 10,000	Southern California, 4 roads that were well-maintained freeways to older roads. Measured 4 road types: local, arterial, freeway, collectors. See Table 6 for lane counts for each location.	5m horizontal	Approx 6 hr sampling periods	Mean wind speed over sample periods ranged from 0.7 to 3.7m/s	500 to 150K cars/day (refer to Table B-3)
Cowherd and Grelinger (1998), Denver, CO (2 sites downwind of intersection)	4.3 (midblock) 5.8 (at intersection)	0.21 to 0.70	Not given	Intersection representative of recently sanded arterials in late winter in Denver	2m vertical, 3 to 5m horizontal	24-hr avg	Not given	41,000 to 68,000 veh per day.

[1]EF is emission factor.

APPENDIX C: SUPPORTING MATERIAL FOR CONVERSION RATIO METHOD FOR ANNUALIZING 24-HR CONCENTRATIONS

Process 3 of the PM_{10} protocol, Threshold Screening, employs a conversion ratio (CR) to estimate a transportation project's annual incremental contribution to PM_{10} concentrations. The conversion ratio (CR) for PM_{10} was calculated based on monitored concentration data to approximate annual average values based on 24-hr data. The CR is a ratio of annual to 24-hr concentrations. This formulation is one of many possible approaches to approximating annual concentrations. The CR can be used to annualize the daily estimates in the threshold test by multiplying the 24-hr estimate by the CR. This simplified approach was taken to utilize real-world concentration data for the qualitative hot-spot analysis. Monitored PM_{10} data from 1998 through 2000 compiled by the California Air Resources Board were used to compute the CR for each county (see Table C-1) in California as follows:

CR = (annual average[1]) / (maximum 24-hr concentrations)

The numerator corresponds to an annual average concentration and the denominator corresponds to a 24-hr value. Therefore, to annualize the project increment values, the CR for the county where the proposed project will be located is multiplied by the 24-hr increment value from Table 3.

[1] Calculated by CARB as the average *of quarterly means*.

Table C-1: 24-hr toAnnual average- PM_{10} concentration conversion ratios (CR) for all California counties.

Air Basin	County	CR *	Comment **	Air Basin	County	CR *	Comment **
Great Basin Valleys	Inyo	**0.08**	**Consultation**	Sacramento Valley (Continued)	Solano	0.39	
	Mono	**0.25**	**Consultation**		Sutter	0.40	
Lake County	Lake	0.49			Tehama	0.48	
Lake Tahoe	El Dorado	0.48			Yolo	0.32	
Mojave Desert	Kern	0.43		Salton Sea	Imperial	**0.19**	**Consultation**
	Los Angeles	0.34			Riverside	0.44	
	San Bernardino	0.42		San Diego	San Diego	0.48	
Mountain Counties	Calaveras	0.51		San Francisco Bay Area	Alameda	0.35	
	El Dorado	0.44			Contra Costa	0.32	
	Mariposa	0.51			Marin	0.49	
	Nevada	0.36			Napa	0.36	
	Plumas	0.44			San Francisco	0.41	
	Sierra	0.60			San Mateo	0.46	
North Central Coast	Monterey	0.52			Santa Clara	0.35	
	San Benito	0.42			Solano	0.28	
	Santa Cruz	0.52			Sonoma	0.40	
North Coast	Del Norte	0.51		San Joaquin Valley	Fresno	0.33	
	Humboldt	0.41			Kern	0.43	
	Mendocino	0.46			Kings	0.38	
	Sonoma	0.50			Merced	0.36	
	Trinity	0.40			San Joaquin	0.31	
Northeast Plateau	Lassen	0.37			Stanislaus	0.37	
	Modoc	0.31			Tulare	0.41	
	Siskiyou	0.32		South Central Coast	San Luis Obispo	0.42	
Sacramento Valley	Butte	0.34			Santa Barbara	0.56	
	Colusa	0.42			Ventura	0.37	
	Glenn	0.37		South Coast	Los Angeles	0.55	
	Placer	0.41			Orange	0.44	
	Sacramento	0.31			Riverside	0.51	
	Shasta	0.48			San Bernardino	0.44	

* CR is calculated by dividing the annual average maximum into 24-hr county maximum for each year; the maximum ratio is reported.

