Exhibit F

TO CITY OF SARATOGA DETAILED COMMENTS
ON THE STATE ROUTE 85 EXPRESS LANES PROJECT INITIAL STUDY
FEBRUARY 25, 2014

EXHIBIT

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TO CITY OF SARATOGA DETAILED COMMENTS
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FEBRUARY 25, 2014

Analyzing, Documenting, and Communicating The Impacts of Mobile Source Air Toxic Emissions in the NEPA Process

Requested by:

American Association of State Highway
and Transportation Officials (AASHTO)

Standing Committee on the Environment

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ABSTRACT

An increased awareness and concern for motor vehicle air toxic emissions has prompted state transportation agencies for the need to address air toxic emissions as part of their environmental review process. This study develops information and guidelines on available analytical models and techniques to assess mobile source air toxic (MSAT) impacts and how this information can be communicated in the environmental assessment. The study reviews and provides recommendations on available analytical modeling tools to use in MSAT assessments along with the identification of model strengths and weaknesses. A methodology has been developed which guides the transportation analyst in identifying the appropriate level of analysis using typically available information and potential level of exposure based on the size of the transportation project. Five potential levels of analysis are identified based on both technical and policy considerations so as to guide the transportation analyst in applying a consistent set of criteria for developing a MSAT assessment. Details are presented on how to conduct the MSAT assessment as well as on the amount of information which should be included at each level of analysis. Recommendations are provided on how best to communicate these findings as part of an environmental assessment document.

SUMMARY OF FINDINGS

The Clean Air Act Amendments of 1990 designated 188 air toxic pollutants as Hazardous Air Pollutants (HAPs) and required the U.S. Environmental Protection Agency (EPA) to undertake a number of studies and regulatory activities to reduce HAP emissions. Public concern about evaluating these toxic air pollutants in the National Environmental Policy Act (NEPA) process increased in the 1990s stemming from such studies as the National Air Toxics Assessment (NATA) program—a nationwide modeling and risk assessment study that estimated the cancer and non-cancer risk from air toxics for each census tract in the United States. NATA estimated that every county in the United States experiences an overall cancer risk of greater than 10^{-5} or 10 in 1 million (i.e., 10 cancer cases per million population over a lifetime of constant exposure) from all sources. The MATES II study, which estimated mobile source-related risks in the California South Coast region, assigned 90% of the total cancer risk to mobile sources with 70% of the total risk assigned to diesel particulate matter (DPM) from mobile sources.

The EPA 2001 Mobile Source Air Toxic (MSAT) Rule identified 21 hazardous air pollutants as MSATs. EPA identified six of the 21 pollutants as of greatest concern due to their high relative emissions and risk and because state agencies have indicated that these pollutants are major mobile source pollutants of concern. These six pollutants have become known as the "priority MSATs"[1] and are:

- Acetaldehyde
- Acrolein

[1] These priority MSATs are subject to change based on improved understanding of ambient levels and health effects. In particular the proposed new MSAT rule on the Control of Hazardous Air Pollutants from Mobile Sources (Federal Register, Vol. 71, No. 60, page 15813 and 15814, March 29, 2006) discusses the MSATs which pose the greatest risk at current levels based on updated information (includes naphthalene).

- Benzene
- 1,3-Butadiene
- Formaldehyde
- Diesel particulate matter plus diesel exhaust organic gases (DPM+DEOG)

A history of regulatory actions for non-mobile sources of air toxics has lead the public to ask that assessments be made for mobile source air toxics when part of a Federal action. NEPA process requires that major Federal actions that "significantly affect the quality of the human environment" undergo assessment of their environmental impact. With the recent availability of motor vehicle air toxic emission factors from MOBILE6.2, the feasibility of assessing air toxics as part of NEPA requires review and evaluation. If air toxic assessments are feasible, the NEPA process can then be used to disclose the potential impact, analyze alternatives and possibilities for mitigation, and inform the public about the impacts of air toxic emissions from a proposed project.

Based on the research findings five levels of analyses are suggested depending upon the size of the project, the project activity level, the level of concern, the proximity of the project to sensitive population groups, and available information. Each level of analysis requires additional user information and suggested levels of more detailed analysis are balanced with the size of the potential project impact.

Results

Identification of Emission and Dispersion Models

Modeling tools are widely available that are capable of predicting MSAT impacts from transportation projects. These tools have varying histories and applications in MSAT analyses. This study focused on identifying possible emission factor and air quality dispersion models

applicable to transportation projects that could be used in a NEPA setting. The emission factor models identified for detailed review included EMFAC2002, MOBILE6.2, and the U.S. EPA MOVES model currently in development (based on a review of the most current plans). Identified for each emission factor model was the applicable source category, input data requirements, the functionality of the model, types and applicability of output data, the MSAT species modeled, how the model estimates the MSAT emission factors, and known limitations or deficiencies with the priority MSAT species. While the use of these emission factor models are prescribed in federal policy and regulations the summary of information provides a convenient tool for the transportation analyst showing the emission factor models' applicability and capability specific to MSAT issues.

The air dispersion models that were reviewed include CALINE3, CALINE4, CAL3QHC(R), HYROAD, AERMOD, ISCST3, and CALPUFF. These models were selected based on their applicability and history in transportation-related settings. The types of transportation facilities to which these models may be applicable include roadways at ground level without intersections (e.g., freeway widening projects), roadways at ground level with intersections (e.g., traffic signal improvement), elevated freeways, parking lots, transit bus garages, rail lines with locomotive traffic, and intermodal freight terminals. Identified for each model are the meteorological requirements, site/geometry characterization, handling of the near field dispersion, availability of traffic simulation, how mobile source emissions are characterized, and removal process (chemical decay, wet/dry deposition), available model outputs, how MSAT may be treated and known limitations for transportation settings.

Information provided in these tables provides a starting point and basis for the transportation analyst to identify which modeling tool to potentially use in a MSAT assessment.

The summary presented for each model provides the analyst with a list of features that may be important to the transportation facility that is under review for MSAT assessment.

Assessment of Model Strengths and Weaknesses for Transportation Projects

To enable the transportation analyst to select the best modeling tools for MSAT assessment, emission factor and air dispersion models were assessed for their major strengths, weakness, limitations, and relative uncertainties for air toxic assessment for different types of transportation facilities. For each emission factor or air quality model, a matrix was developed listing strengths, weakness, limitations, and uncertainties associated with different types of transportation projects. For the emission factor models specific issues include: speed dependency by vehicle type, facility type, species, validation of the model, and underlying database; for air quality models specific issues include: meteorology, geometry, site characterization, dispersion parameters, traffic modeling capabilities, interaction between traffic and meteorology, decay for reactive pollutants, and emission linkages. No assessments were made for the MOVES model, as a draft air toxic version is not yet available. Similarly, the California EMFAC model does not currently contain an air toxic module and a future version of the model will only provide MSAT emissions on a county-by-county basis based on the California Air Resources Board speciation profiles.

This set of matrices provides the practitioner with specific information for use in assessing the ability, limitations and associated uncertainty for the emission factor and dispersion models focused on transportation-related MSAT issues for nearly all transportation situations evaluated under NEPA. The identified strengths and weaknesses add to the transportation analyst's understanding of how these tools can be used in transportation MSAT assessments. In particular, information on model weaknesses may help the transportation analyst understand why a given model may not be suitable for use in an MSAT assessment. When considering the relative strengths and

weaknesses of different models, the findings present a clearer picture of which modeling tools should be used in a given MSAT assessment. This information has been used in developing the recommendations on the modeling approaches for analyzing MSATs in the NEPA process.

Health Impacts of Mobile Source Air Toxics and Current Range in Concentration

To assist the transportation analyst in assessing the relative impact of the transportation project versus current conditions, an assessment was performed for each MSAT documenting the potential health impacts and range of concentrations occurring throughout the United States. Health effects of MSATs typically examined in risk assessments include carcinogenic and chronic non-carcinogenic effects. The study identified the carcinogenic potency for 12 of the MSATs, as well as the weight of evidence, type of evidence and the basis for the carcinogenicity finding. The Reference Concentrations (RfCs) is used to establish the safe non-cancer chronic exposure level. For most pollutants that have both carcinogenic and non-carcinogenic impacts, the 1 per million carcinogenic risk occurs at a lower concentration than the chronic RfC. An exception is formaldehyde.

The most current assessment of nationwide MSAT concentrations is available through EPA's National Air Toxic Assessment (NATA) national scale assessment. This assessment modeled 1999 outdoor air concentrations at census tract level resolution. For those MSATs not modeled as part of NATA, observed 2005 concentrations from the EPA's AirData Reports were used to develop estimates of background level concentrations. The distributions of observed concentrations are composed of varied numbers of samples, ranging from 29 to 388. In most cases the observed distributions are expected to be higher than the modeled distributions, as most modeled concentrations do not include background concentrations and observed concentrations were usually targeted at locations of expected high concentration.

The spatial patterns of observed and modeled concentrations suggest that most of the priority MSATs are of widespread[2] concern. In addition, naphthalene now appears to be of widespread concern (based on OEHHA's cancer potency value).

During environmental impact assessment of potential projects, estimation of background pollutant concentrations may be based on either pollutant measurements or air dispersion modeling. The optimal approach is local monitoring of the pollutants of interest. For MSATs the appropriate monitoring duration is at least one year, since monitoring of shorter duration can be biased due to seasonal patterns in ambient concentrations. Use of monitoring data from the EPA's AirData Reports is a cost-effective alternative to expensive local monitoring, if data are available at a nearby location. If no representative monitoring data are available, NATA model predictions can be used. NATA model predictions are available for every U.S. census tract for 1999, and are scheduled to be available for 2002 when a new round of modeling is completed in 2007[3].

Suggested Procedures for Analyzing MSAT

Suggested procedures have been developed on how to select and apply the best available models and associated techniques for MSAT impact assessment in the NEPA process. The suggested approach uses both policy and technical considerations to determine the need and appropriateness for conducting a MSAT assessment. A set of policy and technical questions have been developed, and in conjunction with the responses to these questions should help guide the transportation analyst in determining an appropriate level of analysis under NEPA. The set of policy-related questions will help identify the appropriate level of analysis based on information

[2] For onroad and nonroad mobile sources, EPA estimates that approximately 110 million people live in areas of the U.S. where the combined upper-bound lifetime cancer risk from mobile source air toxics compounds exceeds 10 in a million. This risk is dominated by the emissions of benzene, acetaldehyde, and 1,3-butadiene

[3] In addition, EPA intends to have available by mid-2007 NATA-like assessment tools that can be used to estimate *future year* background concentrations. It is also possible that some states may develop an estimate of future background concentrations and these could potentially be used in an analysis.

about the scope of the project, its likely impact to the community, and the general public's level of concern. Coupled with the policy-related questions are technical questions which identify the appropriate level of technical analysis based on health risk considerations. This combined set of questions will help to scope the transportation project for air toxic risk, with the policy questions identifying the appropriate level of analysis and the technical questions addressing the technical feasibility of the desired policy-level analysis.

The set of questions appears in Exhibit 1-1. The first level of analysis requires no review; subsequent levels require increasingly more data and analysis to demonstrate the projects potential MSAT impact. The first level of analysis identifies whether the project has either a categorical exclusion. At the second level, a qualitative analysis is recommended. This level of analysis is applicable when there is little chance for increased air toxic exposure or the uncertainty is so large that quantitative assessment is unlikely to convey any useful information to the reader of the NEPA document. It is anticipated that many of the most typical and smaller transportation projects will fall into this analysis category. The types of projects that will typically be found in this level of analysis are projects which improve operations or safety without substantially adding new capacity and therefore are anticipated to have very low potential impact. Examples include: freeway widening projects where increased capacity remains below the screening threshold level[4] of 125,000 AADT; new interchanges where a new arterial segment is built to connect to an existing highway and the project's activity level remains below the 100,000 AADT threshold screening level; and a new interchange project developed to serve a new residential development where the project's activity level is below the screening threshold level of 40,000 AADT. These health-based screening thresholds were developed based on an

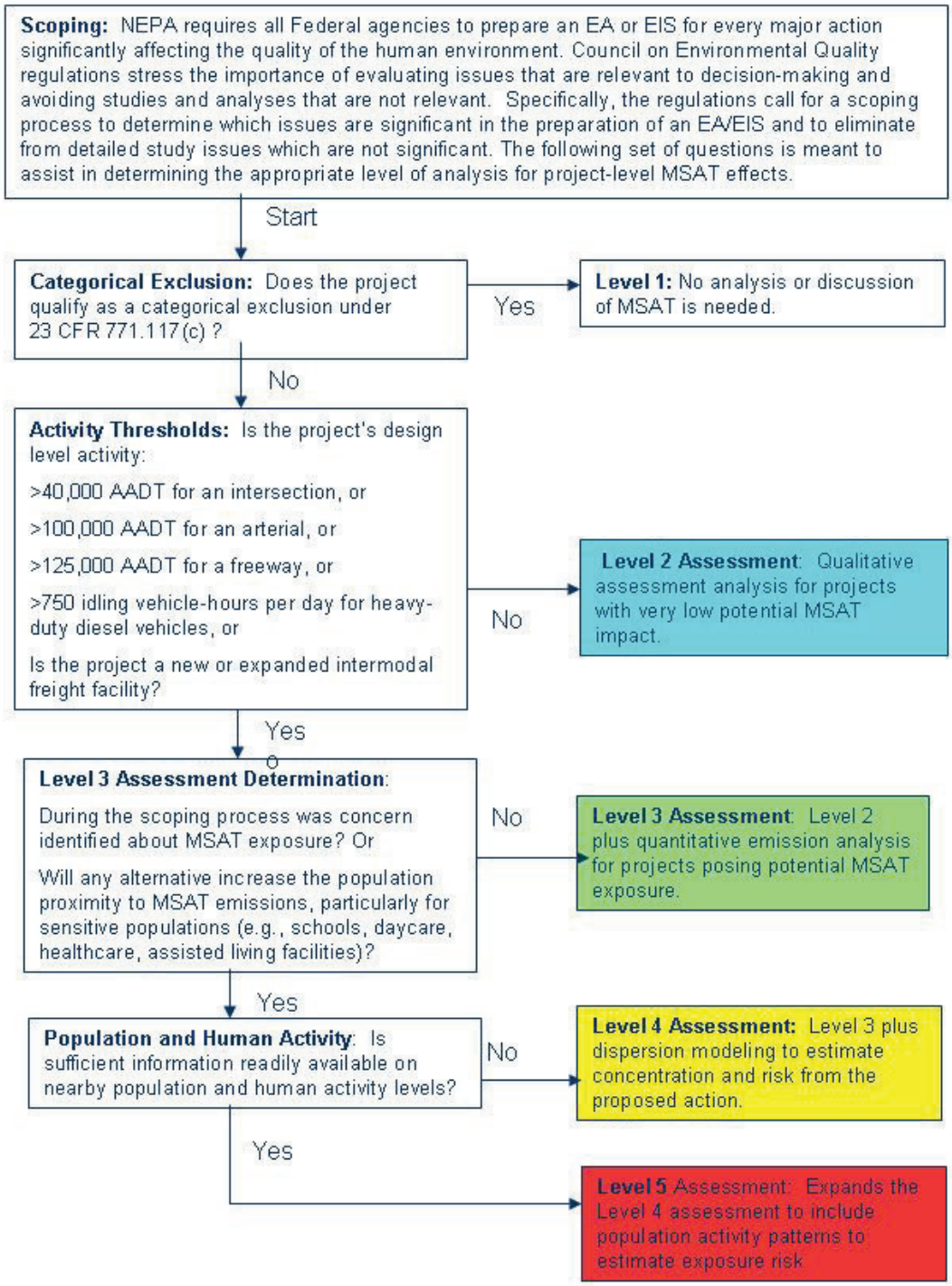
[4] Appendix C contains detailed discussion for the basis of these threshold screening levels.

analysis of the key air toxic risk driver of benzene for three types of project settings based on a one in a million threshold risk level.

