Quantitative Particulate Matter Hot-Spot Analysis Best Practices Guidebook

Version 2.0

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15. Abstract
This guidance package summarizes case study material based on real-world experience for modeling quantitative PM hot-spot impacts. Key components of the package include an overview of the PM hot-spot analysis procedure, guidance for estimating the level of effort required for an analysis, guidance on how to review and quality assure AERMOD modeling results, a discussion of potential project features that may help reduce PM impacts, and guidance on best practices to streamline the development of PM hot-spot analysis documents. The package also includes a checklist to facilitate AERMOD modeling reviews and summarizes recently completed documents about hot-spot analysis.

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Cover graphic illustrates the kind of vehicles and traffic that contribute to particulate matter (PM) hot spots, as well as forms of transportation that can help mitigate PM concentrations.

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Abstract

Background: Since December 2012, the U.S. Environmental Protection Agency (EPA) has required that certain transportation projects perform a quantitative particulate matter (PM) hot-spot assessment to inform transportation conformity determinations. As of this writing, implementation of the PM hot-spot analysis requirement is still in its early stages. These guidance materials are designed to assist with the completion of conformity-related PM hot-spot analyses by offering guidance and best practices based on lessons learned from analyses performed to date and other resources.

Methods: To develop this best practices guidebook material, Sonoma Technology, Inc., worked closely with Caltrans headquarters and District staff as a team to identify and document practical lessons learned that can help conserve project time and resources. The team reviewed EPA guidance documents, solicited and evaluated feedback from Caltrans staff during STI's PM hot-spot training classes, reviewed Interagency Consultation comments to identify key questions about the hot-spot analysis procedure and level of effort required, and obtained from Caltrans District staff important observations regarding their experiences with recent project analyses. Modeling scenario analyses were also completed to identify project features and potential mitigation measures that may help reduce PM impacts and help project analysts meet conformity requirements in challenging project situations.

Results: This guidance package summarizes case study material based on real-world experience for modeling quantitative PM hot-spot impacts. Key components of the package include an overview of the PM hot-spot analysis procedure, guidance for estimating the level of effort required for an analysis, guidance on how to review and quality assure AERMOD modeling results, a discussion of potential project features that may help reduce PM impacts, and guidance on best practices to streamline the development of PM hot-spot analysis documents. The package also includes a checklist to facilitate AERMOD modeling reviews and summarizes recently completed documents about hot-spot analysis.

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1. Introduction

Under the transportation conformity requirements, quantitative particulate matter (PM) hot-spot analyses must be conducted to assess potential near-road air quality impacts from certain transportation projects. The requirement applies in areas designated by the U.S. Environmental Protection Agency (EPA) as being PM nonattainment and maintenance areas under the U.S. Clean Air Act. PM hot-spot analysis is a complex procedure and involves detailed emissions and dispersion modeling, substantial data processing, and extensive interagency consultation. Since December 2012, several Caltrans District offices, including Districts 6, 7 and 8, have overseen or completed quantitative PM hot-spot analyses. Important lessons have emerged from these project evaluations.

1.1 Purpose of This Guidebook

This guidebook provides Caltrans analysts with best practice materials, based on recent experience, to support PM hot-spot analyses. Use of this guidebook will reduce project analysis time and cost, and will help analysts forecast the level of effort needed to complete hot-spot analysis steps. This guidebook also includes practical advice to streamline analysis documentation.

This guidebook includes evaluation results that will improve project modeling by helping Caltrans analysts understand how key project variables affect PM emissions and near-road concentrations. This guidebook also includes reference information to help analysts understand potential PM mitigation approaches. Finally, the guidebook documents real-world experiences and lessons learned from Caltrans staff who have had an opportunity to complete PM hot-spot analyses.

1.2 Guidebook Document Organization

This guidebook is organized into several best practice topic chapters. **Chapter 2** summarizes the level of effort needed to complete a quantitative PM hot-spot analysis; this information will help Caltrans staff develop improved schedules and budgets for completing hot-spot analyses. **Chapter 3** documents procedures and provides a checklist for analysts to use when reviewing and quality-checking AERMOD dispersion modeling analyses. **Chapter 4** presents scenario analysis results highlighting how key project variables affect near-road PM concentrations; the results provide a reference to support developing potential mitigation options. **Chapter 5** provides information and best practices for developing and streamlining PM hot-spot documentation, and includes the tables of contents from recently completed hot-spot analysis documents. **Chapter 6** documents practical experiences and lessons learned for conducting a quantitative PM hot-spot analysis, based on discussions with Caltrans District staff and insights gleaned from interagency consultation documents. In addition, the guidebook includes an appendix on AERMOD dispersion modeling.

2. PM Hot-Spot Analysis Needs

2.1 Introduction

This chapter provides information and estimated ranges regarding the level of effort needed to complete a quantitative particulate matter (PM) hot-spot analysis for transportation projects. This information is intended to help Caltrans managers and project analysts develop improved schedules and budgets for completing PM hot-spot analyses. In addition, this information can frame appropriate schedules and work scopes for consultants who may help Caltrans conduct all or portions of a PM hot-spot analysis.

The information in this chapter is presented according to the time needed to complete analyses. Once a project analyst refines the range of staff time needed to complete their individual project assessments, other rules of thumb may be used to translate those time costs into funding needs. For example, level-of-effort estimates provided here can be used in conjunction with rough guidelines for estimating labor costs developed by the American Association of State Highway and Transportation Officials (AASHTO) Standing Committee on Research. According to AASHTO's template for preparing National Cooperative Highway Research Program (NCHRP) funding requests,[1] "*as a general guideline, the present cost for research usually averages about $200,000 for 100 percent of a professional employee's time per year. This figure represents a fully loaded, professional rate that would include an individual's direct salary and benefits and an agency's overhead or indirect costs. Average rates for supporting staff might be approximately one-half those of professionals.*"

2.1.1 How Were These Estimates Developed?

The estimates in this chapter are derived from discussions with Caltrans District staff members who have real-world experience with conducting PM hot-spot analyses, and from STI's Caltrans-sponsored work completing PM hot-spot analyses and developing and illustrating the use of PM hot-spot analysis methods and tools. The estimates are also based on STI's National Cooperative Highway Research Program (NCHRP)-sponsored work preparing national guidance to support PM hot-spot analyses and STI's Near-Road Air Quality Pooled Fund-sponsored work to prepare and complete numerous emissions and air quality modeling scenarios.

Examples of resources that were evaluated to prepare these estimates include:

- Reviews of Interagency Consultation comments received through the Southern California Association of Governments (SCAG) Transportation Conformity Working Group (TCWG);

[1] This template is available online at http://web.transportation.org/nchrp/scod/Format.aspx.

- Lessons learned from Caltrans District staff involved in completing the High Desert Corridor project's PM hot-spot assessment;
- Feedback from Caltrans staff received during STI's PM hot-spot training classes; and
- Guidance documents created by the U.S. Environmental Protection Agency (EPA) to support quantitative PM hot-spot assessments.

2.1.2 Overview of PM Hot-Spot Analysis Procedure

The overall procedure for conducting a quantitative PM hot-spot analysis consists of eight work steps, plus development of final documentation that presents the conclusion of the conformity analysis and supporting material. This sequence is outlined in prior guidance (Quantitative Particulate Matter Hot-Spot Analysis Guidance, Version 3.2, dated November 26, 2014). **Figure 1** summarizes this process in a flowchart and this guidance document closely follows the work steps presented in this figure.

From a planning and management perspective, some work steps in Figure 1 can be performed simultaneously while other work steps must be performed sequentially. **Figure 2** provides a precedence diagram of work steps in a PM hot-spot analysis. The sequence of work suggested here differs somewhat from the flow diagram in Figure 1. For planning purposes, it is advantageous to determine background concentrations early in the analysis process, as this information can be used to help define the analysis approach; determine the need for a no-build scenario; and plan for the data, time, and resources needed to complete the entire analysis. For example, if the background PM concentration for a project area is greater than the National Ambient Air Quality Standards (NAAQS), a build vs. no-build comparison must be conducted; with sufficient planning, much of the work for the build and no-build scenarios could occur simultaneously.

Interagency consultation and documentation are required for all aspects of the PM hot-spot analysis, and plans must be made to budget for the time and resources needed to complete interagency consultation and documentation. These work steps are included in the diagram in Figure 2.

2.2 Guidance for Estimating Level of Effort to Complete PM Hot-Spot Analysis

Figure 3 provides an estimated level of effort needed to complete each major work step of the PM hot-spot analysis procedure shown in Figure 1; the level of effort is given in terms of the approximate amount of time needed (days, weeks, or months) to complete the work. Figure 3 is meant to help analysts visualize which work steps require the most effort. For example, Step 2 (Determine Overall Approach) is estimated to take from a few days to a few weeks to complete, depending on several factors. The factors impacting the level of effort for each work step are discussed in detail in the sub-sections that follow Figure 4.

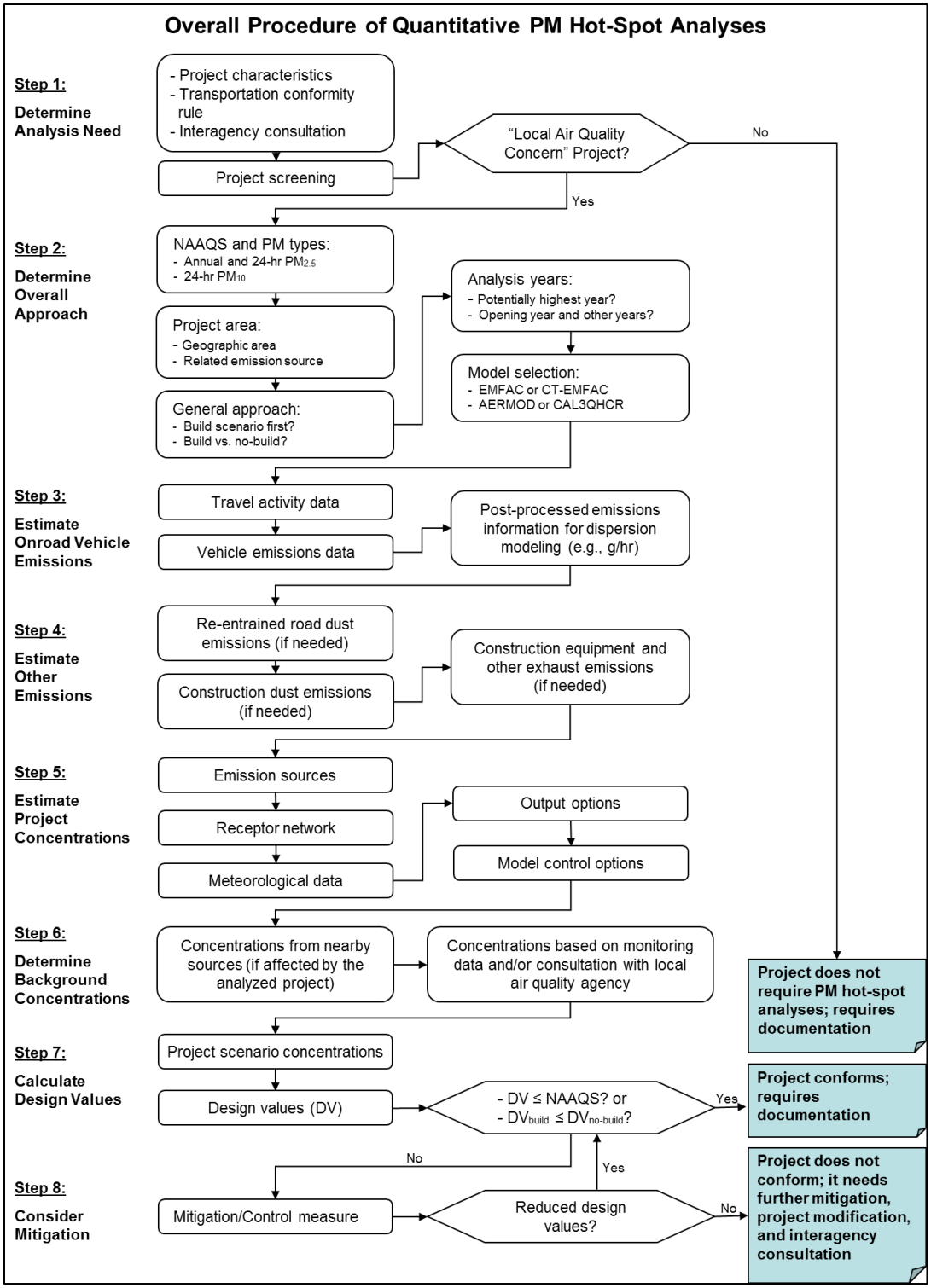


Figure 1. Quantitative PM hot-spot analysis procedures for a transportation project in California. PM hot-spot analyses involve a final documentation step with project conformity determination (blue boxes). Note that EPA is in the process of removing CAL3QHCR from the list of preferred air quality models for use in PM hot-spot analyses and other regulatory applications (see https://www3.epa.gov/ttn/scram/appendix_w-2016.htm).

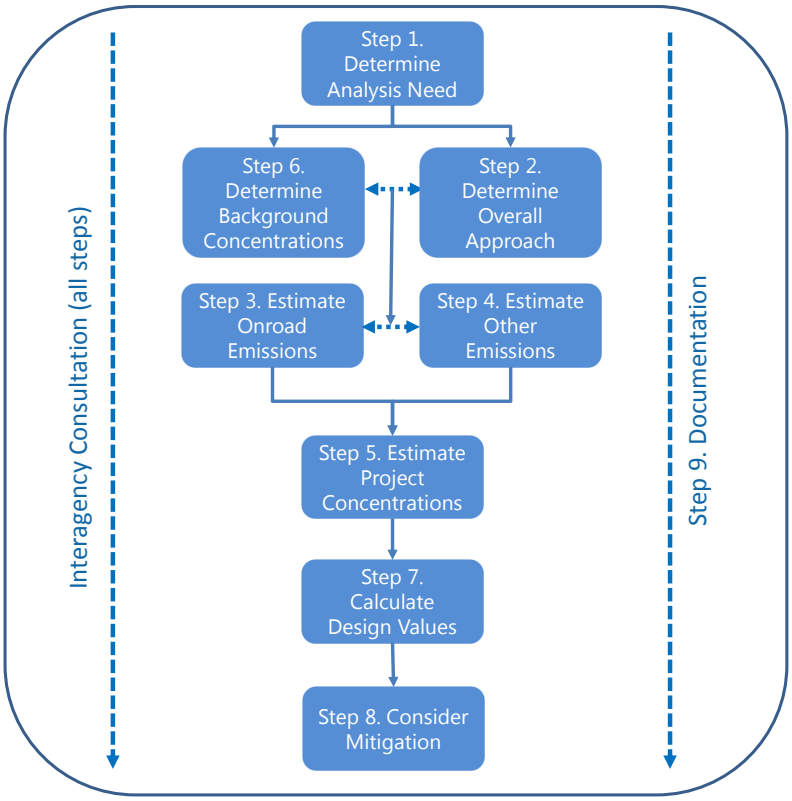


Figure 2. Precedence diagram for key work steps in a quantitative PM hot-spot analysis. Interagency consultation and documentation are required for all aspects of the PM hot-spot analysis.

Analysis Steps	How Long Will It Take?		
	Days	Weeks	Months
Step 1: Determine analysis need			
Step 2: Determine overall appoach			
Step 3: Estimate onroad vehicle emissions			
Step 4: Estimate other emissions			
Step 5: Estimate project concentrations			
Step 6: Determine background concentrations			
Step 7: Calculate design values			
Step 8: Consider mitigation			
Step 9: Documentation			
Complete PM hot-spot analysis			

Figure 3. Approximate level of effort required to complete PM hot-spot analysis steps. The bars indicate the relative amount of time required to complete each step. The actual time needed to complete these steps will vary widely by project type, geographic setting, calendar years to be assessed, interagency consultation, and other factors.

To provide additional information for planning each work step, the level of complexity (low, medium, high) and the uncertainty associated with the level-of-effort (low, medium, high) were estimated for each work step. This information is presented graphically for each work step; Figure 4 provides a sample chart representing a task that is of low complexity and has a low level of uncertainty.

On average, the overall PM hot-spot analysis process will likely require at least several months of calendar time. However, it is important to realize that each project is unique, and the actual level of effort needed to complete a hot-spot analysis depends on many factors, including the complexity of the project, the specific PM NAAQS to be evaluated (PM_{10}, $PM_{2.5}$, or both), the analysis years, and build alternatives under consideration. Other important factors can be difficult to predict, such as the availability of usable input data sets. Also, the proposed project and its build alternatives are revised during the analysis process; these changes will likely require additional data and modeling work, extending the time needed to complete a PM hot-spot analysis.

Over time, some staff members will gain considerable experience and expertise regarding PM hot-spot assessments. Those staff members with substantial experience in near-road emissions modeling and dispersion modeling will be able to carry out the technical aspects of these analysis steps more efficiently.

These level-of-effort estimates do not consider the time needed to develop travel activity data from a travel demand model. However, the estimates do account for the time needed for project analysts to work with travel demand modelers to identify data needs and acquire the necessary travel activity data.

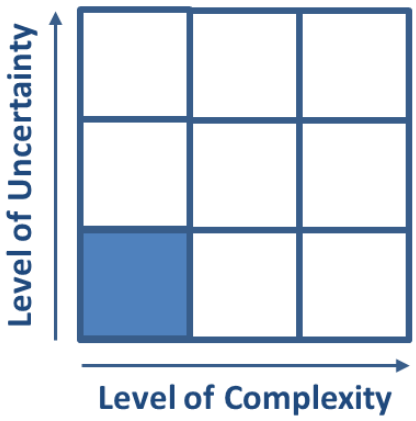


Figure 4. Sample plot of the complexity and uncertainty associated with various work steps.

Step 1: Determine Analysis Need

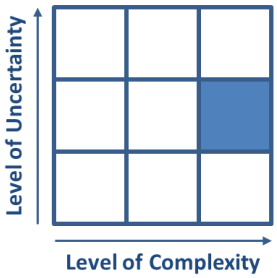
Step 1 focuses on evaluating whether a given project is a project of local air quality concern (POAQC) and, therefore, requires a quantitative PM hot-spot analysis. PM hot-spot analyses are not required for projects that are not POAQCs. The POAQC determination requires an analysis of traffic volume and truck percentage data for the base year (representing recent data to characterize "existing" conditions) and analysis years (typically corresponding to peak emissions over the timeframe from a project opening year to a 20-year planning horizon), with the no-build case and all build alternatives for the proposed project. This information must be presented to the appropriate air quality conformity working group for concurrence on the final POAQC determination.

This work step involves communicating data needs to travel demand modelers, acquiring the appropriate traffic volume data from the modelers, analyzing traffic volume and truck percentage data, preparing an analysis summary that supports a POAQC determination, and presenting that information to an interagency consultation group. This effort is of low complexity and is likely to require a few days of analyst time. In addition, project analysts should plan additional calendar time to arrange a meeting with EPA and the interagency consultation group to address comments or concerns that may be raised about the POAQC analysis and determination. For some projects, concurrence on a POAQC determination will require multiple discussions with the interagency consultation group. Projects that are obviously POAQCs or likely to be POAQCs may receive a quick concurrence from the interagency consultation group.

Step 2: Determine Overall Approach

Step 2 involves determining general analysis scales and approaches, including the relevant PM NAAQS to be considered, the appropriate project area and analysis years to be analyzed, the project scenarios to be evaluated, and the modeling tools to be used. This work step is moderately complex and may require a few days to a few weeks of analyst time. Analysts must coordinate through interagency consultation to identify appropriate input data sets and determine the details of the modeling approach. At this stage, project analysts will need to develop a modeling protocol that summarizes the proposed analysis approach, as well as the data, models, and assumptions to be used in the analysis, to give to EPA and the interagency consultation group. Developing a modeling protocol can take several additional days of analyst time, but this should be considered part of the work effort needed to document the analysis (Step 9).

Step 3: Estimate On-road Vehicle Emissions



Step 3 focuses on preparing link-level travel data for the project and estimating PM emissions from on-road vehicles using the latest EPA-approved EMFAC-based model. An important consideration for this step is that the detailed travel data for one or more project alternatives may be updated several times during the course of the project. If such updates occur, previously completed emissions estimates may need to be redone during the course of the analysis, which would require additional analyst time.

In addition, link-level travel data, including both traffic volumes and speeds, must be allocated to each hour of the day to support the preparation of hourly emissions estimates for use in dispersion modeling. Travel data from travel demand models is reported for multi-hour periods, such as morning peak, midday, afternoon peak, and night. These data must be assigned to the individual hours included in each period so that hourly emissions estimates can be prepared, and some coordination with travel demand modelers may be required to ensure that the data are properly understood.

Once final travel data are obtained and prepared, project analysts must use EMFAC-based modeling data to estimate on-road vehicle emissions. EMFAC2014, developed by the California Air Resources Board, received EPA approval for use in PM hot-spot analyses on December 14, 2015. When using EMFAC2014, analysts will use the Project-Level Assessment mode (EMFAC2014-PL) to generate PM emission rates for conformity analysis. To produce emission estimates, these emission rates must be combined with activity data outside of EMFAC2014 using a spreadsheet or other tool. Alternatively, Caltrans tools (e.g., CT-EMFAC[2] and EM4AQ[3]) can be used to perform the step of combining emission rates and activity data.

Given these complexities, this work step may require a few weeks of analyst time. Project analysts will spend the majority of this time using the EMFAC-based model to estimate on-road vehicle emissions.

[2] CT-EMFAC is a California-specific project-level analysis tool that models on-road vehicle emissions for criteria pollutants, mobile source air toxics (MSATs), and carbon dioxide (CO_2). By providing project-level travel activity data, analysts can use CT-EMFAC to estimate on-road vehicle emissions for an existing or a proposed transportation project. The current version of CT-EMFAC is directly based on EMFAC2014 emission factor data; no separate EPA approval is needed to allow CT-EMFAC to be used for conformity analyses.

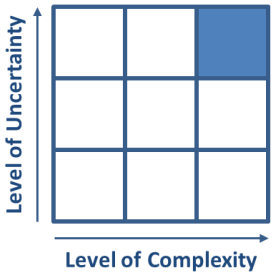
[3] The Emissions for Air Quality Tool (EM4AQ) is a Microsoft Excel spreadsheet-based tool which supports quantitative PM hot-spot analyses by processing CT-EMFAC particulate matter (PM) emission factors data and project-specific travel activity data to generate emissions input for AERMOD air quality modeling. EM4AQ calculates hourly PM emission rates for roadway sources defined in the AERMOD View user interface and includes automated features to generate an hourly emission rate file formatted for use in AERMOD runs.

Step 4: Estimate Other Emissions

Step 4 focuses on estimating PM emissions from other sources, such as re-entrained road dust, construction equipment, or major facilities with significant PM sources, such as bus terminals or rock quarries. In many cases, project analysts will only need to model emissions directly related to on-road motor vehicles (Step 3), but some time will be required to review the project setting to determine whether other potentially significant PM sources merit inclusion in the analysis.

The complexity of this step will also be influenced by the pollutant being evaluated. For PM_{10}, re-entrained road dust must be modeled, but for $PM_{2.5}$, road dust would be considered if it was a significant source of $PM_{2.5}$ emissions in the region (e.g., in Southern California). This work step may require a few days to a few weeks of analyst time, depending on the types and quantities of non-vehicle emissions sources that must be estimated.

Step 5: Estimate Project Concentrations



Step 5 focuses on dispersion modeling with AERMOD. Using detailed meteorological information and the emissions data estimated in Steps 3 and 4, this step involves estimating PM concentrations in the project area for the project build scenario (and no-build scenario when needed). Dispersion modeling is the most complex technical work step in the analysis, and may require several weeks to several months of analyst time to complete, depending on the complexity of the project, availability of computing resources, the amount of staff experience with AERMOD and dispersion modeling, and the availability of AERMOD-ready meteorological data.

Regarding meteorological inputs, AERMOD-ready data for a representative monitoring site may be available from the local air district. If this is not the case, it will be necessary to process the meteorological data using the AERMET tool, which formats the data for use in AERMOD and performs the meteorologically related calculations needed to set up an AERMOD run. In some cases, meteorological data from a representative site may be in a format that is not easily read by AERMET, which will require additional preprocessing to reformat the data for AERMET use. In addition, EPA generally requires that the meteorological data for the period modeled be 90% complete (e.g., the representative monitor has collected usable data at least 90% of the time). This completeness requirement may mean that data from multiple sites or years need to be evaluated to identify an appropriate meteorological data set. Given these issues, if AERMOD-ready meteorological data are not available, analysts can expect to spend significant additional work effort, up to a few weeks, acquiring and quality assuring raw meteorological data and preparing those data for use in AERMOD.

Other AERMOD-related tasks, such as configuring roadway links as emissions sources and setting up receptor networks for the project site, are facilitated by the AERMOD View graphical interface for AERMOD. The effort required for these tasks is a function of the scope and complexity of the project being modeled, but the tasks are likely to require several days to a few weeks of analyst time.

In addition, as noted under Step 3, the detailed travel data and associated emissions data for one or more project alternatives may be updated several times during the course of the project. If such updates occur after initial AERMOD simulations have been run, these model runs may need to be redone with revised emissions inputs, which would require additional analyst time.

Step 6: Determine Background Concentrations

Step 6 involves selecting appropriate ambient monitoring sites for determining background PM concentrations for the project area, acquiring the necessary ambient PM monitoring data, and calculating the background concentrations. Selecting a representative PM monitor requires analysis of several factors, including the distance of the monitor from the project site, the prevailing wind patterns in the area, and the density and mix of emissions sources near the monitor and project sites. In cases where no single monitor is appropriate for the project area, data from multiple monitors near the project site will need to be used, and a representative value interpolated.

In addition, EPA has established data completeness criteria requiring that 75% of scheduled samples in each calendar quarter of each calendar year are available for background concentration calculations, so analyst time is required to determine whether data completeness criteria requirements are met. In some cases, analysts may need to identify and remove data that have been influenced by an "exceptional event" (i.e., an event that affects air quality but is not reasonably controllable or preventable). However, only data for which exceptional event documentation has been reviewed and concurred upon by EPA can be excluded from background concentration calculations; these data records are readily identifiable in data sets made available by EPA.