** Imperial, Mono, and Inyo counties have 24 hour max concentration > 1000 ug/m^3 that are dominated by wind blown dust. Consultation with the air district is recommended.

APPENDIX D: SUPPORTING CALCULATIONS FOR "ROAD EQUIVALENTS" USED IN THE RELOCATE AND REDUCE APPROACH , TO ESTIMATE TRADEOFFS BETWEEN BUILD AND NO-BUILD PM_{10} EMISSIONS OF PROPOSED PROJECTS

Overview

The "road equivalents" used in the relocate and reduce approach were derived to use as a relative comparison between impacts of vehicle-miles traveled on different facility types. Road equivalents will be used to estimate tradeoffs between build and no-build PM_{10} emissions of proposed projects. Emission factors predicted by the AP-42 equation are a function of silt loading and silt loadings vary based on road type and location (county and state). Silt loadings for California have been published by the California Air Resources Board and these data are used to compute the road equivalents printed in this appendix. However the use of more updated or directly applicable data (such as measurements at the project site) is recommended. When applying this technique to other regions or areas, if local silt loading data is available and more appropriate than California data, substitute the local data for the silt loading values included in **Table D-1** and regenerate the equivalents using the approach described below.

Road equivalents can be used to represent relative emission *impacts* by representing the impact of vehicle travel on one road type in terms of a common road type. The approved U.S. EPA equation to calculate paved road emission factors (E) for re-entrained dust was used to estimate impacts, so this equation is briefly described. The E was given in Equation 1, and is repeated here for clarity:

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

where:

E = particulate emission factors (in g/VMT)
k = base emission factor (in g/VMT) for PM equal or less than a given diameter
sL = road surface silt loading (in g/m^2)
W = average weight of the vehicles traveling the road (in tons)

To compare the PM_{10} impacts of one mile of travel on different road types, for example to compare typical per-mile emissions for freeways with that of local roads, the following ratio can be examined:

$$(1mile)*E_{freeways}/(1mile)*E_{local}$$

The terms k and $(W/3)^{1.5}$ cancel out because k is a constant for all E for PM_{10} since it is a factor of the upper particle size considered, and W is a fleet average. The ratio will be used in a localized area and so the average fleet weight is considered approximately equal in the area considered. There is error inherent in this approximation, however for this qualitative assessment it can be neglected. The ratio above reduces to:

$$\frac{E_{freeways}}{E_{local}} = \frac{\left(sL_{freeways}/2 \right)^{0.65}}{\left(sL_{local}/2 \right)^{0.65}}$$

Similarly, when comparing freeways with major streets or collectors the appropriate ratio can be calculated. Table D-1 summarizes $(sL/2)^{0.65}$ for freeways, major streets and collectors, and local roads; this table includes specific silt loading values for California for all counties (with the exception of counties listed in the footnote). For the specific project area, the appropriate silt values must be substituted and the ratios re-computed. Equivalents were given in Table 5. of the protocol.

Table D-1: Example of relative emissions per mile based on facility type, AP-42 methodology and CARB county-specific silt loading values (sL).

Facility type	sL (ARB county-specific)	$(sL/2)^{0.65}$
freeways	0.020	0.050
major street/highway	0.035[1]	0.072[1]
collector	0.035[2]	0.072[2]
local road	0.320[3]	0.304[3]

[1]All counties except: Los Angeles, Orange, Riverside, San Bernardino where sL=0.037
[2]All counties except: Los Angeles, Orange, Riverside, San Bernardino where sL=0.037 and Imperial where sL=0.320
[3]All counties except: Los Angeles, Orange, Riverside, San Bernardino where sL=0.240

From the data in Table D-1, one mile traveled on a local road would contribute approximately the same PM_{10} emissions as 6 miles traveled on a freeway (0.304/0.050). Similarly, one vehicle traveling one mile on a local road would have the same PM_{10} impact as 6 vehicles each traveling one mile on the freeway. Using this approach, road equivalents for each type of road were computed and are listed in Table 5. The discussion below provides an illustration using the road equivalents concept.