The third level of analysis develops a quantitative estimate of emissions for the proposed action and represents project settings which have a high potential for MSAT emissions to concentrate at high enough levels to be of potential concern. The fourth level of analysis expands upon the emission analysis by including dispersion modeling to estimate concentration and outdoor risk levels. The fifth level of analysis incorporates population activity patterns to estimate exposure risk.

Details are provided on the suggested steps needed in order to complete each level of analysis. Suggestions and tools are provided from which the analyst can develop model inputs or factors for use in the analysis. This includes suggested procedures to estimate changes in emissions based on projected speeds, fleet mix, and traffic volume as well as to account for changes in exposure distance if changed under the proposed action. Also, presented are suggested procedures that may be used to estimate background concentration and emission trends. For the more quantitative analyses (Levels 3-5), specific air quality and exposure models are suggested as well as discussion on the impacts from unavailable information on MSAT analysis and a summary on the credible scientific evidence to evaluate adverse impacts from MSATs.

Exhibit 1. Recommendation Flowchart
(ICF International, NCHRP 25-25 Task 18)



Communication of MSAT Analysis Results and Health Impacts

The human health risk assessment literature discusses communication of analysis results through interpretation of health risk assessment (HRA) results, discussion of uncertainty in HRA, and overall presentation of the results. Considerable literature exists on how to communicate risk to the public; the primary points applicable to risk analyses of MSATs for transportation projects under NEPA include the following:

- Describe the project emission sources, the relevant MSATs, and the types of cancer and non-cancer health risks they pose.
- Define clearly the criteria for a significant impact of the project in the NEPA context.
- Explain and reference the information on toxicity, exposure, and dose-response that the transportation agency takes as given for purposes of the analysis.
- Identify and explain any health studies undertaken in the project area that are relevant to the MSAT analysis. Also, include reports outside the project area which are in areas of similar emission and exposure potential.
- Distinguish clearly among the types of health risks and their heath metrics (e.g., unit risk factor, cancer risk, reference concentration level, hazard quotient, etc.) used in the analysis.
- For each impact metric, show a comparison of the results for each project alternative and the selected criterion of significance.
- Compare project impacts to other exposure information, such as regional or county-level MSAT emission inventories and measured MSAT concentrations as well as

similar size scale facilities such as intermodal facilities, rail yards, bus terminals, travel plazas, parking facilities, and ports of varying size range and activity levels.

- Show MSAT results and comparisons in easy-to-understand graphical formats where possible.
- Provide a discussion of uncertainty. The uncertainty discussion should support the agency's decision on what level of MSAT analysis to perform.
- The discussion of uncertainties should include information on modeled ambient concentrations and exposure estimates. A discussion of uncertainties should also qualitatively describe the level of confidence attributed to toxicity information by environmental and health agencies.

Uncertainty in MSAT Analysis

The health risk assessment literature contains extensive coverage of the uncertainties involved in human health risk assessment. Some recent EISs have included discussions of uncertainties to comply with the CEQ regulations addressing incomplete and unavailable information. Based on the review of the uncertainty information and the current state of the science, the following conclusions may be drawn concerning the treatment of uncertainty in NEPA project analyses:

- Transportation projects vary widely in the need for and usefulness of MSAT analysis. Uncertainty is a substantive issue for smaller projects.
- Use of health risk assessment, with its attendant uncertainties, is warranted for some of the larger projects due to the larger risks posed.

- The primary purpose of NEPA is disclosure of information to facilitate selection among alternatives. This purpose includes disclosure of information to the public to support informed commenting on the analysis.
- The public demand for information in NEPA documents may exceed the level of analysis in which the agency has confidence for purposes of alternative selection and impact assessment. Thus, agencies may need to educate the public about uncertainties in the analysis to forestall comment that seeks to stop the project rather than guide the selection of alternatives under NEPA.
- The regulatory driver for discussion of uncertainty within the NEPA document is the CEQ regulations addressing incomplete and unavailable information (40 CFR 1502.22).
- A large uncertainty range in MSAT results does not automatically invalidate their use in comparing alternatives. Relative (not absolute) differences among alternatives, when calculated by consistent methodology, are generally valid for purposes of ranking alternatives.
- Many MSAT analyses show a decline in emissions over time regardless of the project, and the difference between future alternatives is typically much less than the overall secular reduction. However, this does not relieve the study from characterizing differences among the project alternatives, even in the presence of uncertainty.

Conclusions

This study enables transportation agencies to effectively develop an approach to evaluate and communicate the impacts of toxic air pollutants emitted from surface transportation sources. The study provides a suggested approach for the transportation analyst to follow in the following areas:

- MSAT impacts for transportation projects and programs under the National Environmental Policy Act;
- Suggested procedures in applying air quality and emission factor models and other technical methods in the analysis of MSAT assessments;
- A health based MSAT screening procedure for the level of detail needed in the analysis that balances the level of detail, analytic rigor, and resource requirements with the likely magnitude and significance of project impacts;
- How to communicate MSAT project level impacts in the NEPA documents that is consistent with the limitations and uncertainties with current modeling tools and in the absence of National Ambient Air Quality Standards (NAAQS)

In addition, the study provides to the transportation community as a whole an approach which:

- Promotes consistency among MSAT evaluation methods so that the relative impacts of roadway projects and programs can be compared and;
- Assure that the quality of MSAT analysis for NEPA documents is sufficient to meet statutory and regulatory requirements, to support agency decision-making, and to adequately inform the public about the air toxic impacts of projects in the NEPA context.

CHAPTER 1. Introduction

This document is designed to assist transportation agencies in evaluating the impacts of toxic air pollutants emitted from surface transportation sources. These pollutants are known as mobile source air toxics or MSATs. NCHRP's purposes in issuing this best state of practice are to:

- Provide technical guidance to analysts who are responsible for evaluating MSAT impacts of transportation projects and programs under the National Environmental Policy Act (NEPA, 42 U.S.C. 4321 et seq.);
- Determine best practices in applying models and other technical methods in the analysis of MSATs;
- Recommend project screening procedures that will result in levels of detail, analytic rigor, and resource requirements that are commensurate with the likely magnitude and significance of project impacts;
- Promote consistency among MSAT evaluation methods so that the relative impacts of roadway projects and programs can be compared; and
- Assure that the quality of MSAT analysis for NEPA documents is sufficient to meet statutory and regulatory requirements, to support agency decision-making, and to adequately inform the public about the air quality impacts of projects in the NEPA context. These goals are codified in the NEPA implementing regulations of the Council on Environmental Quality (CEQ, 1978) and the U.S. Department of Transportation (US DOT, 1979).

The information presented here is intended for air quality analysts, project managers, and technical reviewers within transportation agencies and their contractors. It is assumed that the

reader is familiar with the basic regulatory frameworks for the NEPA process and air quality assessment. It is also assumed that the reader has some familiarity with air quality impact analysis methods for transportation projects. The details of procedures established in other guidance issued by air quality regulatory agencies are not repeated here, but references are provided to guidelines that the reader may wish to review.

The Need for MSAT Analysis

The Clean Air Act Amendments of 1990 designated 188 air toxic pollutants as Hazardous Air Pollutants (HAPs) and required the U.S. Environmental Protection Agency (EPA) to undertake a number of study and regulatory activities to reduce HAP emissions. Public concern about evaluating these toxic air pollutants in the NEPA process increased in the 1990s, partly due to several pivotal agency studies (Houk and Claggett 2006). Chief among these studies and rules were the EPA National Air Toxics Assessment (EPA 2000), the California South Coast Air Quality Management District MATES II study (SCAQMD 2000), and the EPA "MSAT Rule" (EPA 2001). The National Air Toxics Assessment (NATA) was a nationwide modeling and risk assessment exercise that estimated the cancer and non-cancer risk from air toxics for each county in the U.S. NATA estimated that every county in the U.S. experiences an overall cancer risk of greater than 10^{-5} or 10 in 1 million (i.e., 10 cancer cases per million population over a lifetime) from all sources. The MATES II study, which estimated mobile source-related risks in the South Coast region, assigned 90% of the total cancer risk to mobile sources with 70% of the total risk assigned to diesel particulate matter (DPM) from mobile sources.

The EPA 2001 MSAT Rule identified 21 hazardous air pollutants as mobile source air toxics. Table 1 lists the 21 MSATs identified by EPA. EPA decided to focus short-term work on six of the 21 pollutants as the MSATs of greatest concern due to their high relative emissions and

toxicity (EPA 1999a, as cited in MSAT Rule) and because state agencies have indicated that these pollutants are major mobile source pollutants of concern (EPA MSAT Rule, Preamble). These six pollutants have become known as the "priority MSATs" and are listed below:

- Acetaldehyde
- Acrolein
- Benzene
- 1,3-Butadiene
- Formaldehyde
- Diesel particulate matter plus diesel exhaust organic gases (DPM+DEOG)

Table 1. Agency Lists of HAPs Associated with Mobile Sources (ICF International, NCHRP 25-25 Task 18)

CAA Hazardous Air Pollutant		US EPA: 2001 MSAT Rule	FHWA: Priority MSAT	FAA: Aircraft-Related*
1	Acenaphthene†			†
2	Acenaphthylene†			†
3	Acetaldehyde	●	●	●
4	Acrolein	●	●	●
5	Anthracene†			†
6	Arsenic Compounds	●		
7	Benzene	●	●	●
8	Benzo(a)anthracene†			†
9	Benzo(a)pyrene†			†
10	Benzo(b)fluoranthene†			†
11	Benzo(ghi)perylene†			†
12	Benzo(k)fluoranthene†			†
13	1,3-Butadiene	●	●	●
14	Chromium Compounds	●		
15	Chrysene†			†
16	Dibenz(a,h)anthracene†			†
17	Diesel Exhaust/ DPM+DEOG††	●	●	
18	Dioxins/Furans	●		
19	Ethylbenzene	●		●
20	Fluoranthene†			†
21	Fluorene†			†
22	Formaldehyde	●	●	●
23	n-Hexane	●		●
24	Indeno(1,2,3-cd)pyrene†			†
25	Lead Compounds	●		●
26	Manganese Compounds	●		
27	Mercury Compounds	●		
28	Methyl Tertiary Butyl Ether	●		
29	Naphthalene	●		●
30	Nickel Compounds	●		
31	Phenanthrene†			†
32	Polycyclic Organic Matter (POM)	●		●
33	Propionaldehyde			●
34	Pyrene†			†
35	Styrene	●		●
36	Toluene	●		●
37	2,2,4-Trimethylpentane			●
38	Xylene	●		●

* Includes commercial aircraft, general aviation (GA) aircraft, and ground service equipment (GSE).

† As polycyclic organic matter (POM) or polycyclic aromatic hydrocarbons (PAH) given as a group of 7-PAH or 16-PAH. These compounds may also be components of the pollutant Diesel Exhaust/ DPM+DEOG listed separately in table.

†† Includes particle-bound POM and PAH compounds that are also listed separately in this table.

Sources: EPA 2001, FHWA 2006, FAA 2003.

As concern about MSATs has mounted, the Federal Highway Administration (FHWA) and state departments of transportation have increasingly received requests for MSAT analysis in agency-funded environmental impact statements (EISs). The issue of air toxics has been raised with several major highway projects around the country, resulting in lengthy deliberations and in some cases, litigation (FHWA 2004, FHWA 2006).

At the same time, the Federal Aviation Administration (FAA) has also received increasing requests for MSAT analysis in its EISs for airport projects. Airport projects typically involve MSAT emissions from multiple source classes including aircraft, on-road vehicles, and off-road sources such as aircraft ground service equipment and construction equipment. Experience in the early 2000s with MSAT analysis for major EISs at large airports such as Los Angeles International, Chicago O'Hare (FAA, 2005a), and Philadelphia International led to FAA's issuance of interim MSAT guidance (FAA 2005b). California agencies have long required MSAT analysis as well as health risk assessment in Environmental Impact Reports (EIRs), which are the California state-level counterpart to NEPA EISs.

MSATs in NEPA Studies for Transportation Projects

Most projects focus on priority MSATs as they represent the bulk of total health risk. All of the priority MSATs can cause respiratory health effects, and all except acrolein are EPA-designated probable or known carcinogens. Benzene, a known carcinogen, and DPM are viewed as especially harmful. The MATES II study identifies DPM as the primary cancer risk factor out of all MSATs.

Proximity to transportation facilities, typically roadways, has been established as a primary factor leading to community exposure and potentially increased risk. Numerous studies in recent years have found adverse health impacts that seem to be linked to proximity to a

roadway, including increased incidence of asthma and cancer. (Houk and Claggett 2006; for one summary of studies, see John Hopkins Workshop, 2004). According to FHWA, "many of the findings are from studies that do not measure exposures and have relatively low numbers of subjects. The possibility exists that there is a correlation between road proximity and health risk, but that finding is not conclusive." (FHWA *ca.* 2004). However, the public health community perspective is best reflected in the summary document from the John Hopkins Workshop (2004) which documents "In conclusion, a substantial and growing body of evidence from epidemiologic studies indicates that residence in close proximity to roadways with high traffic density is associated with increased risk of a broad spectrum of health outcomes in adults and children. The scientific evidence is stronger for the health outcomes of mortality, lung function, and lung cancer in adults, and for respiratory symptoms including asthma/wheezing and lung function in children. The interpretation of study results for asthma medication or health care use, cancer in children, and atopy are less consistent."

More recent studies support a finding of increased risk from exposure in proximity to transportation facilities. For example, two recent studies, Gauderman *et al.* (2005) and McConnell *et al.* (2006), both observed a statistically significant association of increasing childhood asthma rates with decreasing distance to freeways in several California towns[5]. The weight of the current evidence indicates that it is reasonable to use proximity to a transportation project facility as a screening tool in NEPA evaluations of MSATs.

In NEPA air quality studies of criteria pollutants, the threshold for "significant" impacts is commonly taken to be an ambient concentration standard. Section 109 of the CAA states that National Ambient Air Quality Standards (NAAQS) are to be set at levels that, "allowing an

[5] Both of these studies used routinely available emissions and air quality modeling tools for conducting their analyses, indicative of acceptance of these tools within the scientific and public health research community.

adequate margin of safety, are requisite to protect the public health." In contrast to criteria pollutants, no NAAQS have been established for HAPs or for MSATs in particular (lead is designated as both a criteria pollutant and a HAP). Until the 1990s, ambient measurements of HAPs were rare, and concentrations of HAPs commonly found in the ambient air were not thought to present a significant health risk.

However, increased measurement and further study of HAPs and associated health risks have shown that for some locations and activity levels, HAPs may pose a health risk. However, unlike criteria pollutants, HAPs in general are not ubiquitous (although exceptions exist e.g., benzene and PAH) and do not have a "bright line" or threshold value for cancer where no effects are observed. For these reasons, as well as the relatively high level of remaining uncertainty associated with many of the HAPs' health effects, no NAAQS have been established for the HAPs.

Absent NAAQS for HAPs, a number of states have established guideline levels for ambient HAP concentrations. The guidelines are usually based on occupational limits set by the U.S. Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH), and similar bodies, because health impact data for non-workplace populations exposed to ambient HAP levels typically have not been available. To derive ambient guideline levels, state agencies typically reduce the OSHA/NIOSH limits according to assumed ratios of exposure time for occupational versus ambient settings, and by additional factors of safety (typically an order of magnitude) to account for sensitive non-workplace populations. These guideline levels vary widely among states and do not carry the legal force of a standard. Some states apply their ambient HAP guidelines only to stationary emission sources and exempt all mobile sources. Some NEPA analyses of mobile sources have attempted to apply state guidelines, whether officially applicable or not. The usefulness of such

applications has been limited by the high level of uncertainty in workplace-derived guideline levels and the scarcity of data on ambient background concentrations of HAPs.