Once data representativeness and completeness have been evaluated, the data can be used to calculate a background concentration. The level of effort in this task is determined, in part, by the NAAQS in effect for the project, as the NAAQS for annual $PM_{2.5}$, 24-hr $PM_{2.5}$, and 24-hr PM_{10} are calculated in different ways. The calculation method for 24-hr PM_{10} is the most straightforward, as the background concentration is determined by selecting the appropriate ranked 24-hr concentration from the three most recent years of air quality data.[4]

Caltrans has developed tools to support and speed calculation of background PM concentrations. These tools include (1) an ArcGIS web-based mapping resource to help analysts visualize and identify

[4] The first, second, third, or fourth highest 24-hr PM_{10} concentration is selected based on the number of daily observations available during the three-year period.

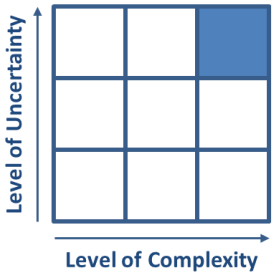
PM air quality monitors to represent their project site (see http://www.arcgis.com/home/content.html; note that a user name and password for ArcGIS need to be requested from Caltrans), and (2) a background concentration and design value calculation tool, available from the Caltrans air quality website (see http://www.dot.ca.gov/hq/env/air/pages/dvtool_license.htm) that automates background PM concentration calculations once an analyst has assembled monitoring data. However, because of the issues described above, calculating background concentrations can be tedious and time-consuming. Also, the processes to determine the representative monitoring location(s), address data completeness issues, and select appropriate calculation methods require interagency consultation. Therefore, determining background concentrations may require a few days to a few weeks of analyst time.

Step 7: Calculate Design Values

Step 7 involves calculating design values for the project, which are compared to the applicable NAAQS to determine whether or not a project meets transportation conformity requirements. Design values represent a combination of the background concentration calculated in Step 6 and the modeled concentrations generated in Step 5. For example, to calculate a design value for the annual $PM_{2.5}$ standard, the receptor with the highest modeled average annual concentration is identified, and the highest modeled concentration value is added to the background concentration value.

The process for selecting the modeled concentration varies according to the applicable NAAQS, but this process is relatively straightforward once AERMOD runs are completed and background concentrations have been calculated. In addition, Caltrans developed DVTool to automate the design calculation process. Therefore, calculating design values should require no more than a few days of analyst time.

Step 8: Consider Mitigation



Step 8 involves identifying and analyzing mitigation and control measures, when needed, to reduce PM emissions. This work step also involves developing additional emissions and dispersion modeling scenarios to quantify the benefit of proposed mitigation. If mitigation measures need to be considered for the project, several weeks to several months of analyst time may be necessary to complete this step, depending on the complexity of the project and proposed mitigation scenarios. This is a highly complex step since it requires additional rounds of emissions modeling, dispersion modeling, and analysis.

Step 9: Documentation

Step 9 involves documenting the PM hot-spot analysis to support the conclusions made in the conformity analysis. In general, drafting the final PM hot-spot analysis document will require a few weeks of analyst time. This includes time spent developing any necessary modeling protocols, as well as participating in interagency consultation and tracking key conversations and discussions with interagency consultation participants. Project analysts should anticipate significant additional time, in some cases weeks or months, for reviews, revisions, and a final conformity determination from U.S. Federal Highway Administration (FHWA).

3. AERMOD Modeling Review and Quality Assurance Guidance

3.1 Introduction

Chapter 3 documents procedures and methods to use when reviewing and quality-checking PM hot-spot dispersion modeling analyses. This material also supports interagency consultation. A PM hot-spot analysis involves many data processing and modeling steps, but the focus of this chapter is on AERMOD dispersion modeling, the most complex aspect of the analysis. The guidance provided here can be applied when reviewing AERMOD modeling completed either by Caltrans district staff or by outside contractors. Because Caltrans has licenses for the AERMOD View graphical user interface, this chapter includes specific examples tailored to AERMOD View.

This chapter is divided into two main sections. The Overview section highlights the three most common AERMOD modeling errors that QA reviewers should look for when reviewing PM hot-spot analyses, and provides suggestions on how to correct those errors. The overview also provides a modeling review checklist to assist reviewers in implementing an effective QA review process. This checklist can be used to quickly and systematically step through the important elements of an AERMOD modeling review. The QA Guideline section supplements the modeling review checklist with additional information on conducting AERMOD QA reviews. The QA guideline provides detailed steps that should be followed in a QA review, information on how to examine AERMOD inputs and outputs, and typical errors that occur in an AERMOD modeling analysis. The QA guideline also includes annotated AERMOD View screenshot examples to assist QA reviewers as they examine modeling data.

3.2 Overview

3.2.1 Common AERMOD Modeling Errors

When reviewing a PM hot-spot modeling analysis, QA analysts should pay special attention to common issues that can lead to significant errors in AERMOD modeling results. **Table 1** summarizes the top three issues encountered during modeling reviews, along with suggestions for identifying and addressing these issues. These and other common AERMOD modeling errors are discussed in more detail in the QA guideline.

Table 1. Top three issues encountered during an AERMOD modeling analysis review.

Issue	Discussion	Correction
Incorrect Emission Rate Input	Emission rate input units are grams per second (g/s) for volume sources, and grams per second per square meter (g/s-m^2) for area sources. Using the wrong emission rate will lead to inaccurate modeling results.	Double-check emission rates and units. AERMOD View provides the option to enter data in English units, but model input and output files always list emission rates in the International System of Units (SI units). Users must carefully check that units have not been transposed when setting up and interpreting model runs.
Incorrect Source and/or Receptor Placement	The location of modeled sources and receptor points is a critical element of the model input. Location errors for either sources or receptors will lead to inaccurate modeling results.	The easiest way to check for accurate source and receptor placement is to inspect the model input visually. This can be accomplished by exporting model input data to a GIS platform or inspecting the graphics within AERMOD View.
Incorrect Source Parameter Calculations	Emission source input parameters are calculated based on physical characteristics of the source. For example, volume sources require input of initial lateral and vertical dimensions (σ_y and σ_z). Incorrect assumptions used in calculating these values can lead to modeling errors.	Ensure that EPA's Transportation Conformity Guidance (U.S. Environmental Protection Agency, 2015) was followed when calculating source input parameters. For example, properly adjust the source height to reflect the mix of trucks and light-duty vehicles.

3.2.2 Checklist for Reviewing PM Hot-Spot Analysis Materials

The checklist in Table 2 walks QA reviewers through a PM hot-spot AERMOD modeling analysis. The checklist can be used to

1. Ensure each component of the modeling analysis is systematically examined
2. Emphasize elements contained in EPA's PM Hot-Spot Guidance
3. Document the QA review

Analysts can complete this checklist while conducting the QA review, and use it to document the modeling elements that were examined and record any comments or deficiencies with the analysis. Sections in this checklist containing the phrase "Pathway Inputs" refer to the specific AERMOD or AERMOD View input pathway where users specify the necessary modeling inputs.

Table 2. PM hot-spot modeling review checklist.

Model Component	Checked	Deficiencies and/or Comments
A. General Modeling Setup		
• Did the modeling cover the analysis years selected for the project?		
• Did the analysis cover the expected build (and no-build, as needed) alternatives for the project?		
• Was the correct version of AERMOD used?		
• Is a consistent coordinate system used across all data input?		
• Was the modeling protocol discussed and approved during interagency consultation?		
B. Control Pathway Inputs		
• Was the flat terrain option used? If not, then why?		
• Were regulatory default model options used (other than the flat terrain option)?		
• Was the urban dispersion option used? If so, is it appropriate, and was an appropriate population value used?		
• Is the pollutant set to PM10 or PM-10 for PM_{10} processing? Is it set to PM25, PM-2.5, PM2.5, or PM-25 for $PM_{2.5}$ processing?		
• Is the AERMOD model output type set to "concentration"?		
C. Source Pathway Inputs		
• Are roadway sources properly and consistently characterized?		
• Are non-roadway sources properly characterized?		
• Are the correct PM emission units used in the model (g/s for volume sources and g/s-m^2 for area sources)?		
• Are temporal variations of emissions (e.g., peak hours vs. off-peak hours) properly characterized?		
• Are the source locations correct?		
• If using urban source groupings, are the proper sources identified?		
• Are there significant local terrain features in the vicinity of the project? If so, were they handled appropriately in the model setup?		

Model Component	Checked	Deficiencies and/or Comments
D. Receptor Pathway Inputs		
• Does the receptor network have adequate coverage and spacing?		
• Are the flagpole receptor heights appropriate (typically 1.8 m)?		
• What is the proximity of receptors to roadway sources, and were EPA's receptor siting requirements met?		
• If sensitive receptors (e.g. schools, hospitals) were identified during interagency consultation, were they included in the receptor network?		
• Are the receptor locations correct?		
E. Meteorological Pathway Inputs		
• Did the modeling analysis use five years of meteorological data?		
• Is the meteorological data set representative of conditions at the project site?		
• Do the meteorological data meet EPA's data completeness requirements?		
• Are the meteorological data reasonable?		
F. Output Pathway Inputs		
• Are the required concentration-averaging statistics being produced?		
• Are the appropriate plot and post files defined?		
• Do the modeled concentrations represent source group "ALL"?		
G. Model Output Data		
• Were the AERMOD log files scanned for error, warning, and informational messages?		
• Does the AERMOD output file verify less than 10% of the meteorological data is missing?		
• Are the results reasonable, and were AERMOD concentrations visually checked in the context of project features, sources, and receptors?		
H. Background Concentrations		
• Were the sources of background data checked?		
• Are seasonal distributions of background concentration data reasonable?		

Model Component	Checked	Deficiencies and/or Comments
• Have EPA-approved exceptional events been excluded from the background concentration calculations?		
• Did analysts check the availability of EPA-approved modeled future-year background concentrations?		

3.3 Quality Assurance Guideline for PM Hot-Spot Modeling Results

This section discusses each element of the QA checklist. Each section of this QA guideline also includes annotated AERMOD View screenshots and highlights common errors that might be encountered.

A. General Modeling Setup

- **Did the modeling cover the analysis years selected for the project?** Hot-spot analyses should evaluate potential impacts for the project build scenarios; the analyses should represent the period beginning when the project will open to traffic and ending with the last year of the area's transportation plan. The modeling analysis should evaluate the years when peak emissions from the project are expected to occur.
- **Did the analysis cover the expected build (and no-build, as needed) alternatives for the project?** All hot-spot analyses should address the proposed build scenario (sometimes referred to as the preferred alternative) for the project. If the design values for the build scenario exceed the National Ambient Air Quality Standards (NAAQS), a no-build scenario should also be modeled to compare with the build scenario.
- **Was the correct version of AERMOD used?** EPA updates AERMOD frequently. The newest version available should be used when starting a hot-spot analysis. The current regulatory version can be checked using EPA's Support Center for Regulatory Atmospheric Modeling (SCRAM) website (https://www.epa.gov/scram).
- **Is a consistent coordinate system used across all data input?** AERMOD source and receptor locations can be defined using either user-defined coordinates or pre-defined systems such as the Universal Transverse Mercator (UTM) coordinate system. Because coordinate systems cannot be mixed within an AERMOD run, QA reviewers should verify that the coordinates used are consistent across all model data. Please refer to Supplement 3 of the PM hot-spot modeling guidance (Bai et al., 2014) for further information on coordinate input to AERMOD.

- **Was the modeling protocol discussed and approved during interagency consultation?** Before conducting the detailed modeling analysis, project analysts need to develop a modeling protocol and discuss the proposed protocol and overall analysis approach with the interagency consultation group. Having interagency agreement on the proposed models, methods, data, and assumptions will help expedite project review from interagency consultation participants.

B. Control Pathway Inputs

- **Was the flat terrain option used? If not, then why?** The regulatory default option in AERMOD is to incorporate terrain into the analysis. However EPA recommends using the flat terrain option for most PM hot-spot analyses. If the project area is located in an area of localized complex terrain, interagency consultation will assess the need for including terrain in the AERMOD analysis.
- **Were regulatory default model options used (other than the flat terrain option)?** EPA has established regulatory default options in AERMOD that should typically be used for PM hot-spot analyses. The default options are automatically enabled in AERMOD unless they are overridden by a non-default option in the Control Pathway section. Except for the flat terrain option, other non-default options should be avoided unless approved through interagency consultation.
- **Was the urban dispersion option used? If so, is it appropriate, and was an appropriate population value used?** When the project is located in an urban area, the urban dispersion option should be selected to enable AERMOD's urban dispersion algorithms. Otherwise the rural dispersion option should be selected. If the urban dispersion option is enabled, a population value for the urban area is required. QA reviewers should verify that the appropriate dispersion option (rural or urban) was selected, and (if necessary) verify that an appropriate population was used. Unless otherwise specified through interagency consultation, ensure the urban dispersion option was applied for all emissions sources in the project.
- **Is the pollutant set to PM10 or PM-10 for PM_{10} processing? Is it set to PM25, PM-2.5, PM2.5, or PM-25 for $PM_{2.5}$ processing?** When modeling PM_{10} impacts, the pollutant should be set to PM10 or PM-10. When modeling $PM_{2.5}$ impacts, the pollutant should be set to PM25, PM-2.5, PM2.5, or PM-25. AERMOD recognizes these identifiers and can apply

Common Control Pathway Errors

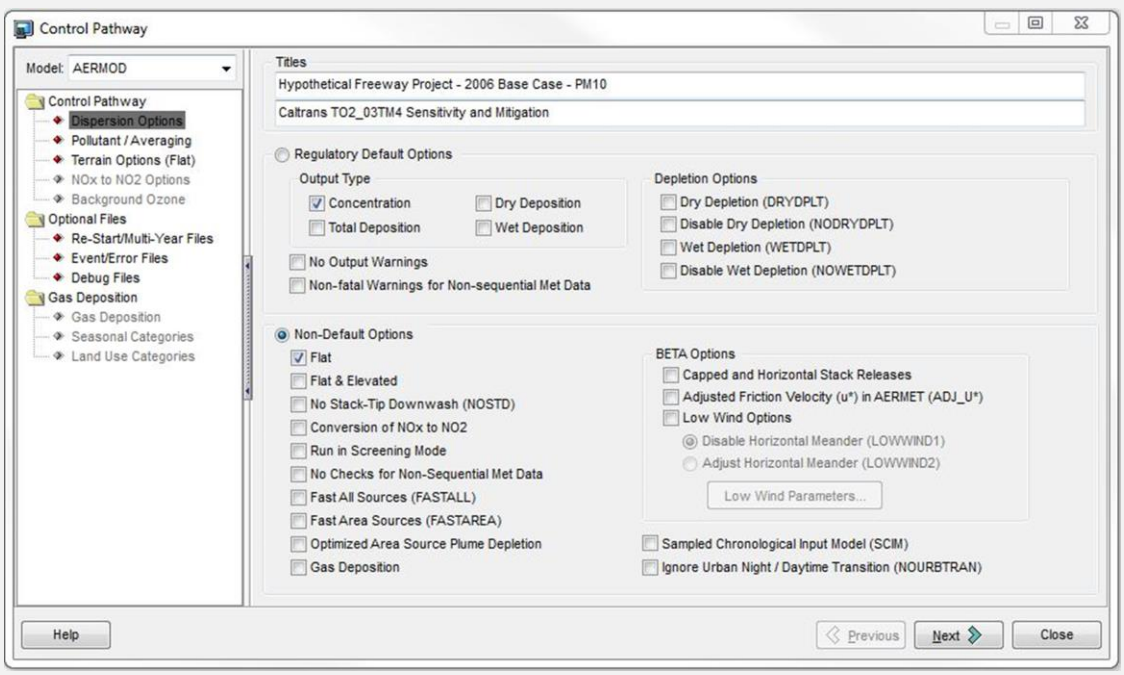
- Inappropriate population value specified for the urban dispersion option.
- Incorrectly using non-default options (except for the flat terrain option).
- Incorrectly using the debug options in the final modeling (using model debug options can result in excessive model run times and create very large debug output files).

appropriate processing algorithms. AERMOD can only model one pollutant at a time; therefore, separate AERMOD runs are required if both PM_{10} and $PM_{2.5}$ are analyzed.

- **Is the AERMOD model output type set to "concentration"?** AERMOD should be set to calculate concentration values. The deposition and depletion options should not be selected.

Control Pathway Input Example

This screenshot illustrates a correct setup for the AERMOD View Control Pathway section. The output type selected is "Concentration" and the only non-default option selected is "Flat" terrain. No Depletion or BETA options are selected.



C. Source Pathway Inputs

- **Are roadway sources properly and consistently characterized?**

  Volume or area sources – Roadway sources can be characterized as a series of adjacent volume or area sources. Volume and area sources require different input parameters and will yield different concentration outputs (see further discussion of this topic and example volume and areas source results in **Appendix A**). These input parameters should be carefully reviewed to ensure accurate representation of the roadways. Section J.3 of EPA's quantitative PM hot-spot analysis guidance (U.S. Environmental Protection Agency, 2015) provides

information on characterizing roadway emissions sources. All roadways in the project should be consistently characterized by area or volume sources, but not both.

Source release heights – The source release heights and calculation methods should be reviewed. Typically the release height is 1.3 m for light-duty vehicles and 3.4 m for heavy-duty vehicles. To account for mixed traffic fleets, EPA suggests using either a traffic volume weighted approach or an emissions-weighted average for estimating source release heights (U.S. Environmental Protection Agency, 2015). The traffic volume-weighted approach is simpler and is commonly used; however, the emissions-weighted approach is more accurate and will usually result in lower modeled concentrations, since most of the PM (but not the vehicle miles traveled) will be from trucks, which will raise the source release height. Further discussion of the volume- and emissions-weighted approaches is provided in Appendix A, as well as sample modeling results from AERMOD simulations that use these two approaches.

Common Source Pathway Errors

- Using incorrect emission rate units for volume and area sources.
- Incorrectly calculating vertical and lateral dimension parameters for volume sources.
- Using incorrect source location for area sources. AERMOD requires coordinates for the southwest corner of an area source, or for all vertices for an irregularly shaped area source.

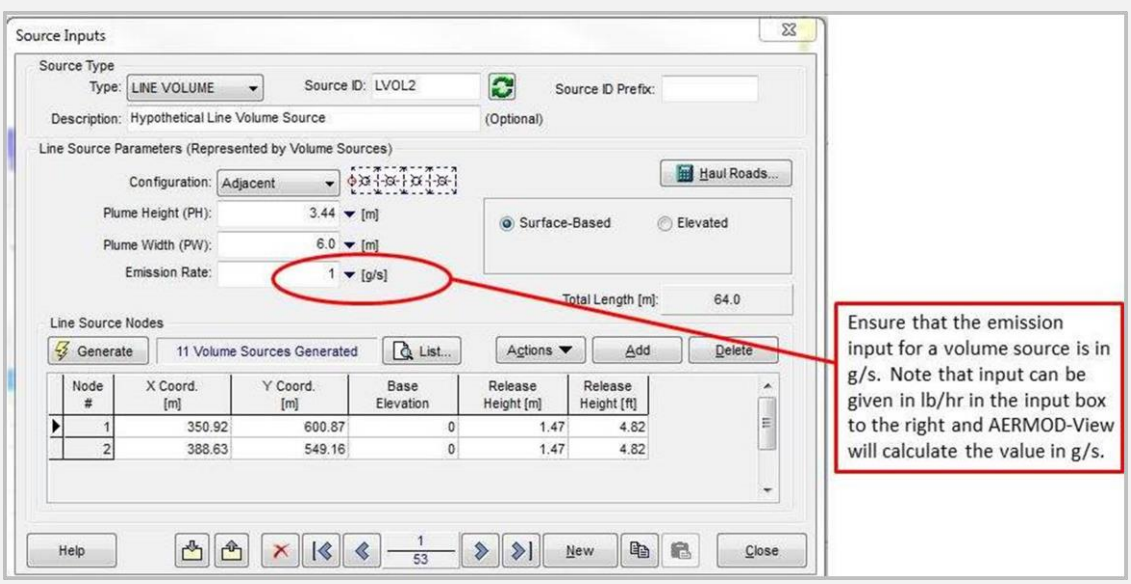
- **Are non-roadway sources properly characterized?** Some PM hot-spot analyses may include non-roadway sources, such as transit terminals, rail lines, or parking lots, that are substantially affected by the transportation project. QA reviewers should verify that non-roadway sources identified through interagency consultation were included and properly characterized in the modeling analysis. Additional information on modeling non-roadway sources can be found in Supplement 3, "Guidance for Using AERMOD to Complete Particulate Matter Hot-Spot Analyses," in the *Qualitative Particulate Matter Hot-Spot Analysis Guidance* (Bai et al., 2014), EPA's quantitative PM hot-spot analysis guidance (U.S. Environmental Protection Agency, 2015), or the AERMOD User's Guide (U.S. Environmental Protection Agency, 2004).
- **Are the correct PM emission units used in the model (g/s for volume sources and g/s-m^2 for area sources)?** The model files should be reviewed to ensure that the correct emission rates and emission rate units have been used. The emission rate units for volume and area sources should be g/s and g/s-m^2, respectively.
- **Are temporal variations of emissions (e.g., peak hours vs. off-peak hours) properly characterized?** Temporal variability in vehicle emissions is an important factor to include in the modeling analysis. Variable emissions over the day of the week and hour of the day generated from EMFAC are incorporated into AERMOD using the EMISFACT keyword. The QA review should include an examination of EMISFACT scalars to ensure that they have been entered into AERMOD View correctly and accurately. When using EMISFACT, the base

emission rate for the source itself is multiplied by the emission rate scalars entered via the EMISFACT keyword to produce hourly emissions values. Typically, the base emission rate is input as 1 g/s (or 1 g/s-m^2 for area sources) so that the EMISFACT scalars represent the actual hourly emissions. Alternatively, hourly emission rates for each AERMOD source can be specified in an input file, which is provided to AERMOD through the HOUREMIS keyword.

- **Are the source locations correct?** The location of the emissions sources relative to other nearby sources and receptors is a critical aspect of source characterization in the model. QA reviewers can use AERMOD View to graphically examine the location of sources and receptors. An advantage of using AERMOD View for viewing graphics is that the dimensions of area and volume sources are shown on the map. This can help QA reviewers determine whether the source dimension values entered into the model are reasonable.

Line-Volume Input Example

This screenshot illustrates a sample setup for an AERMOD View LINE VOLUME source, and indicates where analysts can check that the emissions are properly characterized in units of g/s. As described in the screenshot, the g/s emission rate can be calculated from lb/hr within AERMOD View. When using EMISFACT scalars, the base emission rate should be 1 g/s, as shown in the figure.



- **If using urban source groupings, are the proper sources identified?** When using the urban dispersion option in AERMOD, users can select which sources should be treated as urban sources in the Source Pathway section. Unless otherwise specified through interagency

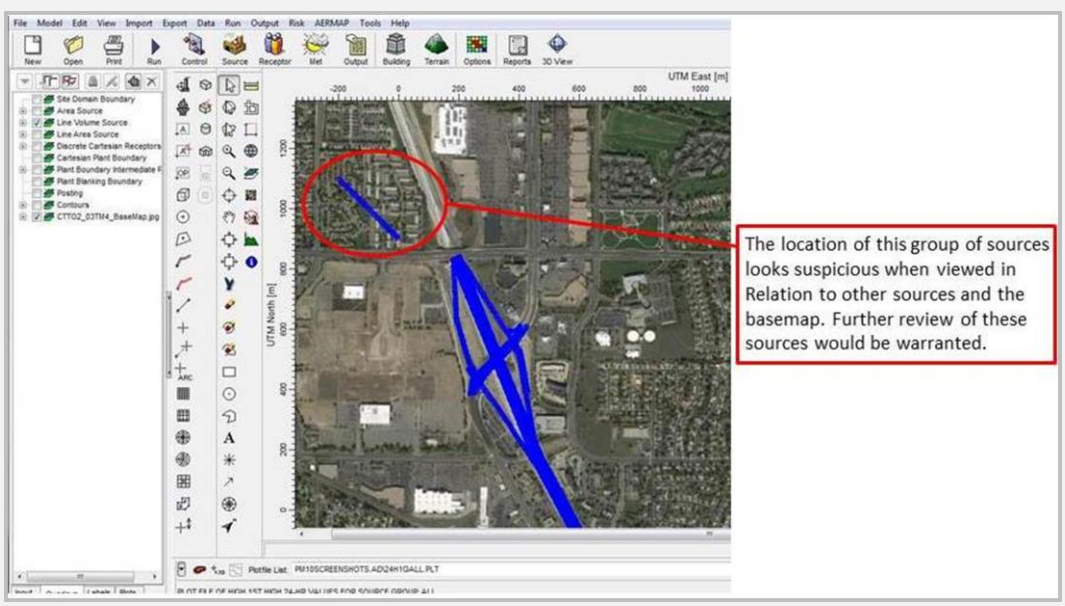
consultation, ensure that the urban dispersion option was applied for all emissions sources if the project is in an urban area.

- **Are there significant local terrain features in the vicinity of the project? If so, were they handled appropriately in the model setup?** For most roadway projects, AERMOD's non-default flat terrain option should be used. However, when significant terrain features are located in close proximity to the project site, it may be necessary to incorporate terrain into the analysis. If interagency consultation concluded that terrain should be included in the analysis, a review of AERMAP output should be completed to determine if the elevations and height scale values were properly extracted and calculated from electronic terrain files.

  Some roadway projects have either elevated or depressed roadways that must be evaluated in the modeling. These conditions can affect concentrations due to elevated plumes (elevated roadways) or canyon effects (depressed roadways). As with complex terrain, interagency consultation should be used on a case-by-case basis to determine how to include the roadway features in the modeling.

Identifying Incorrect Source Locations in AERMOD View

This AERMOD View screenshot shows a graphical view of project sources overlaid on a satellite image. A line of volume sources appear to be incorrectly located, and not aligned with the highway. This example illustrates how visual inspection of the emission source layout can uncover errors in the model input.



D. Receptor Pathway Inputs

- **Does the receptor network have adequate coverage and spacing?** A receptor network should be developed to estimate concentrations at appropriate receptor locations and should cover the area substantially affected by the project. In the near-road environment, daytime pollutant concentrations are known to decrease by 50% or more within 100 to 150 m from the edge of the roadway and to return to background levels within 300 to 600 m (Karner et al., 2010; Health Effects Institute, 2010). Therefore, receptors should be placed with finer spacing (e.g., 25 m apart) near roads (e.g., up to 100 m from the road edge), and with wider spacing (e.g., 100 m apart) further from roads (e.g., from 100 to 600 m from the road edge). Typically, maximum modeled concentrations occur at the receptors nearest to the road. If maximum modeled concentrations occur at receptors further from the road, QA reviewers should examine whether source placement errors occurred, and whether the coverage and spacing of the receptors need to be adjusted.