Illustration of Road Equivalents Concept

To illustrate the use of road equivalents the following two scenarios will be compared:

Scenario 1: Addition of 8,500 vehicles per day to an intersection
Scenario 2: Addition of 10,000 vehicles per day to a freeway

Using the data in Table 5. the vehicles added to the intersection in Scenario 1 can be expressed in terms of freeway equivalents. Assume the approaches to the intersection are collector roads, then for the intersection:

- (1.4 freeway vehicle-miles / 1 collector vehicle-mile) × 8,500 collector vehicle-miles = 11,900 equivalent freeway vehicle-miles.
- The 8,500 vehicles through the intersection is equivalent to 11,900 vehicles on the freeway on a per mile basis. Compared to Scenario 2 in which 10,000 vehicles were added to the freeway, we can qualitatively say that the PM_{10} impacts of Scenario 1 are greater than the impacts of Scenario 2.

APPENDIX E: PM_{10} MITIGATION AND CONTROL MEASURES IN PROPOSED PROJECTS AND HOW TO APPLY BENEFITS TO THE QUALITATIVE PROTOCOL

Overview

Factors for controlling PM_{10} emissions due to re-entrained dust from paved road travel include (1) reduction in silt loading on roadways, and (2) reduction in VMT. In this Appendix, street sweeping techniques are examined in detail to illustrate how the use of mitigation options may be accounted for when conducting the qualitative PM_{10} analyses discussed in this Protocol. Landscaping, paving shoulders, and adding curbs are additional examples of PM_{10} mitigation measures. Mitigation approaches may be applied to analyses through estimates of silt loading reductions or by applying a percent reduction in emission factor. Any reductions applied to the proposed project emissions should be discussed through interagency consultation. There are two places in the protocol, discussed here, where mitigation benefits can be applied: in the Relocate and Reduce approach and in the Threshold Screening approach.

Example Using Street Sweeping in the Relocate and Reduce Approach

Field tests of eighteen different types of 'efficient' street sweepers found removal efficiencies ranging from 26% to 94% (Fitz 1999). Sweepers were tested with repeated tests and efficiencies varied more by sweeper type than by test run. Two sweepers had one test each below 30% efficiency, however the mean efficiency over all sweepers and tests was 76%. The Maricopa County, Arizona PM_{10} plan specifies that efficient sweepers initially remove 80% of the silt on roadways and conventional sweepers remove 30% (Maricopa Association of Governments 2001). The Maricopa Association of Governments (MAG) assumes surface loadings return to original values on the 9th day after sweeping with reduced benefits on days 2-8 after the sweeping day. At this time, there are no known studies to support this assumption. Also, it should be noted that in one study PM_{10} concentrations measured after sweeping were higher than concentrations measured before sweeping (Fitz 1998). For this example, it is assumed that a street sweeping program will provide for regular sweeping such that original silt loadings will be reduced by 30% and maintained at that loading. Based on this approximation, the 'road equivalents' discussed in APPENDIX D: Supporting calculations for "road equivalents" used in The relocate and reduce approach , to estimate tradeoffs between build and no-build PM10 emissions of proposed projects can be modified. **Table E-1** illustrates that a *30% reduction in silt loads* due to street sweeping translates into a *20.7% reduction in PM_{10} emissions* according to the AP-42 paved road PM_{10} emission factor formula (described in Equation 1 and Appendix D).

Table E-1. Example effects of mitigation on emissions per mile, based on facility type, AP-42 methodology, CARB county-specific silt loading values (sL), and an assumed 30% reduction in silt loads due to mitigation.

Facility type	sL_{ARB} (ARB county-specific)	$(sL_{ARB}/2)^{0.65}$	$sL_{70\%}$ (reduced by 30%)	$(sL_{ARB}/2)^{0.65}$	% Reduction in emissions
freeways	0.020	0.050	0.014	0.039	20.7 %
major street/highway	0.035[1]	0.072	0.024	0.057	20.7%
collector	0.035[2]	0.072	0.025	0.057	20.7%
local road	0.320[3]	0.241	0.224	0.241	20.7%

[1]All counties except: Los Angeles, Orange, Riverside, San Bernardino where sL=0.037
[2]All counties except: Los Angeles, Orange, Riverside, San Bernardino where sL=0.037 and Imperial where sL=0.320
[3]All counties except: Los Angeles, Orange, Riverside, San Bernardino where sL=0.240

Table E-2 was created using data from Table E-1 and Table 5 (the road equivalents table). Data from Table E-1 can be used to show that one mile traveled on a mitigated local road would contribute approximately the same PM_{10} emissions as about 4.8 miles traveled on a freeway with no mitigation program (0.241/0.050). Similarly, one vehicle traveling one mile on a local road that has a regular sweeping program would have the same PM_{10} impact as about 5 vehicles each traveling one mile on the freeway. Road equivalents comparing swept roads with roads that have no sweeping are summarized in Table E-2. These values would be used in place of those listed in Table 5. in the Protocol. Table 5 is currently used in Chart 4, the relocate and reduce approach.