Typically, the scientific basis of the state guideline is not sufficiently robust to support a determination that a concentration that exceeds the guideline level would actually represent a significant impact in the context of NEPA. The large uncertainties in the scientific understanding of health effects of HAPs as well as in the methodologies for estimating HAP emissions and concentrations continue to prevent the establishment of NAAQS or single-number standards for MSATs under NEPA. Instead, quantification of health impacts relies on health risk assessment which is subject to large uncertainties of its own.

Many NEPA analyses have estimated emissions but not the resulting concentrations or health risk. An emissions inventory analysis provides information on total emissions levels that can be used to satisfy the NEPA purpose of comparing project alternatives. This approach depends on the assumption that potential impacts of the alternatives are adequately represented by the aggregate emissions. The uncertainties involved in estimating emissions alone are considerably less than those involved in estimating risk. By only estimating emissions, the typical NEPA analysis will use resources to improve the emission inventory to support better relative aggregate comparison of the project alternatives for NEPA decision making, but at the cost of not estimating the absolute risk magnitude comparison.

HAPs other than MSATs are normally not evaluated separately in NEPA analyses of surface transportation projects. MSATs as a class, and priority MSATs in particular, should be good surrogates for all relevant HAPs because most are species of volatile organic compounds (VOC) or particulate matter (PM). The speciation distributions of VOC emissions are generally similar for broad classes of transportation sources. The speciation of PM emissions differs markedly between

gasoline and diesel sources, but less so within these source classes. In most cases, if emissions of priority MSATs are insignificant, then emissions of other transportation HAPs will also be insignificant and need not be analyzed in detail. Nevertheless, the analyst should be alert for emission sources for which priority MSATs may not be good surrogates for other HAPs. In these cases priority MSAT emissions, which are mostly associated with on-road diesel sources, may not be accurate indicators of other HAP emissions[6]. Common examples of mobile sources with characteristics different from diesels include all-gasoline fueled fleets, alternative fueled or hybrid-electric vehicles, and aircraft and equipment having gas turbine engines (most non-aircraft gas turbines in transportation use are in military vehicles). Transportation projects may also include stationary sources, such as maintenance facilities, that may emit HAPs other than MSATs.

Agency Approaches to HAP/MSAT Analysis

Agencies with air quality responsibilities have taken a number of approaches to HAP analysis. Though the agency methods usually do not differentiate between MSATs and other HAPs, the principles are valid for any pollutant. These approaches can be distinguished by whether they employ the principles of human health risk assessment (HRA). Appendix A provides details on the characteristics of each agency's approach that are relevant for developing MSAT analysis methods for NEPA studies. While this information is not a complete compendium of agency HAP approaches, the materials reviewed were chosen for their completeness, originality or exemplary status, and potential applicability to the development of MSAT analysis approaches.

A clear difference in philosophy and purpose exists between those agencies that require HRA and those that do not. Agencies that require HRA are those that are charged to be

[6] Note this only applies to diesel PM and that other VOC-based HAPs (e.g., benzene) do not track diesel sources.

protective of air quality and health. Many, but not all, of the state and regional agencies that require HRA have jurisdiction in California where the HRA mandate has a long-established history. For an example of a non-California authority, see the Minnesota Pollution Control Agency guidance (MPCA 2004) which requires HRA for some stationary sources and certain projects under Minnesota's NEPA-like Environmental Review Program. These agencies' guidelines include consideration of the uncertainties in HRA but place priority on public disclosure and mitigation of potential risks. In the NEPA/CEQA context these agencies are rarely project sponsors and their agency mission does not include promotion, funding, or construction of transportation projects. All of the HRA methodologies examined are similar in approach and in the algorithms used, but differ in the specific modeling assumptions, the exposure and toxicity values, and impact/risk criteria that the analyst is required to use.

The agencies examined above whose MSAT guidance does not generally require HRA take a much more cautionary approach toward conducting HRA's due to uncertainties in the analysis. FHWA concepts that projects should be screened by type, activity level, and receptor location are well-established and are valid if the thresholds are set at appropriate values. The FAA guidance is particularly cautionary toward uncertainties, in part because the current state-of-the-science does not yet allow accurate estimates of ultrafine particle emissions (most PM emissions from gas turbines are of less than 0.1 micron aerodynamic diameter). Recent studies directed at improving this understanding include the APEX and UNA-UNA studies (Wey, 2006). Both FHWA and FAA note that their guidelines are subject to updating as the science of MSAT analysis improves.

Health Risk Assessment Concepts and Their Application to Transportation Agencies

Many human health risk assessments have used the four-step HRA process to describe potential impacts and risks associated with a site that has potentially hazardous materials, or with

a stationary facility subject to New Source Review permitting. An MSAT method might apply this process as the California air quality agencies and others have. However, transportation agencies cannot be expected to carry out all the steps; some of the steps call for expertise in health science or demographics, rather than transportation expertise. A mapping of the four steps to transportation agency capabilities is shown in Table 2 below.

Table 2. Health Risk Assessment Process and Transportation Agencies (ICF International, NCHRP 25-25 Task 18)

Health Risk Assessment Step	Typical Technical Activities	Level of Uncertainty	Within purview of transportation agencies?
1. Data Collection	Determine sources and pollutants emitted	Lowest	Yes
2. Exposure Assessment	Source Activity/ Emissions Inventory	Medium	Yes
	Dispersion Modeling/ Ambient Concentrations	Medium	Yes
	Receptor/Population Characteristics	Variable	Maybe
3.Toxicity (Dose-Response) Assessment	Health effects research for target receptor/population	High	No
4.Risk Characterization	Quantitative individual risk calculation	High	Yes, if steps 2 and 3 information exists

Use of this Study Relative to the FHWA Policy Document

This document should be viewed as a report which provides suggestions to state DOTs on when and how to select and apply currently available techniques for analyzing and predicting the impacts of MSATs in the NEPA process based on current best practices. This document summarizes how to document and communicate the potential MSAT impacts. On the other hand, the FHWA interim guidance document (FHWA, 2006) is a FHWA policy document which describes procedures and advises FHWA Division offices on when to analyze MSAT in the NEPA process for highways.

Toxicity Information for Priority MSAT Analysis

Table 3 indicates that transportation agencies clearly cannot carry out Step 3, Toxicity Assessment, by themselves. Rather, they will need to rely on health science agencies to do so. However, transportation agencies can apply in their own methodologies the health-based toxicity data provided by health science agencies. The toxicity data would include several metrics of toxicity and impact. All metrics must be considered in order to encompass all possible impacts. These metrics are described below. Health risk assessments have commonly used the same basic equations to calculate these metrics. Some variations have been used, including adjustment factors, to account for special circumstances. For metrics of impact, a quantitative criterion level must also be used to evaluate whether an adverse impact has been estimated.

It is helpful to consider these metrics and criteria along two dimensions as shown in Table 3: cancer versus non-cancer, and acute versus chronic. Acute refers to health impacts of short-term exposure, typically 24 hours or less. Chronic refers to longer-term exposures, typically one year to a lifetime. Exposure for periods greater than 24 hours is sometimes subdivided in the literature into additional subcategories such as sub-chronic. For purposes of this guidance, chronic refers to all exposure that is not acute; i.e., 24 hours to lifetime. Table 3 summarizes the toxicity metrics and the impact criteria used in a typical HRA for NEPA projects.

Table 3. Summary Matrix of Health Effects Metrics (ICF International, NCHRP 25-25 Task 18)

Health Outcome \ Time Scale		Acute	Chronic
Cancer	Toxicity Metric	**Not Applicable**	Unit risk factor (probability of cancer per μg/m^3)
	Impact Metric/ Criterion	**Not Applicable**	Cancer risk (probability) or excess lifetime cancer risk (probability).
Non-Cancer	Toxicity Metric	EPA acute chronic reference concentration or risk-specific dose, CA acute reference exposure level	EPA chronic reference concentration or risk-specific dose, CA chronic reference exposure level
	Impact Metric/ Criterion	Acute Hazard Quotient (HQ) and Hazard Index (sum of HQs)	Chronic Hazard Quotient (probability) and Hazard Index (fractional index, sum of HQs)

Cancer Risk. To measure risks from developing cancer, many risk assessments have used the metric Cancer Risk (CR), or Excess Lifetime Cancer Risk (ELCR). This metric represents the probability that an individual will develop cancer in his or her lifetime as a result of exposure to the substance in question. EPA generally considers risks (CR or ELCR) of less than 10^{-6} (one in a million) to be acceptable and acts to reduce cancer risks greater than 10^{-4} (1 in 10,000). Considered as criteria for project impacts, these risk levels would roughly bracket the existing risk levels from background air pollution. Even in remote areas of the U.S., EPA has estimated that risks from background levels of air pollution are in the range of 1×10^{-5} (Guinnup 2003 as cited in FHWA ca. 2004). The MATES II study estimated the average carcinogenic risk in the South Coast Air Basin from all sources at about 1.4×10^{-3} or 1,400 per million people (SCAQMD 2000a). The definition of the degree of project impact at which risk becomes excessive—the impact criterion—is a social and policy decision that would be addressed by each local community.

The calculation of CR/ELCR is dependent on a Unit Risk Factor (URF) as an input parameter, defined as the probability that a person will get cancer from exposure to the source over 70 years, per 1 microgram/cubic meter (μg/m3) concentration of the pollutant of interest.

URFs are determined in Step 3 of the risk assessment process. As noted above, transportation agencies are clearly dependent on health science agencies for this step. In a NEPA project MSAT analysis, the URFs normally are taken as a given and the CR/ELCR is derived as the ratio of a modeled concentration (in µg/m3) to the URF.

Non-Cancer Risk. To measure non-cancer risks, many risk assessments have used the metrics Hazard Quotient (HQ) and Hazard Index (HI). HQs are fractional indices that can be derived for various pathways or target human health/organ systems. An HQ is the ratio of an exposure concentration for a given compound to the RfC for that compound. The sum of HQs for several compounds is an HI. An HQ or HI less than one indicates that no adverse health effects are expected, while an HQ or HI in excess of one indicates that adverse effects are possible. HQ and HI estimates cannot be interpreted as a probability of adverse health effects.

The calculation of HQ and HI is dependent on a Reference Concentration (RfC) or California Reference Exposure Level (REL) as an input parameter for toxicity. EPA characterizes an RfC/REL as "an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily inhalation exposure of the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime." (EPA 2006b.) The same concept may also be expressed as a Risk-Specific Dose (RSD) which is an estimate of exposure like the RfC/REL but with the value set to reflect a specific risk level such as 10^{-5}. As with URFs, the RfCs/RELs are determined in Step 3 of the risk assessment process. For MSATs, the inhalations RfCs/RELs are expressed as ambient concentrations. In a NEPA project MSAT analysis, the RfCs/RELs normally are a given and each HQ is derived as the ratio of a modeled concentration (in µg/m3) to the RfC/REL.

Table 4 lists the current U.S. values of the toxicity metrics for the priority MSATs.

Table 4. Values of Hazard and Risk Metrics for Inhalation for the Priority MSATs (ICF International, NCHRP 25-25 Task 18)

Priority MSAT	Cancer Risk		Noncancer Effects (Hazard)		
	Chronic (Lifetime)		Acute	Chronic	
	US EPA IRIS (URF*)	California OEHHA/ARB (URF*)	California OEHHA/ARB (REL**)	US EPA IRIS (RfC**)	California OEHHA/ARB (REL**)
Acetaldehyde	2.2×10^{-6}	2.7×10^{-6}	Not estimated	9	9.0
Acrolein	Not assessed in program	Not estimated	0.19	0.02	0.06
Benzene	7.8×10^{-6}	2.9×10^{-5}	1,300	30	60.
1,3-butadiene	3×10^{-5}	1.7×10^{-4}	Not estimated	2	20.
Diesel Exhaust/ DPM+DEOG	Assessed; value not estimated	3.0×10^{-4}	Not estimated	5	5.0
Formaldehyde	1.3×10^{-5}	6.0×10^{-6}	94.	Not assessed	3.0

* Unit Risk Factor (URF): Probability of cancer per person per 70-year exposure, per 1 $\mu g/m^3$ concentration.
** Reference Concentration (RfC) or Reference Exposure Level (REL): Continuous lifetime concentration ($\mu g/m^3$) at which no adverse health impacts are observed.

Sources: CARB 2006a, EPA 2006b.

Table 4 shows that while some values exist for the priority MSATs, some values are missing or are inconsistent across jurisdictions. This missing and inconsistent information points to the need for continued scientific research and indicates the limitations of such MSAT health impact analysis with the current state of scientific knowledge.

Exposure Information for Priority MSAT Analysis

For those MSAT analyses that derive quantitative estimates of risk, the basis for the exposure calculation is ambient concentrations output from modeling. Various metrics of exposure can be selected according to policy choice, characteristics of the source and the study area. In modeling terms this determines the selection of the receptor locations to be selected as output for the dispersion modeling results.

A single location of maximum modeled concentration, sometimes referred to as the Point of Maximum Impact (PMI), is often chosen. When combined with conservative (tending to

overstate impact) assumptions of population type and exposure duration (e.g., lifetime exposure of sensitive groups), a worst-case risk estimate is created that can be used as part of a screening process. If all metrics calculated from this worst case fall within acceptable levels of risk, then adverse impacts may be assumed not to occur.

Projects that are large or located in close proximity to receptors may fail such a screening test, and must analyze the interaction between concentrations by receptor location and the variations in degree of exposure by location in order to produce a more realistic risk estimate. Metrics that might be selected in this case include the following:

- Known locations of sensitive populations—facilities or population centroid locations where the impact of exposure might be relatively great (i.e., high response per dose in a given population).
- Population weighted ambient concentrations
- Reasonable Maximal Exposure (RME)—hypothetical maximum exposure expected from the project.
- Maximum Exposed Individual Resident (MEIR) and Maximum Exposed Individual Worker (MEIW)—hypothetical individual who might receive maximum exposure.

An analysis might need to use any or all of these metrics depending on the characteristics of the project and the study area. All of these metrics are most useful when the project impact can be characterized adequately by the conditions at one or a small set of worst-case locations. However, if a project is estimated to have impacts that exceed criteria or threshold levels over a wide area, then a risk estimate covering the entire affected population is needed. Population risk estimates are often needed in evaluating project alternatives that have maximum impacts which are

of similar magnitude, but that differ in the number or extent of receptors affected. A typical NEPA example would be alternative alignments for a highway segment within a single community. To compare alternatives meaningfully, modeled concentrations for the set of receptors throughout the study area are processed along with the exposure assumptions for the area represented by each receptor. The aggregated result of the analysis is a type of population risk estimate, and is typically represented graphically using shading or contours overlaid on a base map.

Exposure estimates and similar data can be displayed using graphic techniques that express both the values and the accompanying uncertainties. A number of techniques have been developed for this purpose (Eaton *et al.* 2003, Howard and MacEachren 1996). Examples include:

- Gradients of shading, hue, or color saturation,
- Contours drawn with visual cues such as thick or dashed lines and in/out arrows,
- Representation of areas as "clouds" rather than with defined boundaries,
- Use of paired views in which one shows the data and the other shows the reliability and uncertainty.

This technique is common in NEPA analysis for other disciplines, notably noise. In community noise analysis of transportation projects, overall noise levels may be represented by contours and incremental changes in noise levels due to the project may be represented by a map overlain by a grid with an indicator of change shown in each grid cell.

Research Approach

The research plan for this study consisted of four major tasks:

- **Task 1—Identification of Emission and Dispersion Models** This task identified currently available analytic tools applicable to predicting MSAT impacts for

transportation projects. This included both emission factor models and air quality dispersion models that would likely be used in a NEPA setting. For each of the emission factor models it was identified which MSAT species the model had been developed for, how the models can be extended/applied for the other MSAT species, and known limitations or deficiencies with the "priority" MSATs. Similarly, the air quality models were identified as to their applicability for use in transportation projects, their meteorological requirements, and their site/geometry characterization, their handling of the near field dispersion, traffic simulation, how mobile source emissions are characterized, and their removal process. This identification allows users to better understand the tools and resources available for characterizing MSAT impacts for the wide variety of transportation projects.