Common Receptor Pathway Errors

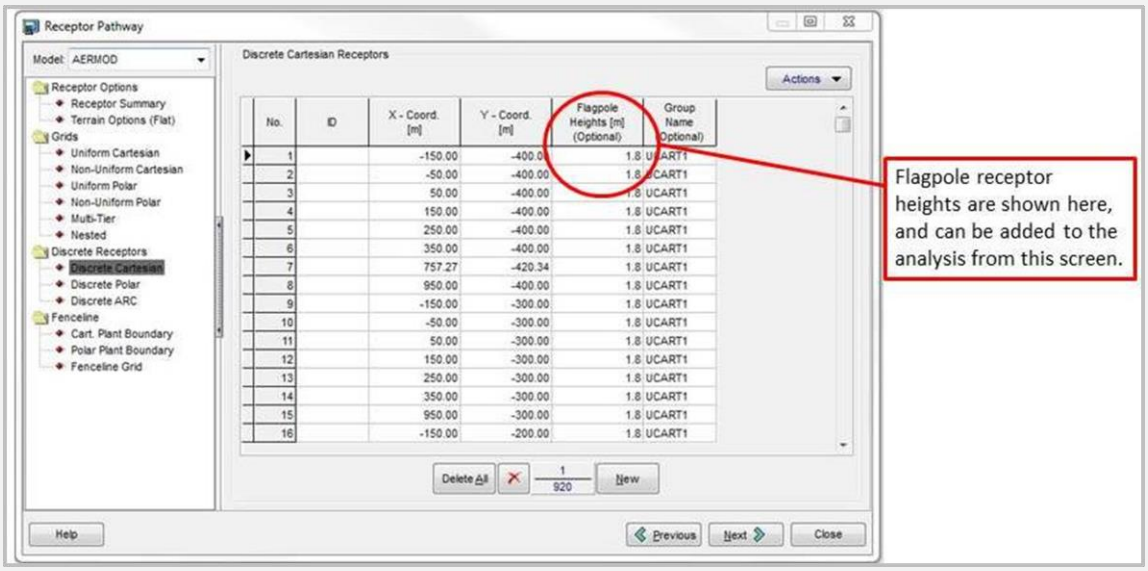
- Placing receptors inside volume source exclusion zones or within emissions sources.
- Receptor network does not extend far enough from sources to capture peak impacts. Daytime near-road pollutant concentrations decrease to ambient background levels within a few hundred meters of the roadway.
- Failure to use the flagpole option to define receptor heights. When the flagpole option is not used, AERMOD defaults to a receptor height of 0.0 m.

- **Are the flagpole receptor heights appropriate (typically 1.8 m)?** The flagpole receptor height is the height above ground level at which air concentrations are calculated. For most PM hot-spot analyses, the appropriate flagpole height is 1.8 m above ground level. The default receptor height in AERMOD is at ground level (0 m); therefore the flagpole height must be specified in the AERMOD control pathway via the flagpole receptor option.
- **What is the proximity of receptors to roadway sources, and were EPA's receptor siting requirements met?** Receptors should be placed in areas that are considered ambient air (i.e., where the public generally has access), as near as 5 m from the roadway edge. Receptors should not be placed within a roadway emissions source, within 5 m of a roadway edge, or inside a volume source exclusion zone in AERMOD. Receptors should also not be placed in areas where the public generally does not have access, such as the median strip of a highway, a right-of-way on a limited-access highway, or an approach to a tunnel.
- **If sensitive receptors (e.g., schools, hospitals) were identified during interagency consultation, were they included in the receptor network?** In some cases there are sensitive receptors, such as schools or hospitals, located in close proximity to a roadway project. If sensitive receptors were identified through interagency consultation, QA reviewers should verify that the receptor network includes these sensitive receptor sites.

- **Are the receptor locations correct?** The easiest way to check for accurate receptor placement is to inspect model input visually. This can be accomplished by exporting model input data to a GIS platform, or inspecting the graphics within AERMOD View. When using UTM coordinates, AERMOD View can also export receptor locations to Google Earth to verify the receptor network relative to satellite imagery.

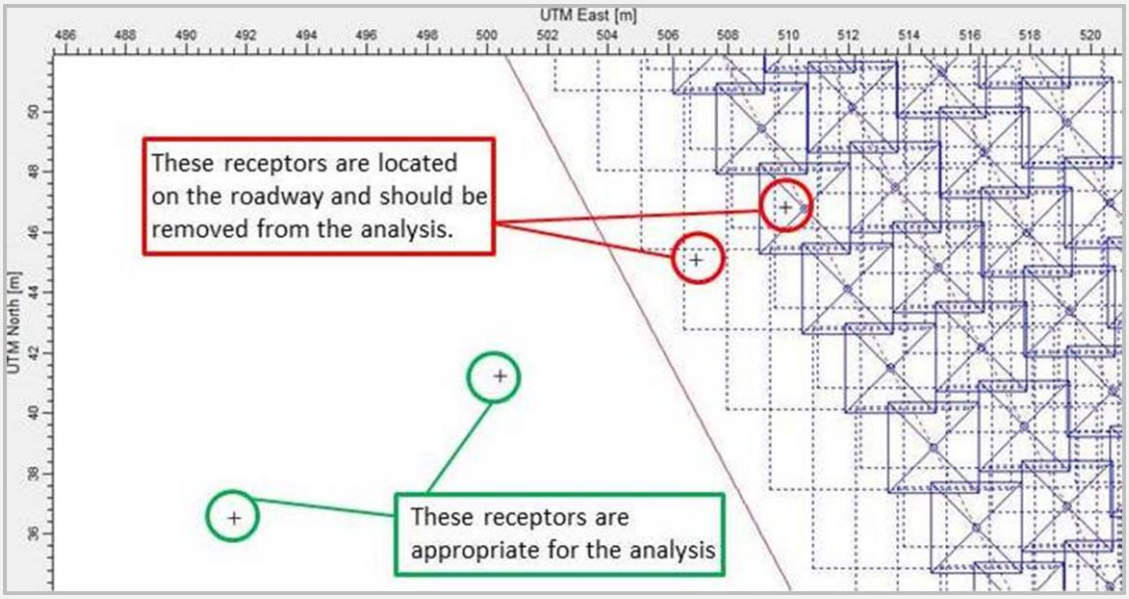
Reviewing Receptor Heights in AERMOD View

This screenshot shows a list of discrete receptors in AERMOD View. The flagpole height for these receptors is 1.8 m above ground level, which is a typical receptor height for PM hot-spot analyses.



Inappropriate Receptor Placement

In this AERMOD View screenshot, a close examination of the receptor locations and the roadway sources reveals that two receptors (red circles) are located on the roadway and either within a volume source or inside a volume source exclusion zone. These two receptors are not appropriate in a PM hot-spot analysis. Receptors that are appropriate for the analysis are shown in green circles.



E. Meteorological Pathway Inputs

- **Did the modeling analysis use five years of meteorological data?** PM hot-spot analyses require five years of offsite meteorological data, or one full year of site-specific meteorological data. QA reviewers should verify that complete meteorological data sets that meet these requirements were used in the analysis. In most cases, the five years of meteorological data will be consecutive, but the use of non-consecutive years may appropriate in cases where data from the most representative meteorological data site are incomplete for some years but are complete and of high quality for other years. This use of non-consecutive years should be agreed upon through interagency consultation. Using non-consecutive years of data requires some additional work effort because AERMOD does not allow time gaps in the meteorological input files. Analysts may alter the "year" field in their meteorological input files as needed to remove time gaps and produce files without time gaps.

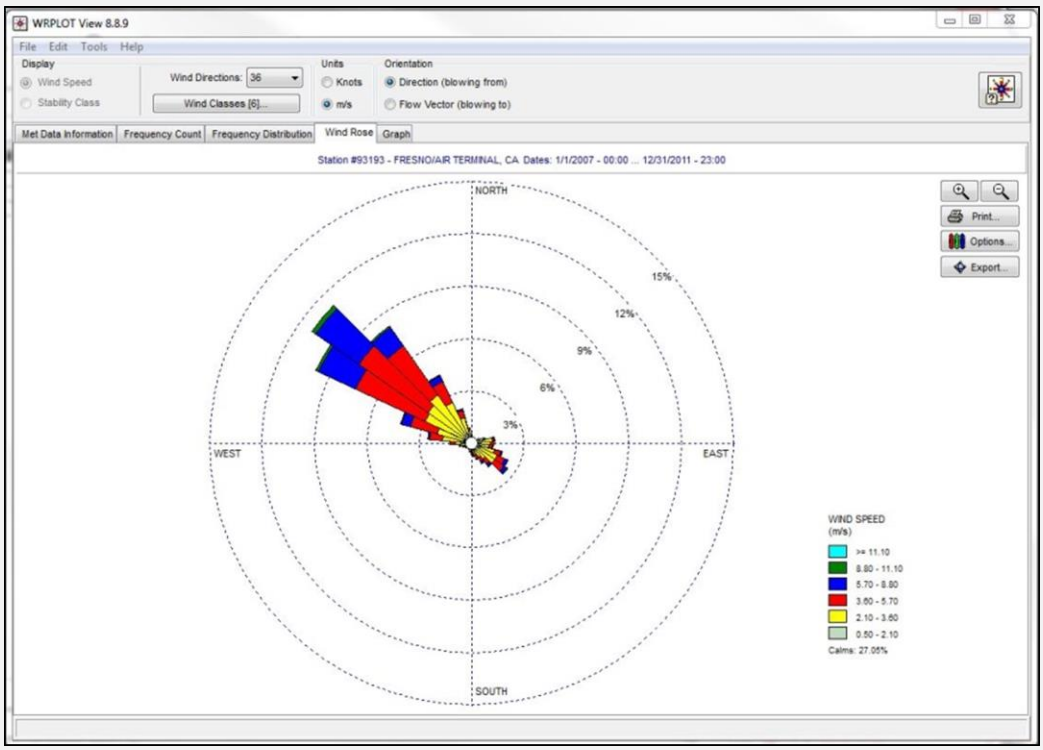
- **Is the meteorological data set representative of conditions at the project site?** A key factor of an accurate modeling analysis is ensuring that the meteorological data set is representative of the atmospheric conditions at the project site. QA reviewers should verify that the meteorological data sets determined through interagency consultation were properly incorporated into the analysis. Check both the surface and upper air data sets.
- **Do the meteorological data meet EPA's data completeness requirements?** The meteorological data used in the AERMOD modeling should be of high quality, without significant missing data, and should span the required duration. QA reviewers should check that the meteorological data are at least 90% complete for temperature, wind speed, and wind direction, determined by quarter. The overall percentage of missing meteorological data (not calculated on a quarterly basis) is shown at the end of the AERMOD output file.
- **Are the meteorological data reasonable?** The AERMOD-ready meteorological data files should be reviewed to ensure the data are complete and reasonable. The WRPLOT graphing tool, which is packaged with AERMOD View, can be used to accomplish this review task. The WRPLOT tool generates wind roses from AERMOD-ready meteorological data. This graphic option is valuable for reviewing the distribution of wind speeds and directions. Using wind rose plots, QA reviewers can evaluate the reasonableness of the meteorological data.

Common Meteorological Pathway Errors

- Incomplete meteorological data.
- Less than five years of meteorological data.
- Incorrect time zone for the meteorological data specified in AERMET. This can be checked by plotting a time series of the temperature data.
- Wind data are identified as vector means rather than scalar means.

Wind Rose Plots

Wind rose plots show the distribution of wind speed and direction in a meteorological data set. Click the "Wind Rose" button in the AERMOD View meteorological input pathway to generate a wind rose. Reviewing the wind rose can help determine if any unexpected wind distributions exist in the data set that should be investigated further.



F. Output Pathway Inputs

- **Are the required concentration-averaging statistics being produced?** AERMOD must be configured to provide output in the appropriate statistical form to calculate project design values. The modeled values represent the future air quality concentrations in a transportation project area that can be compared with the statistical form of each PM NAAQS. The output pathway should be set up to calculate the statistical averages, shown in Table 3, for PM_{10} and $PM_{2.5}$ analyses. The pollutants and concentration averaging periods (e.g., 24-hr) listed in the AERMOD Output Pathway must also be listed in the AERMOD Control Pathway.
- **Are the appropriate plot files and post files defined?** Plot files are valuable for reviewing model results graphically; they also provide an optimal format for exporting model output data to spreadsheets. Post files are used to post-process model results with background

concentrations. QA reviewers should check that plot files for the desired pollutants and averaging periods are being produced so that model results can be processed and evaluated properly.

- **Do the modeled concentrations represent source group "ALL"?** AERMOD can generate output for any combination of emissions sources using the SRCGROUP option. The modeled concentrations used for conformity determinations should always be from model output using source group "ALL".

Common Output Pathway Errors

- Incorrect statistical form of PM_{10} and $PM_{2.5}$ output was used in the analysis. For example, the annual $PM_{2.5}$ NAAQS require period average instead of 24-hr average AERMOD concentrations.
- Plot files were not created for the required averaging periods. These files are needed to examine output graphically.

Table 3. $PM_{2.5}$ and PM_{10} statistical averages.

NAAQS	Required AERMOD Results	AERMOD Output Options
Annual $PM_{2.5}$	5-year average of annual concentrations	OU PLOTFILE ANNUAL ALL plotfile.out OU POSTFILE ANNUAL ALL PLOT postfile.out
24-hr $PM_{2.5}$ (Tier 1 Analysis)	5-year average of annual 98th percentile 24-hr average concentrations	OU PLOTFILE 24 ALL 1ST plotfile.out OU RECTABLE 24 EIGHTH OU POSTFILE 24 ALL PLOT postfile.out
24-hr $PM_{2.5}$ (Tier 2 Analysis)	Daily 24-hr average concentrations for 5-year modeling period	OU PLOTFILE 24 ALL 1ST plotfile.out OU POSTFILE 24 ALL PLOT postfile.out
24-hr PM_{10}	Sixth-highest 24-hr average concentration (when using 5 years of meteorological data).	OU PLOTFILE 24 ALL SIXTH plotfile.out OU RECTABLE 24 SIXTH OU POSTFILE 24 ALL PLOT postfile.out
	Second-highest 24-hr average concentration (when using one year of meteorological data).	OU PLOTFILE 24 ALL SECOND plotfile.out OU RECTABLE 24 SECOND OU POSTFILE 24 ALL PLOT postfile.out

G. Model Output Data

- **Were the AERMOD log files scanned for error, warning, and informational messages?** AERMOD produces three types of messages to alert users of potential problems in the model run. *Error* messages indicate a serious issue that caused AERMOD to fail. *Warning* messages suggest potential problems in the modeling that should be investigated. *Informational* messages should be reviewed, but generally do not affect the validity of the model results. In addition, the log file contains information about receptors that are detected within AERMOD volume source exclusion zones.[5] Descriptions of each AERMOD message are provided in Appendix C of the AERMOD User's Guide (U.S. Environmental Protection Agency, 2004).

Using AERMOD Output to Identify Modeling Errors

Many of the common AERMOD errors included in Table 1 and throughout this QA Guideline can be identified by reviewing contour plots of the AERMOD concentrations. When reviewing these plots, analysts should look for

- Unreasonably high or low concentrations, suggesting potential errors in the emission rates.
- Unreasonably located peak concentrations, suggesting potential errors in emission source locations.

Analysts should also review the output file headers to ensure the correct data were produced for the PM NAAQS evaluated.

- **Does the model output verify less than 10% of the meteorological data is missing?** The AERMOD output file message summary lists the total number of hours processed, the number of calm hours identified, and the number (and percent) of missing hours. Review this information to evaluate whether an unusually high number of missing hours exists in the data set. The percentage of missing hours should be less than 10%; otherwise a warning message will be generated in the AERMOD output file.
- **Are the results reasonable, and were AERMOD concentrations visually checked in the context of project features, sources, and receptors?** An important aspect of the QA review is determining whether the results are reasonable. QA reviewers should use AERMOD View's graphic capabilities to visually inspect the results.
  - **Contour Plots –** Analysts should review contour plots of the AERMOD concentrations in the context of the project features and emissions sources. The highest modeled concentrations should occur near the emissions sources, and should decrease further from the sources. Thus, if the modeling results show project-level impacts that increase with greater distance from the road, the modeling inputs should be evaluated more closely.

[5] In the AERMOD log file, search for the phrase "source-receptor combinations for which calculations may not be performed."

QA reviewers can also use concentration plots to infer which sources are causing the highest impacts by inspecting the proximity of concentration maxima to emissions sources. If the contour plot shows a strong gradient extending into areas with low receptor density, then the receptor network may need to be revised to extend dense receptors into the areas with the strong gradient.

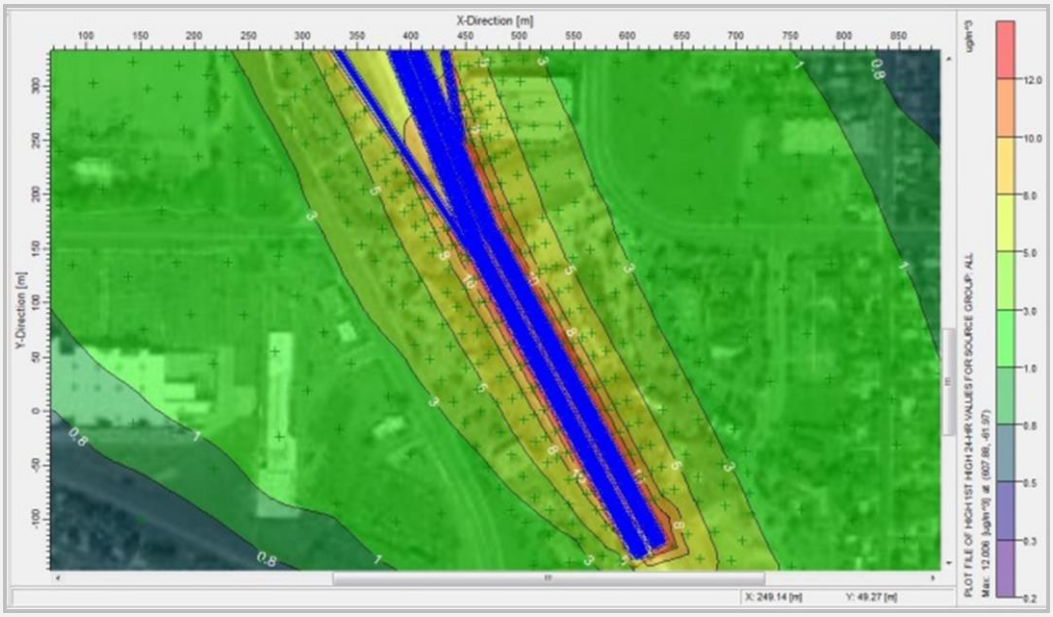
Finally, QA reviewers can use the contour plots to examine the magnitude of impacts from the project. AERMOD concentrations that are far outside the range of expected values are often the result of errors with emission rate inputs.

- **Source and Receptor Locations –** AERMOD View includes a utility that exports model data (e.g., sources, receptors, and concentrations) to Google Earth so that it can be visually inspected while overlaid on aerial imagery of the project site. Using this utility, QA reviewers can further examine whether sources and receptors are properly located.
- **NAAQS, Design Value –** The output from the modeling analysis represents concentration impacts from project sources (roadway and non-roadway), as well as from any nearby sources that are affected by the project. The project design value is the sum of the modeled concentration from the project and the background concentration. QA reviewers should ensure that the proper modeled values have been added to the correct background values to establish the project design values. For example, the 24-hr $PM_{2.5}$ modeled value should be added to the 24-hr background $PM_{2.5}$ value.

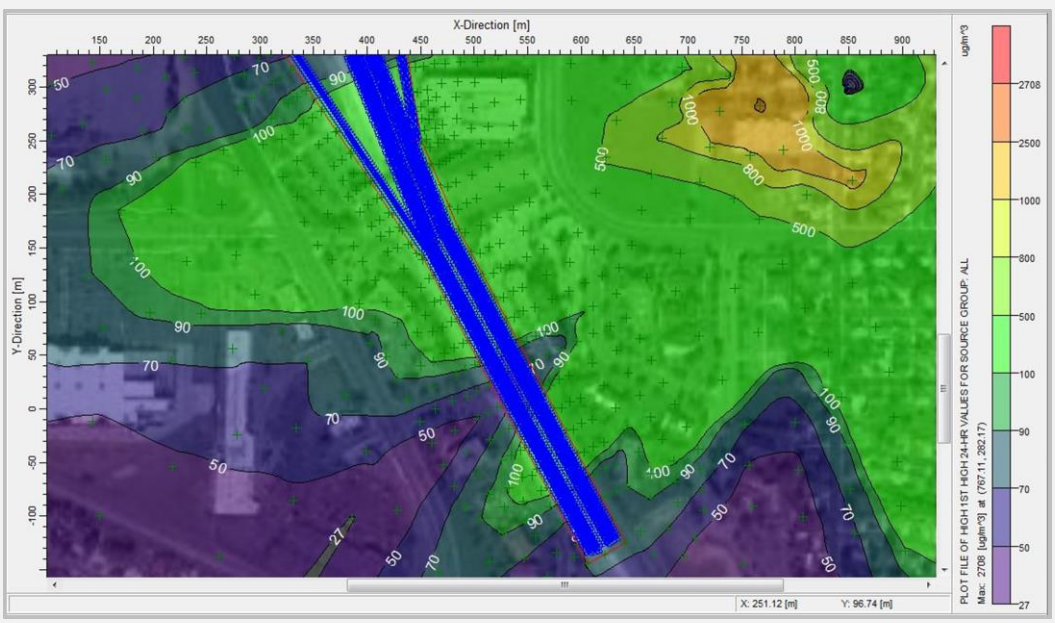
Using Contour Plots to Review AERMOD Output

The figures below show AERMOD PM_{10} concentration plots overlaid on a base map in AERMOD View. Using graphical output similar to this is valuable for QA review. Plot 1 shows concentrations as they would be expected from a typical roadway project, with the highest concentrations closest to the blue roadway emissions sources. Plot 2 shows unrealistic concentration contours that are unrelated to the roadway project. The AERMOD source locations in Plot 2 would need to be examined more carefully.

PM_{10} Concentration Contour Plot 1



PM_{10} Concentration Contour Plot 2



AERMOD View Log Files

AERMOD output files show a summary of the highest modeled 24-hr $PM_{2.5}$ concentrations.

```
*** AERMOD - VERSION  14134 ***   *** Hypothetical Freeway Project - 2006 Base Case - PM2.5          ***        02/19/15
*** AERMET - VERSION  14134 ***   *** Caltrans TO2_03TM4 Sensitivity and Mitigation                  ***        14:50:13
                                                                                                                 PAGE 878
 **MODELOPTs:   NonDFAULT CONC      FLAT      FLGPOL

                                        *** THE SUMMARY OF HIGHEST 24-HR RESULTS ***

                                 ** CONC OF PM_2.5   IN MICROGRAMS/M**3                        **
                                                   DATE                                                          NETWORK
GROUP ID                       AVERAGE CONC     (YYMMDDHH)            RECEPTOR  (XR, YR, ZELEV, ZHILL, ZFLAG)   OF TYPE  GRID-ID
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

ALL      HIGH   1ST HIGH VALUE IS      8.74795c ON 07020124: AT (     450.84,      249.35,    10.00,    10.00,    1.80)  DC
         HIGH   8TH HIGH VALUE IS      7.32815c ON 07020824: AT (     451.32,      143.63,    10.00,    10.00,    1.80)  DC

 *** RECEPTOR TYPES:  GC = GRIDCART
                      GP = GRIDPOLR
                      DC = DISCCART
                      DP = DISCPOLR

 *** AERMOD - VERSION  14134 ***   *** Hypothetical Freeway Project - 2006 Base Case - PM2.5          ***        02/19/15
 *** AERMET - VERSION  14134 ***   *** Caltrans TO2_03TM4 Sensitivity and Mitigation                  ***        14:50:13
                                                                                                                 PAGE 879
```

H. Background Concentrations

- **Were the sources of background data checked?** Monitored background data is generally from a monitor that is near the project area, is in a location that has similar PM emissions sources as the project site, and has similar wind patterns. Section 8.3 of the Transportation Conformity Guidance (U.S. Environmental Protection Agency, 2015) provides several options for establishing background values. Because PM hot-spot analyses evaluate future conditions, EPA's guidance provides options for adjusting background values to represent estimated future conditions. QA reviewers should examine the source(s) of background data and determine whether the selected values follow the Transportation Conformity Guidance procedures.
- **Are seasonal distributions of background concentration data reasonable?** Because PM concentrations can vary significantly by season, background concentrations may in some cases be separated by season and combined with modeled values for the corresponding season. If the PM hot-spot analysis used seasonally distributed background data, QA reviewers should check to ensure that these distributions were properly calculated and combined with the associated modeled values.
- **Have EPA-approved exceptional events been excluded from the background concentration calculations?** Analysts should document any monitoring data excluded from the analysis because EPA granted a data exclusion under the Exceptional Events Rule. Only data that have been flagged and concurred as being from exceptional events can be excluded;

"exceptional-type" events or data flagged but not concurred as being exceptional cannot be excluded from the monitoring data analysis.

- **Did analysts check the availability of EPA-approved modeled future-year background concentrations?** To account for future emission changes, it may be appropriate in some cases to use future background concentrations calculated from EPA-approved chemical transport modeling results. Analysts should check the availability and applicability of any EPA-approved modeled future-year background concentrations through interagency consultation.