Table E-2. Estimated 'road equivalents' between mitigated and unmitigated facilities including street sweeping activities only.

These types of travel can be approximated as equivalent.			
1 vehicle mile on mitigated facility type	**Equivalent vehicle miles on unmitigated facility**		
	Freeway	**Local**	**Major/highway/collector**
freeway	0.8	0.1	0.5
local road	4.8	0.8	3.3
major street/highway or collector	1.1[1]	0.2	0.8

[1]Entry used in example in appendix text.

In order to apply benefits of a mitigation measure (e.g. street sweeping) into the Relocate and Reduce Approach the following steps can be taken:

1. Determine the percent decrease in silt loadings resulting from mitigation activity (30% is assumed in the street sweeping activity illustrated here).

2. Use CARB default silt loading values and compute the quantities: $(sL/2)^{0.65}$ for the original silt loadings and the mitigated silt loadings such as was done in Table E-1 (produces an estimate of the change in emissions).

3. Convert VMT to freeway-equivalent vehicle miles for the mitigated facility as described in Appendix D (see example shown in Table E-2).

4. Continue the relocate and reduce steps using the mitigated freeway-equivalent values.

<u>An example of road equivalents where street sweeping mitigation is included in one of the proposed project scenarios</u>:

Two scenarios will be compared:

> Scenario 1: Addition of 8,500 vehicles per day to an intersection where street sweeping will be used for all of the approaches in an approved program. The approaches are collector roads.
>
> Scenario 2: Addition of 10,000 vehicles per day to a freeway

First, determine the percent reduction in the silt loading for the sweeping program. For this example, the sL will be reduced by 30% as a result of that mitigation effort. Therefore, the values in tables E-1 and E-2 can be used directly. Next, convert the miles traveled on the approaches (collector roads) to equivalent freeway miles using the mitigated values in Table E-2. For the intersection in Scenario 1 the resulting freeway miles for additional 8,500 vehicles per day on the mitigated collector road is found as follows:

(1.1 freeway vehicle-miles / 1 mitigated collector vehicle-mile) $\times$ 8,500 collector vehicle-miles = 9,690 equivalent freeway vehicle-miles.

Therefore, the 8,500 vehicles through the intersection converts to 9,690 freeway-equivalents. When we compare this value to Scenario 2 in which 10,000 vehicles were added to the freeway, we can qualitatively say that the PM_{10} impacts of scenario 2 are greater than the impacts of scenario 1 when mitigation is used for the intersection project but not for the freeway project.

Note the different result illustrated in this example, compared to the unmitigated example of the same scenarios used in Appendix D. With this illustration, the mitigation allows the project to qualitatively pass the PM_{10} test, where the unmitigated project failed the test.

Example Using Street Sweeping and the Threshold Screening Approach

To apply mitigation benefits in the threshold screening approach, we again look at the AP-42 equation (Equation 1). The AP-42 equation can be used to estimate emission factors in units of grams per mile, whereas the threshold screening approach uses concentration estimates to determine if incremental additions to concentrations by proposed projects will result in a PM_{10} hotspot. For this example, concentration decreases can be equated to decreases in emission factors. This makes sense because emissions and concentrations for this qualitative hot-spot analysis are related through vehicle miles traveled and dilution (wind) parameters (since secondary formation of particles is not considered in this protocol). Therefore, for mitigation techniques that reduce silt loading values, AP-42 can be used to compute the relative decrease in emission factors and this percent decrease can then be applied to project-related incremental concentrations.