- **Task 2—Assessment of Models Strength and Weakness for Transportation Projects—**This task assessed the major strengths, weakness, limitations and relative uncertainties of the emission factor and air quality dispersion models for air toxic assessment for different types of transportation facilities. Matrices were developed listing transportation projects and emission factor or air quality models identifying their associated strengths, weakness, limitations, and uncertainties. Issues assessed for the emission factor models include: speed dependency by vehicle type, facility type, species, validation of the model, and underlying database; for air quality models issues addressed include: meteorology, geometry, site characterization, (e.g., building near the source), dispersion parameters, traffic modeling capabilities, interaction between traffic and meteorology, decay for reactive pollutants and emission linkages. The set of matrices provide practitioners with specific information for use in

assessing the ability, limitations and associated uncertainty for the emission factor and dispersion models focused on transportation issues. Additionally, a discussion of the air toxic impact and associated health impact for each MSAT was developed relative to the current range of MSAT concentrations found in urban and rural areas for use in transportation specific projects. This information will enable practitioners to communicate the impact of a transportation project relative to existing conditions.

- **Task 3—Recommended Procedures for Analyzing MSATs in NEPA—** Recommendations are developed on how to select and apply the best available models and associated techniques for MSAT impact assessment in the NEPA process. The approach to the selection process used both technical and policy considerations as to the need and appropriateness for conducting a mobile source air toxic assessment. A set of questions are developed to guide the transportation analyst on the appropriate level of analysis under NEPA. Up to five levels of analysis are considered depending upon the transportation project under consideration. The policy-related questions help to identify the appropriate level of analysis based on the scope of the project, its likely impact to the community, and the general public's level of concern. Technical questions identify the feasibility of conducting the analysis given the scope of the project and information available. The findings from this task provide a consistent approach for practitioners to make MSAT analyses of transportation projects. Additionally, the approach provides the practitioner with a justification and basis for the level of MSAT analysis conducted under the NEPA process.

- **Task 4—Recommendations in Communicating and Documenting MSAT Health Impacts in NEPA—**Guidance is developed for each level of analysis on the

information needed to document potential MSAT impacts. Incorporated into the level of analysis is the uncertainty based on the analytical technique recommended and associated health effects. Some recommendations for inclusion in the guidance are: an objective description of the current state of health science, acknowledgement of the on-going research, and current local MSAT concentrations as well as trends in MSAT emissions. As part of this effort a review was performed on the current approaches used by transportation agencies to communicate MSAT health impacts and incorporate the approaches which have proven effective into the guidance. The recommendations will allow transportation practitioners to provide clear and effective communication on MSAT issues to both the technical and public audience. The guidance establishes a clear and consistent methodology for practitioners to effectively communicate MSAT findings for transportation projects, including increases in MSAT risk exposure and their associated health impacts.

CHAPTER 2. Findings

In this Chapter we present the findings of the research based on the proposed research scope as presented in the Work Plan (ICF Consulting, 2005). The findings focus on six key areas of investigation:

- Identification of modeling tools in support of MSAT analysis
- Assessment of modeling tools' strengths and weaknesses
- Health Impacts of Mobile Source Air Toxics and Current Range in Concentration
- Recommendations on the best approach for analyzing MSATs
- Communication of MSAT analysis results and health impacts
- Uncertainty in MSAT analysis.

Both the findings and their meaning in terms of use, policies, and recommended procedures are discussed in this section. Supporting details are presented in the Appendix as appropriate.

Identification of Currently Available Modeling Tools in Support of MSAT Analysis

Modeling tools are widely available to predict MSAT impacts from transportation projects. These tools have varying histories and applications in MSAT analyses. This effort focused on identifying possible emission factor and air quality dispersion models applicable to transportation projects that would likely be used in a NEPA setting.

The emission factor models identified for detailed review include EMFAC2002, MOBILE6.2, and the U.S. EPA MOVES model currently in development (based on a review of the

most current plans).[7] For each emission factor model we identify the applicable source category, input data requirements, the functionality of the model, types and applicability of output data, the MSAT species modeled, how the model estimates the MSAT emission factors, and known limitations or deficiencies with the priority MSAT species. Table 5 through Table 7 show the findings from the examination of the emission factor models and evaluations available for these three models.

While the use of these emission factor models are prescribed in federal policy and regulations the summary presented here provides a convenient summary to the transportation analyst showing the emission factor models' applicability and capability specific to MSAT issues. The tables show some of the known limitations of the emission factor models associated with specific MSATs.

[7] Other models are available (e.g., Microfac, MEASURE, CMEM, TRANSIMS) (Singh and Sloan, 2005) ,but these are emission factor models that require extensive supporting information to develop emissions and are not specifically endorsed by EPA or CARB and use of these other models would require a lengthy approval process for their use and application.

Table 5. Mobile 6.2—Application for MSATs—Functionality and Limitations (ICF International, NCHRP 25-25 Task 18)

Model	MOBILE6.2[1]
Agency	US EPA OTAQ
Availability	www.epa.gov/otaq/m6.htm
Source Categories	Onroad mobile sources for 1955-2050 calendar years
Input Requirements	Calendar year, minimum and maximum temperature, and fuel volatility
Optional Inputs	Vehicle registration/distributions, speeds and speed distributions, VMT, diesel sales fractions by vehicle type. Alternative-fueled vehicle fractions. Ambient conditions: temperature, humidity, solar load, altitude. Time parameters: season, month (January or July), and time of day. Fuel parameters: Reid Vapor Pressure of gasoline and oxygenated fuel, diesel fuel sulfur content. Control programs:Stage II, Inspection and Maintenance, anti tampering programs. Tier standards and alternative fuels included: Fuel % aromatics, % olefins, % benzene, E200 (% of vapor a gasoline produces at 200 F), E300, oxygenate type and fractional volume, sulfur content of diesel. Engine starts per day, soak times, vehicle speed distributions. Hydrocarbon species and particle size cutoff. Alternative pollutant emission ratios, parameters.
Outputs	Gram per mile emission rates for all pollutants; heavy-duty diesel has idle PM emission rate option in grams per hour; Other idle emission rates estimated from 2.5 mph average speed bin
MSAT Pollutants	The following MSATs are explicitly modeled in MOBILE6.2: Name — Code Benzene — BENZ Methyl Tertiary Butyl Ether — MTBE 1,3-Butadiene — BUTA Formaldehyde — FORM Acetaldehyde — ACET Acrolein — ACRO Organic Carbon Portion of Diesel Exhaust PM — OCARBON Elemental Carbon Portion of Diesel Exhaust PM — ECARBON Total Carbon Portion of Gasoline Exhaust PM — GASPM Lead Portion of Exhaust Particulate — Lead

Table 5. Mobile 6.2—Application for MSATs—Functionality and Limitations (ICF International, NCHRP 25-25 Task 18) *(continued)*

Functionality	VOC, CO, NOx based on test results over drive cycles Toxics calculated as fractions of VOC or PM based on technology groups, driving cycles, normal and high emitters, and gasoline fuel properties
MSATs	Based on large number of tests for variety of fuels Accounts for impacts of emissions control technology, normal vs. high emitters, fuel properties
Priority	Six priority MSAT emissions explicitly modeled using the same algorithms as the MOBTOX[2] emission model All gas phase MSAT dependent upon vehicle speed, temperature, RVP and fuel sulfur
1) Acetaldehyde	Explicitly modeled in MOBILE6.2 Also function of fuel ethanol
2) Acrolein	Explicitly modeled in MOBILE6.2 Not modeled in MOBTOX. Calculated as 0.06-0.45% of TOG based on vehicle type/technology. [8] Based on limited data from older vehicle technology
3) Benzene	Explicitly modeled in MOBILE6.2 Also function of fuel benzene, aromatic content Component of both exhaust and evaporative emissions. 1996 NATA comparison showed 90% of annual average site concentrations agree within a factor of 2. [3]
4) 1,3-Butadiene	Explicitly modeled in MOBILE6.2 Also function of fuel olefins and how well the catalyst is functioning.
5) Exhaust PM	Results independent of speed for both gasoline and diesel fueled vehicles Estimates for light- and heavy-duty vehicles Does NOT include effects of high load/acceleration, malfunctioning vehicles (smokers), deterioration, ambient temperature, oxygenated fuel, extended idle Little information on gasoline PM emissions or high-emitters Model generally valid within approximately a factor of 2 for diesel PM. [3]
6) Formaldehyde	Explicitly modeled in MOBILE6.2 Also strong function of fuel MTBE for gasoline vehicles

Table 5. Mobile 6.2—Application for MSATs—Functionality and Limitations (ICF International, NCHRP 25-25 Task 18) *(continued)*

Other	MTBE also explicitly modeled for exhaust and evaporative emissions; only in gasoline vehicles Other MSATs estimated through "ADDITIONAL HAPS" command, but requires user-provided external datafiles specifying: ratios of MSAT to VOC (e.g., gaseous HAPs), ratios of MSAT to PM (e.g., PAHs),or basic emission rates plus deterioration factors (e.g., metals) by fuel types. [4] Default (csv) data files for several fuels available in MOBILE6.2 zip archive. [7] Either the ratio or emissions factor method may be used to predict emissions of: Dioxin/Furans; Nickel Compounds; Arsenic Compounds; Manganese Compounds; Chromium Compounds; Mercury Compounds; Xylene; Styrene; n-Hexane; Naphthalene; Toluene; Ethyl benzene; Polycyclic Organic Material (POM - 16 separate compounds)
Known Limitations	PM based on PART-5 model. Does not include effects of high-load conditions, malfunctioning vehicles (smokers), vehicle deterioration, temperature, speed, or fuel oxygenate. Toxic to VOC ratios for heavy-duty vehicles are based on limited data from older technology vehicles and may require revision. [3, 5] Toxic to VOC ratios assumed to be constant in all modes of vehicle operation. [6] Improvement also needed for: [3] MSAT emissions from HDVs; Toxic fractions from different diesel formulations; Low temperature cold starts; Gasoline PM emissions Sensitive to vehicle speeds, registration distribution, VMT fractions by vehicle classes, temperature, and RVP and other fuel properties. Particularly pronounced for regional emission inventories. [9]

Table 5. Mobile 6.2—Application for MSATs—Functionality and Limitations (ICF International, NCHRP 25-25 Task 18) *(continued)*

References	
1	User's Guide to MOBILE6.1 and MOBILE6.2, Mobile Source Emission Factor Model U.S. EPA, August 2003. Available at http://www.epa.gov/otaq/models/mobile6/420r03010.pdf
2	MOBTOX was a modified version of MOBILE5 to simulate MSAT emissions. Its algorithms were peer reviewed and documented, but its use was very difficult. It has been supplanted by MOBILE6.2 (Ref 1,3)
3	Richard Cook, U.S.EPA Highway Vehicle Emission Models and Data for Estimating Air Toxics, Air Toxics Workshop, Transportation Research Board Annual Meeting, January 9, 2005.
4	Upgrading MOBILE to Include Air Toxic Emission Factors Proposed MOBILE6.2 Project Description, EPA, May 15, 2001. Available at http://www.epa.gov/otaq/models/mobile6/m62scop.pdf
5	Estimation of Motor Vehicle Toxic Emissions and Exposure in Selected Urban Areas, NESCAUM, October, 1999 Available at http://www.nescaum.org/committees/aqph/MSPeerReview/ExSumm.html
6	Rich Cook, Developing Air Toxic Emission Inventories for Mobile Sources, Air Toxics Risk Assessment Modeling Tools Symposium, Region 5, July 15-17, 2003
7	ZIP-file archive of MOBILE6.2, including external datafiles (csv) for producing emissions of additional HAPs available at http://www.epa.gov/otaq/models/mobile6/mobile62.zip
8	Rich Cook and Edward L. Glover, Technical Description of the Toxics Module for MOBILE6.2 and Guidance on Its Use for Emission Inventory Preparation, U.S. EPA OTAQ, EPA420-R-02-029, November 2002
9	Cook et al., Preparing Highway Emissions Inventories for Urban Scale Modeling: A Case Study in Philadelphia, submitted for publication, 2005.

Table 6. EMFAC 2002—Application for MSATs—Functionality and Limitations (ICF International, NCHRP 25-25 Task 18)

Model	EMFAC2002 (v2.20) [1]
Agency	California Air Resources Board
Availability	http://www.arb.ca.gov/msei/on-road/latest_version.htm
Source Categories	Emissions from the California on-road fleet from 1970–2040 by county, basin, air district, or statewide
Input Requirements	Geographic area, calendar year, month or season, title, model years included, inspection and maintenance (I/M) programs, emission mode, and output options.
Optional Inputs	Specific output options dependent on the report type requested.
Outputs	Total emissions, grams per activity emission rates, or basic emission rates (BER; for each vehicle class and model year) of pollutants.
MSAT Pollutants	Particulate Matter (PM) and lead are the only explicitly modeled MSATs in EMFAC2002 Hydrocarbons (HC) may be expressed as TOG, ROG, THC, or CH_4. MSATs may then be computed externally as a fraction of PM or appropriate HC based on technology groups and fuel properties.
Functionality	Calculates emission rates of HC, CO, NOx, PM, lead, SO_2 and CO_2 for 45 model years for each vehicle class by calendar year, twenty four hourly periods, month of the year, and air district, air basin, county, or subcounty in California. [2] Operates in three modes: *Burden* (tons/day) appropriate for regional inventories, *Emfac* (grams/activity) for areawide average emissions, and Calimfac (grams/mile) for detailed basic emission rates.
MSATs	Only PM and lead calculated directly.
Known Limitations	"Future refinements to EMFAC will include the incorporation of toxic air contaminants, greenhouse gases and a direct interface to travel demand models and geographic information systems" [2], however, most MSATs must now be calculated externally. ARB plans to internalize calculations on speciation of MSAT based on emission inventories of PM and TOG in EMFAC. This could include as many as 55 species determined as fractions of total PM and 720 species based on TOG. [3] However, the level of detail is only sufficient for inventory calculations, not emissions factors segregated by vehicle class or operating mode and, therefore, not appropriate for hotspot assessment. [4] Also, the emissions factors are based on data for the California fleet, and therefore differ from those used for MOBILE or MOVES.
References	

1 Emfac2001 (version 2.08) / Emfac2002 (version 2.20) User's Guide, CARB.
Available at http://www.arb.ca.gov/msei/on-road/downloads/docs/users_guide_pdf.zip
2 Overview of the EMFAC Emissions Inventory Model, California Air Resources Board's Emissions Inventory Series, Vol. 1, Issue 6
Available at http://www.arb.ca.gov/msei/on-road/briefs/emfac7.pdf , 2003.
3 ARB speciation profiles and size fractions are discussed at http://www.arb.ca.gov/ei/speciate/speciate.htm
4 Personal communication: Larry Hunsaker, CARB, 4/3/2006

Table 7. MOVES—Application for MSATs—Functionality and Limitations (ICF International, NCHRP 25-25 Task 18)

Optional Inputs	Not yet known.
Outputs	Core model outputs will be emission factors and total emissions. Will provide emission estimates at three scales: macroscale (county), mesoscale (link/travel analysis zone), microscale (roadway up to corridor)
MSAT Pollutants	Will be based on updated data for MSATs currently being collected.
Functionality	Will simulate all criteria pollutants in MOBILE and NONROAD, air toxics as currently explicitly modeled in MOBILE6.2, and greenhouse gases (N2O, CO2 and CH4). Will provide life cycle (well to pump) analysis incorporating Argonne's GREET model. Uses "binning" approach to aggregate any driving pattern into seconds in (speed, engine/vehicle specific power) bins and pairs with emission rates. The "binning" for physical and operational characteristics such as engine size, model year and speed will use the Physical Emission Rate Estimator (PERE) to predict fuel economy associated with each "bin".
MSATs	Based on analysis of influences on toxic fractions - fuel composition, hot/cold starts, vehicle types and technologies, driving cycles/modal distributions, and other factors shown to influence toxic fractions (e.g., ambient temperature) Emission will be based on operating mode subdivided into bins of speed and vehicle specific power and are likely to be chained off of calculated hydrocarbon and particulate matter emissions as done for MOBILE. [3] Mass emission rates may be indexed to the mass fuel consumed through the use of PERE if enough supporting information is available.
Known Limitations	Not yet known.
References	
1	Megan Beardsley, MOVES Update, CRC On-road Emissions Workshop, March 29, 2004. Available at http://www.epa.gov/otaq/models/ngm/may04/crc0304u.pdf
2	Koupal, et al., EPA's Plan for MOVES: A Comprehensive Mobile Source Emissions Model Available at www.4cleanair.org/MOVES.pdf
3	Megan Beardsley, personal communication (March, 2006).