AERMOD View Log Messages

AERMOD View output files show error messages, warning messages, and informational messages. This section of the output files should be carefully reviewed to ensure there were no problems with the model run. The output file also shows the percentage of missing meteorological data identified (5.59% in this example). Descriptions of the error, warning, and informational messages can be found in the AERMOD User's Guide (U.S. Environmental Protection Agency, 2004).

```
 --------- Summary of Total Messages --------

A Total of            0 Fatal Error Message(s)
A Total of           13 Warning Message(s)
A Total of        14306 Informational Message(s)

A Total of        43824 Hours Were Processed

A Total of        11855 Calm Hours Identified

A Total of         2451 Missing Hours Identified (  5.59 Percent)


   ******** FATAL ERROR MESSAGES ********
              ***  NONE  ***


   ********   WARNING MESSAGES   ********
SO W320    7929        VPARM: Input Parameter May Be Out-of-Range for Parameter          QS
MX W441   40471        METQA: Vert Pot Temp Grad abv ZI set to min .005, KURDAT=    11081407
MX W441   40472        METQA: Vert Pot Temp Grad abv ZI set to min .005, KURDAT=    11081408
MX W441   40473        METQA: Vert Pot Temp Grad abv ZI set to min .005, KURDAT=    11081409
MX W441   40474        METQA: Vert Pot Temp Grad abv ZI set to min .005, KURDAT=    11081410
MX W441   40475        METQA: Vert Pot Temp Grad abv ZI set to min .005, KURDAT=    11081411
MX W441   40476        METQA: Vert Pot Temp Grad abv ZI set to min .005, KURDAT=    11081412
MX W441   40477        METQA: Vert Pot Temp Grad abv ZI set to min .005, KURDAT=    11081413
MX W441   40478        METQA: Vert Pot Temp Grad abv ZI set to min .005, KURDAT=    11081414
MX W441   40479        METQA: Vert Pot Temp Grad abv ZI set to min .005, KURDAT=    11081415
MX W441   40480        METQA: Vert Pot Temp Grad abv ZI set to min .005, KURDAT=    11081416
MX W441   40481        METQA: Vert Pot Temp Grad abv ZI set to min .005, KURDAT=    11081417
MX W441   40482        METQA: Vert Pot Temp Grad abv ZI set to min .005, KURDAT=    11081418

   ************************************
   *** AERMOD Finishes Successfully ***
   ************************************
```

4. Potential PM Mitigation Measures

4.1 Introduction

If a hot-spot analysis shows that the project results in higher PM concentrations (combined with appropriate background concentrations) than the relevant NAAQS and the no-project scenario, the project fails to pass the conformity test. Project sponsors need to consider mitigation to reduce PM impacts from the project.

The U.S. Environmental Protection Agency (EPA) identified five general categories of mitigation measures: (1) retrofitting, replacing vehicles/engines, and using cleaner fuels; (2) reducing truck and bus idling; (3) redesigning the project; (4) controlling fugitive dust; and (5) controlling other sources of emissions (U.S. Environmental Protection Agency, 2015). However, current experience and practical insights suggest that these mitigation measures are difficult to directly incorporate into a highway project. In general, the mitigation actions identified by the EPA are more feasible for regional-level implementation (e.g., changing vehicle fleet, reducing idling, and controlling dust and other emissions sources in the project area).

At the project level, key factors that influence PM emission levels and air quality impacts include fleet turnover, fleet mix and volumes, average travel speed, and distance between emissions sources and receptors. Section 4.2 explores the influence of these factors on project-level PM impacts. Section 4.3 and Section 4.4 present project-level scenario comparisons, using a hypothetical highway project, to explore the following questions:

- **Fleet turnover:** What are the project benefits of fleet turnover, and how do they change over time? Can delaying the project build year reduce PM impacts by taking advantage of the emissions and air quality benefits of fleet turnover?
- **Fleet mix and volumes:** How are project PM impacts related to fleet mix (i.e., percentage of truck traffic)? How will restricting heavy-duty diesel traffic access to the project reduce PM impacts over time?
- **Travel speed:** How do travel speed restrictions impact project-level PM emissions and concentrations? What are the benefits of restricting speed limits to an emission-optimized level?
- **Truck lane:** Are there benefits associated with establishing a dedicated truck lane? If truck traffic is restricted to the innermost lane (closest to the median), what is the potential reduction in PM concentrations for a nearby receptor (i.e., a location where PM concentrations are modeled)?
- **Receptor distance:** What are the benefits of creating a buffer zone between the roadway and nearby receptors? How do benefits vary with increasing distance?

The results discussed in the following sections provide quantitative reference materials and help identify potentially useful mitigation options. The factors discussed will vary under different project conditions. Project analysts need to model their unique project and site characteristics to obtain project-specific data.

4.2 Summary of PM Impacts from Major Factors

Fleet Turnover

Fleet turnover is the gradual penetration over time of newer, lower-emitting vehicles into the vehicle fleet, and the simultaneous gradual removal of older, higher-emitting vehicles. All else held constant, a fleet of vehicles "today" emits more exhaust PM emissions per mile of travel than a similar but newer "future-year" vehicle fleet. As shown in **Figure 5**, the EMFAC2014 data for five counties in California indicate that fleet average $PM_{2.5}$ running exhaust emission factors decrease by approximately 50% to 90% from 2015 to 2050; reductions of fleet average PM emissions are more significant in the near term (e.g., by 2025) than in later years (2025 to 2050). For projects, fleet turnover benefits are more substantial for $PM_{2.5}$ than for PM_{10}. PM_{10} emissions are a combination of exhaust, which is affected by fleet turnover, and tire wear, brake wear, and dust emissions, none of which are affected by fleet turnover (tire wear, brake wear, and dust emissions are modeled as a function of miles driven and vehicle weight; see Section 4.4.1 for details).

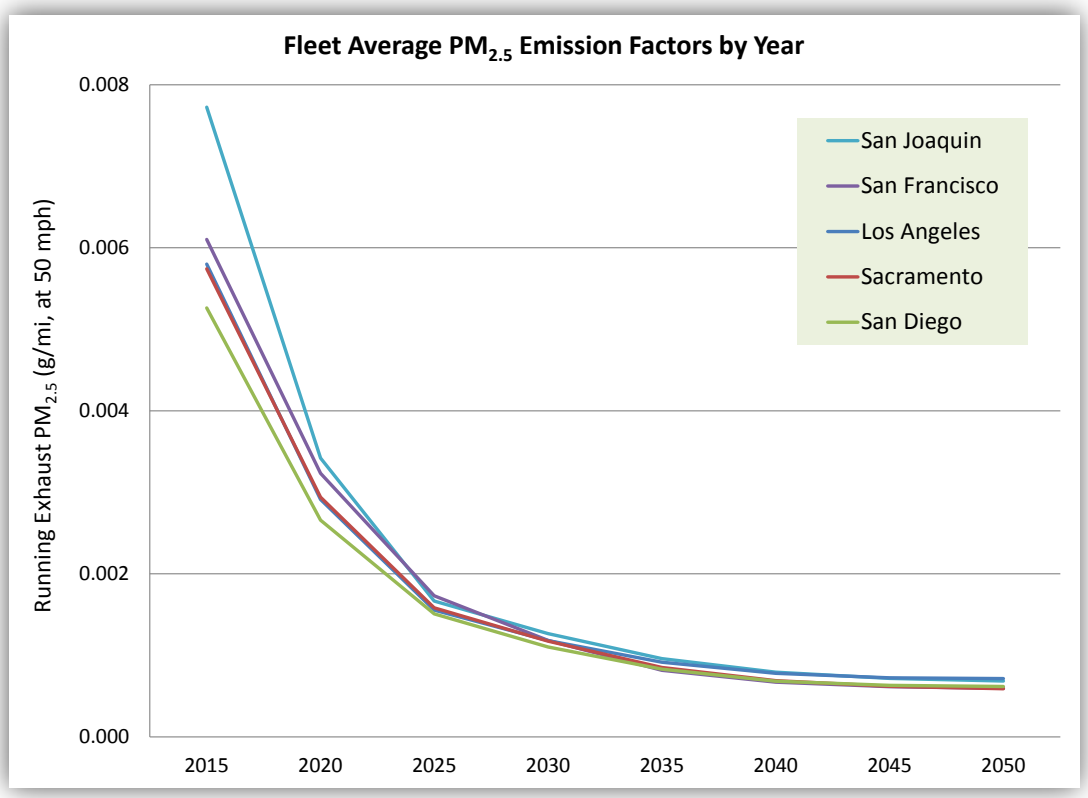


Figure 5. Changing fleet average $PM_{2.5}$ emission factors by calendar year due to fleet turnover.

Fleet Mix and Volumes

Fleet mix and volumes refer to the fraction of the fleet assigned to different vehicle types, such as cars and trucks, and the absolute number of vehicles assigned to each type. Changing fleet mix by reducing the percentage or volume of truck traffic can reduce fleet average PM emissions. Using Los Angeles County as an example, EMFAC2014 emissions data suggest an average truck mile in 2015 equals approximately 27 non-truck miles (mostly light-duty and medium-duty vehicles) in terms of running exhaust $PM_{2.5}$ emissions at 50 mph; beyond 2025, accounting for the effects of fleet turnover, an average truck mile results in 4 to 9 times more $PM_{2.5}$ running exhaust emissions than an average non-truck mile. At the project level (see Section 4.4.2), reducing the fraction of heavy-duty diesel traffic has a large impact on peak PM concentrations in both current and future years. However, the magnitude of the PM reduction depends on analysis year; also, the project benefits of reducing truck traffic are larger for PM_{10} than for $PM_{2.5}$.

Travel Speed

For PM hot-spot modeling purposes, travel speed includes the assumed distribution of speeds for the entire fleet at a project site, separated into peak and off-peak travel periods. Minimum per-mile

PM running exhaust emissions typically occur during free-flow traffic conditions at speeds between 40 and 50 mph; therefore, shifting vehicle flow from high speed ranges to medium speed ranges may reduce PM emissions. For example, Los Angeles County 2015 fleet average $PM_{2.5}$ emission factors (g/mi) decrease by 20% when vehicle speeds move from 65 mph to 50 mph. Therefore, restricting speed limits to an emissions-optimized level may reduce PM emissions and peak PM concentrations. However, at the project level, speed change benefits are limited, because they affect only running exhaust PM emissions. As exhaust emissions decline over time (with fleet turnover), tire wear, brake wear, and dust emissions become a larger fraction of on-road PM emissions, and these modeled emissions are not a function of travel speed. Therefore, the benefits of speed changes are much smaller than benefits of fleet turnover and fleet mix changes (see Section 4.4.3 for scenario comparison details).

Increasing Distance Between Sources and Receptors

PM hot-spot modeling typically estimates PM concentration impacts beginning at distances as short as 5 m from a road edge, assuming public access to that location. Near-road pollutant concentrations drop substantially, however, with increasing distance from a road. Literature has shown that peak pollutant concentrations decrease by 50% or more within approximately 150 meters of heavily traveled roads, and most pollutant concentrations decay to background levels within 300 to 600 meters of the road edge (Karner et al., 2010). Therefore, increasing the distance between emissions sources (vehicles) and receptors reduces modeled PM impacts. For example, restricting heavy-duty diesel traffic to the innermost lane on a freeway link can have a moderate impact on peak near-road PM concentrations (see Section 4.4.4 for scenario comparison details). If feasible, creating a buffer zone that distances the road from sensitive receptors will significantly reduce roadway-related PM impacts.

Other Factors Affecting Modeled PM Concentrations

In addition to the concepts just discussed, modeled PM concentrations will vary substantially depending on how the AERMOD dispersion model is configured. EPA guidance offers analysts many options for configuring AERMOD parameters such as emissions sources and emission release heights. Various alternatives (e.g., using volume vs. area sources) result in different modeled PM concentrations, as discussed in detail in Appendix A.

4.3 Development of Modeling Scenarios

To illustrate changes in peak PM concentrations against different project factors and design concepts, EMFAC emissions modeling and AERMOD dispersion modeling were performed for various scenarios for a hypothetical highway project. This modeling work leverages and expands on prior work conducted for Caltrans and other transportation agencies via a near-road air quality pooled

fund. The pooled fund work involved developing MOVES-based near-road PM concentrations. MOVES is the EPA on-road emissions model used by states other than California. (California uses EMFAC.) For the assessments discussed here, the prior pooled fund work was expanded upon by developing EMFAC-based near-road PM concentrations. The findings presented here are tailored to California and are consistent with, and reinforce, the complementary work completed for the pooled fund partnership. Work completed here also extends the pooled fund analyses to assess near-road PM impacts from speed restrictions, dedicated truck lanes, and receptor buffer zones.

4.3.1 Hypothetical Project

The hypothetical transportation project used for developing modeling scenarios is based on a sample project included in the EPA's three-day PM hot-spot training class (see https://www.epa.gov/state-and-local-transportation/project-level-training-quantitative-pm-hot-spot-analyses). As shown in **Figure 6**, the sample project reflects a freeway expansion build scenario (adding one general purpose lane to the existing three-lane freeway in each direction), with travel activity changes on freeway segments and major connecting arterial roadways. Roadway link specification and travel activity information for the sample project were adapted from the EPA's training materials, but do not necessarily represent data from any real-world specific road network, transportation project, or time period.

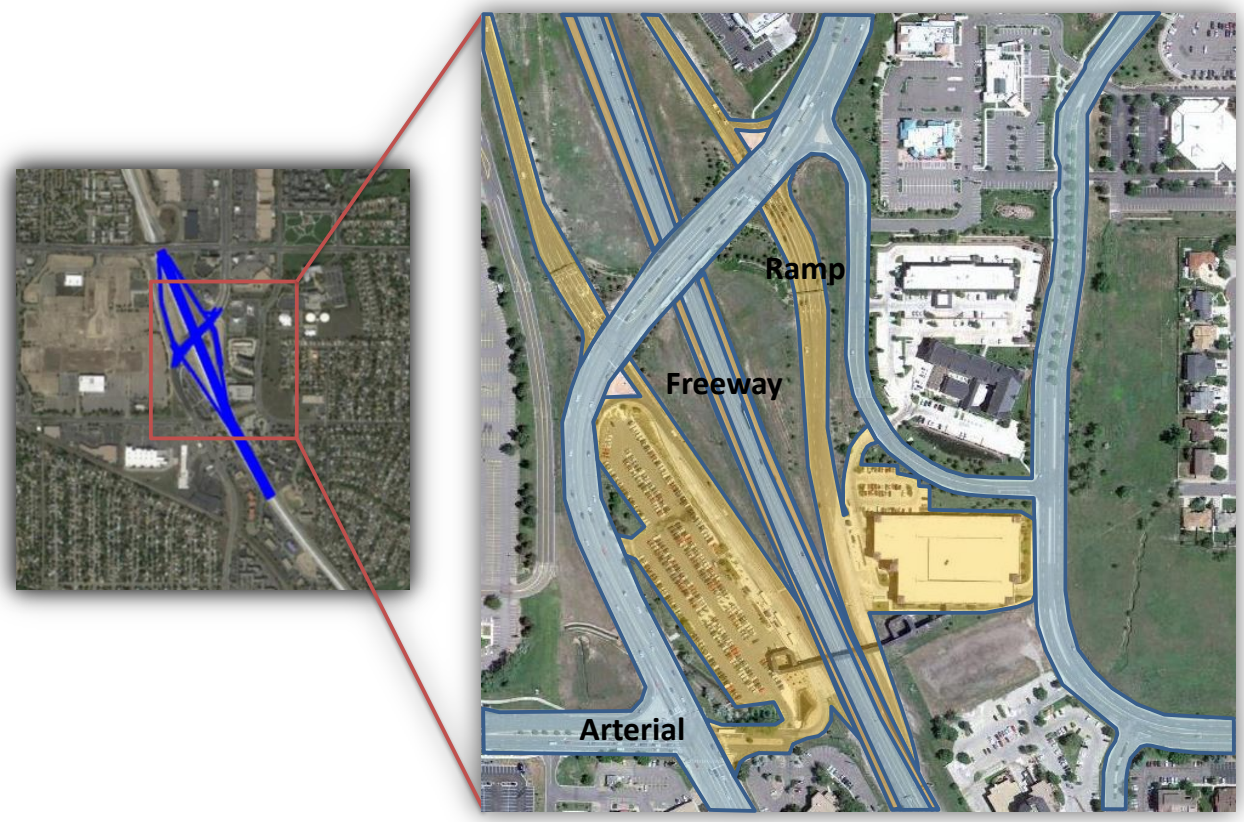


Figure 6. Hypothetical transportation project, showing modeled roadway links (blue elements) and aerial image.

AERMOD View, a user interface tool for the EPA's AERMOD model, was used to set up the dispersion modeling scenarios. The freeway links in the hypothetical project are 12 m wide across four traffic lanes in each direction. Other roadway links are either 3 or 6 m wide (i.e., one or two traffic lanes in each direction). As shown in Figure 7, in AERMOD simulations, each freeway link is defined as four series of adjacent volume sources, with each series of volume sources representing a 3 m-wide traffic lane; a single series of adjacent volume sources was defined for each of the other roadway links, with a volume source width equal to the link width.

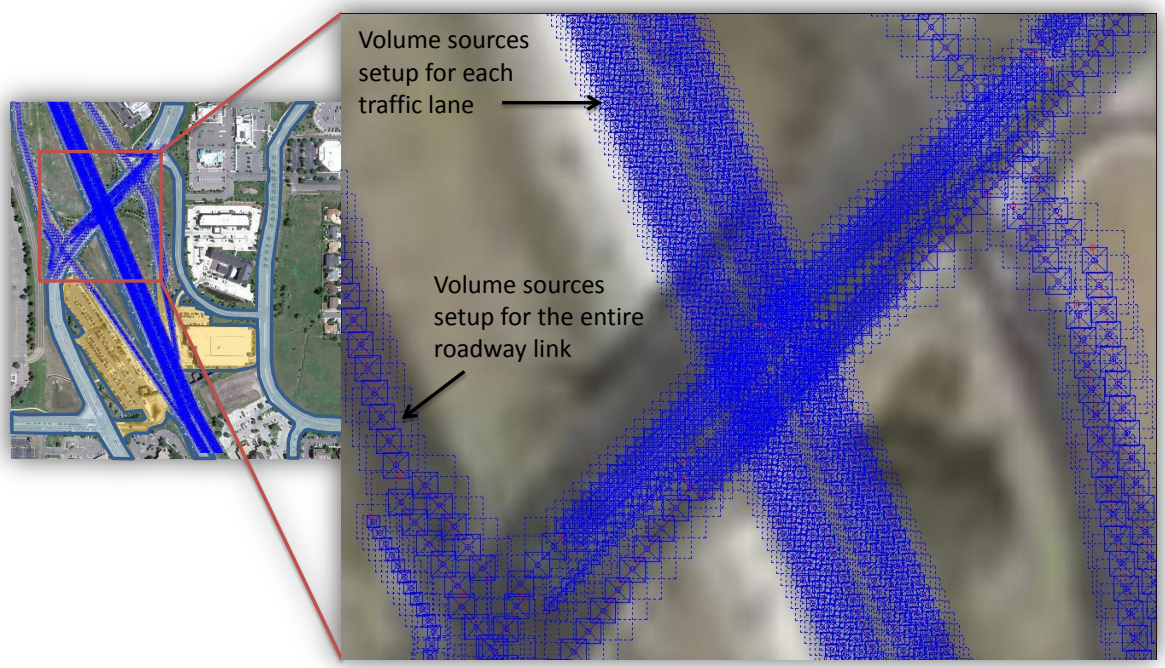


Figure 7. Adjacent volume sources setup in AERMOD modeling for the hypothetical project.

The AERMOD simulations developed for the hypothetical project employ five years (2007–2011) of surface and upper-air meteorological data for the Fresno, California, area. The EMFAC2014 model (version 1.0.1) was used to calculate PM_{10} and $PM_{2.5}$ emissions for the hypothetical project scenarios. Emissions from running exhaust, brake wear, and tire wear were included for both PM_{10} and $PM_{2.5}$. In In the AERMOD simulations, road dust emissions were included for PM_{10}, but not for $PM_{2.5}$. The estimated PM emissions were used as AERMOD modeling inputs, which vary across model scenarios and depend on analysis years, fleet mix (i.e., percentage of truck traffic), and average travel speed. A network of modeling receptors in AERMOD View was created; the receptors were placed from 5 m up to approximately 1 km from the edge of the roadway, and were spaced 5 m to 100 m from each other. These modeling approaches were selected to be consistent with EPA guidance.

4.3.2 Modeling Scenarios

For a given volume of traffic, emissions, and therefore near-road PM concentrations, depend largely on several key factors: vehicle fleet age, fleet mix, average traffic speed, and distance between emissions sources and receptors. In the following sections, each of these factors is discussed, and their potential project-level PM impacts are quantified in specific modeling scenarios. Other variables, such as meteorology, can affect near-road PM concentrations; however, the discussion presented in this chapter focuses on variables that are, at least in concept, within the realm of what might be modified when designing a given project.

As summarized in Table 4, several groups of modeling scenarios were developed to examine the potential project-level mitigation impacts. These modeling scenarios were based on a 2015 hypothetical transportation project with annual average daily traffic (AADT) of 125,000 vehicles, 8% diesel trucks, and link-level traffic speeds that vary by roadway type (e.g., freeway versus arterial links). This base case reflects a highway example that would likely be a project of air quality concern (POAQC), as described by the EPA in its 2006 rulemaking (U.S. Environmental Protection Agency, 2006). For each scenario, based on EMFAC and AERMOD modeling results, the impacts by the predicted peak PM concentrations were quantified. These impacts reflect the maximum of all predicted concentrations closest to the roadway edge (i.e., at 5 m from roadway edge, except where otherwise specified).

Table 4. Summary of modeling scenarios developed for evaluating project-level PM impacts.

Modeling Factor	Description	Expected Changes	Mitigation Concepts
Fleet Age	Eight modeling analysis years: 2015, 2020, 2025, 2030, 2035, 2040, 2045, and 2050 (8% diesel trucks for all analysis years).	Vehicle fleet becomes cleaner (with lower emissions) over time due to fleet turnover, and therefore reduces project-level PM emissions.	Postponing projects (with a later analysis year) to take additional fleet turnover benefits may reduce PM impacts.
Fleet Mix	Three fleet mix conditions for two analysis years: 8%, 20%, and 40% trucks (2015 and 2035 fleets); volume-weighted vs. emissions-weighted average calculations.	Heavy-duty trucks have higher per-mile PM emissions than passenger vehicles; a project with less heavy-duty truck traffic tends to have lower PM emissions and near-road concentrations.	Restricting or rerouting heavy-duty truck traffic may reduce project PM impact.
Speed Limit	Two speed limit options for a 2015 fleet with 8% diesel trucks: regular speed limit of 65 mph vs. low speed limit of 50 mph for freeway links.	PM emissions vary by vehicle travel speed; per-mile PM running exhaust emissions are lower in medium speeds.	Restricting speed limit toward an emission-optimized level may reduce PM impact from the project.
Truck Lane Placement	A dedicated truck lane scenario for a 2015 fleet with 8% diesel trucks: truck traffic on each freeway link is restricted to the inner dedicated lane (closest to the median).	PM concentrations at a receptor decrease when the emissions sources are moved farther away.	Moving truck traffic to the inner dedicated lane, therefore farther from near-road receptors, may reduce project PM impact.
Receptor Distance	Three near-project receptor distances in one test case scenario for a 2015 fleet with 8% diesel trucks: 5, 10, and 20 m from the edge of traffic lanes.	PM concentrations at a receptor decrease with increased distance from emissions sources.	Moving modeled receptors to be included in a hot-spot analysis farther from the project (e.g., through purchasing additional right-of-way) may reduce the project impact.

4.4 Analysis Results

The PM emissions and concentrations results for the preceding modeling scenarios are presented in Table 5 and further discussed in the following sections. Contour plots of peak 24-hr PM_{10} concentrations in AERMOD View are also presented. For example, Figure 8 shows a sample contour map for the truck lane placement scenario; contour plots for other modeling scenarios were similar (not shown). Note that the results presented here are based on peak AERMOD modeled PM concentrations, rather than PM design values that are the combination of modeled concentrations and background concentrations used to compare with NAAQS in the conformity determination. However, the comparison results and conclusions from this analysis would be similar if design values were used, given that design values were developed to capture high concentrations predicted within the transportation project.

Table 5. Summary of PM emission and concentration results for the modeled scenarios.

Modeling Factor	Description	EMFAC2014-Based Emissions (kg/day)		AERMOD-Predicted Peak Concentration (μg/m^3)		
		PM_{10}	$PM_{2.5}$	24-Hour PM_{10}	24-Hour $PM_{2.5}$	Annual $PM_{2.5}$
Base Case	2015 fleet, 8% diesel trucks, no dedicated truck lanes, receptor at 5 m from road	15.20	2.65	31.00	5.48	2.43
Fleet Age	2020 fleet, 8% diesel trucks	14.25	2.09	28.30	4.20	1.86
	2025 fleet, 8% diesel trucks	13.81	1.89	27.47	3.81	1.68
	2030 fleet, 8% diesel trucks	13.65	1.84	27.18	3.72	1.64
	2035 fleet, 8% diesel trucks	13.56	1.80	27.83	3.76	1.65
	2040 fleet, 8% diesel trucks	13.53	1.78	26.96	3.62	1.59
	2045 fleet, 8% diesel trucks	13.51	1.77	26.93	3.61	1.58
	2050 fleet, 8% diesel trucks	13.50	1.77	26.91	3.60	1.58
Fleet Mix	2015 fleet, 20% diesel trucks	22.56	3.82	44.50	7.63	3.37
	2015 fleet, 40% diesel trucks	34.92	5.76	64.51	10.82	4.77
	2035 fleet, 20% diesel trucks	20.07	2.05	39.73	4.14	1.82
	2035 fleet, 40% diesel trucks	31.00	2.46	57.41	4.66	2.05
Speed Limit	2015 fleet, 8% diesel trucks, freeway link speed limit = 65 mph	15.24	2.70	31.10	5.61	2.48
	2015 fleet, 8% diesel trucks, freeway link speed limit = 50 mph	15.11	2.57	30.82	5.31	2.34
Truck Lane Placement	2015 fleet, all trucks on inner lanes	15.20	2.65	28.92	5.08	2.27
Receptor Distance	2015 fleet with 8% diesel trucks, receptor at 10 m	15.20	2.65	26.51	4.70	1.94
	2015 fleet with 8% diesel trucks, receptor at 20 m	15.20	2.65	20.89	3.67	1.55

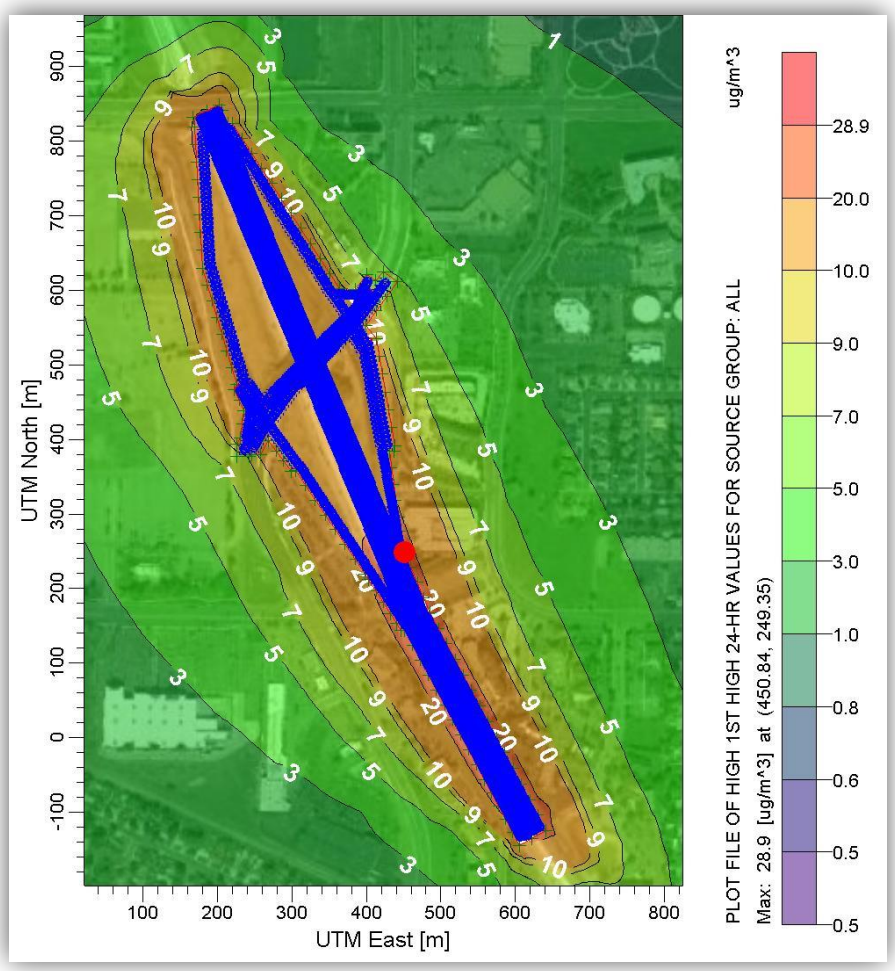


Figure 8. Sample contour plot of AERMOD-predicted peak 24-hr average PM_{10} concentrations for the hypothetical project under the truck lane placement modeling scenario. The red dot shows the location of the maximum peak concentration value (28.9 µg/m^3).