To apply mitigation benefits to the threshold screening process the incremental emissions for the proposed project are adjusted by the reduction in emission factors resulting from lower silt loading (sL). The procedure can be described in four steps. First, the analyst must determine how much the sL will be reduced as a result of the mitigation effort. Once that information is available, the percent reduction in emission factor (and concentrations) is determined. This is done using the approach described in the creation of Table E-1 and detailed below (step 2 below). The resulting percent decrease in concentrations is applied to the project incremental concentration value previously determined in the threshold process. These steps can be summarized as follows:

1. Determine the percent decrease in silt loadings resulting from street sweeping activity.

2. Compute the resulting percent decrease in emission factors by considering other variables in AP-42 as constant and using default ARB silt loadings. The following equation is used:

$$\textit{\% emission factor decrease} = 100\%*[(original(sL/2)^{0.65}-mitigated(sL/2)^{0.65})/original(sL2)^{0.65}]$$

3. Equate the percent decrease in concentrations with the percent decrease in emission factors.

4. Multiply the incremental concentration by the percent decrease resulting from mitigation to compute the new ‘mitigated’ incremental value.

Example of applying percent decreases in concentrations to the threshold screening approach with a street sweeping program:

This example is based on the information in the example analysis described for Process 3, Threshold screening; please refer to that text prior to reading this example (see example analysis that begins on page 13).

In step F3.2 of the example, the 24-hr incremental concentration was 5.8 $\mu g/m^3$. To include the mitigation benefits, first determine the percent decrease in silt loadings. For this example, assume that street sweeping would be used and would result in a 30% reduction in silt loading. The data in Table E1 could then be used directly. Concentration reductions would be estimated as follows:

The incremental value selected would then be reduced by 20.7% (from Table E-1).

Mitigated incremental value = (100%-20.7%)*5.8 $\mu g/m^3$ = 4.6 $\mu g/m^3$
This value would then be compared to the allowable threshold of 20 $\mu g/m^3$. In addition, this value would be used to calculate the annual incremental value using the appropriate CR.

APPENDIX F: COMMENTS RECEIVED AND RESPONSES PREPARED

Comments Received from FHWA

Below are comments received from FHWA, and a detailed response to each of the comments. Wherever a response states, "addressed," it means the protocol was edited to address the concern raised. In some cases, the protocol was not changed, but additional information is provided in the response to offer a more detailed explanation of the basis for the protocol's design. Note that the FHWA comments refer to page numbers in the April 11, 2003 protocol version (conference paper delivered to the Air & Waste Management Association; available at: http://aqp.engr.ucdavis.edu/PM%20Issues/DraftPaper70067.pdf).

<u>Comment 1:</u>

> It needs to be clarified that this protocol is for conformity purposes (project level hot spot analysis) only, but not for NEPA.

Response

> Addressed—edited the "Introduction" section.

<u>Comment 2:</u>

> Page 2 - the methodology discussed only includes AP-42 methodology, and did not include tailpipe emissions. Hot spot analysis is required to include all emissions from the project.

Response

> The protocol takes both tailpipe and road dust emissions into consideration:

a. The Project Comparison approaches (Steps 1 and 2 of the protocol) both involve comparing the study project to projects operating in the real world. The "real world" projects are defined to be those where observed PM_{10} concentrations do not exceed the NAAQS. By definition, concentrations observed in the real world are a function of all contributing emissions, and thus the Project Comparison approaches consider tailpipe and road dust emission contributions.

b. The Threshold approach (Step 3 of the protocol) is based on observed PM concentrations near roads, and the real-world observations are a function of both tailpipe and road dust emissions. In most situations, road dust largely accounts for the PM_{10} concentrations observed. However, there may be situations where a road being studied has an unusually high percentage or number of heavy-duty diesel vehicles. The studies used to create the Threshold approach did not report traffic with unusually high numbers or percentages of diesel vehicles (see Appendix B). It is therefore not appropriate to use the Threshold approach in cases where diesel traffic is unusually heavy and tailpipe PM contributions exceed those found on more typical roads; this constraint is addressed through the project eligibility check list contained in Table 1 of the protocol.

c. The Relocate and Reduce approach (Step 4 of the protocol) is designed conservatively (meaning it errs on the side of being environmentally protective) by considering only road dust impacts. However, relocate-and-reduce situations resulting in reduced road dust will also likely result in reduced tailpipe emissions. For example, if a project moves traffic from a local road with high silt loads to a freeway with low silt loads, road dust is reduced. In addition, the traffic that is now on the freeway, instead of the local road, will likely travel with fewer stop-and-go conditions. Traffic congestion relief should also reduce stop-and-go driving on the local road. Studies show that diesel vehicle PM emissions are greater under load and accelerations than during cruise (e.g., see Clark et al., 2002), a result familiar to most people (picture exhaust smoke from trucks accelerating from a stop). Thus, the Relocate and Reduce approach is applicable in situations that result in simultaneous reductions of both road dust and tailpipe emissions.