The air dispersion models that were considered for detailed review include CALINE3, CALINE4, CAL3QHC(R), HYROAD, AERMOD, ISCST3 and CALPUFF. These models were selected based on their applicability in transportation-related settings. The types of transportation facilities to which these models may be applicable include: roadways at ground level without intersections (e.g., freeway widening projects), roadways at ground level with intersections (e.g., traffic signal improvement), elevated freeways, parking lots, transit bus garages, rail lines with locomotive traffic, and intermodal freight terminals (e.g., locomotive to truck transfer, ship to truck, etc.). For each model we identified the meteorological requirements, the site/geometry characterization, the handling of the near field dispersion, the availability of traffic simulation, how mobile source emissions are characterized, and removal process (chemical decay, wet/dry deposition), available model outputs, how MSAT may be treated and known limitations for transportation settings. Table 8 through Table 14 show the findings from the examination of the air quality models.

At the present time the choice of the most appropriate modeling tool is not prescribed by policy and the information provided in these tables provides a starting point and basis for the transportation analyst to identify which modeling tool to use in a MSAT assessment. The summary presented for each model provides the analyst with a list of features that may be important to the transportation facility that is under review for MSAT assessment. The tables also show some of the known limitations of the air quality models associated with specific MSATs. This information—when combined with the assessment of the strengths and weaknesses of the models as discussed in the next section—will provide the necessary information for transportation analysts to determine the best modeling choice for use in an MSAT assessment.

Table 8. CALINE3—Application for MSATs—Capabilities and Limitations (ICF International, NCHRP 25-25 Task 18)

Model	The Calpuff Modeling System [1]
Agency	Earth Tech, Inc.
Availability	Developed and maintained by Earth Tech, but available from the EPA as a "preferred or recommended model" primarily for long-range transport http://www.epa.gov/scram001/dispersion_prefrec.htm#calpuff
Design/Applicable Use	A non-steady-state, multi-layer, multi-species gaussian puff dispersion model. Simulates temporal and spatially varying meteorology for pollution transport, transformation and removal. Includes algorithms for subgrid scale effects. Includes algorithms for wet scavenging and dry deposition, and chemical transformation. Applicable for a limited number of point, area, volume sources. Capabilities for complex terrain and/or meteorology and long-range transport (MESOPUFF replacement) Range from tens of meters to hundreds of kilometers.
Meteorological Requirements	Requires same minimum data as ISC3, but can also use multiple stations. Met preprocessor including diagnostic regional wind field generator and boundary layer calculations for both land and over water (CALMET). Can also operate with single station winds.
Site/Geometry Characterization	Can simulate complex terrain, over water transport, coastal interaction, and building downwash (Huber-Snyder; Schulman-Scire). Area source algorithm uses slug formalism rather than polygons. Also simulates volume sources.
Dispersion Characteristics	Includes downwash, plume rise, wet/dry removal, and puff splitting/elongation. Fumigation and wind shear effects are included. Uses surface roughness, Monin-Obukhov length scale for turbulence, solar radiation in dispersion parameterization from CALMET. Includes several options for gaussian dispersion coefficients: turbulence measurements, similarity theory from estimate of surface heat and momentum flux, or Pasquill-Gifford dispersion coefficients.
Traffic Simulation	None included.
Emissions Characterization	Specified by area (mass/area-s) or volume (mass/s). User specified initial sigma-z for area and initial sigma-y and sigma-z for volume sources. Need to externally determine emissions from emission factor model. No linkages to mobile source emission factors.
Species Included	Generally not specific. However, does include some chemistry for sulfur and nitrogen compounds.
Removal Processes	Wet/dry removal simulated using a full resistance model for dry deposition and empirical scavenging coefficients for the wet removal Has capabilities for user-specified diurnal cycles of transformation rates for all species modeled.
Outputs	Three general output file types are produced: a list file with output overview, a restart file, and unformatted files of species concentrations and deposition amounts, and information for visibility calculations. The concentration files can be read into the post processing routine, CALPOST, to generate concentrations at receptors for given averaging periods. Similar capability for deposition.
MSAT Pollutants	Any inert MSATs may be obtained by specifying appropriate emission, deposition, and decay rates.
Other Known Limitations for Transportation Projects	Application in the Portland Air Toxic Study showed that for the best understood mobile source air toxic emission (benzene) that modeled concentrations were generally within a factor of two of the observed concentration and in several cases within the range of uncertainty of the observed concetration[2] Also, the study identified that estimates of area source benzene were overestimated.
References	
1	A User's Guide to the Calpuff Dispersion Model, Earth Tech, Inc., 196 Baker Ave., Concord, MA, 01742, January, 2000.
2	Relationship between motor vehicle emissions of hazardous pollutants, roadway proximity, and ambient concentrations in Portland, OR Cohen, J., Cook, R., Bailey, C., Carr, E., Environmental Modeling and Software 20 (2005) 7-12.

Table 9. CALINE4—Application for MSATs—Capabilities and Limitations (ICF International, NCHRP 25-25 Task 18)

Model	The California Line Source Model, version 4 (CALINE4) [1]
Agency	California Department of Transportation (Caltrans)
Availability	Available from Caltrans at: http://www.dot.ca.gov/hq/env/air/calinesw.htm
Design/Applicable Use	Caline4 (aka CL4) is essentially Caline3 with additional parameters for enhanced characterization. Designed for roadway air emissions under free flow conditions with line sources for near-field, steady-state, short-term modeling. Applicable range is few meters to 500 m from roadway.
Meteorological Requirements	Wind speed and direction, standard deviation of wind direction, stability class, and mixing height as for Caline3. CL4 uses standard deviation of wind direction (sigma-theta) to characterize dispersion. Applies uniform meteorological conditions over the domain.
Site/Geometry Characterization	Improves Caline3 by adding additional capabilities for intersection, street canyon, and parking facility simulation capabilities. Also allows declaration of acceleration/deceleration times, but this formulation is considered outdated for current vehicle technology.
Dispersion Characteristics	Improves over Caline3 by adjusting initial sigma-z by residence time over roadway; initial sigma-z increased by mixing zone residence time; sigma-z based on initial sigma-z and value of sigma-z at a distance traveled by each line segment over the mixing zone based on Smith [2] power curves using Pasquill stability class with adjustment for vehicle heat flux based on traffic volume. Sigma-y parameterized based on observed sigma theta and Draxler [3] Lagrangian diffusion time.
Traffic Simulation	Improves Caline3 by adjusting for residence time idle and vehicle heat flux effects on vertical dispersion. Additional methods included for bluff or street canyons and parking lots.
Emissions Characterization	As in Caline3, emissions are determined from links with specified volume, gram per mile emission factor, and road width. Improves Caline3 by adding an intersection module which includes vehicle idle. However, this intersection modal emission calculation is considered outdated and no longer appropriate for today's fleet.
Species Included	CO, other inert gases, PM, and option for NO2 with deterioration.
Removal Processes	Deposition determined by specifying single deposition and settling velocity as done in Caline3. NO2 option uses "Discrete Parcel Method" first-order reaction with sunlight and ozone and requires NO2 photolysis rate constant.
Outputs	Model predicted concentrations for hourly intervals for each receptor for each traffic or intersection link, emissions, and meteorological condition specified.
MSAT Pollutants	Only PM treated directly. Other inert MSATs may be treated via inert gas calculations.
Other Known Limitations for Transportation Projects	Model formulation does not allow wind speeds less than 0.5 m/s. Model approximations restrict surface roughness to between 3 and 400 cm. Source heights limited between +/- 10m and sigma-theta between 5 and 60°. Model does not perform well if terrain is sufficiently rugged to cause spatial variability in the wind field. Mixing zone widths expected to be at least 10m and link lengths less than 10 km but at least as large as the mixing zone width. Tendency for freeway scenarios is more often overpredict (> factor of 2, 12-15%) than underpredict (< factor of 2, 1-7%). Tendency for freeway scenario to overpredict when winds are light (1-2 m/s)
References	**1** CALINE4 - A Dispersion Model for Predicting Air Pollutant Levels Near Roadways, Paul E. Benson, Office of Transportation Laboratory, California Department of Transportation Available at http://www.dot.ca.gov/hq/env/air/calinemn.htm **2** Smith, F.B. A Scheme for Estimating the Vertical Dispersion of a Plume From a Source Near Ground Level, Air Pollution Modeling, No. 14, CCMS/NATO, 1972. **3** Draxler, R.R. Determination of Atmospheric Diffusion Parameters, *Atmospheric Environment*, Vol. 10, No. 2, pp 99-105, 1976.

Table 10. HYROAD—Application for MSATs—Capabilities and Limitations (ICF International, NCHRP 25-25 Task 18)

Model	The Hybrid Roadway Intersection Model (HYROAD) [1]
Agency	ICF Consulting and KLD Associates, under sponsorship of FHWA and NCHRP.
Availability	Publicly available from the EPA as an "alternative model" http://www.epa.gov/scram001/dispersion_alt.htm#hyroad
Design/Applicable Use	An integrative model that simulates traffic (a microscale transportation model which simulates individual vehicle movement), emissions (composite emission factors and distribution of emissions based on the traffic simulation), and dispersion. Applicable range is up to 500 m from roadway and hourly concentrations of CO, PM, or other inert pollutants, including MSATs. Dispersion is simulated with a Lagrangian puff and gridded, non-uniform wind and stability field derived from traffic module outputs. Designed for roadway intersections with up to 5 approach and departure legs for short-term high concentration episodes.
Meteorological Requirements	Wind speed, direction, sigma-theta, stability class, mixing height, temperature Determines a set of meteorological fields (wind speeds and turbulent mixing) conditions over the domain influenced for each signal phase.
Site/Geometry Characterization	Detailed site-specific geometry, including turn bays and through lanes, turn movements, signal cycle timing, width of median, width of lanes, lane restrictions (e.g., HOV), pedestrian traffic crossing for all approach and departure links.
Dispersion Characteristics	Lagrangian puff approach based on CALPUFF. Puffs are transported and dispersed according to local, non-uniform wind fields influenced by vehicle-induced flows and wakes under varying signal phase conditions. [2] Enhanced vertical dispersion over roadways. Initial sigma-y is mean lane width. Initial sigma-z is 1.5 m.
Traffic Simulation	Includes microscopic traffic simulation model (TRAF-NETSIM) as basis for generating traffic information. TRAF-NETSIM logic determines individual vehicle movements according to car-following logic based on neighboring vehicles, traffic control devices, and driver behavior each second. Relies on user supplied traffic volume, fleet mix, and turning motions.
Emissions Characterization	Base emission factors from MOBILE5 or MOBILE6 are included as inputs, but are used in a regression analysis to calculate composite emission factors based on current conditions at each time period. Vehicle speed and acceleration distributions tracked by signal phase and roadway segment, then used in emissions calculations to calculate a weighted average emission rate for the appropriate speed correction factor by driving cycles; emissions are distributed around intersection based on fuel consumption. Spatial and temporal distribution of emissions is based on vehicle operation predictions rather than uniformly distributed. Spatial allocation at discrete 10-m block lengths; developed to integrate with modal emissions modal (accel, cruise, idle)
Species Included	Model set for CO only. Inert species only. Code may be modified or results post processed to treat other species.
Removal Processes	Deposition and settling based on parameterization by Ermak [3] with single, specified velocity for each. No reactive decay treatment.
Outputs	Output file from traffic simulation module includes all traffic parameters (turning movements, queue length, speeds, volumes, delay, etc.) at each node in the traffic simulations. Output file from dispersion simulation provides concentrations at each receptor for each time period in dispersion simulation.
MSAT Pollutants	No MSATs treated directly. PM and other inert MSATs may be obtained by making minor changes in the code or post processing.
Other Known Limitations for Transportation Projects	Minimum wind speed is 0.3 m/s. HYROAD model evaluation comparison with CAL3QHC demonstrated better performance over CAL3QHC for three intensively monitored intersections; as well as for a set of SLAMS "hot-spot" monitoring sites [4] Requires more input information than CAL3QHC - primarily intersection geometry Limited to intersection settings
References	
1	USER'S GUIDE TO HYROAD -- THE HYBRID ROADWAY INTERSECTION MODEL, Systems Applications International, Inc. and KLD Associates, Inc.SYSAPP-02-073d, July 2002.
2	Eskridge, R.E., and Catalano J.A., ROADWAY – A Numerical Model for Predicting Air Pollutants Near Highway's – User's Guide, EPA/600/8-87/010, Atmospheric Sciences Research Laboratory, USEPA/ORD, Research Triangle Park, NC, March 1987.
3	Ermak D.L. An analytical model for air pollutant transport and deposition from a point source. Atm. Env., Vol. 11. pp. 231-237, 1977.
4	HYROAD Model Formulation, prepared by ICF Consulting, SYSAPP-02/047d, July 2002.

Table 11. CAL3QHC(R)—Application for MSATs—Capabilities and Limitations (ICF International, NCHRP 25-25 Task 18)

Model	CAL3QHC and CAL3QHCR [1]
Agency	US EPA
Availability	Publicly available from the EPA as an "other preferred or recommended model" http://www.epa.gov/scram001/dispersion_prefrec.htm#cal3qhc
Design/Applicable Use	CAL3QHC and CAL3QHC-R combine the Caline3 dispersion model with a traffic queuing algorithm to estimate running and idling emissions at intersections. R-version differs by allowing up to 1-year of meteorology. Applicable range is three meters to 150 m from roadway.
Meteorological Requirements	Same as Caline3. Applies uniform conditions over the domain.
Site/Geometry Characterization	Same as Caline3, but requires intersection specifications for queue links. Can simulate up to 120 roadway links/segments.
Dispersion Characteristics	Same as Caline3. Also includes the ISCST2 calm processing routine (CALMPRO).
Traffic Simulation	Improves Caline3 by adding traffic queuing algorithm that calculates queue length, delay, volume/capacity; R-version allows a year of traffic/signalization data, volume variation by hour/day of week.
Emissions Characterization	Generally same as Caline3, but improves estimation by including characterization of idling emissions while vehicles are queued.
Species Included	Same as CALINE3, but also Includes capability of PM.
Removal Processes	Same as Caline3.
Outputs	Model predicted concentrations for hourly intervals for each receptor for each meteorological condition. Model will report 1-hour and 8-hour average CO as well as 24-hour or annual average PM concentration Long version output also lists each link contribution to the maximum concentration.
MSAT Pollutants	In addition to CO the model includes the capability for the analysis of particulate matter (PM).
Other Known Limitations for Transportation Projects	Traffic operational characteristics (delay and capacity) based on 1985 Highway Capacity Manual. Selected by EPA as recommended guideline model for estimating CO concentrations near intersections based on model comparison study using the then available New York City Route 9A data and MOBILE4.1 model [2] Intersections with unbalanced flow volumes (traffic volume dominate in one direction) leads to excessive queue length estimate and historical over prediction of CO; MOBILE6 has reduced idle emission >50% relative to M4.1 which leads to improved model performance Model does not simulate situations with wind speeds less than 1 m/s
References	
1	User's Guide to CAL3QHC Version 2.0: A Modeling Methodology for Predicting Pollutant Concentrations Near Roadway Intersections USEPA Office of Air Quality Planning and Standards, RTP, NC 27711, EPA-454/R-92-006 (Revised), September, 1995.
2	DiCristofaro, D., Strimaitis, D. Mentzer, R, Evaluation of CO Intersection Modeling Techniques Using a New York City Database", Sigma Research Corporation, EPA Contract No. 68D90067, Work Assignment 3-2 (1992), 156 pp.