4.4.1 Impact of Fleet Age

Figure 9 shows modeled $PM_{2.5}$ and PM_{10} emissions by source type from EMFAC and modeled maximum 24-hr PM_{10}, 24-hr $PM_{2.5}$, and annual $PM_{2.5}$ concentrations from AERMOD for the eight fleet age modeling scenarios (2015, 2020, 2025, 2030, 2035, 2040, 2045, and 2050). Overall, PM exhaust emissions are projected to decline substantially between 2015 and 2025 due to fleet turnover. In these scenarios, the road dust and brake wear dominate PM_{10} and $PM_{2.5}$ emissions.

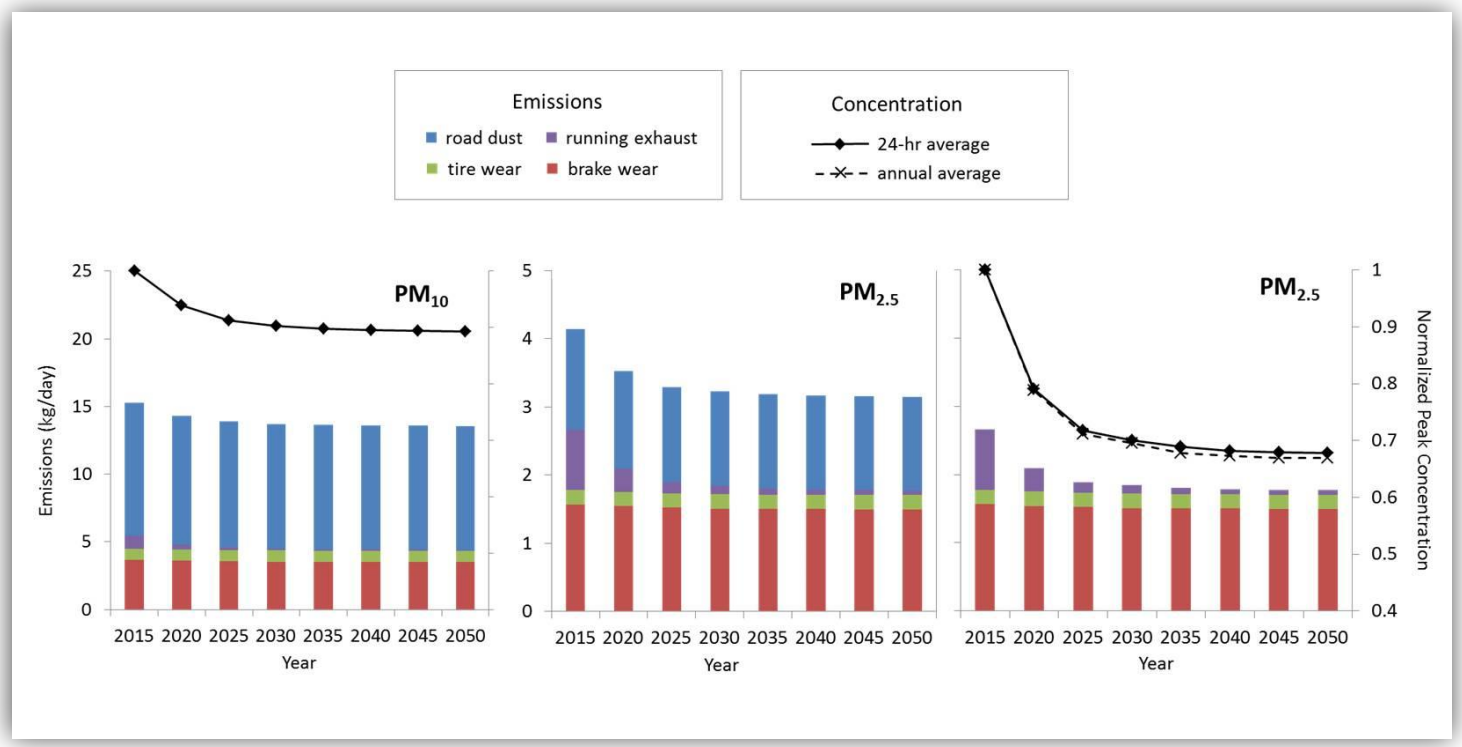


Figure 9. Sensitivity of PM emissions (bars) and normalized peak PM concentrations (lines) to fleet turnover for the hypothetical project with 125,000 total AADT. For $PM_{2.5}$, the plot in the center includes road dust emissions, while the plot on the right does not. For this case study, road dust was not included in the AERMOD $PM_{2.5}$ modeling.

Normalized peak PM concentration results indicate that fleet turnover is a large driver of $PM_{2.5}$ reductions in the near term (2015–2025) but a relatively small driver of $PM_{2.5}$ reductions in later years (2030–2050). Because the fleet turnover benefits are applicable only to vehicle exhaust emissions, the magnitude of the benefits for transportation projects decreases over time, with road dust, brake wear and tire wear becoming a more important driver of $PM_{2.5}$ sources in future years (the $PM_{2.5}$ concentration line chart does not reflect road dust emissions in Figure 9; the $PM_{2.5}$ emissions bar chart at the bottom of Figure 9 includes road dust emissions). Because PM_{10} emissions are already dominated by nonexhaust-related sources, the impact of fleet turnover on PM_{10} emissions and concentrations is much smaller, especially beyond 2025. These results illustrate that, at the project level, PM emissions and concentrations are becoming less dependent on fleet age (exhaust) and more driven by vehicle miles traveled (e.g., brake wear, tire wear, and road dust) over time.

4.4.2 Impact of Fleet Mix

Diesel trucks have much higher PM emissions than passenger vehicles on a per-mile basis. **Figure 10** shows modeled $PM_{2.5}$ and PM_{10} emissions by source type and maximum 24-hr PM_{10}, 24-hr $PM_{2.5}$, and annual $PM_{2.5}$ concentrations for the three fleet mix modeling scenarios (40%, 20%, and 8% of total AADT from diesel trucks). The modeling results suggest a strong correlation between reduced fraction of diesel truck traffic and decreased PM emissions and concentrations. For the hypothetical roadway project, changing the 2015 fleet mix from 40% to 8% diesel trucks can reduce the PM emissions and concentrations by half. In future years, the fleet mix impact is still substantial for PM_{10}, but it becomes less significant for $PM_{2.5}$ (see **Figure 11**)

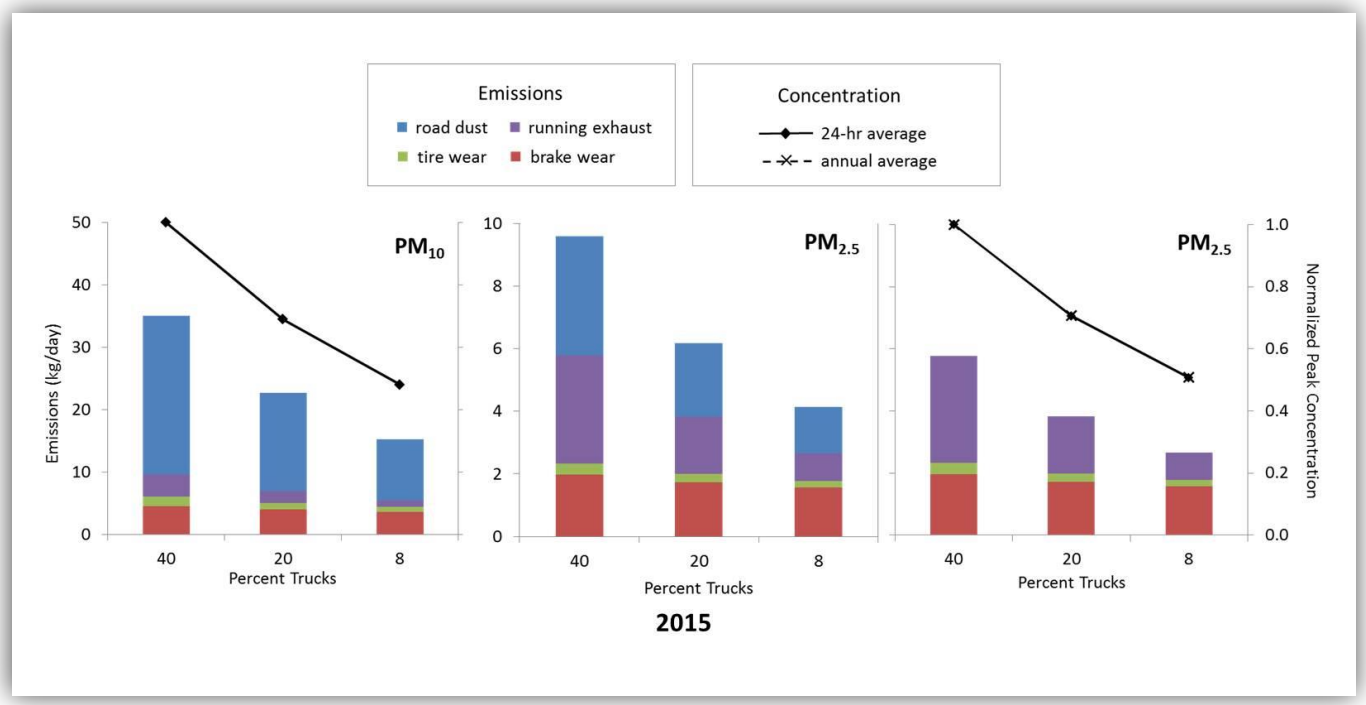


Figure 10. PM emissions (bars) and concentrations (lines) against 2015 fleet mix levels. For $PM_{2.5}$, the plot in the center includes road dust emissions, while the plot on the right does not. For this case study, road dust was not included in the AERMOD $PM_{2.5}$ modeling.

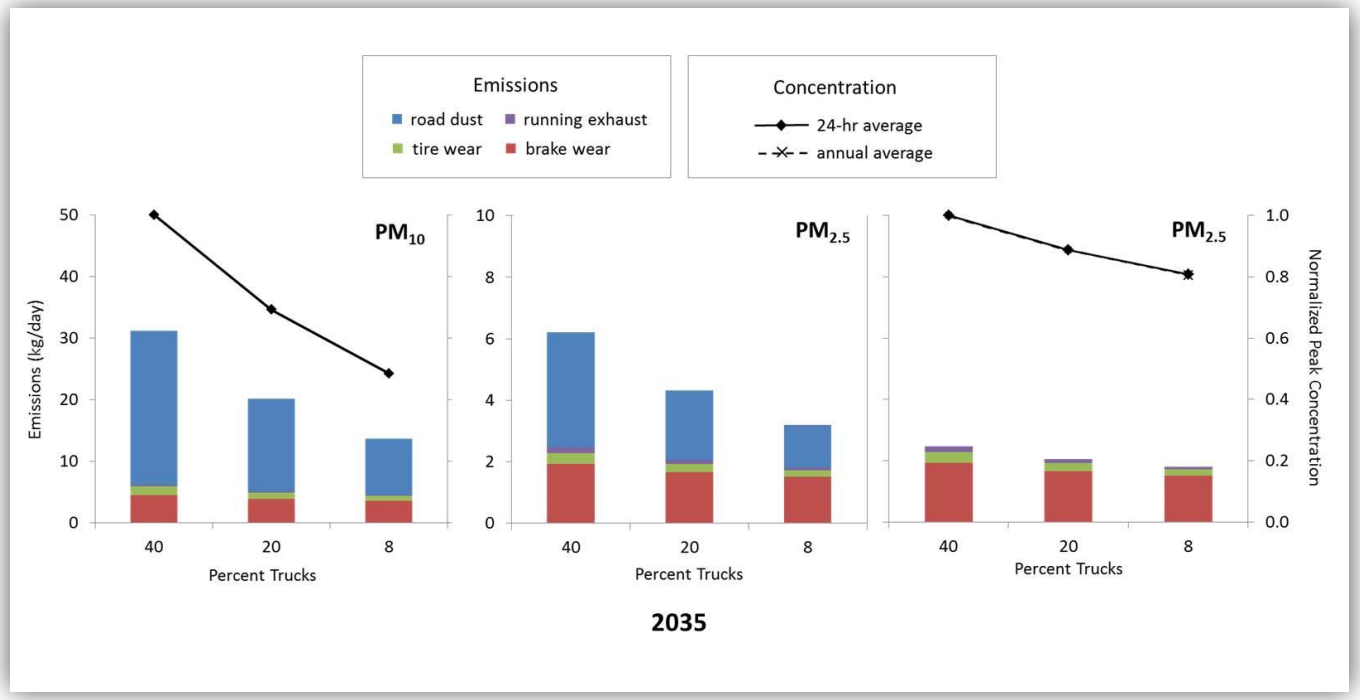


Figure 11. PM emissions (bars) and concentrations (lines) against 2035 fleet mix levels. For $PM_{2.5}$, the plot in the center includes road dust emissions, while the plot on the right does not. For this case study, road dust was not included in the AERMOD $PM_{2.5}$ modeling.

4.4.3 Impact of Speed Limit

Running exhaust emissions from motor vehicles vary by speed. Typically, the highest per-mile emissions occur under stop-and-go conditions with very low average speeds (e.g., under 30 miles per hour). Per-mile emissions also start to increase when vehicles are running at a high speed (e.g., above 60 mph). The minimum per-mile emissions usually occur during free-flow traffic conditions at speeds between 40 and 50 mph. Most highway projects are developed for congestion relief and therefore, by design, will result in reductions, per vehicle, of per-mile level emissions. Therefore, an additional mitigation concept is to restrict high-speed vehicle traffic. Figure 12 shows the normalized PM running exhaust emission factors as a function of vehicle speed for three vehicle categories specified in the EMFAC2014 model. Moving traffic from high speed (e.g., 65 mph) to a medium speed (e.g., 50 mph) by speed restrictions can reduce per-mile PM emissions and potentially mitigate near-road impacts.

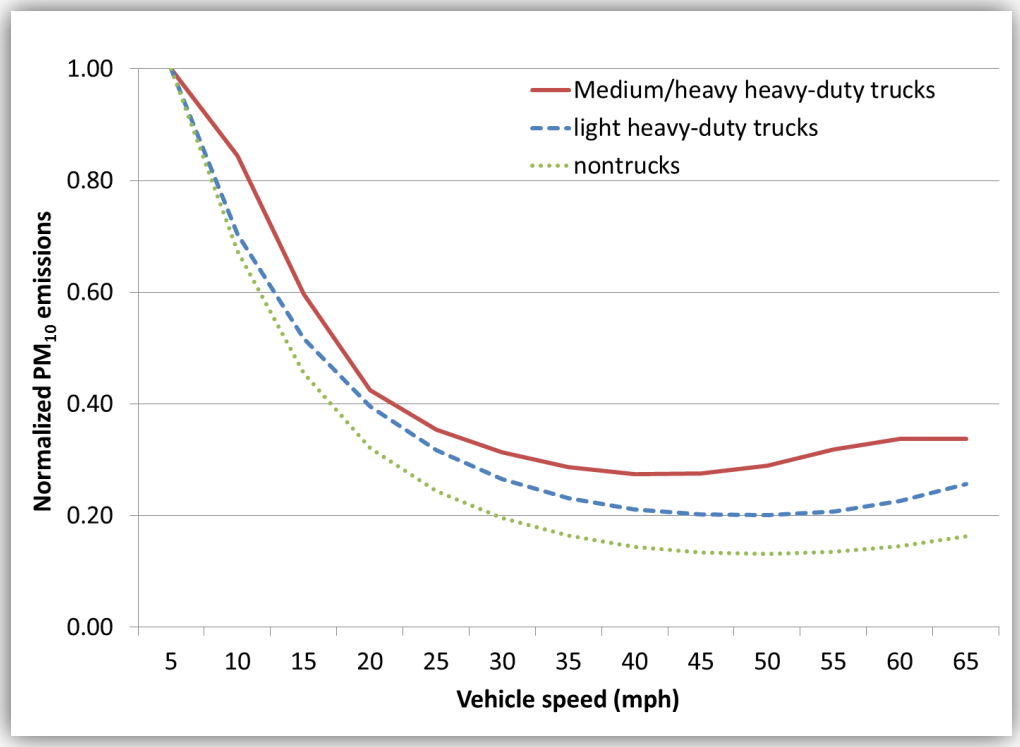


Figure 12. Normalized PM_{10} running exhaust emission factors as a function of vehicle speed for trucks and nontrucks. Illustration based on emissions data from EMFAC2014 (PL mode) for 2015 analysis year in Fresno County, California.

Two scenarios were modeled by setting freeway traffic to a high speed of 65 mph (representing a typical speed-limit scenario) and a medium speed of 50 mph (representing a restricted speed-limit scenario), respectively, for the hypothetical project. The restricted speed-limit scenario resulted in

lower PM emissions and near-road concentrations than the high speed-limit scenario; however, the differences are minimal, with percent reductions of 1%, 5%, and 6% for peak 24-hr PM_{10}, 24-hr $PM_{2.5}$, and annual $PM_{2.5}$ concentrations. As discussed earlier (see Figures 9 through 11), running exhaust PM emissions account for a small proportion of total project PM emissions; as a result, for both $PM_{2.5}$ and PM_{10}, the project impact of restricted speed to an optimized emission scenario tends to be minimal.

4.4.4 Impact of Truck Lane Placement

To examine the effects of relocating PM emissions sources, a scenario with hypothetical dedicated truck lanes was modeled. Compared to the base case where truck traffic occurs in any one of the four mixed-flow lanes (each with 8% truck traffic), this test scenario restricted truck traffic to the lanes adjacent to the median. As shown in Figure 13, with the dedicated truck lanes, truck traffic associated with higher PM emissions was generally moved away from the near-road receptors, although there is a tradeoff associated with relocating some trucks on the opposite side of the median closer to the receptor. The model results from this truck lane placement scenario indicate that, overall, there is a modest reduction (approximately 7%) in maximum 24-hr PM_{10}, 24-hr $PM_{2.5}$, and annual $PM_{2.5}$ concentrations when all heavy-duty truck traffic is restricted to the inner freeway lane.

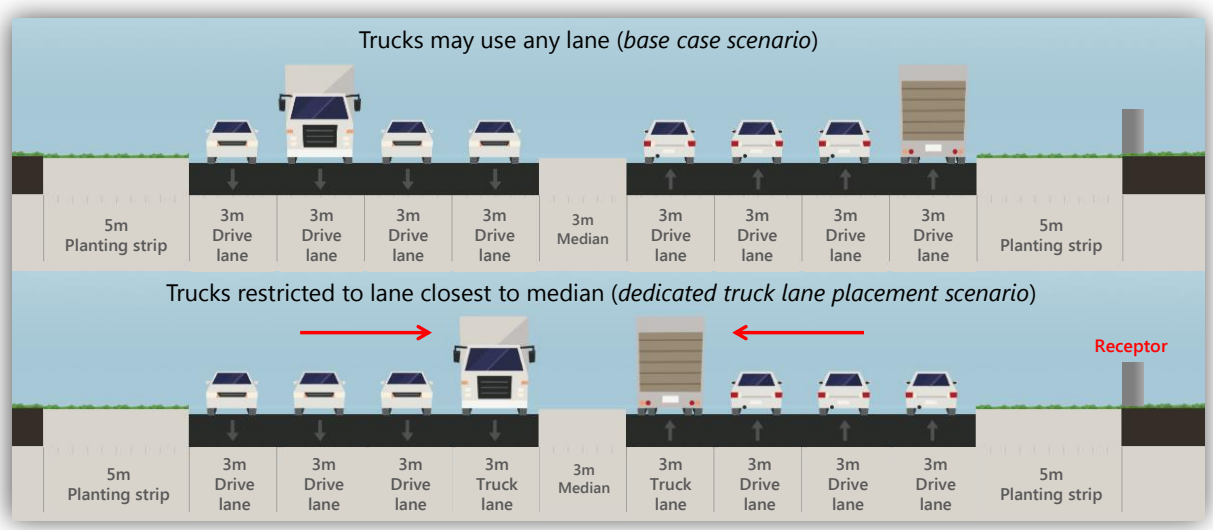


Figure 13. Graphic illustrating the base case scenario where trucks may use any lane (top) versus the truck lane placement scenario where truck travel is restricted to the innermost lanes, closest to the median (bottom). Red arrows help illustrate the trade-off of relocating trucks: trucks on the side of the freeway closest to the receptor (right side of the median) are relocated farther from the receptor; however, trucks traveling in the lanes farthest from the receptor (left side of the median) are relocated closer to the receptor. Image created using STREETMIX (http://streetmix.net).

4.4.5 Impact of Receptor Distance

Figure 14 shows a transect plot from one of the AERMOD modeling scenarios developed as part of this study to illustrate the relationship between PM concentrations and distance from roadway. The AERMOD modeling results suggest a rapid decrease in PM concentrations within the first 100 m of the roadway and a more gradual reduction with increasing distance beyond 100 m from the roadway. This pattern of concentration changes is similar for $PM_{2.5}$ and PM_{10}, and it is generally consistent with the near-road literature (Karner et al., 2010). As shown in Figure 15, in our test scenario, compared to the concentrations for receptors at 5 m from the edge of the project traffic lanes, the modeled 24-hour average PM concentrations decrease by 14% and 33% for receptors at 10 m and 20 m. For annual average $PM_{2.5}$ concentrations, the reductions are 20% and 36% for receptors at 10 m and 20 m from the roadway. Placing a receptor farther away from a roadway (e.g., by creating a buffer zone along the analyzed roadways) may effectively decrease the peak PM concentrations in the project area and therefore reduce the project PM impact.

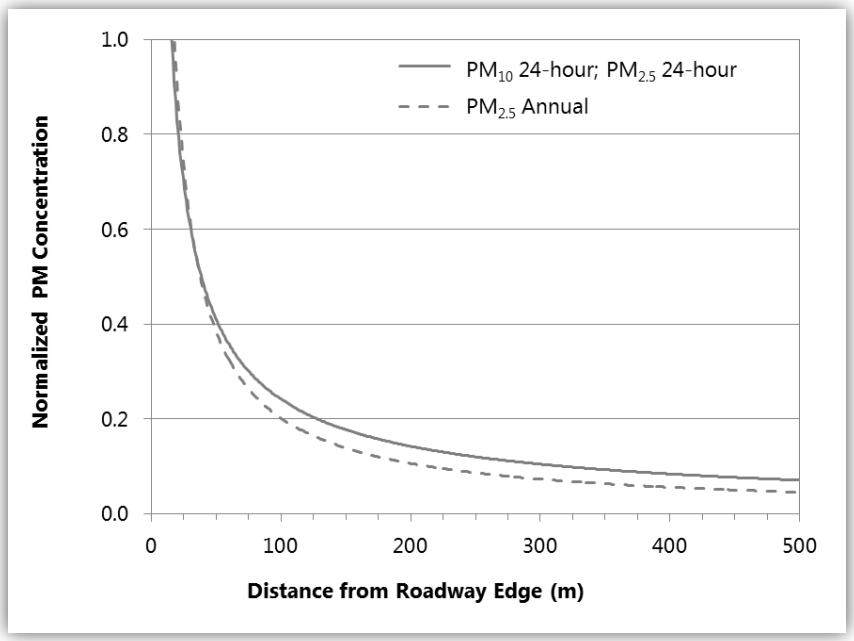


Figure 14. Normalized 24-hr PM_{10}, 24-hr $PM_{2.5}$, and annual $PM_{2.5}$ concentrations as a function of distance from the roadway. Data are from the restricted speed scenario (freeway speed of 50 mph), as discussed in the text in the Impact of Speed Limit section.