Comment 3:

Page 4, Table 1 #3 – Hot spot analysis applies to all Federal non-exempt projects. The conformity rule does not allow projects to be immediately screened out if they are not regionally significant. [The only possible way is if the State in its conformity SIP defined regionally significant in terms of VMT, and if that VMT level was based on emissions and associated concentrations.]

Response

Addressed—we deleted text in table to correct for comment.

Comment 4:

Page 4, Table1 #6 – we disagree that all projects not included in a conforming plan and TIP can be screened out. This will exclude all projects in rural areas (or in some cases, donut areas) that are subject to hot spot analysis.

Response

Addressed—added footnote to table to deal with rural areas.

Comment 5:

Page 4, Table 1 #7, what is the definition of "dominated." How high a percentage do non-vehicular sources need to be?

Response

We have included additional guidance material in Appendix A, under a section entitled, "Background Information Concerning Situations Where PM_{10} Concentrations are Dominated by Non-Vehicular Sources." Current federal policies are vague on the specific amount or percentage of on-road emissions that might be considered insignificant, or dominated by other source categories. The protocol language is broad enough to allow for a "common sense" interpretation of whether on-road vehicles are important contributors. In addition, if it is unclear whether on-road vehicles are "dominated" by other sources, the protocol user is directed to seek clarification through interagency consultation. Through interagency consultation, we would expect that agencies would readily be able to identify areas that fall under this category. For example, in California, on the eastern side of the Sierra Nevada mountains, there are PM_{10} nonattainment areas due to overwhelming dust storms originating from the dry lake beds and deserts; traffic contributes only negligibly to the local problem (see Appendix A).

Comment 6:

Page 5, the use of Steps 1 – 4 implies that this is a sequential process when in fact the steps are discreet. May want to change the word “step” to “process”.

Response

Addressed.

Comment 7:

Step 1, Project Comparison: Maintenance Areas. We questioned the validity of this entire procedure. It assumes that the entire region would have the same background concentration, which may not be always true.

Response

The Protocol assumes that, by default, since the area is attainment, then the highest background concentrations will not exceed the NAAQS. This is a supportable premise, since if the opposite were true, then by legal definition the area would have to be designated a nonattainment area by EPA.

Comment 8:

Similarly, the method also assumes that the PM-10 concentration in the project analysis year is not worse than the attainment year. Again this may not be always true.

Response

Again, unless the area is predicted to become nonattainment by the analysis year, then the presumption must be that the highest background concentrations do not exceed the air quality standards. Thus, by definition, every project in existence is already in compliance with the standards. A similar concept was incorporated into the CO protocol and approved by EPA (the CO protocol is available from Caltrans at: http://www.dot.ca.gov/hq/env/air/index.htm).

Comment 9:

Most importantly, the regional analysis cannot substitute for the hot-spot analysis. Existing monitors may show the area is in attainment. However, what if the background concentrations near the proposed project are actually much higher than the regional background concentrations and there is no existing monitor in the area? Localized concentrations could actually be above the standard.

Response

The protocol uses existing law as the starting framework for analysis. While conceptually we would agree that in an attainment area it may be possible to find a location that exceeds the air quality standards, the framework of the Clean Air Act presumes that attainment areas are, by definition, free from nonattainment problems. We therefore start with that premise in building the protocol. We assume that if hot-spot problems exist, then by definition the area would be nonattainment. Conceptually, for analysis purposes the analyst needs to rely upon the premise that an attainment or maintenance region does not have violations of the air standards taking place. If that premise is not supportable, then there is no distinction to be made between areas that attain the standard, and those that do not, and this defies logic.

Comment 10:

Step 3, Threshold Screening. We do not understand why it is "inherent in the Threshold Screening approach" that regional PM-10 concentrations do not exceed the NAAQS in the project analysis year. This seems to be confusing regional analysis with hot-spot analysis.

Response

Addressed—the Threshold Screening approach is only appropriate in areas where the NAAQS are not being exceeded. We have added a sentence to state, “Inherent in the Threshold Screening approach is an understanding that regional and microscale PM_{10} concentrations do not exceed the NAAQS in the project analysis year.”