Table 12. ISCST3—Application for MSATs—Capabilities and Limitations (ICF International, NCHRP 25-25 Task 18)

Model	The Industrial Source Complex (Short-Term) Model, version 3 [1]
Agency	US EPA
Availability	Publicly available from the EPA as an "alternative model" http://www.epa.gov/scram001/dispersion_alt.htm#isc3
Design/Applicable Use	Short-term, steady-state Gaussian plume model to assess concentrations resulting from a wide variety of emission sources. Can account for: settling and dry deposition of particles; downwash; point, area, and volume sources; plume rise; separation of point sources; and terrain. Can use the Emissions Modeling System for Hazardous Pollutants (EMS-HAP) to process an emission inventory for input. Is also coupled with the Building Profile Input Program (BPIP) and the Building Profile Input Program for PRIME (BPIPPRM) to calculate building heights and projected building widths for structures. As of December, 2005, AERMOD has supplanted ISC as EPA's preferred model. Effective operating range from tens of meters up to 50 km
Meteorological Requirements	Wind speed, direction, stability, and mixing height. Also, precipitation for wet deposition. Calm processing routine may be employed to avoid low wind speed values and resulting unrealistically high concentrations.
Site/Geometry Characterization	Specifications for area and volume source and combinations for line source modeling. Area sources may be rotated. Requires surface roughness. May include building wake effect characterization.
Dispersion Characteristics	Gaussian plume diffusion. Uses a numerical integration approach for area sources. Initial sigma-y and sigma-z can be specified based on source sizes.
Traffic Simulation	None explicitly included.
Emissions Characterization	Specified by point (mass/s), area (mass/area-s), or volume (mass/s). Include a plume rise calculation for point sources. Need to externally determine emissions from emission factor model. Not directly linked to mobile source emission factor model.
Species Included	Not specific. Any species may be included.
Removal Processes	Employs dry and wet deposition options for both gas and particle emissions under the TOXICS option. Simple exponential decay included with user specified half-life.
Outputs	A variety of output files may be produced for a various averaging periods for both air concentrations and deposition amounts. Generally, output files produce resultant pollutant concentrations at specified receptors from individual or groups of sources. Various types of averaging may be done and various values (e.g., 1st, 2nd highest peak concentration) selected. Various formats are available in different output files, including: maximum or threshold exceedance; sequential results for post processing, including for various averaging times; high value summaries, generally for plotting packages; and (unformatted) files of threshold exceedances for inclusion in the TOXST model.
MSAT Pollutants	No species are treated explicitly. Any MSATs may be obtained by specifying appropriate emission, deposition, and decay rates. and if used gas specific information on reactivity, solubility, ratio of gas to liquid phase concentration (Henry's law constant)
Other Known Limitations for Transportation Projects	Requires specification of either urban or rural location. Minimum wind speed of 1.0 m/s. No enhanced traffic induced dispersion or turbulent mixing. Found to underpredict near field concentrations at a truck stop setting due to dated discrete parameterization scheme of Pasquill-Gifford. Also evaluated for long-term average performance at a truck stop. [2] Requires user to develop external link between Mobile emission factor model and expected mass per unit time emission rate
References	
1	USER'S GUIDE FOR THE INDUSTRIAL SOURCE COMPLEX (ISC3) DISPERSION MODELS, US EPA, Office of Air Quality Planning and Standards, Emissions, Monitoring, and Analysis Division, Research Triangle Park, North Carolina 27711, September 1995
2	Modeling Hotspot Transportation-Related Air Quality Impacts using AERMOD and HYROAD, W. Seth Hartley and E. Carr of ICF Consulting and C. Bailey, National Vehicle and Fuel Emission Laboratory, Office of Transportation and Air Quality, EPA, Ann Arbor, MI presented at Guideline on Air Quality Models: Applications and FLAG Developments -- An AWMA Specialty Conference, Denver, CO April 26-28, 2006

Table 13. AERMOD—Application for MSATs—Capabilities and Limitations (ICF International, NCHRP 25-25 Task 18)

Model	The AMS/EPA Regulatory Model (AERMOD) [1]
Agency	US EPA
Availability	Publicly available from the EPA as a "preferred or recommended model" http://www.epa.gov/scram001/dispersion_prefrec.htm#aermod
Design/Applicable Use	Gaussian plume with updated PBL turbulence parameterization A next generation model designed as the ISCST3 successor; still formulated as a steady-state Gaussian plume model Range from tens of meters up to 50 km
Meteorological Requirements	Meteorological data required to run the dispersion model is prepared with the AERMET [2] preprocessor. Generally, the same meteorological data is required as for ISC, although the boundary layer parameterization in the model is different: a continuous Monin-Obukhov length parameterization replaces the older discrete stability class scheme in ISC. Minimum meteorological requirements are hourly surface observations of wind speed and direction, ambient temperature, opaque or total sky cover, and the morning upper air sounding (1200 GMT). Station pressure is also recommended, but not required. Calm processing routine may be employed to avoid low wind speed values, but is not necessary. If not used then instrument threshold minimum wind speed is required.
Site/Geometry Characterization	Generally same as ISCST3 (with PRIME). Also uses local Bowen ratio (sensible/latent heat) and albedo. Uses local upwind surface roughness to determine dispersion. Area sources may be modeled as polygons or circles.
Dispersion Characteristics	ISC structure with improved parameterizations for: terrain interaction and building downwash (PRIME), urban dispersion, CBL Gaussian in horizontal with a bi-Gaussian probability density function in the vertical, plume splitting into elevated stable layer and re-enter to the boundary layer, and plume meander, surface characteristics may be changed by direction and month, use of the latest understanding of boundary layer parameterization, uses continuous growth functions for dispersion based on turbulence based on measure or boundary layer theory, includes a mechanical mixed layer near ground
Traffic Simulation	None included.
Emissions Characterization	Generally similar to ISC3. Specified by point (mass/s), area (mass/area-s), or volume (mass/s). AERMOD differs in treatment of volume sources only in initial plume size by adding the square of the initial plume size to the square of the ambient plume size. Need to externally determine emissions. No linkages to mobile source emission factors.
Species Included	Not specific. Any species may be included.
Removal Processes	Has current dry and wet deposition algorithms based on Argonne National Lab [3] and peer review [4] Simple exponential decay included with user specified half-life.
Outputs	A variety of output files may be produced for a variety of purposes and include an array of results. Generally, output files produce resultant pollutant concentrations at specified receptors from individual or groups of sources, although error and restart files are also produced. Various types of averaging may be done and various values (e.g., 1st, 2nd highest peak concentration) selected. Various formats are available in different output files, including: maximum or threshold exceedance; sequential results for post processing, including for various averaging times; high value summaries, generally for plotting packages; and (unformatted) files of threshold exceedances.
MSAT Pollutants	No species are treated explicitly. Any inert MSATs may be obtained by specifying appropriate emission, deposition, and decay rates.
Other Known Limitations for Transportation Projects	Model evaluation studies to date have focused primarily on elevated source of emissions, with the notable exception of the Prairie Grass Database which showed the model to underpredict the short-term peak; long-term average performance not known. No enhanced traffic induced dispersion or turbulent mixing.
References	

1 USER'S GUIDE FOR THE AMS/EPA REGULATORY MODEL - AERMOD (REVISED DRAFT), US EPA, Office of Air Quality Planning and Standards, Emissions, Monitoring, and Analysis Division, Research Triangle Park, North Carolina 27711, November 1998.

2 USER'S GUIDE FOR THE AERMOD METEOROLOGICAL PREPROCESSOR (AERMET) (REVISED DRAFT), US EPA, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina 27711, November 1998.

3 Wesely, M. L, P. V. Doskey, and J.D. Shannon, Deposition Parameterizations for the Industrial Source Complex (ISC3) Model, Draft ANL Report, ANL/ER/TM-nn, DOE/xx-nnnn, Argonne National Laboratory, Argonne, Illinois 60439, 2001.

4 Walcek, C., G. Stensland, L. Zhang, H. Huang, J. Hales, C. Sweet, W. Massman, A. Williams, J, Dicke, Scientific Peer-Review of the Report "Deposition Parameterization for the Industrial Source Complex (ISC3) Model." , The KEVRIC Company, Durham, NC, 2001.

Table 14. CALPUFF—Application for MSATs—Capabilities and Limitations (ICF International, NCHRP 25-25 Task 18)

Model	The Calpuff Modeling System [1]
Agency	Earth Tech, Inc.
Availability	Developed and maintained by Earth Tech, but available from the EPA as a "preferred or recommended model" primarily for long-range transport http://www.epa.gov/scram001/dispersion_prefrec.htm#calpuff
Design/Applicable Use	A non-steady-state, multi-layer, multi-species gaussian puff dispersion model. Simulates temporal and spatially varying meteorology for pollution transport, transformation and removal. Includes algorithms for subgrid scale effects. Includes algorithms for wet scavenging and dry deposition, and chemical transformation. Applicable for a limited number of point, area, volume sources. Capabilities for complex terrain and/or meteorology and long-range transport (MESOPUFF replacement) Range from tens of meters to hundreds of kilometers.
Meteorological Requirements	Requires same minimum data as ISC3, but can also use multiple stations. Met preprocessor including diagnostic regional wind field generator and boundary layer calculations for both land and over water (CALMET). Can also operate with single station winds.
Site/Geometry Characterization	Can simulate complex terrain, over water transport, coastal interaction, and building downwash (Huber-Snyder; Schulman-Scire). Area source algorithm uses slug formalism rather than polygons. Also simulates volume sources.
Dispersion Characteristics	Includes downwash, plume rise, wet/dry removal, and puff splitting/elongation. Fumigation and wind shear effects are included. Uses surface roughness, Monin-Obukhov length scale for turbulence, solar radiation in dispersion parameterization from CALMET. Includes several options for gaussian dispersion coefficients: turbulence measurements, similarity theory from estimate of surface heat and momentum flux, or Pasquill-Gifford dispersion coefficients.
Traffic Simulation	None included.
Emissions Characterization	Specified by area (mass/area-s) or volume (mass/s). User specified initial sigma-z for area and initial sigma-y and sigma-z for volume sources. Need to externally determine emissions from emission factor model. No linkages to mobile source emission factors.
Species Included	Generally not specific. However, does include some chemistry for sulfur and nitrogen compounds.
Removal Processes	Wet/dry removal simulated using a full resistance model for dry deposition and empirical scavenging coefficients for the wet removal Has capabilities for user-specified diurnal cycles of transformation rates for all species modeled.
Outputs	Three general output file types are produced: a list file with output overview, a restart file, and unformatted files of species concentrations and deposition amounts, and information for visibility calculations. The concentration files can be read into the post processing routine, CALPOST, to generate concentrations at receptors for given averaging periods. Similar capability for deposition.
MSAT Pollutants	Any inert MSATs may be obtained by specifying appropriate emission, deposition, and decay rates.
Other Known Limitations for Transportation Projects	Application in the Portland Air Toxic Study showed that for the best understood mobile source air toxic emission (benzene) that modeled concentrations were generally within a factor of two of the observed concentration and in several cases within the range of uncertainty of the observed concetration[2] Also, the study identified that estimates of area source benzene were overestimated.
References	
1	A User's Guide to the Calpuff Dispersion Model, Earth Tech, Inc., 196 Baker Ave., Concord, MA, 01742, January, 2000.
2	Relationship between motor vehicle emissions of hazardous pollutants, roadway proximity, and ambient concentrations in Portland, OR Cohen, J., Cook, R., Bailey, C., Carr, E., Environmental Modeling and Software 20 (2005) 7-12.

For both the emission factor and air quality models, the model summaries allow users to better understand the tools and resources available for characterizing MSAT impacts for the wide variety of transportation projects which state DOTs may be called upon to assess or provide review comment. The results from this task provide a convenient summary of available models and techniques which the transportation analyst can use in MSAT impact assessment for a wide variety of transportation projects.

Assessment of Model Strengths and Weaknesses for Transportation Projects

To enable the transportation analyst to select the best modeling tools for MSAT assessment, emission factor and air dispersion models were assessed for their major strengths, weakness, limitations, and relative uncertainties for air toxic assessment for different types of transportation facilities. For each emission factor or air quality model, a matrix was developed listing strengths, weakness, limitations, and uncertainties associated with different types of transportation projects. For the emission factor models specific issues include: speed dependency by vehicle type, facility type, species, validation of the model, and underlying database; for air quality models specific issues include: meteorology, geometry, site characterization, dispersion parameters, traffic modeling capabilities, interaction between traffic and meteorology, decay for reactive pollutants, and emission linkages. No assessments were made for the MOVES model, as a draft air toxic version is not yet available. Similarly, the California EMFAC model does not currently contain an air toxic module and a future version of the model will only provide MSAT emissions on a county-by-county basis based on the California Air Resources Board speciation profiles (http://www.arb.ca.gov/ei/speciate/speciate.htm).

Table 15 shows the findings from the examination and evaluation of the MOBILE6.2 emission factor model. Appendix B contains a list of recent studies evaluating the performance of emission factor and air quality dispersion models focused on transportation air quality issues.