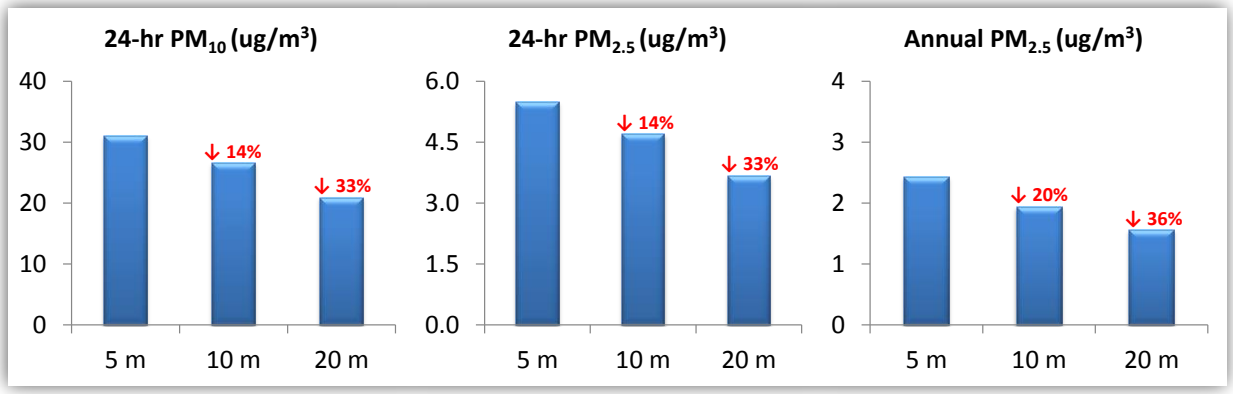


Figure 15. PM concentrations for receptors at 5 m, 10 m, and 20 m from roadway. EPA modeling guidance suggests receptor distances beginning at 5 m.

4.5 Controlling Other Sources in the Project Area

EPA's quantitative PM hot-spot analysis guidance notes that, in some cases, emissions sources in the project area that are not directly affected by the project may need to be included in the PM hot-spot modeling analysis (U.S. Environmental Protection Agency, 2015). This situation would occur when impacts from nearby stationary sources (e.g., power plants or rail terminals) are not captured in the background concentrations that have been established for the project area. For example, fugitive dust sources that emit PM_{10} at near-ground levels may have very localized air quality impacts that would not be captured at a background monitoring site several kilometers away. Examples of such sources include a rock quarry, a cement plant, or a bulk material handling operation (e.g., a coal pile at a power plant). Any such sources that need to be included in a PM hot-spot analysis would be identified during the interagency consultation process, and the technical approach for modeling these sources would be documented by the project analyst in the modeling protocol.

For such projects that include the modeling of nearby emissions sources that are not related to the project, there may be opportunities to assist in the application of emissions controls to one or more of these sources, thereby reducing the modeled PM concentrations that are added to background concentrations to calculate a project design value. This approach would require working with the local air district to evaluate PM controls currently in place at nearby sources as well as opportunities for installing additional controls. For example, if the dispersion modeling for the project area included a railway yard that significantly influenced PM concentrations for certain receptors, it could be possible to help fund additional emission controls for the railway yard (e.g., related to locomotives and freight transportation activities), so that the overall PM impact for the railway yard and the project area would be reduced.

In addition to PM impacts within a project area, sources outside of the project area will also contribute to background PM concentrations used for project analysis. There may be opportunities to assist in controlling one or more of these emissions sources to reduce the background PM levels.

However, quantification of the benefits of such controls would require additional effort and consultation with interagency partners, including local air quality management agencies.

4.6 Conclusions and Recommendations

The scenario testing and analyses described in this chapter illustrate several key variables that influence project-level PM emissions and concentrations. In the near term, fleet turnover is an important driver in reducing $PM_{2.5}$ concentrations; however, in future years, fleet turnover will have a much smaller impact on reducing project PM emissions and concentrations due to the increased significance of road dust and brake wear. Limiting the fraction of diesel truck traffic yields relatively larger reductions in near-road PM concentrations. Project-level PM emissions vary by speed, but restricting traffic from high speeds to an optimized emissions speed only showed minimal impact on near-road concentrations. Increasing the distance between emissions sources and receptors reduces project PM impacts. A hypothetical truck lane placement scenario suggested relatively small reductions in maximum $PM_{2.5}$ and PM_{10} concentrations near the roadway; however, PM concentrations at near-road receptors may decrease rapidly by distance from the edge of the project traffic lane.

Translating the variables and modeling results discussed in this chapter into PM mitigation measures at the project level is complex. The results presented here provide quantitative information that project sponsors and analysts can consider when developing practical mitigation actions, such as limiting diesel truck traffic, designing dedicated truck lanes, and creating sufficient buffer zones to move sensitive receptors farther away from the roadway. Depending on the project type and characteristics, the mitigation options may be more or less amenable to implementation. For example, there may be opportunities to restrict or redirect heavy-duty truck traffic along a roadway near a port facility, compared to a project within a dense residential community. In many real-world cases, there could be limited options for modifying project features to reduce PM impacts, and a single mitigation measure may be insufficient to reduce project impacts. Implementing multiple strategies and mitigation actions may be necessary to increase air quality benefits.

5. Best Practices to Streamline PM Hot-Spot Analysis Documents

5.1 Introduction

U.S. Environmental Protection Agency's (EPA) "Transportation Conformity Guidance for Quantitative Hot-spot Analyses in $PM_{2.5}$ and PM_{10} Nonattainment and Maintenance Areas" (U.S. Environmental Protection Agency, 2015) states that all quantitative PM hot-spot analyses should include sufficient documentation to support a determination that a project meets the conformity requirements (40 CFR 93.116 and 93.123). Compared to emissions and air dispersion modeling, the documentation process entails far less technical complexity. However, documentation can be time-consuming, especially since it includes addressing interagency consultation review comments. In most cases, the review process includes several rounds of comments and revisions, and in some cases additional and perhaps unanticipated technical analyses become necessary. Project analysts may spend weeks to months ushering documentation through the review process and obtaining final concurrence on the conformity determination.

Although Section 3.10 of the EPA Guidance provides some general information about documenting PM hot-spot analyses, details on how to best apply this guidance for specific projects are still evolving. To help streamline the documentation process and potentially reduce the amount of time spent on avoidable document revisions, project analysts should

1. Understand the level of detail sought by interagency consultation participants.
2. Review documentation from successfully completed PM hot-spot analyses (this body of work will grow over time).
3. Plan ahead to allocate sufficient time and resources to develop the necessary documentation; experience to date suggests it is easy to underestimate the time needed.
4. Develop a modeling protocol, and document all interagency consultation correspondence, decisions, and agreements. Also document models, methods, data, and results.

Chapter 5 provides information and best practices for developing and streamlining PM hot-spot documentation. These best practices were developed from several sources, including

- The EPA Guidance.
- PM hot-spot documents from previously completed analyses.
- Comments from EPA and other interagency consultation participants on previous projects.
- Caltrans district staff experiences documenting PM hot-spot analyses.

5.2 Development and Organization of PM Hot-Spot Analysis Documents

As mentioned by EPA, documentation should support the conclusion that the project meets conformity requirements, and should enable someone else to reproduce the modeling analysis.[6] The documentation should also be clear on how the EPA Guidance was applied to the analysis, and should describe all assumptions that affected predicted concentrations.

The EPA Guidance provides a brief list of components that should be included in the documentation; however, interagency experience suggests PM hot-spot documents should include additional information. Table 6 provides key information to include. The information is divided into 10 topic areas, which are discussed in more detail in subsequent sections. The topic areas are presented in the same order an analyst will follow to complete a hot-spot assessment. Each project is unique; analysts should organize documentation in the way that best suits the project. Analysts should also consider that much of the material developed for the PM hot-spot document may also be useful for other environmental impact assessment reports.

5.2.1 Introduction

The introduction should discuss the purpose and regulatory context for the analysis. The regulatory context should explain what part of the quantitative PM hot-spot conformity requirement (40 CFR 93.123(b)(1)) applies to the project, and should reference appropriate sections of any National Environmental Policy Act (NEPA) documents that have been prepared for the project. Project analysts should also include an overview of the proposed project, including the project's scope,[7] when construction will begin and end, and when the project is expected to be open to traffic.

Table 6. Topics areas and information to include in PM hot-spot analysis documents.

Topic Area	Information to Include
1. Introduction	• Document purpose. • Regulatory context for the analysis. • Overview of the proposed transportation project.
2. Interagency Consultation	• Interagency consultation participants and process. • Correspondence, decisions, and agreements.

[6] Project analysts should consider submitting large data volumes, such as meteorological data and the AERMOD input control files, as an electronic attachment rather than including it in the written documentation.
[7] A transportation project's scope includes the key elements of the project: for example, adding an interchange, building a new highway, widening an existing highway, or expanding a bus terminal.

Topic Area	Information to Include
3. Analysis Need	• Summary of the project of air quality concern (POAQC) decision and considerations.
4. Analysis Approach	• Description of proposed project, including expected completion date. • Geographic area covered by the project and the analysis. • Analysis year(s) examined, with justification. • Summary of the overall analysis approach. • Description of the project alternatives and no-build case. • Applicable PM National Ambient Air Quality Standards (NAAQS). • Types of PM emissions modeled. • Travel activity data and sources for the analysis year(s).
5. Emissions Modeling	• Model and version used (e.g., EMFAC2014-PL). • Inputs, data sources, and emissions modeling assumptions. • Project characterization (in terms of links). • Modeling results. • Description of significant nearby PM sources and justification for including or excluding them from the analysis. • Methods, data inputs, and results for estimating emissions from re-entrained road dust, construction, and any nearby sources.
6. Air Quality Modeling	• Model and version used (e.g., AERMOD version 16216). • Meteorological data sites and sources. • Justification of meteorological site selection. • Surface characteristics. • Emissions source characterization and layout. • Receptor network, including any sensitive receptors. • Justification for any receptors removed from the analysis. • Modeling results. • Approvals for use of graphical user interfaces (e.g., AERMOD View) or MPI.
7. Background Concentrations	• Background concentration(s) used for the analysis. • Monitoring site(s) selected. • Justification of ambient site selection. • Methods and assumptions used to calculate background concentrations.
8. Design Values and Conformity Determination	• Methods used for calculating design values. • Design value results. • Conclusion of how the project meets conformity requirements.
9. Mitigation (as needed)	• Mitigation or control measures to be implemented. • Quantification of expected benefits of mitigation. • Methods and assumptions used to quantify expected benefits of mitigation. • Written implementation commitments.
10. Conclusion	• Restate conclusion of how the project meets conformity requirements.

5.2.2 Interagency Consultation

A dedicated section of the PM hot-spot document should describe how the interagency consultation and public participation requirements (40 CFR 93.105) were met. This section should describe the interagency consultation process, list participating agencies, and document discussions and decisions. It is helpful to include a table summarizing key decisions and considerations, even if certain details are repeated or discussed elsewhere in the document.

5.2.3 Analysis Need

Project analysts should provide a brief summary to describe why a quantitative PM hot-spot analysis is needed for the project. The summary should state the applicable PM NAAQS in question[8] and explain the criteria used to determine whether the project was a POAQC. The POAQC determination involves analyses and interagency consultation focused on project location and anticipated changes in diesel traffic. Analysts should document the project analysis results and POAQC determination procedure.

5.2.4 Analysis Approach

This broad topic area covers many aspects of the overall analysis, as summarized in Table 6, that need to be documented. Analysts may dedicate entire sections to specific aspects of this topic, particularly if they are complex or additional justification is needed. Important aspects of the analysis approach topic area are discussed in more detail below.

Project Description, Analysis Area, and Analysis Years

Analysts should describe the proposed project, including scope, geographic area, and expected completion date. It is useful to include a map showing the project area in the context of NAAQS nonattainment and maintenance areas. Maps or annotated satellite images should be used to illustrate the project and analysis area; documentation should explain the rationale for selecting the analysis area, including input from interagency consultation. For larger projects, it may be appropriate to focus the analysis only on portions of the project that are expected to have the highest air quality concentrations and, consequently, the most likely new or worsened NAAQS violations. As a result, there may be multiple analysis areas within the overall project area. Finally, the documentation should describe the analysis year(s) examined and the factors considered in determining the year(s) of peak emissions.

[8] A quantitative PM hot-spot analysis is required for federally supported transportation projects that are located in PM_{10} and/or $PM_{2.5}$ nonattainment and maintenance areas and are determined to be POAQCs.

General Analysis Approach

Project analysts should describe the overall analysis methods, including the applicable PM NAAQS and the analyses conducted. For projects with several potential build alternatives, provide information about the project alternatives, clearly state which project alternative was selected for the analysis, and provide a rationale for that decision. Analysts should also remember to describe the no-build alternative if a no-build analysis was conducted.

Types of PM Emissions Considered

Document the types of PM emissions considered. All hot-spot analyses will consider direct PM emissions from vehicle exhaust, tire wear, and brake wear. Re-entrained road dust must be included in all PM_{10} hot-spot analyses. The inclusion of other types of PM emissions, such as start emissions, idling emissions, re-entrained road dust (for $PM_{2.5}$), and construction emissions, should be documented if they are applicable to the project. Justification should be provided as to why these other types of PM emissions were included in (or excluded from) the analysis. PM emissions from nearby sources that substantially affect the project area and are not already accounted for in the background concentrations should also be documented. For completeness, documentation should state that PM precursors and secondary particles are not considered in the hot-spot analysis, since air quality impacts from secondary formation processes are beyond the scope of a project-level analysis.

Travel Activity Data

Documentation should summarize traffic activity data used in the analysis, such as traffic volumes, fleet mix (truck volumes or percentage), and average travel speed. The data should be defined for different periods within the day (e.g., peak and off-peak hours). Detailed, link-level traffic data can be included in an appendix.

5.2.5 Emissions Modeling

Analysts must document the model and version used (e.g., EMFAC2014-PL), as well as modeling inputs, assumptions, and results. Describe how EMFAC-based emissions data were characterized in terms of links. Documentation should also clarify if local data or model default values were used for key input parameters, and local data sources (if any) should be documented. If any PM emissions from re-entrained road dust, construction activity, or nearby sources are included in the analysis, analysts must also document the models, methods, data, and assumptions used to develop these emissions estimates. Detailed emissions data and estimates for other PM emissions sources can be included in an appendix.

5.2.6 Air Quality Modeling

Analysts must document the model and version (e.g., AERMOD version 16216, using version 9.3 of the Lakes Environmental AERMOD View[9] graphical user interface), modeling options, emissions source layout, receptor network, and meteorological data inputs used. To keep documentation concise and easy to follow, consider summarizing key model inputs in a table.

If the parallel (MPI) option is selected in AERMOD View, project analysts must provide additional documentation validating that the MPI executable included in AERMOD View achieves identical results to the original EPA AERMOD executable. Project analysts should seek a validation report from Lakes Environmental, but should understand that this validation report may not be available in a timely manner and may not include the emissions source types and configurations used in the PM hot-spot analysis. If the validation report is unavailable, outdated, or inadequate, project analysts may need to perform additional validation tests and document those results. Since EPA must approve all regulatory applications involving the MPI version of AERMOD, project analysts should submit the necessary documentation earlier rather than later in the analysis process, to help streamline the overall conformity determination process.

Receptors

Documentation should describe the approach used to define receptors for the analysis. Information about the receptor height, layout, spacing, and extent should be included, using figures as needed to illustrate the receptor network and its spatial relationship with the emissions sources in the project. A detailed listing of each receptor is generally not necessary, as there may be thousands of receptors in the dispersion modeling analysis. Project analysts should highlight any sensitive receptors that were included in the analysis, and document and justify (with figures as appropriate) receptors that were deemed inappropriate for the hot-spot analysis and therefore removed.

Sources

The documentation should describe the approach used to define the emissions sources, including how the emissions sources were characterized (in terms of volume or area sources in AERMOD). Use figures to illustrate source layout and examples in the project area; document the methods and assumptions used to calculate emission source widths, release heights, and initial plume dimensions. If any other nearby emissions sources were included in the analysis, document how those sources were characterized in AERMOD. Document whether the urban dispersion option was invoked in AERMOD, what population was used to characterize urban dispersion, and how the population was determined.

[9] AERMOD View is a commercial graphical user interface that is often used to facilitate air dispersion modeling with AERMOD.

Meteorological Data

Document the representative surface and upper-air meteorological data sites selected for the air quality modeling analysis, the sources of those data (e.g., the agency that ran AERMET and provided the data), and the years of meteorological data selected. For many projects in California, there will likely be several surface meteorological stations to choose from. Project analysts must justify why the meteorological sites were selected, and provide a rationale for why other potential sites in the area were not chosen. The factors considered when selecting representative meteorological data should be documented, and could include

- Proximity of the meteorological monitoring site to the project area.
- Similarity of surface characteristics (e.g., land use) between the meteorological monitoring site and the project area.
- Period of time over which data were collected.
- Topographic characteristics within and around the project area.
- Wind patterns between the monitor and project area.
- Data completeness.[10]

Project analysts should provide supporting data to justify site selection. These data could include a spatial plot with underlying satellite imagery showing land use around the project and nearby meteorological stations, and wind roses for each meteorological station that was considered.

In addition, project analysts should provide a summary of the surface characteristics[11] values used to develop the AERMOD-ready meteorological data, and how those surface characteristics were developed. If representative meteorological data for the project were not available in AERMOD-ready format, project analysts should include additional information about how AERMET was applied to develop AERMOD-ready data.

Results

Finally, analysts should document the AERMOD results, highlighting the hot-spots that are modeled in the project. Contour plots of the predicted PM concentrations should be included. It is useful to include a table summarizing AERMOD results for the highest 10 receptors in the analysis.

[10] The completeness requirement for meteorological data is 90% for temperature, wind speed, and wind direction, determined by quarter.

[11] Surface characteristics required by AERMET include roughness length, albedo, and Bowen Ratio. Surface roughness is of particular importance, since AERMOD is most sensitive to surface roughness compared to the albedo and Bowen Ratio.

5.2.7 Background Concentrations

The background concentration[12] calculated for the hot-spot analysis, as well as monitor(s) used in the analysis, monitoring data sources, and the methods and assumptions used to determine the background concentration must be documented. Much of this documentation is similar to what is needed for selection of meteorological monitors (see above). The documentation should include the justification for the monitor(s) selection, and the rationale for why other monitors in the area were not chosen. Document factors considered when selecting ambient monitors to represent background concentrations. These include

- Similarity of characteristics (e.g., density and mix of emissions sources, land use, terrain) between the monitor location and the project area.
- Distance of monitor from the project area.
- Wind patterns between the monitor and project area.
- Data completeness.[13]

To support background monitor selection, analysts should include maps that show all the monitors located around the project. Maps with underlying satellite imagery are useful for showing land use around the project and nearby monitoring stations. If possible, wind roses for each monitoring station should be developed. Analysts should include a table with all monitors around the project area, including monitors considered but not used to compute background concentrations. The table should include site locations, monitor type, sampling frequency, data completeness, and monitor design values.

Finally, analysts should document any monitoring data excluded from the analysis because EPA granted a data exclusion under the Exceptional Events Rule.[14] Importantly, only data that have been flagged and concurred as exceptional events can be excluded; "exceptional-type" events or data flagged but not concurred as exceptional cannot be excluded from the monitoring data analysis.

5.2.8 Design Values and Conformity Determination

Project analysts should include an overview of how the project design values[15] for the applicable PM NAAQS were calculated. Clearly state the design values calculated for the receptors with the maximum concentration for each analysis year, and compare these values to the applicable PM

[12] Background concentration describes the PM concentration in the project area due to emissions from sources other than the project itself. Background concentrations are typically determined from ambient monitoring data.
[13] The normal data completeness requirement for air quality monitoring data is 75% of scheduled samples in each calendar quarter of each year.
[14] Exceptional events are defined by EPA as unusual or naturally occurring events that affect air quality, but are not reasonably controllable or preventable. Examples include wildfires and dust storms.
[15] The project design value combines modeled PM concentrations from the project with background PM concentrations. Project Design values are compared to the NAAQS and, if necessary, between build and no-build scenarios, to determine project-level conformity.

NAAQS. If the design value at one or more receptors exceeds the applicable PM NAAQS, results from the build/no-build comparison must be included for all receptors where the design value exceeded the applicable PM NAAQS.

To meet project-level conformity, the project must not create new violations of the applicable PM NAAQS, increase the frequency or severity of any existing violation of the NAAQS, or delay timely attainment of the NAAQS and interim milestones. Documentation should clearly state how the project meets these conformity tests (40 CFR 93.116 and 93.123) for the applicable $PM_{2.5}$ and/or PM_{10} NAAQS.

5.2.9 Mitigation

If any mitigation or control measure(s) were required to demonstrate project-level conformity, the documentation must describe the mitigation or control measure(s) to be implemented, the methods and assumptions used to quantify expected benefits, and associated written implementation commitments. Document any additional emissions and air quality modeling analyses performed to demonstrate conformity.

5.2.10 Conclusion

Project analysts may wish to restate the conclusion of how the project meets conformity requirements 40 CFR 93.116 and 93.123 for the applicable PM NAAQS.

5.3 Best Practices for Streamlining PM Hot-Spot Analysis Documentation

This section provides some general best practices that project analysts should keep in mind throughout the PM hot-spot documentation process. In addition to the other information presented in this chapter, these practices can help analysts streamline the documentation process and potentially reduce interagency review time.

- Understand the requirements for documenting the PM hot-spot analysis by reviewing the information provided in the EPA Guidance, this guidebook, and previously completed PM hot-spot analysis documents.
- Organize the documentation according to the examples included with this guidebook (see Section 5.4), or using other previously completed PM hot-spot analysis documents.
- Document throughout the analysis, not just as a final step after the analysis is complete. *Before* conducting the analysis, consider documenting and sharing the proposed analysis approach with the interagency consultation group. This is sometimes referred to as

developing a *modeling protocol*. Preparing a detailed modeling protocol that includes the proposed models, methods, data, and assumptions can help ensure interagency agreement with the proposed approach. This can prevent costly re-analysis and re-documentation.

- Justify key decisions and assumptions in the analysis. A key decision is any decision that could affect predicted concentrations and design values. For example, a decision on declaring urban sources in AERMOD could affect predicted PM concentrations.
- Include figures and tables to illustrate important aspects of the analysis and to summarize key methods, assumptions, decisions, and results.
- Keep the documentation concise and organized, using appendices or attachments to include larger volumes of supporting data as appropriate. There are no hard rules governing the size of the documentation. Large and complex projects with several analysis areas, multiple build alternatives, and mitigation scenarios may require more extensive documentation.

5.4 Examples of PM Hot-Spot Analysis Documents

This section cites three examples of completed PM hot-spot analysis documents that can be used as starting points to document a new project; two examples are from California, the other from Indiana. The discussion provides a summary table of contents for each project document. The examples highlight important elements to cover in the documentation. Since each project is unique, the exact organization, contents, and level of documentation detail will vary by project.

5.4.1 Caltrans District 7 High Desert Corridor (HDC)

The HDC project is one of the first California projects for which a quantitative PM hot-spot analysis was completed. The analysis was reviewed by the Southern California Association of Governments (SCAG) Transportation Conformity Working Group (TCWG). In June 2014, and again in September 2015, the TCWG deemed the documentation acceptable for NEPA circulation, and on January 4, 2016, the HDC project received a final project-level conformity determination from U.S. Federal Highway Administration (FHWA). The PM hot-spot analysis documentation for this project is available at http://www.scag.ca.gov/programs/Pages/ProjectLevel.aspx; look for the "September 2015" link under quantitative analysis.[16]

The HDC project provides a good example of a complex California PM hot-spot analysis involving interagency consultation. When examining the HDC documentation, analysts should note two important limitations. First, the HDC hot-spot analysis only needed to consider PM_{10}. Second, although the HDC project was in a PM nonattainment area, it was in a region where background PM_{10} concentrations were well below the NAAQS. As a result, only a modeling analysis of the build

[16] For additional information, including the project-level conformity determination letter, see the HDC Final Environmental Impact Report at http://www.dot.ca.gov/d7/env-docs/docs/hdc/.

scenario was needed to demonstrate project-level conformity; a no-build modeling analysis was not necessary. Analyses that need to consider a comparison of the build and no-build scenarios, and potentially other mitigation scenarios, will be even more complex than the HDC analysis and will require additional documentation.

HDC PM Hot-Spot Analysis Document Organization

1. Introduction
2. Project Description and Location
3. Project Purpose and Need
4. Project Alternatives – Preferred Alternative Selected
5. Interagency Consultation
6. Hot-Spot Analysis Methodology
7. National Ambient Air Quality Standard
8. Types of Emissions Considered
9. Emission and Dispersion Models
10. Meteorology and Climate
11. Air Quality Trend Analysis
12. Background Concentration
13. Analysis Years and Traffic Data
14. Calculation of Design Values and Determine Conformity

Attachment A: Methods and Assumptions Submitted to TCWG
Attachment B: Wind-Generated Fugitive Dust Emissions from a Passing High-Speed Train by California High Speed Rail
Attachment C: Request to EPA for Determination of Acceptability of Lakes' AERMOD View MPI
Attachment D-1: Summary of 2020 Emission Rate Inputs by Period
Attachment D-2: Summary of 2040 Emission Rate Inputs by Period
Attachment E: Memorandum to EPA for Consultation on Surface and Upper Air Data
Attachment F-1: Summary of 2020 Forecast Travel Activity Data by Period
Attachment F-2: Summary of 2040 Forecast Travel Activity Data by Period

5.4.2 Caltrans District 8 I-15 Express Lanes

The I-15 Express Lanes project is another California project for which a quantitative PM hot-spot analysis has been completed. The analysis was reviewed by the TCWG, and in June 2015 the documentation was deemed acceptable for NEPA circulation. On January 4, 2016, the project received a final project-level conformity determination from FHWA. This conformity determination was reconfirmed on April 26, 2016. The PM hot-spot analysis documentation for this project is

available at http://www.scag.ca.gov/programs/Pages/ProjectLevel.aspx; look for the "May 2015" link under quantitative analysis.[17]

The I-15 Express Lanes project is also a good example of a complex California PM hot-spot analysis involving interagency consultation. Unlike the HDC project, the I-15 project hot-spot analysis needed to consider both $PM_{2.5}$ and PM_{10}. Also, because the I-15 project is in a region where background $PM_{2.5}$ and PM_{10} concentrations were close to or above the NAAQS, a modeling analysis of both the build and no-build scenarios was conducted to demonstrate project-level conformity.