Comment 11:

The concentrations near the comparison project must not exceed the NAAQS for the analysis year. Also, is Table 3 (on P. 9) supposed to be used as an example? This needs to be clarified.

Response

Addressed—additional text has been added to clarify the role of Table 3; and supplemental explanatory material has been added as Appendix B to further describe the underlying assumptions behind the information included in Table 3.

Comment 12:

Step 4, Relocate and Reduce: Build vs. No-Build. In the 1993 transportation conformity rule preamble, EPA explains that in order for a new violation to be considered as relocation and reduction of an existing violation, 2 conditions must be met: (1) the new project is the area substantially affected by the project (which in this case, it was defined as within 100 m) and (2) the predicted design value for the “new” site would be less than the “design value at the “old” site without the project (i.e., a net air quality benefit.) It seems that this step does not address the 2nd part of the requirements.

Response

Addressed—explicit recognition of the EPA 1993 preamble criteria is now included at the beginning of this approach, to guide protocol users in understanding the regulatory basis for how the analysis approach should be applied. Also, steps F4.1 and F4.2 explicitly ask users to compare build vs. no-build traffic volumes in the vicinity of the proposed project; and step F4.3 explicitly considers impacts within 100m of the project to insure that potential overlapping contributions are added together. Combined with the regulatory citation we are now including, we believe this gives readers ample guidance to user the protocol appropriately.

Comments Received from the California Air Resources Board

Comment 1:
The methodology uses the 99th percentile PM_{10} concentration to determine the peak 24-hour concentration for an area. Since the revised version of the PM_{10} standard that employed the 99th percentile was withdrawn, the peak value rather than the 99th percentile value should be used for appropriate comparison with the national standard. To maintain a conservative approach, we would suggest using the maximum 24-hour concentration and the maximum annual concentration that occurs in the most recent three year period.

Response
Addressed —EPA reports that the standard was 'corrected' and the current regulation is based on the peak 24-hr concentration (see information dated March 9, 2004, available at www.epa.gov/air/data/whatsnew.html). The corrected standard requires that 24-hr average PM_{10} concentrations not exceed 150 ug/m^3 more than once per year. The text now specifies the use of the maximum 24-hour concentration. Tables and appendices have been updated to reflect the change.

Comment 2:
While it is appropriate to convert the peak 24-hr impacts to an annual impact, we don't believe the methodology used in the report is the correct way to derive a conversion factor. The report uses the ratio between the peak ambient 24-hr concentration and the annual average, and then selects the highest value observed across all sites. However, the fundamental factors that control the variability between 24-hr and annual average ambient concentrations are not necessarily those that control why 24-hr emission impacts would be different from annual impacts. Areas with strong seasonal variation in PM concentrations are often due to the impacts of sources such as residential wood combustion and the influence of secondary ammonium nitrate. In contrast, emission impacts from roadways depend upon traffic volume (which could vary by time of day and time of year) and rainfall (which affects silt loading). As an alternative, perhaps UC Davis could use the emission inventory estimates for paved roads, and compare the ratio of peak emissions (time of day, day of week, month) to the annual emissions to derive a ratio. It may well turn out with a ratio which is about the same, but it would be better linked with the phenomena that drives the variability.

Response
CARB suggested using emissions inventory estimates to derive the conversion ratio in place of measured ambient concentrations, as recommended in the protocol. This is a good suggestion and we considered this approach during protocol development. We decided to employ the ambient data in order to estimate, to some degree, the impacts of some of the other influences on ambient PM concentrations that would be important in converting 24-hr estimates to annual estimates (e.g., weather conditions that affect silt loading). We hypothesized that actual measured ambient concentrations are a better indicator of the relationship between 24-hr and annual average concentrations, rather than modeled emissions inventory results. We therefore decided to continue use of a concentration-based conversion ratio, rather than one based on emissions estimates.

Tabulated conversion ratios were updated to reflect the use of the 24-hr maxima rather than 99th percentile. A conversion ratio is estimated for each of the three most recent yeas of available data (1998, 1999, and 2000 in this case) by dividing the maximum annual concentration by the maximum 24-hr concentration, then taking the largest of the three values as the conversion ratio. Using the largest value is conservative; the methodology predicts the largest annual average project increment from the observed short term worst case increments.