Table 15. Emission Factor Models—MOBILE6.2: Relative Strength and Weaknesses (S/W) for Analysis of Air toxics from Transportation Projects (ICF International, NCHRP 25-25 Task 18)

	A	B	C	D	E
1	**Emission Factor Models: MOBILE6.2 Relative Strength and Weaknesses (S/W) for Analysis of Air Toxics from Transportation Projects**				
2	**Facility Type**	**Speed Dependency by Vehicle Type**	**Species**	**Validation of Model and Underlying Database**	
3	Arterial	S: Emissions characterized and verified by expected speed distribution.	S: Emissions will increase with VMT for all species. Includes accounting for high-emitting gas phase vehicles and fuel properties. Gas-phase toxics are based on up-to-date in-use and certification data and accounts for aggressive driving behavior and air conditioning use.	S: Gaseous MSAT missions based on VOC emissions from tens of thousands of tests over driving cycles and more than 50 technical reports. For example, benzene emission factor from Van Nuys Tunnel study for 1995 and MOBILE6.2 agreed to within 20%. Many of the reports have received external scientific peer review. [1]	
4		W: Requires anticipated values of speed and fleet distributions at facility, as well as fuel properties. Does not change DPM emission rate with speed.	W: Heavy-duty gasoline and diesel vehicles emissions are based on limited (≤ 5) dataset of older technology vehicles. Model does not include effects of malfunctioning vehicles or high load conditions for DPM. [1]	W: Other than 6 MSATs explicitly modeled, requires user-defined emission rates or scale factors to VOC or PM. MOBILE6 PM emission rates known to have limitations. Model does not account for HDV fuel properties on toxic emissions. HDV toxic emissions database limited to those used in MOTOX5B. 2	
5	Freeway	S: Emissions characterized and verified by expected speed distribution.	S: Emissions will increase with VMT for all species. Includes accounting for high-emitting gas phase vehicles and fuel properties. Gas-phase toxics are based on up-to-date in-use and certification data and accounts for aggressive driving behavior and air conditioning use.	S: Gaseous MSAT missions based on VOC emissions, validated in tens of thousands of tests over driving cycles and more than 50 technical studies. Many of the reports have received external scientific peer review.[1]	
6		W: Requires anticipated values of speed and fleet distributions at facility, as well as fuel properties. Based on limited high speed driving test cycles.	W: Heavy-duty gasoline and diesel vehicles emissions are based on limited (≤ 5) dataset of older technology vehicles. Model does not include effects of malfunctioning vehicles or steep grade conditions for DPM. [1]	W: Other than 6 MSATs explicitly modeled, requires user-defined emission rates or scale factors to VOC or PM. MOBILE6 PM emission rates known to have limitations. Tunnel studies, which have no transient operation, have shown reasonably good agreement (factor of 2) (HEI Research Report No. 107 - Emissions from Diesel and Gasoline Engines Measured in Highway Tunnels and Gertler, A. and Sagebiel, J., What Have Tunnel Studies Told Us About Mobile Source Air Toxic Emissions?, Presented at CRC Air Toxics Modeling Workshop, Woodlands, TX, February 26-27, 2002. MOBILE6.2 and measured DPM data. MOBILE6.2 does not account for HDV fuel properties on toxic emissions. HDV toxic emissions database limited to those used in MOTOX5B. 2	
7	Interchange/Ramps	S: Emissions characterized and verified by expected speed distribution. For LDGV aggressive driving adjustments are included for gas-phase air toxics. Adjustments based on analysis of FTP and UC driving cycles.	S: Emissions will increase with VMT for all species. Includes accounting for aggressive driving for benzene, 1,3 butadiene and formaldehyde. Based on 12 vehicles measured by CARB. Gas-phase toxics are based on up-to-date in-use and certification data and air conditioning use.	S: Gaseous MSAT emissions based on VOC emissions, validated in tens of thousands of tests over driving cycles for speed effects. For LDGV algorithms adjusted for aggressive driving for running and start emissions for all speeds and roadway types.	
8		W: Requires anticipated values of speed and fleet distributions at facility, as well as fuel properties. Does not include any adjustments for acceleration effects for HDV. Does not change DPM emission rate with speed.	W: Heavy-duty gasoline and diesel vehicles emissions are based on limited (≤ 5) dataset of older technology vehicles. Model does not include effects of malfunctioning vehicles or acceleration for DPM. [1]	W: Other than 6 MSATs explicitly modeled, requires user-defined emission rates or scale factors to VOC or PM. Acceleration effects for LDGV based on limited dataset. Does not account for any HDV acceleration effects. Model does not account for HDV fuel properties on toxic emissions. HDV toxic emissions database limited to those used in MOTOX5B. 2	
9	Intersection	S: Emissions characterized and verified by expected speed distribution. For LDGV aggressive driving adjustments are included for gas-phase air toxics. Adjustments based on analysis of FTP and UC driving cycles.	S: Emissions will increase with VMT for all species. Includes accounting for aggressive driving for benzene, 1,3 butadiene and formaldehyde. Based on 12 vehicles measured by CARB. Gas-phase toxics are based on up-to-date in-use and certification data and air conditioning use. Idle emission rates for DPM are explicitly modeled.	S: Gaseous MSAT emissions based on VOC emissions, validated in tens of thousands of tests over driving cycles for speed effects. For LDGV algorithms adjusted for aggressive driving for running and start emissions for all speeds and roadway types. Also validated in a Connecticut field study evaluating MOBILE6.2 emission ratios against benzene/toluene ratios at seven sampling locations.3	
10		W: Requires anticipated values of speed and fleet distributions at facility, as well as fuel properties. Does not include any adjustments for acceleration effects for HDV. Does not change DPM emission rate with speed.	W: Heavy-duty gasoline and diesel vehicles emissions are based on limited (≤ 5) dataset of older technology vehicles. Model does not include effects of malfunctioning vehicles or acceleration for DPM. [1]	W: Other than 6 MSATs explicitly modeled, requires user-defined emission rates or scale factors to VOC or PM. Acceleration effects for LDGV based on limited dataset. Does not account for any HDV acceleration effects. Model does not account for HDV fuel properties on toxic emissions. HDV toxic emissions database limited to those used in MOTOX5B. 2	
11	Parking Area/Travel Center/Intermodal Facility	S: Emissions characterized and verified by expected speed distribution.	S: Emissions will increase with VMT for all species. For benzene, includes evaporative emissions for both hot soak and resting. Idle emissions for DPM explicitly modeled.	S: Gaseous MSAT emissions based on VOC emissions, validated in tens of thousands of tests over driving cycles and more than 50 technical reports. [1]	
12		W: Requires anticipated values of speed and fleet distributions at facility, as well as fuel properties. Does not change DPM emission rate with speed. Idle emission rates are only explicitly reported for DPM.	W: . Heavy-duty gasoline and diesel vehicles emissions are based on limited (≤ 5) dataset of older technology vehicles. Model does not include effects of malfunctioning vehicles or high load conditions for DPM. [1]	W: Other than 6 MSATs explicitly modeled, requires user-defined emission rates or scale factors to VOC or PM. Benzene evaporative emissions based on proprietary vapor equilibrium model developed by GM. Mobile6 PM emission rates known to have limitations. Model does not account for HDV fuel properties on toxic emissions. HDV toxic emissions database limited to those used in MOTOX5B. 2	
13					
14	1 U. S. EPA Highway Vehicle Emission Models and Data for Estimating Air Toxics, Richard Cook, USEPA OTAQ, Air Toxics Workshop,				
15	Transportation Research Board Annual Meeting, January 9, 2005.				
16	Available at: http://www.trbairquality.com/miscdocs/wi2005/H)%20Onroad%20TRB2005ks2.pdf				
17	2 The specific studies which comprise the data set for the MOBTOX5B algorithms are described in Appendix D of the 1999 document, "Analysis of the				
18	Impacts of Control Programs on Motor Vehicle Toxics Emissions and Exposure in Urban Areas and Nationwide" (EPA-420/R-99-029),				
19	http://www.epa.gov/OMS/regs/toxics/tox_archive.htm#1				
20	3 Nadim, F.; Iranmahboob, J.; Holmen, B.; Hoag, G.E.; Perkins, C.; Dahmani, A.M. (2003) Application of computer models to assess the effects of emission-reduction				
21	programs for a sustainable urban air quality management. Conference paper at "Application of Technology in Urban Development." Iranian Academic Association.				
22	Application of Technology in Urban Development, Dec 2003, Iran.				

Table 16 through Table 22 show the findings from the examination and evaluation of the CALINE3, CALINE4, CAL3QHC(R), HYROAD, AERMOD, ISCST3 and CALPUFF models. This set of tables provides the practitioner with specific information for use in assessing the ability, limitations and associated uncertainty for the emission factor and dispersion models focused on transportation-related MSAT issues. For each model and each type of transportation project the following parameters and their implications were evaluated in evaluating the models strengths and weaknesses:

Meteorology – site specific wind speed and direction, traffic induced vehicle wake effects, variation in wind direction, capable of modeling a full year

Geometry – capable of specify line source as link, multiple link capabilities and consideration of median, facilitate user with spatial information layout

Site Characteristics – consider grade differences, characterizes obstacles, or structures

Dispersion Parameters – adjustments to ambient dispersion due to vehicle movement, heat exhaust, consideration on horizontal and vertical dispersion effects

Traffic Modeling Capabilities – include a microscopic traffic simulation model or an approximation

Interaction between Traffic and Meteorology – number of vehicles considered as impact on near road flow field,

Reactive Decay –assess near field changes of reactive pollutants

Emission Linkages - capability for linking emission factor model with dispersion model for simulating project emissions to include traffic volume, speeds, link variations, spatial and temporal variation, modal considerations

Table 16. Air Quality Models—CALINE3: Relative Strength and Weaknesses (S/W) for Analysis of Air toxics from Transportation Projects (ICF International, NCHRP 25-25 Task 18)

Transportation Project	Meteorology	Geometry	Site Characterization	Dispersion Parameters	Traffic Modeling Capabilities	Interaction between Traffic and Met	Reactive Decay	Emission Linkages
Roadway Widening	**S**:Includes site specific meteorological data; **W**: Does not include wind generation induced from traffic	**S**: Can include additional lane(s) as well as median width change	**S**:Includes options for specifying at-grade, depressed, and bridge; **W**: Does not consider obstacles or structures outside lanes	**S**: includes enhanced roadway dispersion effects based on residence time **W**: Does not consider change in near field flow direction due to vehicle movement activity; adjustment for vehicle heat flux effects on vertical dispersion	**W**:User specified volume for each link only	**W**: none - roadway dispersion not dependent upon number of vehicles; heat flux not dependent upon number of vehicles	**W**: None	**W:** No capability to vary emissions as a function of transient vehicle operations within the link
HOV Lane Addition	**S**:Includes site specific meteorological data; **W**: Does not include wind generation induced from traffic	**S**: can include additional lane as well as median with change; **W**: Does not recognize lane restriction	**S**:Includes options for specifying at-grade, depressed, and bridge; **W**: Does not consider obstacles or structures outside lanes	**S**: includes enhanced roadway dispersion effects based on residence time **W**: Does not consider change in near field flow direction due to vehicle movement activity; adjustment for vehicle heat flux effects on vertical dispersion	**W**: User specified volume for each link - does not recognize lane restriction	**W**: none - roadway dispersion not dependent upon number of vehicles; heat flux not dependent upon number of vehicles	**W**: None	**S:** HOV lane modeled as separate link**; W:**No capability to vary emissions as a function of transient vehicle operations within the link
Roadway Intersection	**S**:Includes site specific meteorological data; **W**: Does not include wind generation induced from traffic	**W**: No specific capability for modeling intersections	**S**:Includes options for specifying at-grade, depressed, and bridge; **W**: Does not consider obstacles or structures outside intersection	**S**: includes enhanced roadway dispersion effects based on residence time **W**: Does not consider change in near field flow direction due to vehicle movement activity; adjustment for vehicle heat flux effects on vertical dispersion	**S**: Can specify multiple links to separate idle activity from running emissions **W**: specification of varying links must be done outside of model	**W**: none - roadway dispersion not dependent upon number of vehicles; heat flux not dependent upon number of vehicles	**W**: None	**S:** User-specified emission factor for each links; **W**: No capability to vary emissions as a function of transient vehicle operations within the link; no separate idle emission link
Interchange/ Ramp	**S**:Includes site specific meteorological data; **W**: Does not include wind generation induced from traffic; uniform flow field	**S**: Can include curved alignments through multiple link as well as bridge type sections;	**S**:Includes options for specifying at-grade, depressed, and bridge; **W**: Does not consider obstacles or structures outside ramp.	**S**: includes roadway dispersion effects based on residence time over roadway **W**: Does not consider change in near field flow direction due to vehicle movement activity or exhaust heat flux effects	**W**:User specified volume for each link only	**W**: roadway dispersion not dependent upon number of vehicles	**W**: None	**W:** Only user-specified emission factor for each link. **W**: No capability to vary emissions as a function of transient vehicle operations within the link
Parking Area/ Travel Center/ Intermodal Facility	**S:** Includes site specific meteorological data;	**W**: No parking link type specification; would need to specify multiple links to characterize area	**W**: Does not consider obstacles or structures outside of area	**W**: modeling of activity on link will automatically be adjust for induced mechanical turbulence based on road width residence time; does not consider change in near field flow field due to exhaust heat flux	**W**: User specified volume for each link; user must explicitly translate volume based on transient time at facility	None	**W**: None	**W:** No capability to vary emissions as a function of transient vehicle operations within the link

Table 17. Air Quality Models—CAL3QHC: Relative Strength and Weaknesses (S/W) for Analysis of Air toxics from Transportation Projects (ICF International, NCHRP 25-25 Task 18)

Meteorology	Geometry	Site Characterization	Dispersion Parameters	Traffic Modeling Capabilities	Interaction between Traffic and Met	Reactive Decay	Emission Linkages
S:Includes site specific meteorological data; "R" version of model may model a full year **W**: Does not include wind generation induced from traffic	**S**: Can include additional lane(s) as well as median width change	**S**:Includes options for specifying at-grade, depressed, and bridge; **W**: Does not consider obstacles or structures outside lanes	**S**: includes enhanced roadway dispersion effects based on residence time **W**: Does not consider change in near field flow direction due to vehicle movement activity; adjustment for vehicle heat flux effects on vertical dispersion	**W**:User specified volume for each link only	**W**: none - roadway dispersion not dependent upon number of vehicles; heat flux not dependent upon number of vehicles	**W**: None	**W:** User-specified emission factor for each link; No capability to vary emissions along link
S:Includes site specific meteorological data; "R" version of model may model a full year **W**: Does not include wind generation induced from traffic	**S**: can include additional lane as well as median with change; **W**: Does not recognize lane restriction	**S**:Includes options for specifying at-grade, depressed, and bridge; **W**: Does not consider obstacles or structures outside lanes	**S**: includes enhanced roadway dispersion effects based on residence time **W**: Does not consider change in near field flow direction due to vehicle movement activity; adjustment for vehicle heat flux effects on vertical dispersion	**W**: User specified volume for each link - does not recognize lane restriction	**W**: none - roadway dispersion not dependent upon number of vehicles; heat flux not dependent upon number of vehicles	**W**: None	**S:** HOV lane modeled as separate link**; W:** User-specified emission factor for each link; No capability to vary emissions along link
S:Includes site specific meteorological data; "R" version of model may model a full year **W**: Does not include wind generation induced from traffic	**S**: Includes capabilities full capability for modeling intersections	**S**:Includes options for specifying at-grade, depressed, and bridge; **W**: Does not consider obstacles or structures outside intersection	**S**: includes enhanced roadway dispersion effects based on residence time **W**: Does not consider change in near field flow direction due to vehicle movement activity; adjustment for vehicle heat flux effects on vertical dispersion	**S**: Estimate vehicle queue based on 1985 Highway Capacity Model and Deterministic Queuing Theory; user may specific signal cycle length, saturation flow rate, signal type and arrival rate **W**: Queue lengths maybe overestimated in overcapacity conditions leading to overestimates of concentration	**W**: none - roadway dispersion not dependent upon number of vehicles; heat flux not dependent upon number of vehicles	**W**: None	**S:** User-specified emission factor for each separate queue and running links; **W**: No capability to vary emissions along link
S:Includes site specific meteorological data; "R" version of model may model a full year **W**: Does not include wind generation induced from traffic; uniform flow field	**S**: Can include curved alignments through multiple link as well as bridge type sections;	**S**:Includes options for specifying at-grade, depressed, and bridge; **W**: Does not consider obstacles or structures outside ramp.	**S**: includes roadway dispersion effects based on residence time over roadway **W**: Does not consider change in near field flow direction due to vehicle movement activity or exhaust heat flux effects	**W**:User specified volume for each link only	**W**: roadway dispersion not dependent upon number of vehicles	**W**: None	**W:** Only user-specified emission factor for each link. **W**: No capability to vary emissions along link
S:Includes site specific meteorological data; "R" version of model may model a full year	**W**: No parking link type specification; would need to specify multiple links to characterize area	**S**:Includes options for specifying at-grade, depressed, and bridge; **W**: Does not consider obstacles or structures outside of area	**S**: modeling of activity as a queue link will prevent model adjustment for horizontal dispersion from vehicle movement activity	**W**: User specified volume for each link; user must explicitly translate volume based on transient time at facility	None	**W**: None	**W:** Only user-specified emission factor for each link.