I-15 Express Lanes Project PM Hot-Spot Analysis Document Organization

1. Introduction
2. Build Alternative Description
3. Protocol Purpose and Methodology
4. Particulate Matter NAAQS Evaluated
5. Emissions Inventory
6. Dispersion Modeling
7. Particulate Matter Monitoring Stations
8. Determination of Background Concentrations
9. Calculation of Design Values for Conformity Determination

Attachment A: Traffic Volumes and Emissions Calculations
Attachment B: EPA Monitor Values Reports
Attachment C: Lakes AERMOD MPI Validation Analysis and Report
Attachment D: AERMOD Output Reports

5.4.3 Indiana I-69 Section 5 Bloomington to Martinsville (Indiana I-69)

The Indiana I-69 PM hot-spot analysis was completed and concurred on through interagency consultation during spring of 2013, and the project received a conformity determination from FHWA on June 26, 2013. The PM hot-spot analysis documentation for this project is available at http://www.in.gov/indot/projects/files/I69/2013/05/AirQualityTechReport.pdf. The Indiana I-69 project report is cited here because it has been used by EPA (e.g., at the 2014 Transportation Research Board conference and in other public forums), as a good example of how to document a PM hot-spot analysis. The I-69 report is an example of abbreviated documentation for a relatively simple project in an area where background PM did not exceed the NAAQS. Because the I-69 project is a simple case, it has somewhat limited applicability to California projects. In California, EPA has requested more detailed information and documentation for analyses in areas like the South Coast,

[17] For additional information, including the project-level conformity determination letter, see the environmental assessment report at http://rctc.org/projects/interstate-15/i-15-corridor-improvement-project.

where background PM concentrations are above the NAAQS and the conformity test is harder to meet.

Indiana I-69 PM Hot-Spot Analysis Document Organization

1. Introduction
2. Interagency Consultation
3. Overview of the Analysis Approach
4. Determine Need for PM Hot-Spot Analysis
5. Determine Approach, Models, and Data
    a. Geographic Area and Emission Sources
    b. Analysis Approach and Year(s)
    c. PM NAAQS Evaluated
    d. Type of PM Emissions Modeled
    e. Models and Methods
    f. Project-Specific Data
6. Estimate On-Road Vehicle Emissions
7. Road Dust, Construction, and Additional Sources
8. Air Quality Model, Data Inputs, and Receptors
9. Background Concentrations from Nearby and Other Sources
10. Calculate Design Values and Determine Conformity
11. Mitigation or Control Measures
12. Documentation of the PM Hot-Spot Analysis
13. Conclusion

Attachment A: Traffic Volumes
Attachment B: MOVES Link Data Input Files
Attachment C: MOVES Outputs (Emission Rates for AERMOD Modeling)
Attachment D: MOVES and AERMOD Input Data Assumptions and Parameters
Attachment E: AERMOD Outputs for Top 10 and Lowest Receptors

6. Real-World PM Hot-Spot Analysis Experiences

This discussion documents practical PM hot-spot analysis experiences and lessons learned to date; it is based largely on (1) discussion with staff from Caltrans District 7 regarding their experiences completing PM hot-spot analyses for the High Desert Corridor (HDC) project; (2) discussions with Caltrans District staff who participated in PM hot-spot training classes (conducted from 2014 through 2017); and (3) insights gleaned from interagency consultation documents from the Southern California Association of Governments (SCAG) Transportation Conformity Working Group (TCWG) meetings.

The material in this chapter follows the typical sequence of work steps to complete a PM hot-spot assessment, as outlined in Figure 1.

6.1 Step 1: Determine Analysis Needs

How is interagency consultation conducted to determine a project of air quality concern (POAQC)? What are the main challenges during the interagency consultation process?

Interagency consultation is always required to determine whether a project is a POAQC. For example, SCAG has established a formal process through the TCWG to facilitate interagency POAQC determinations in southern California. Projects that clearly qualify as a POAQC, such as the HDC project, may receive a relatively quick POAQC determination. In other cases, particularly for certain projects that are potentially controversial, Caltrans staff has found that interagency consultation can take much longer (e.g., several months) in determining whether a project is a POAQC. Also, in some cases where a project does not explicitly meet POAQC criteria, interagency partners may still determine that it merits a quantitative PM hot-spot assessment because the project's potential air quality impacts are of particular concern.

Best practices: Projects that are clearly POAQCs or likely to be POAQCs may receive a quick concurrence from the interagency consultation group; therefore, the project sponsor may anticipate a quick POAQC determination and begin early planning for the quantitative hot-spot evaluation. This approach has the potential to save startup consultation time.

What criteria can Caltrans use to determine PM hot-spot analysis needs?

For the HDC project, key criteria mainly included traffic volumes and truck percentage.

Best practices: The U.S. Environmental Protection Agency's (EPA) recommendations for determining a POAQC should be viewed as a starting point for discussion, rather than as absolute rules. The conformity regulations, 40 CFR 93.123(b)(1), include several criteria to be weighed when assessing POAQC status, including the level of traffic congestion at intersections, project type, and the location of known PM hot-spots. However, a key factor in determining a POAQC is whether the project involves introducing or affecting a "significant" number of diesel vehicles at the project location. Interagency consultation is required to address the key factors used to determine a POAQC for each project.

6.2 Step 2: Determine Overall Approach

Best practices: In general, detailed information regarding the planned PM hot-spot analysis approach needs to be provided to interagency consultation partners (e.g., via the transportation conformity working group meeting). It is important (and a time-saving technique) to get interagency concurrence on the overall analysis approach *before* starting the detailed modeling work.

How are build alternatives included in the PM hot-spot analysis?

Best practices: There are two practical insights regarding analysis of various project alternatives. The first is related to the travel activity assumptions used to describe a given build alternative. Ideally, traffic data would be finalized prior to starting the PM hot-spot modeling analysis; however, it is more common that travel data are updated several times during the air quality analysis process. Therefore, project analysts should anticipate the need to complete multiple modeling iterations for a given project alternative. The second insight involves ways to reduce the air quality dispersion modeling workload when multiple build alternatives are evaluated for a project. Given that multiple traffic activity versions may need to be assessed for each alternative, Caltrans staff has only performed AERMOD dispersion modeling to assess the "locally preferred alternative."

How is an analysis year determined? Are multiple analysis years (e.g., opening year and horizon planning year) considered? How is the potential highest emissions year determined?

Best practices: Per Section 2.8 of EPA's PM hot-spot analysis guidance (published November 2015), one or more analysis years need to be selected. Typically, Caltrans staff selects an opening year and a horizon planning year approximately 20 years later than the opening year; these two analysis years are also generally consistent with the National Environmental Policy Act (NEPA) analysis. This approach was employed by Caltrans for the HDC project. Justification is needed to show that any selected analysis years would represent years in which peak emissions likely occur. In addition, project analysts should ensure the consistency between a selected analysis year and the timeframe of the area's Regional Transportation Plan.

What dispersion model should be used to complete a PM hot-spot analysis?

Best practices: As of June 2017, EPA allows for either AERMOD or CAL3QHCR to be used when modeling PM concentrations. AERMOD, which was developed by EPA, is a more complex model but is also applicable to a greater array of project and source situations. Caltrans headquarters has arranged for all District offices to have access to a user-friendly version of AERMOD, called AERMOD View. In most cases, Caltrans staff and their outside consultants will use AERMOD View to complete PM analyses; for example, District 7 used AERMOD View when evaluating the HDC project. Note that EPA is in the process of removing CAL3QHCR from the list of preferred air quality models for use in PM hot-spot analyses and other regulatory modeling applications (see https://www3.epa.gov/ttn/scram/appendix_w-2016.htm).

How much detail is needed to support interagency consultation and to document PM hot-spot findings?

Best practices: EPA staff nationally (Ann Arbor) and in Region 9 (San Francisco) recommend an Indiana project write-up (Interstate 69) as a reasonable example of PM hot-spot analysis documentation. I-69 project documentation is available (www.trbairquality.org/files/2013/09/3-3Heil.pdf). However, in practice, Caltrans found that EPA reviewers requested information to supplement the I-69 template. For example, for the HDC project, EPA requested that District 7 provide more detailed information regarding meteorological data preparation (e.g., justification for using meteorological data from a selected air quality monitoring site, instead of an airport). EPA also asked District 7 to provide summaries of the ambient data used to determined background PM concentrations. In general, Caltrans staff's recent experience in southern California has shown that the level of detail requested by EPA in analysis documentation is increasing.

For a complicated project, how long can the PM hot-spot analysis process take?

For complicated projects requiring a quantitative PM hot-spot evaluation, it is prudent to build a lengthy time period (i.e., months to years) into the project assessment process. Although the quantitative PM hot-spot evaluation requirement is relatively recent, experience to date suggests that

most projects should budget at least several months of calendar time to complete the project assessment and prepare draft documents that can be shared with interagency consultation partners. Depending on the feedback received, additional modeling work may be necessary. For example, the entire HDC hot-spot analysis was conducted during a three-year period (elapsed calendar time).

Best practices: Overall, it may be helpful to assume that the PM hot-spot evaluation, review, and approval process could span a year or even longer for projects of modest size and complexity, although the overall analysis time will vary from project to project. Using documentation from a prior approved analysis can be a good starting point and can potentially save time when planning or conducting further analyses and during the documentation process.

6.3 Step 3: Estimate On-Road Vehicle Emissions

What is the best approach for obtaining and handling travel activity data for the analyzed project?

An important consideration is that the PM hot-spot analysis process can begin before detailed travel activity estimates become available for all project alternatives. The travel activity assumptions are the foundation on which the emissions and air quality modeling work is based. Therefore, if activity assumptions change substantially, previously completed emissions and air quality modeling will need to be redone. For example, travel activity data across various build alternatives in the HDC project changed several times during the hot-spot analysis.

Best practices: Project analysts should work closely with traffic activity providers at the outset of the project evaluation to understand as fully as possible the range of anticipated travel activity assumptions applicable to project alternatives. Some preliminary modeling may be necessary using worst case assumptions to get a rough understanding of potential PM impacts.

Another related issue is that truck definitions used by travel activity providers may differ from those used in the EMFAC (e.g., EMFAC-PL) or CT-EMFAC emissions modeling tools. Project analysts should map activity-based truck definitions to those used to complete emissions estimates.

Finally, it is important to emphasize that activity data should be obtained to describe multiple travel periods, such as morning and afternoon peak travel, midday, nighttime, or other off-peak travel. For example, for the HDC, District 7 obtained time period-specific travel activity data (total volume, truck volume, speeds), for morning peak, midday, afternoon peak, evening, and night travel periods.

What resolution of travel activity data is needed to support PM hot-spot analysis?

In general, the resolution of travel activity data should be at the link level. Each link represents a roadway segment for which activity parameters (such as speed and fleet mix) are generally consistent, and these links can be of varying lengths. Link-level activity data needs to be modeled by each time period (e.g., morning peak, midday, afternoon peak, night). District 7 developed a

spreadsheet to organize and process activity data with emission factors to calculate link level emissions for the HDC project.

Is EMFAC-PL used for generating PM emissions factors? What additional tools and modeling steps does Caltrans use to combine emissions factors and travel activity data for calculating project-level PM emissions?

Caltrans developed the CT-EMFAC emissions tool to speed project-level analyses. As of June 2017, the latest version of CT-EMFAC—CT-EMFAC2014 v6.0 (see http://www.dot.ca.gov/hq/env/air/pages/ctemfac_license.htm)—can be used to provide PM emission data by vehicle category for project-level assessment. Because CT-EMFAC2014 is directly based on EMFAC2014-PL emissions data, no additional EPA approval is needed for its use in conformity analyses. Caltrans Headquarters also developed the Emissions for Air Quality Tool (EM4AQ), which includes automated features to generate hourly emissions input for AERMOD by processing PM emissions factor data from CT-EMFAC2014 and project-specific travel activity data.

For the HDC project, District 7 used EMFAC2011-PL to obtain PM emission factors and developed a spreadsheet tool to facilitate the calculation of link-level PM emissions based on EMFAC2011-PL emission factors output.

What difficulties have been overcome when processing PM emissions data for AERMOD use?

For large projects, creating emissions files that can be easily updated as project assumptions change (e.g., as travel activity assumptions are refined) has been a challenge. District 7 learned that some approaches work better than others. When modeling the HDC project, District 7's consultant helped prepare an hourly variable emissions file for AERMOD View; unfortunately, the file was so large (several gigabytes) that it was too difficult to review and update. District 7 therefore used the EMISFACT function in AERMOD View and manually prepared hourly emissions data inputs (copy/paste from a specially formatted spreadsheet) for use through AERMOD View's user interface.

Best practices: Project analysts should anticipate the need to complete multiple emissions runs for any one project scenario, given the likelihood that travel activity assumptions may be refined during the project evaluation process. Therefore, it is useful to set up emissions data using spreadsheet templates or other formats that can be easily updated if revised data become available.

Project analysts also need to carefully match link-level travel activity data with the link-level characterization of emissions sources specified in AERMOD View. For example, when setting up a line-volume source in AERMOD View, analysts must divide total link emissions by time period to calculate gram-per-second emissions rates for each line-volume source. To prevent mistakes in preparing emissions input data for AERMOD View, project analysts should consistently match roadway links (with travel data) and line-volume sources defined in AERMOD View.

To streamline the process of preparing AERMOD-ready emission inputs, project analysts can use the EM4AQ tool. This Excel spreadsheet tool processes CT-EMFAC2014 PM emission factor data and

project-specific travel activity data to generate emissions input for AERMOD. As of June 2017, the latest version of EM4AQ—EM4AQ v1.1—along with a user's guide and a video demonstration for the tool, is available on the Caltrans air quality website.

6.4 Step 4: Estimate Other Emissions

In addition to running exhaust, tire wear, and brake wear emissions, what other emissions need to be included in the PM hot-spot analysis?

In many situations, project analysts will only model emissions directly related to the on-road vehicles operating on the project facility. However, each project site is unique, and some sites may have other important PM sources near enough to the project area that they warrant inclusion in the hot-spot analysis. For example, District 7 included PM_{10} emissions (disturbed dust) from a high-speed railway in the HDC analysis because the proposed rail facility was close enough to the project to potentially contribute to PM_{10} concentrations in the HDC project area. In addition, District 8 included PM emissions from truck activities (trips and idling) at several warehouse-distribution centers in the I-15 Express Lanes analysis because the transportation project was expected to increase diesel truck activity at those facilities.

Best practices: Project analysts should review project settings and determine whether other potentially significant PM sources merit inclusion in the modeling analysis. For example, for PM_{10}, road dust must be modeled; for $PM_{2.5}$, road dust would be considered if it was a significant source of $PM_{2.5}$ emissions in the region. As a best practice in California (especially in Southern California), $PM_{2.5}$ road dust is typically included in the hot-spot analysis. Other sample sources to consider include any major facility, such as a bus or train station, at which substantial numbers of diesel-powered vehicles operate; or quarrying, rock crushing, or cement manufacturing facilities known to generate significant PM_{10} emissions (disturbed dust). If analysts are unsure whether to include other sources in their project assessment, they can consult local air agency staff. For example, District 7 held discussions with the Antelope Valley Air Quality Management District (AVAQMD) and Mojave Desert Air Quality Management District (MDAQMD) to identify potential sources within two miles of the HDC project right-of-way.

6.5 Step 5: Estimate Project Concentrations

6.5.1 General AERMOD Modeling and Analysis

What practical approaches do analysts use to complete AERMOD modeling?

For the HDC project, District 7 conducted two rounds of AERMOD View modeling per EPA's recommendation. The first round involved screening runs using the AERMOD View "FASTALL"

optimization and a limited number of receptors. The second round involved regular AERMOD View runs without the FASTALL feature, and more receptors concentrated at hot-spots identified in the screening run. Because the project spanned 63 miles, District 7 created several different modeling domains to evaluate. For example, they modeled about 8,000 receptors in one domain and about 5,400 receptors in a separate domain. The AERMOD runs included approximately 60 links; each link was represented by a series of adjacent volume sources.

For the I-15 Express Lanes project, District 8 modeled the worst-case 1-mile segment of the project instead of modeling the entire length of the project (16 miles). The worst-case segment had the highest PM emissions and the highest background concentrations in the project area due to the presence of nearby sources. For larger projects, it may be appropriate to focus the PM hot-spot analysis only on portions of the project that are expected to have the highest air quality concentrations and, consequently, the likely new or worsened NAAQS violations. Decisions to limit the focus of a PM hot-spot analysis must be concurred through interagency consultation.

How long do AERMOD runs take? What approaches can analysts use to speed the modeling process?

AERMOD View run times will vary substantially from project to project. In many cases, AERMOD run times can be lengthy due to the large number of emissions sources typically needed to represent the roadways, and the large number of receptors needed to capture the potential concentration of hot-spots in the project area. To speed model runs, analysts have used the Message Passing Interface (MPI) version of AERMOD View, which can take advantage of the multiple processing cores available on most modern computers (i.e., a multi-core CPU). District 7 used AERMOD View MPI for their analyses, and each simulation took approximately five to seven days of computer time to complete, using two or three computers with each computer running with four processing cores.

As of this writing, EPA approval is required to use AERMOD View MPI for PM hot-spot analyses. Districts should allow reasonable time for this approval process to take place, and should document correspondence and interagency consultation results. For example, District 7 requested EPA approval of AERMOD View MPI for the HDC project. The process involved Caltrans working with Lakes Environmental (the developer of AERMOD View) to obtain a validation report showing that AERMOD View MPI produced identical results to the standard EPA version of AERMOD. Furthermore, because District 7 used line-volume sources to represent roadways in the HDC project and the validation report did not consider line-volume sources, EPA asked District 7 to perform additional analysis to demonstrate that AERMOD View MPI produced identical results to the standard EPA version of AERMOD specifically for line-volume sources. After reviewing that analysis, EPA agreed that AERMOD View MPI could be used for the HDC project. Because there are cases where EPA and other agencies may agree to modeling procedures without providing formal written confirmation, it is preferable that the Caltrans project analyst document agreements in writing and distribute that documentation as part of the interagency consultation process.

Best practices: In the HDC project case, EPA asked District 7 to demonstrate that AERMOD View MPI produced results identical to the standard EPA AERMOD versions for the source types used in the PM hot-spot analysis. There is usually a significant time lag between AERMOD updates and the availability of new validation reports from Lakes Environmental; thus, careful planning is needed to get AERMOD View MPI approved for hot-spot modeling use.

In addition, AERMOD View runs will be forced to terminate when the computer is logged out. Therefore, when running long simulations with AERMOD View, Caltrans project analysts should request an IT exemption to prevent computers from logging out and interrupting the model runs.

What can be the most time-consuming aspects of the AERMOD setup and analysis process?

District staff report that it was time-consuming to trace the alignment of links to define link-level volume sources in AERMOD View. In some cases, when adding or editing nodes along roadway links, AERMOD View erased all existing elevation inputs. District staff had to use workaround approaches to save previous elevation inputs prior to editing nodes and reload those inputs back to AERMOD View after changing the volume sources.

Best practices: District staff found that, when adding or editing nodes along roadway links, it was useful to save a copy of the elevation inputs (e.g., in a spreadsheet) and to copy/paste the inputs back to the AERMOD View user interface.

Additionally, it can be time-consuming to load geospatial data and other project information that was generated from other software packages into AERMOD View. For example, when evaluating the HDC project, District 7 used output from a 3D CAD design and modeling software package called MicroStation to create a visual representation of the project design in AERMOD View. Caltrans ran into two obstacles when using MicroStation outputs:

- First, staff had to conduct multiple processing steps to import MicroStation project design data into AutoCAD format, so that it can be imported into AERMOD View; one example involved converting length units to correspond to those used in AERMOD View. The processing steps were needed to ensure the project displayed properly in both the AERMOD View interface and Google Earth.
- Second, District 7's consultant had no experience dealing with Caltrans MicroStation design files, and District 7 had to work extensively with the consultant on this issue.

Are there suggested approaches to quality-assure (QA) AERMOD analysis results?

District 7 conducted QA from several perspectives: (1) checking traffic data (e.g., activity data related to HOV lanes); (2) checking emissions data (vehicle miles traveled and emissions estimates for each roadway link); (3) checking AERMOD concentration results across different sources; (4) using contour plots from the AERMOD View interface to examine the PM concentrations spatially; and (5) checking results for reasonableness.

Best practices: District staff should consider multiple approaches to quality check the AERMOD View modeling process. In addition to reviewing and checking various input data, district staff can also use the informational messages included in AERMOD View output files (e.g., the **aermod.out** file) as reference to ensure that AERMOD View is executed correctly and generates reasonable concentration results. Chapter 3 of this Best Practices Guidebook contains a QA checklist with information to help project analysts review and quality-assure PM hot-spot analyses.

What advice would be useful to Caltrans staff who are using consultants to complete AERMOD analyses?

Best practices: District staff should closely review how the consultant has characterized the emissions sources in AERMOD View (most consultants will use AERMOD View or a similar graphical user interface for AERMOD). EPA has provided various suggestions regarding source characterization and setup; for example, analysts can choose to configure emissions sources as area or volume sources. These configuration alternatives result in different modeled PM concentrations, as discussed in Appendix A. Also, improper source characterization and setup can lead to interagency review comments and necessitate rerunning AERMOD with updated size and placement of sources. District staff should also pay close attention to how the consultant has prepared the emissions inputs for use with AERMOD. As noted earlier, there needs to be consistency between traffic activity and emissions source characterization of the vehicle fleet at the link level.

6.5.2 Meteorological Data

What are some of the complications to be overcome when finding representative meteorological data for your project?

Generally, EPA requires that a meteorological monitor must have collected useable data at least 90% of the time for the data to be deemed "complete" and appropriate for use in a PM hot-spot analysis. The completeness requirement has meant that some Districts have had to review data from multiple sources before being able to find an appropriate meteorological data set. For example, after determining that meteorological data from a nearby airport were not complete, District 7 had to obtain meteorological data from an air quality monitoring site. District 8 found that data from nearby municipal airport meteorological stations had not been audited for data quality or completeness, and therefore were not approved by the local air district. In this case, the local air district provided District 8 with audited and approved data in an AERMOD-ready format from alternative sites.

Best practices: Depending on the data format available, it may be necessary to process meteorological data using the AERMET tool. AERMET formats meteorological data to be input-ready for AERMOD model runs, and performs meteorologically-related calculations needed to set up an AERMOD run. However, some data may be in formats that even AERMET cannot read until the data are manipulated by the project analyst. Therefore, analysts should anticipate that complete meteorological data sets may need substantial processing to be AERMOD-ready. For example, once

District 7 found a representative site with complete meteorological data, they learned that the data were not in a format easily read by AERMET; they subsequently had to reformat the data for AERMET use, run AERMET, and then use the AERMET output to populate their AERMOD runs. Each of these steps was time-consuming, and, for analysts new to the PM hot-spot process, some of these steps may be unexpected.

District staff should review and understand the meteorological sites the consultant selected, and how the consultant justified the site selection. District staff should also review log files from AERMET (the meteorological pre-processor to AERMOD) to ensure the meteorological data used for the modeling analysis meet EPA's completeness criteria. Interagency consultation should be used to help resolve potential problems with meteorological data. For example, recent discussions between EPA and the South Coast Air Quality Management District (SCAQMD) suggested that it might be acceptable to use meteorological data for an inconsecutive five-year period, as long as these five years are close enough.

Finally, it is useful to track whether EPA has released updated versions of the modeling tools needed to complete PM hot-spot analyses; more recent versions may speed data processing.

6.5.3 Sources

What AERMOD View features are Districts finding useful when setting up sources?

District 7 used the Fenceline – Plant Blanking Boundary feature in AERMOD View to define a buffer zone associated with the right-of-way, and then export results to Google Earth. District 7 determined the right-of-way based on visual inspection of fencelines using Google Earth imagery.

What approaches are districts using to speed the process of inputting emissions data to AERMOD View?

District 7 developed a spreadsheet to automatically process PM emissions data and prepare emissions inputs for AERMOD View's line-volume sources. Other districts may find the District 7 spreadsheet format/tool to be of use in streamlining their work.

Caltrans Headquarters has also developed the EM4AQ tool, which includes automated features to generate hourly emissions input for AERMOD View by processing PM emissions factor data from CT-EMFAC2014 and project-specific travel activity data.

6.5.4 Receptors

What receptor layout approaches are being taken by districts?

AERMOD View enables users to place receptors in different ways. One approach is for analysts to have AERMOD View generate a grid of receptors for the project site, and then to manually remove receptors that are inappropriately located, such as receptors within the right-of-way. An alternate approach is to manually place receptors; manual methods avoid placement of receptors in inappropriate locations, but take longer to set up. For the HDC, District 7 first defined a receptor grid, converted the grid to discrete receptors, and then removed unnecessary or inappropriately placed receptors.

Best practices: In AERMOD View, receptors can be arranged perpendicular to the fenceline (the boundary of the right-of-way buffer zone) by using the Plant Boundary Tool to establish a plant boundary around the fenceline and then establishing a Fenceline Grid receptor network based on that boundary. When this approach is used, AERMOD View may place more receptors than needed at locations where two roadways cross. To save setup time, project analysts can leave these extra receptors in the model run because the receptors do not need to be arranged in a perfect grid configuration.

6.6 Step 6: Determine Background Concentrations

How are districts selecting monitoring sites for calculating background ambient concentrations?

For the HDC project (PM_{10} analysis), District 7 determined that an air quality monitoring site in Victorville was representative for calculating background PM_{10} concentrations, based on an evaluation of project proximity, similarity of climate and meteorology, and similarity of land use and level of traffic between the project and the selected monitoring site. During interagency consultation, EPA asked District 7 to document the justification for their site choice, and to include discussions of how the ambient concentrations at the Victorville site compared to other monitoring sites nearby.

What challenges do districts encounter when selecting representative monitoring locations or calculating background concentrations for projects?

For the HDC project, District 7 spent more time than expected to determine the completeness of the available monitoring data. For another project, District 7 worked with the local air district (SCAQMD) to obtain projected future PM concentration data to represent future-year background concentrations. However, after obtaining and evaluating the projected concentrations and comparing them to the monitored data, District staff determined there were no substantive differences between the monitored and projected future-year values.

6.7 Step 7: Calculate Design Values and Determine Conformity

What has been the experience to date regarding the need to analyze AERMOD output and calculate design values?

Caltrans has developed DVTool, a software package that calculates PM design values for comparison to the NAAQS to determine whether a project meets transportation conformity requirements. DVTool uses three consecutive years of background concentration data and one or five years of modeled concentration data from AERMOD to calculate annual $PM_{2.5}$, 24-hr $PM_{2.5}$, or 24-hr PM_{10} design values. DVTool also compares calculated design values for the project build scenario to the corresponding NAAQS and/or to the design values for the project no-build scenario. The results of these comparisons can be used by project analysts to determine conformity.

As of this writing, there is insufficient District experience to document time-saving techniques or insights to process AERMOD output and calculate design values. Caltrans updated DVTool to version 3.0 to implement improvements and incorporate changes to design value calculation methods shown in EPA's November 2015 PM hot-spot guidance. In the future, the use of DVTool by District staff should speed the processing of AERMOD results and background concentration data to calculate design values.

6.8 Step 8: Consider Mitigation

What PM mitigation measures are being considered or incorporated into projects?

As of this writing, there is insufficient District experience to document successful mitigation approaches to alleviate potential conformity issues. District 7 staff commented that toll lanes and truck restrictions could be considered mitigation measures.

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Appendix A. Sensitivity of AERMOD-Predicted PM Concentrations to Selected Source Inputs

EPA's guidance allows analysts some flexibility in configuring certain AERMOD inputs when performing air quality modeling for transportation project PM hot-spot analyses. This appendix includes a discussion of two examples of such AERMOD inputs, and illustrates the sensitivity of predicted PM concentrations to the input options selected.

The first example, in **Section A.1**, addresses the source type options used to represent roadway emissions. When using AERMOD, analysts may define roadway links as either volume sources or area sources. Volume and area sources are configured and modeled using different approaches; predicted PM concentrations vary depending on which of these two source types is chosen. Generally, volume sources more accurately represent roadway conditions, and produce lower PM concentration estimates. They are more time-consuming to model than area sources when using AERMOD; however, AERMOD View simplifies volume source setup.

The second example, in **Section A.2**, demonstrates the approach used to determine plume heights and release heights of volume sources representing a roadway link. Analysts may calculate plume and release heights using either emissions-weighted or traffic volume-weighted information. The two calculation approaches require different levels of work effort, and also result in different predicted PM concentrations. Generally, emissions-weighted plume and release heights more accurately represent roadway conditions, and produce lower PM concentration estimates. However, they are more time-consuming to model.

A.1. Roadway Link Source Type: Volumes and Areas

Analysts can define roadway links as either volume or area sources in AERMOD. EPA describes the AERMOD input parameters required for defining a series of adjacent volume sources or area sources to represent roadway emissions (U.S. Environmental Protection Agency, 2015), and provides detailed illustrations for characterizing roadway emissions as volume sources (see https://www.epa.gov/state-and-local-transportation/project-level-training-quantitative-pm-hot-spot-analyses). This section briefly describes significant differences between the two source types, as treated in AERMOD, and summarize differences in modeled PM concentrations resulting from area sources and volume sources to model three sample highway projects.

Differences between volume and area sources in AERMOD include the extent of their horizontal dimensions, the representation of initial emissions distributions, and emissions plume treatment under low wind speeds.

- **Horizontal dimensions:** In contrast to area sources, which can be rectangles or other polygons and have two parameters to represent horizontal dimensions, a volume source is symmetrical and has a single parameter to represent the horizontal dimension. Therefore, as illustrated in Figure A-1, many more volumes than areas may be required to define a given roadway link. Furthermore, highways with three or more lanes require a series of adjacent volume sources for each lane. Because of the large number of sources required to complete volume source modeling, computer run times may be longer and, if using AERMOD (not AERMOD View), the time needed to set up a model run may increase substantially.

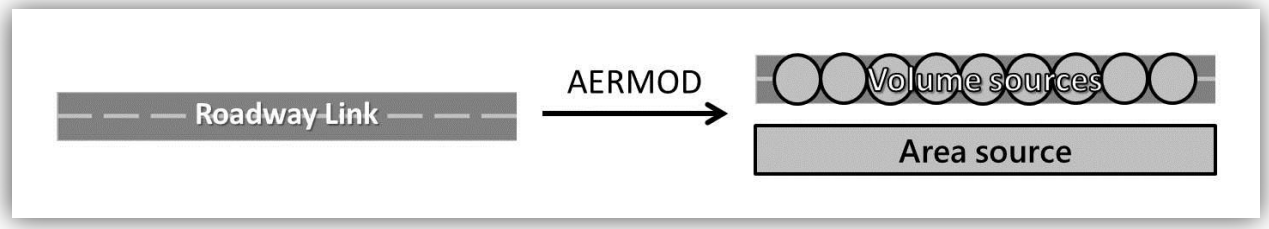

Figure A-1. Illustration of volume source and area source representations of a roadway link in AERMOD.

- **Representation of initial emissions distributions:** AERMOD represents emissions from volume sources using a Gaussian distribution similar in concept to a "bell curve." A Gaussian distribution represents a decrease in emissions density, both horizontally and vertically, as distance increases from the vehicle. In contrast, area source emissions are represented by a uniform distribution. In concept, an area can be visualized as a stick of butter placed over the roadway—the emissions are distributed uniformly throughout the stick of butter, but are not distributed past the edge of the butter's rectangular shape. In reality, emissions, once released and mixed by vehicle turbulence, extend beyond the roadway edge. Thus, the Gaussian distribution (i.e., a volume source) is a more accurate representation of real-world conditions (Figure A-2).

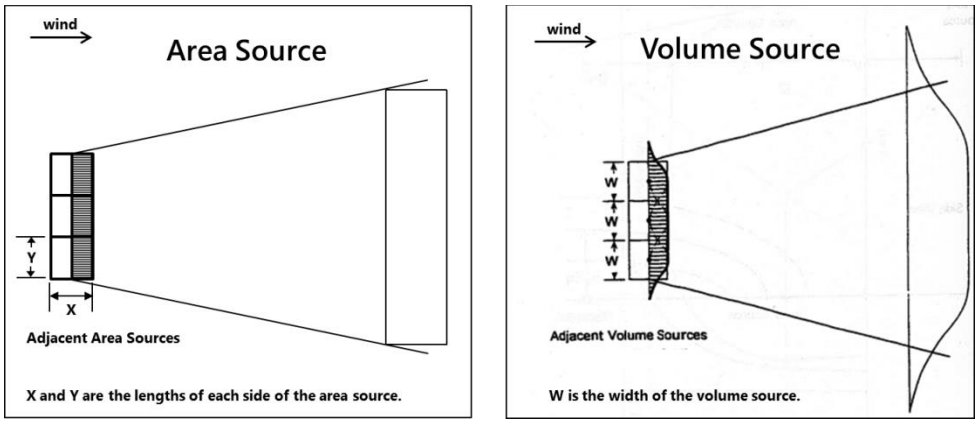

Figure A-2. Simplified illustration of plume dispersion in AERMOD (emissions distributions indicated by hatched areas). Area source emissions distribution is uniform; volume source emissions distribution is Gaussian. Image courtesy of M. Claggett, FHWA.

- **Plume Treatment:** For volume sources, AERMOD implements a plume meander algorithm that accounts for the lateral back-and-forth shifting of an emissions plume under low wind speeds. Use of the volume source approach results in decreased time-averaged pollutant concentrations, since a meandering plume will not impact a given receptor at all times. In contrast, AERMOD does not implement plume meander for area sources. Therefore, AERMOD modeling that employs area sources may overestimate concentrations under low wind speeds.

Two sets of AERMOD simulations were conducted for each of three hypothetical freeway projects. Results from the simulations (Table A-1) illustrate, for the following case studies, that modeled concentrations are consistently higher when area sources are used:

- For maximum 24-hr average $PM_{2.5}$ concentrations, area sources produced results that were up to 44% higher than the results produced by volume sources.
- For maximum annual average $PM_{2.5}$ concentrations, area sources produced results that were up to 18% higher than results produced by volume sources.

For the same three projects, additional simulations were conducted to examine the impacts of plume meander treatment and use of different volume source configurations (use of fewer vs. more volumes). The results show that plume meander treatment accounted for ≥91% of the difference between predicted PM concentrations for volume and area sources. PM concentration impacts of different volume source configurations were also evaluated: for each project; a series of adjacent volume sources were defined with appropriate volume sizes to represent each roadway by link (fewer volumes) and by traffic lane (more volumes), respectively. In theory, the more volumes used, the more refined and accurate the representation of the road; however, when more volumes are used, it is more complex and time-consuming to set up, quality assure, and process model runs. In these test

cases, moving from fewer volumes to more volumes resulted in a minimal difference (≤2%) in modeled PM concentrations.

Table A-1. AERMOD-predicted PM concentrations when using volume sources and area sources for three sample freeway transportation projects.

Sample Project[a]	$PM_{2.5}$ 24-hr Average ($\mu g/m^3$)		$PM_{2.5}$ Annual Average ($\mu g/m^3$)	
	Volumes	Areas	Volumes	Areas
Complex Freeway Expansion	5.85	7.90	2.90	3.31
Simplified Freeway Expansion	7.84	10.30	4.06	4.62
Single Freeway Link	1.17	1.69	0.67	0.79

[a] The Complex Freeway Expansion is a hypothetical project that consists of the addition of HOV lanes, a bus transit terminal with on- and off-ramps, and a park and ride lot with on- and off-ramps. The Simplified Freeway Expansion project consists only of the freeway and arterial roadway links from the Complex Freeway scenario. The Single Freeway Link is a hypothetical 1.1-mile freeway link with three lanes in each direction divided by a median.

When deciding whether to use volume sources or area sources to represent roadway emissions, analysts should consider all factors, including those described above, as well as the design and complexity of the transportation project to be modeled and available computing resources.

A.2. Source Plume Height and Release Height: Emissions-Weighted and Volume-Weighted

Analysts must provide initial plume size inputs for each volume source used to characterize roadway emissions in AERMOD. Two of the parameters that define the plume size, initial vertical dispersion coefficient (proportional to plume height) and release height, vary by vehicle type. Trucks have higher plume and release heights than passenger vehicles; for example, EPA guidance recommends an average release height of 3.4 m for heavy-duty vehicles and 1.3 m for light-duty vehicles. The inputs of the plume size parameters used in an AERMOD simulation for roadway sources are determined from an overall average that reflects a combination of truck and passenger car characteristics. EPA describes two approaches for calculating those average parameters: an emissions-weighted average and a traffic volume-weighted average of light-duty and heavy-duty vehicle contributions (U.S. Environmental Protection Agency, 2015). In general, the emissions-weighted approach requires more effort, because emissions for trucks and passenger vehicles must be estimated separately. However, this approach provides more realistic input values, because trucks typically produce significantly greater emissions than passenger vehicles do, even though they account for a smaller proportion of the entire fleet.

Several pairs of transportation project scenarios were modeled to assess the sensitivity of AERMOD-predicted PM concentrations to the approach used to estimate volume source plume height and release height, Each pair consisted of (1) emissions-weighted average plume and release height inputs, and (2) volume-weighted average inputs. Each pair of simulations was conducted once with PM_{10} emissions, and once with $PM_{2.5}$ emissions, to obtain PM_{10} 24-hr average, $PM_{2.5}$, 24-hr average, and $PM_{2.5}$ annual average concentration estimates. The modeling scenarios for this sensitivity analysis are summarized in Table A-2. Importantly, because trucks account for a greater proportion of PM emissions than traffic volumes within the overall vehicle fleet, the emissions-weighted approach will produce higher plume heights and release heights. For example, as shown in Table A-2, for a modeling scenario with 8% trucks in the fleet, emissions-weighted average plume height and release height are approximately 42% higher than volume-weighted average plume height and release height. As plume and release heights increase, resulting concentration estimates decrease. This occurs because the plume disperses more (travels farther) from a higher height before reaching the near-ground point at which concentrations are calculated.

Table A-2. Modeling scenarios for AERMOD sensitivity simulations.

Scenario ID[a]	Truck Volume (% of AADT)[b]	Average Plume Height (m)		Average Release Height (m)	
		Emissions-Weighted	Volume-Weighted	Emissions-Weighted	Volume-Weighted
1	0	2.6	2.6	1.3	1.3
2	8	4.2	2.9	2.1	1.5
3	20	5.3	3.4	2.6	1.7
4	40	6.1	4.3	3.0	2.1
5	100	6.8	6.8	3.4	3.4

[a] Each scenario corresponds with a pair of AERMOD simulations for PM_{10} and a pair for $PM_{2.5}$ emissions. Each pair corresponds with one simulation using emissions-weighted average plume and release heights, and one using volume-weighted averages. Plume height is calculated as 1.7 times the weighted average of 4.0 m and 1.53 m heavy-duty and light-duty vehicle heights, respectively. Release height is calculated as the weighted average of 3.4 m and 1.3 m release heights for heavy-duty and light-duty vehicles, respectively.

[b] AADT: annual average daily traffic.

All AERMOD simulations for these modeling scenarios were based on a single freeway expansion project, shown at left in Figure A-3. The project includes four 12-m wide freeway links, each comprised of four 3-m lanes. Each freeway link was represented with a series of adjacent volume sources for each 3-m wide lane. The volume sources appear in bright blue in Figure A-3. This project is a highly simplified version of a hypothetical project used in EPA's three-day PM hot-spot training course (see https://www.epa.gov/state-and-local-transportation/project-level-training-quantitative-pm-hot-spot-analyses). The full hypothetical project, shown at right in Figure A-3, consists of freeway

HOV lane additions, a new bus transit terminal with on- and off-ramps, and a park and ride lot with on- and off-ramps (existing features shown in light blue; proposed features shown in gold).

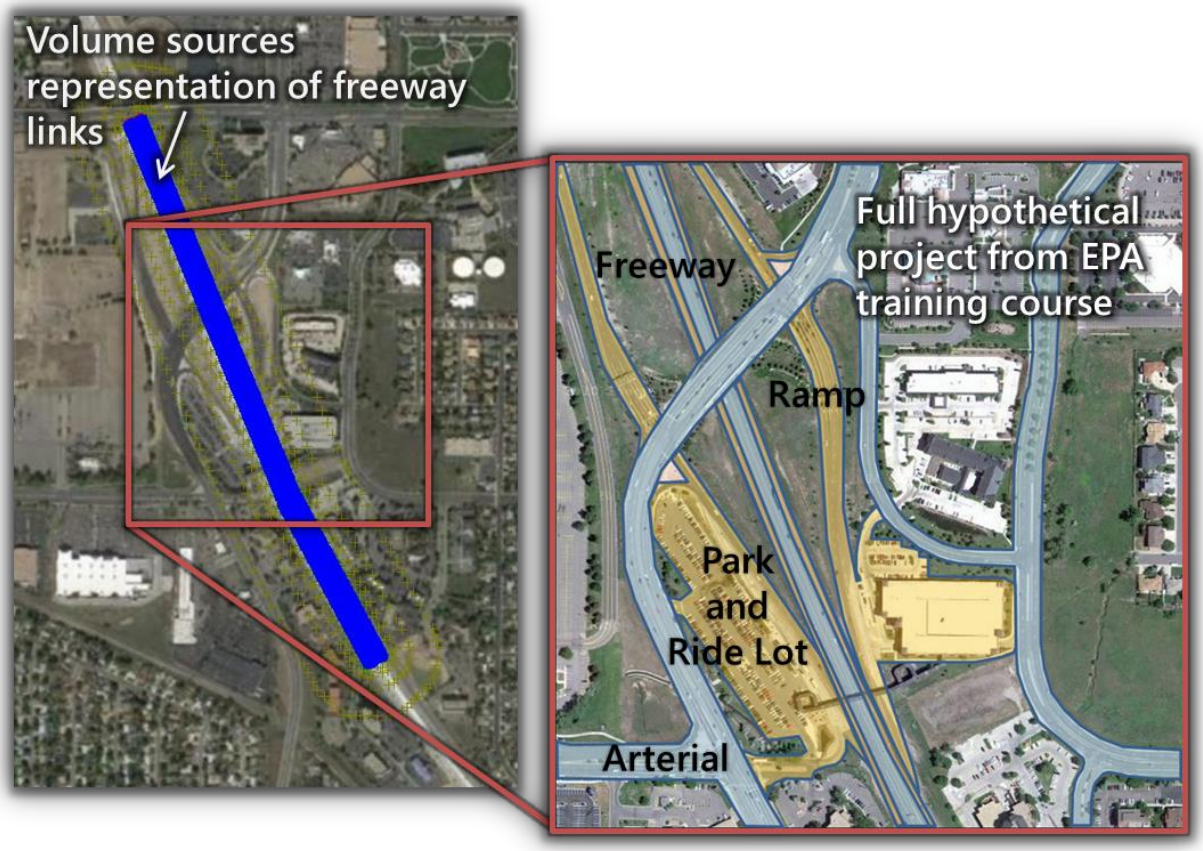

Figure A-3. Freeway expansion project used for AERMOD sensitivity simulations.

AERMOD was run for each pollutant and averaging period for all modeling scenarios using five years (2007-2011) of meteorology data from Fresno, CA. The maximum PM_{10} 24-hr average, $PM_{2.5}$ 24-hr average, and $PM_{2.5}$ annual average concentrations predicted by AERMOD for each of the modeling scenarios are shown in Figures A-4, A-5, and A-6. Design values (DVs) for each scenario were calculated for all modeled receptors using the Caltrans DV calculation tool (DVTool v2.0) with AERMOD modeled data output and background concentration data representative of Fresno, CA (provided with the DVTool v2.0 package). The maximum calculated DVs are shown in Figures A-4, A-5, and A-6 as well. All results displayed in the figures are also listed in Table A-3.

For the modeling scenarios with 8%, 20%, and 40% heavy-duty truck volumes, the maximum AERMOD-predicted concentrations are consistently lower when using emissions-weighted average plume and release heights than when using volume-weighted averages. The lower concentrations are a result of greater dispersion simulated in AERMOD due to larger plume and release heights. In the scenarios with 0% and 100% truck volumes, the plume and release heights are the same whether

emissions- or volume-weighted averages are used. Therefore, the corresponding predicted concentrations and DVs are identical for those scenarios. As the data in Table A-3 show, maximum modeled concentrations range from 8 to 15% lower when using the emissions-weighted approach than when using the volume-weighted approach. Because of the relatively complex procedures for calculating DVs, especially the rounding methods, the relative differences in DVs are not as large. This is demonstrated well by the differences in PM_{10} 24-hr average DVs, for which the final step in the calculation is to round to the nearest 10 µg/m^3. The PM_{10} DV is reduced only in the modeling scenario with 40% truck volume. For both $PM_{2.5}$ 24-hr and annual averages, the DVs are reduced in the scenarios with 8%, 20%, and 40% truck volumes. Although the reductions are relatively small, they have the potential to change a conformity test result when the background concentration is close to, but does not exceed, the relevant National Ambient Air Quality Standards (NAAQS).

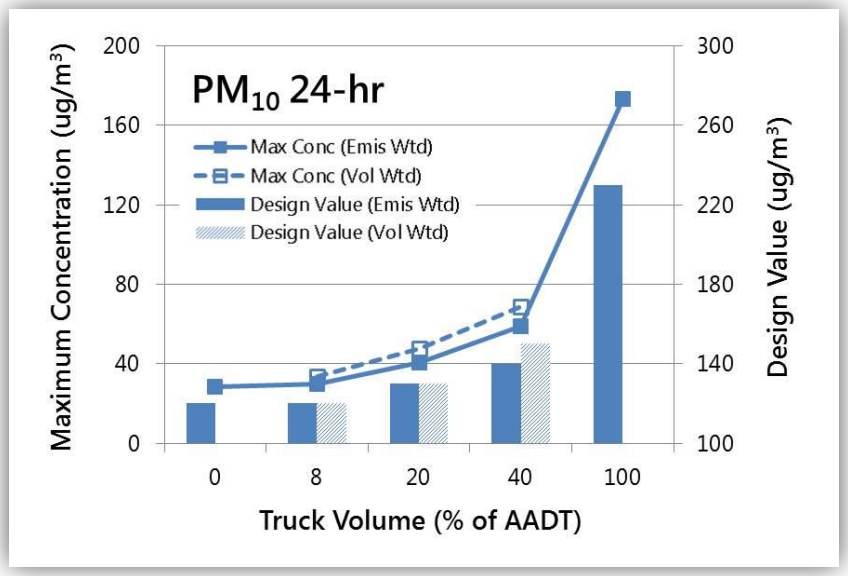

Figure A-4. Maximum PM_{10} 24-hr average AERMOD-predicted concentrations and design values across the range of truck volumes using emissions-weighted (Emis Wtd) and volume-weighted (Vol Wtd) plume and release heights. Emissions-weighted and volume-weighted plume and release heights are the same for 0% and 100% truck volumes; only emissions-weighted results are shown in the figure for those truck volumes.

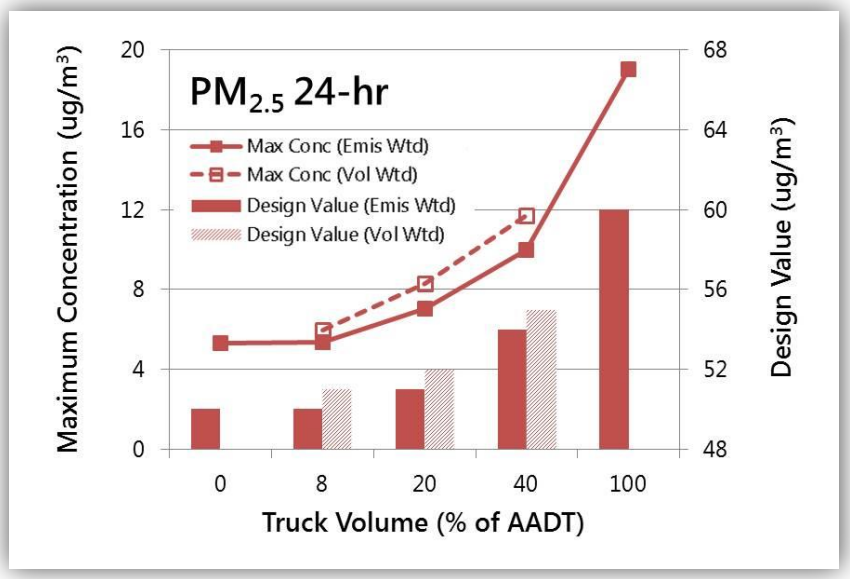

Figure A-5. Maximum $PM_{2.5}$ 24-hr average AERMOD-predicted concentrations and design values across the range of truck volumes using emissions-weighted (Emis Wtd) and volume-weighted (Vol Wtd) plume and release heights. Emissions-weighted and volume-weighted plume and release heights are the same for 0% and 100% truck volumes; only emissions-weighted results are shown in the figure for those truck volumes.

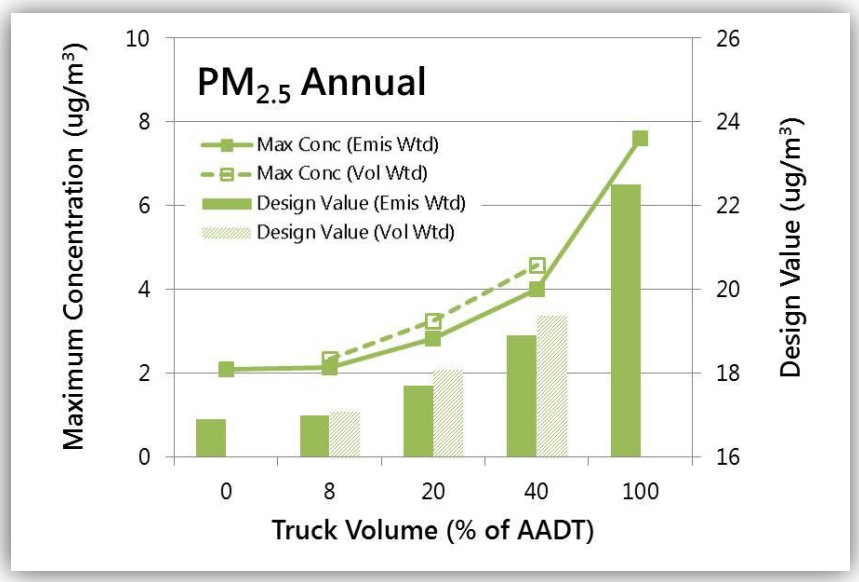

Figure A-6. Maximum $PM_{2.5}$ annual average AERMOD-predicted concentrations and design values across the range of truck volumes using emissions-weighted (Emis Wtd) and volume-weighted (Vol Wtd) plume and release heights. Emissions-weighted and volume-weighted plume and release heights are the same for 0% and 100% truck volumes; only emissions-weighted results are shown in the figure for those truck volumes.

Table A-3. AERMOD sensitivity simulation results.

Truck Volume[a]	Pollutant and Averaging Period	Maximum AERMOD-predicted Concentration (µg/m^3)			Design Value[c]		
		Emissions-Weighted	Volume-Weighted	Difference (%)[b]	Emissions-Weighted	Volume-Weighted	Difference (µg/m^3)[d]
0[e]	PM_{10} 24-hr	28.5		NA[e]	120		NA
	$PM_{2.5}$ 24-hr	5.3		NA	50		NA
	$PM_{2.5}$ Annual	2.1		NA	16.9		NA
8	PM_{10} 24-hr	30.0	33.5	10	120	120	0
	$PM_{2.5}$ 24-hr	5.4	6.0	10	50	51	1
	$PM_{2.5}$ Annual	2.1	2.3	8	17.0	17.1	0.1
20	PM_{10} 24-hr	40.5	47.7	15	130	130	0
	$PM_{2.5}$ 24-hr	7.1	8.3	15	51	52	1
	$PM_{2.5}$ Annual	2.8	3.2	13	17.7	18.1	0.4
40	PM_{10} 24-hr	58.7	68.6	15	140	150	10
	$PM_{2.5}$ 24-hr	10.0	11.7	14	54	55	1
	$PM_{2.5}$ Annual	4.0	4.6	13	18.9	19.4	0.5
100[e]	PM_{10} 24-hr	173.3		NA	230		NA
	$PM_{2.5}$ 24-hr	19.0		NA	60		NA
	$PM_{2.5}$ Annual	7.6		NA	22.5		NA

[a] Truck volume as percentage of AADT.
[b] Percentage decrease of maximum predicted concentration when using emissions-weighted inputs (volume-weighted result minus emissions-weighted result as a percentage of the volume-weighted result).
[c] DVs are calculated using AERMOD-predicted concentrations and sample representative background concentration data.
[d] Absolute decrease of design value when using emissions-weighted result (volume-weighted minus emissions-weighted results).
[e] Plume and release heights are identical using emissions or volume-weighted averages for scenarios with 0% and 100% heavy-duty truck volumes. Therefore, the maximum AERMOD-predicted concentrations and DVs are also identical.
NA = not applicable.

Appendix Reference

U.S. Environmental Protection Agency (2015) Transportation conformity guidance for quantitative hot-spot analyses in $PM_{2.5}$ and PM_{10} nonattainment and maintenance areas. Prepared by the EPA Office of Transportation and Air Quality, Transportation and Climate Division, Washington, DC, EPA-420-B-15-084, November. Available at https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100NMXM.pdf, appendix available at https://nepis.epa.gov/Exe/ZyPdf.cgi?Dockey=P100NN22.pdf.