[1] CAL3QHC is based on the same meteorological algorithms as used in CALINE3, but includes a traffic model queuing algorithm

Table 18. Air Quality Models—CALINE4: Relative Strength and Weaknesses (S/W) for Analysis of Air toxics from Transportation Projects (ICF International, NCHRP 25-25 Task 18)

Transportation Project	Meteorology	Geometry	Site Characterization	Dispersion Parameters	Traffic Modeling Capabilities	Interaction between Traffic and Met	Reactive Decay	Emission Linkages
Roadway Widening	**S**:Includes sigma-theta (std deviation in wind direction); physically accounts for wind direction variation; **W**: Does not include wind generation induced from traffic	**S**: Can include additional lane(s) as well as median width change	**S**:Includes options for specifying at-grade, depressed, and bridge; **W**: Does not consider obstacles or structures outside lanes	**S**: includes enhanced roadway dispersion effects based on residence time:adjustment for vehicle heat flux effects on vertical dispersion **W**: Does not consider change in near field flow direction due to vehicle movement activity	**W**:User specified volume for each link only	**S**: heat flux dependent upon number of vehicles; **W**: roadway dispersion not dependent upon number of vehicles	**W**: only applicable for NO to NO2 conversion	**W:** User-specified based on emission factor model with modal factor based on Colorado DOH model. **W**: No longer appropriate for use with the MOBILE6 or EMFAC emission factor models.
HOV Lane Addition	**S**:Includes sigma-theta (std deviation in wind direction); physically accounts for wind direction variation; **W**: Does not include wind generation induced from traffic	**S**: can include additional lane as well as median with change; **W**: Does not recognize lane restriction	**S**:Includes options for specifying at-grade, depressed, and bridge; **W**: Does not consider obstacles or structures outside lanes	**S**: includes enhanced roadway dispersion effects based on residence time:adjustment for vehicle heat flux effects on vertical dispersion **W**: Does not consider change in near field flow direction due to vehicle movement activity	**W**: User specified volume for each link - does not recognize lane restriction	**S**: heat flux dependent upon number of vehicles; **W**: roadway dispersion not dependent upon number of vehicles	**W**: only applicable for NO to NO2 conversion	**W:** User-specified based on emission factor model with modal factor based on Colorado DOH model. No longer appropriate for use with the MOBILE6 or EMFAC emission factor models.
Roadway Intersection	**S**:Includes sigma-theta (std deviation in wind direction); physically accounts for wind direction variation; **W**: Does not include wind generation induced from traffic	**S**: Includes capabilities for intersections; **W**: requires user to specify accel/deccel time, average number of vehicles handled per cycle per lane and average number of vehicles delayed per cycle per lane	**S**:Includes options for specifying at-grade, depressed, and bridge; **W**: Does not consider obstacles or structures outside intersection	**S**: includes enhanced roadway dispersion effects based on residence time:adjustment for vehicle heat flux effects on vertical dispersion **W**: Does not consider change in near field flow direction due to vehicle movement activity	**W**: User required specification of volumes by link both departure and approach; no direct link to a microscopic traffic simulation model	**S**: heat flux dependent upon number of vehicles; **W**: roadway dispersion not dependent upon number of vehicles	**W**: only applicable for NO to NO2 conversion	**W**: Emission profile developed from user specifying accel/deccel time, average number of vehicles handled per cycle per lane and average number of vehicles delayed per cycle per lane. Information not readily available.
Interchange/ Ramp	**S**:Includes sigma-theta (std deviation in wind direction); physically accounts for wind direction variation; **W**: Does not include wind generation induced from traffic	**S**: Can include curved alignments through multiple link as well as bridge type sections.	**S**:Includes options for specifying at-grade, depressed, and bridge; **W**: Does not consider obstacles or structures outside ramp.	**S**: includes enhanced roadway dispersion effects based on residence time: adjustment for vehicle heat flux effects on vertical dispersion **W**: Does not consider change in near field flow direction due to vehicle movement activity	**W**:User specified volume for each link only	**S**: heat flux dependent upon number of vehicles; **W**: roadway dispersion not dependent upon number of vehicles	**W**: only applicable for NO to NO2 conversion	**S:** User-specified based on emission factor model with modal factor based on Colorado DOH model explicit for accel/deccel. **W**: No longer appropriate for use with the MOBILE6 or EMFAC emission factor models.
Parking Area/ Travel Center/ Intermodal Facility	**S**:Includes sigma-theta (std deviation in wind direction); physically accounts for wind direction variation;	**S**: Includes capabilities for parking lot link type; **W**: requires user to specify transient emission factor (this would include weighted adjustment for cold-starts and hot starts)	**S**:Includes options for specifying at-grade, depressed, and bridge; **W**: Does not consider obstacles or structures outside of area	**S**: adjustments made for vehicle heat flux effects on vertical dispersion based on number of vehicles	**W**: User specified volume for each link; user must explicitly determine travel time/speed	**S**: heat flux dependent upon number of vehicles;	**W**: only applicable for NO to NO2 conversion	**S:** User-specified transient emission factor based on modal factor from Colorado DOH model. **W**: No longer appropriate for use with the MOBILE6 or EMFAC emission factor models. Emissions are uniformly distributed over area.

Table 19. Air Quality Models—HYROAD: Relative Strength and Weaknesses (S/W) for Analysis of Air toxics from Transportation Projects (ICF International, NCHRP 25-25 Task 18)

Transportation Project	Meteorology	Geometry	Site Characterization	Dispersion Parameters	Traffic Modeling Capabilities	Interaction between Traffic and Met	Reactive Decay	Emission Linkages
Roadway Widening	**S:** Includes site specific meteorological data with sigma theta (std deviation in wind direction); physically accounts for wind direction variation.	**S**: Detailed site-specific geometry; includes width of median, width of lanes	**S:** Does allow specification of local surface roughness **W**: Does not consider obstacles or structures outside intersection; does not include options for specifying at-grade, depressed and bridge.	**S**: vehicle-induced flows and wakes; as well as enhanced vertical dispersion over roadway; modeled as multiple-puff release; puff growth is gaussian, but flow field is non-uniform; initial sigma-y is lane width. **W**: not specifically designed to model lane addition of widening; emission release point the same for light and heavy duty vehicles	**S:** user specified traffic volume for each link; microscopic traffic simulation model used to generate other traffic information; tracks vehicle speed and acceleration distributions by 10-meter roadway segment; individual vehicles moved once a second to account for traffic conditions; vehicle movements determined according to car-following logic based on neighboring vehicles, and driver behavior.	**S:** roadway induced buoyancy dependent upon number of vehicles from exhaust heat flux; vehicle speed and acceleration distributions by 10-meter roadway segment for use in induced flows and turbulence - creates non-uniform flow field	**W**: None	**S:** Emission factor from MOBILE6 as inputs, but speed distributions from the traffic module are used in a regression analysis for each time period to calculate composite emission factors whose underlying speed distribution best fits current conditions. Spatial and temporal distribution of emissions based on vehicle operation rather than uniformly distributed. **W:** not current linked to modal emissions model, but does have functional future capability; not specifically designed for lane addition or widening
HOV Lane Addition	**S**: Includes site specific meteorological data with sigma theta (std deviation in wind direction); physically accounts for wind direction variation.	**S**: Detailed site-specific geometry; includes width of median, width of lanes, lane restrictions	**S:** Does allow specification of local surface roughness **W**: Does not consider obstacles or structures outside intersection; does not include options for specifying at-grade, depressed and bridge.	**S**: vehicle-induced flows and wakes; as well as enhanced vertical dispersion over roadway; modeled as multiple-puff release; puff growth is gaussian, but flow field is non-uniform; initial sigma-y is lane width. **W**: not specifically designed to model only HOV lane addition; emission release point the same for light and heavy duty vehicles	**S:** user specified traffic volume for each link; microscopic traffic simulation model used to generate other traffic information; tracks vehicle speed and acceleration distributions by 10-meter roadway segment; individual vehicles moved once a second to account for traffic conditions; vehicle movements determined according to car-following logic based on neighboring vehicles, and driver behavior.	**S:** roadway induced buoyancy dependent upon number of vehicles from exhaust heat flux; vehicle speed and acceleration distributions by 10-meter roadway segment for use in induced flows and turbulence - creates non-uniform flow field	**W**: None	**S:** Emission factor from MOBILE6 as inputs, but speed distributions from the traffic module are used in a regression analysis for each time period to calculate composite emission factors whose underlying speed distribution best fits current conditions. Spatial and temporal distribution of emissions based on vehicle operation rather than uniformly distributed. **W:** not current linked to modal emissions model, but does have functional future capability; not specifically designed for HOV lane addition

Table 19. Air Quality Models—HYROAD: Relative Strength and Weaknesses (S/W) for Analysis of Air toxics from Transportation Projects (ICF International, NCHRP 25-25 Task 18) *(continued)*

Transportation Project	Meteorology	Geometry	Site Characterization	Dispersion Parameters	Traffic Modeling Capabilities	Interaction between Traffic and Met	Reactive Decay	Emission Linkages
Roadway Intersection	**S**: Includes site specific meteorological data with sigma theta (std deviation in wind direction); physically accounts for wind direction variation.	**S**: Detailed site-specific geometry; turn bays, through lanes for approach and departure links, width of median, width of lanes, turn movements, signal cycle timing; **W**: Handles only a maximum of five approach and departure legs	**S:** Does allow specification of local surface roughness **W**: Does not consider obstacles or structures outside intersection; does not include options for specifying at-grade, depressed and bridge.	**S**: vehicle-induced flows and wakes; as well as enhanced vertical dispersion over roadway; modeled as multiple-puff released under varying signal phase conditions; puff growth is gaussian, but flow field is non-uniform; initial sigma-y is lane width. **W**: emission release point the same for light and heavy duty vehicles	**S**: user specified traffic volume for each link; microscopic traffic simulation model used to generate other traffic information; tracks vehicle speed and acceleration distributions by signal phase and 10-meter roadway segment; individual vehicles moved once a second to account for traffic conditions; vehicle movements determined according to car-following logic based on neighboring vehicles, traffic control devices, and driver behavior; pedestrian traffic crossing.	**S**: roadway induced buoyancy dependent upon number of vehicles from exhaust heat flux; vehicle speed and acceleration distributions by signal phase and 10-meter roadway segment for use in induced flows and turbulence - creates non-uniform flow field	**W**: None	**S:** Emission factor from MOBILE6 as inputs, but speed distributions from the traffic module are used in a regression analysis for each time period to calculate composite emission factors whose underlying speed distribution best fits current conditions. Spatial and temporal distribution of emissions based on vehicle operation rather than uniformly distributed**. W:** not current linked to modal emissions model, but does have functional future capability
Interchange/ Ramp	**S**: Includes site specific meteorological data with sigma theta (std deviation in wind direction); physically accounts for wind direction variation.	**S**: Detailed site-specific geometry; width of median, width of lanes; **W**: Does not have link specific for ramps	**S:** Does allow specification of local surface roughness **W**: Does not consider obstacles or structures outside ramp; does not include options for specifying at-grade, depressed and bridge.	**S**: vehicle-induced flows and wakes; as well as enhanced vertical dispersion over roadway; modeled as multiple puff released; puff growth is gaussian, but flow field is non-uniform **W**: emission release point the same for light and heavy duty vehicles	**S**: user specified traffic volume for each link; microscopic traffic simulation model used to generate other traffic information; tracks vehicle speed and acceleration, distributions by 10-meter roadway segment; individual vehicles moved once a second to account for traffic conditions; vehicle movements determined according to car-following logic based on neighboring vehicles, traffic control devices, and driver behavior. **W**: No ramp metering capability	**S**: roadway induced buoyancy dependent upon number of vehicles from exhaust heat flux; vehicle speed and acceleration distributions per 10-meter roadway segment for use in induced flows and turbulence.	**W**: None	**S:** Emission factor from MOBILE6 as inputs, but speed distributions from the traffic module are used in a regression analysis for each time period to calculate composite emission factors whose underlying speed distribution best fits current conditions. Spatial and temporal distribution of emissions based on vehicle operation rather than uniformly distributed**. W:** not current linked to modal emissions model, but does have functional future capability

Table 19. Air Quality Models—HYROAD: Relative Strength and Weaknesses (S/W) for Analysis of Air toxics from Transportation Projects (ICF International, NCHRP 25-25 Task 18) *(continued)*

Transportation Project	Meteorology	Geometry	Site Characterization	Dispersion Parameters	Traffic Modeling Capabilities	Interaction between Traffic and Met	Reactive Decay	Emission Linkages
Parking Area/ Travel Center/ Intermodal Facility	**S**: Includes site specific meteorological data with sigma theta (std deviation in wind direction); physically accounts for wind direction variation.	**W**: No parking link type specification	S: Does allow specification of local surface roughness. **W**: Does not consider obstacles or structures outside of area	**S**: vehicle-induced flows and wakes; as well as enhanced vertical dispersion over road segments; modeled as multiple puff released; puff growth is gaussian. **W**: emission release point the same for light and heavy duty vehicles	**S:** user specified traffic volume for each link; **W:** microscopic traffic simulation model used to generate other traffic information -- not developed for the modeling of parking or internmodal facilities	**S**: induced buoyancy dependent upon number of vehicles from exhaust heat; vehicle speed and acceleration distributions per 10-meter segment for use in induced flows. **W**: not configured for application to parking/intermodal facility	**W**: None	**W:** Not configured to work directly with intermodal facility/parking/travel center; emissions linked to on-road traffic module

Table 20. Air Quality Models—AERMOD: Relative Strength and Weaknesses (S/W) for Analysis of Air toxics from Transportation Projects (ICF International, NCHRP 25-25 Task 18)

Transportation Project	Meteorology	Geometry	Site Characterization	Dispersion Parameters	Traffic Modeling Capabilities	Interaction between Traffic and Met	Reactive Decay	Emission Linkages
Roadway Widening	**S**:Needs site specific meteorological data - wind speed, direction, temperature and cloud cover; **W**: Does not include wind generation induced from traffic; requires morning temperature sounding	**S**: Can model a combination of area and volume source as line sources	**S:** May include nearby building or obstacle wake effect characterization; includes state of the science building wake algorithm (PRIME); surface roughness and ground reflectivity may vary for up to 12 wind directions **W**: Does not include options for depressed source	**S:** Gaussian plume diffusion with numerical integration approach for area sources more accurate than finite-line area source algorithm; can use irregularly shaped (circles or polygon) area sources **W**: Does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	**W**: No traffic modeling capabilities	**W**: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for associated heat flux	**S**: Has simple exponential decay via user specified half-life **W**: Has no chemical reactivity	**W:** Need to externally determine emissions from emission factor model for each area or volume source
HOV Lane Addition	**S**:Needs site specific meteorological data - wind speed, direction, temperature and cloud cover; **W**: Does not include wind generation induced from traffic; requires morning temperature sounding	**S**: Can model a combination of area and volume source as line sources **W**: Does not consider lane restrictions	**S:** May include nearby building or obstacle wake effect characterization; includes state of the science building wake algorithm (PRIME); surface roughness and ground reflectivity may vary for up to 12 wind directions **W**: Does not include options for specifying depressed source	**S:** Gaussian plume diffusion with numerical integration approach for area sources more accurate than finite-line area source algorithm; can use irregularly shaped (circles or polygon) area sources **W**: Does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	**W**: No traffic modeling capabilities	**W**: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for associated heat flux	**S**: Has simple exponential decay via user specified half-life **W**: Has no chemical reactivity	**W:** Need to externally determine emissions from emission factor model for each area or volume source
Roadway Intersection	**S**:Needs site specific meteorological data - wind speed, direction, temperature and cloud cover; **W**: Does not include wind generation induced from traffic; requires morning temperature sounding	**S**: Can model a combination of area and volume source as line sources **W**: Does not consider intersection layout	**S:** May include nearby building or obstacle wake effect characterization; includes state of the science building wake algorithm (PRIME); surface roughness and ground reflectivity may vary for up to 12 wind directions **W**: Does not include options for specifying depressed source	**S:** Gaussian plume diffusion with numerical integration approach for area sources more accurate than finite-line area source algorithm **W**: Does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	**W**: No traffic or intersection queuing capabilities	**W**: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for associated heat flux	**S**: Has simple exponential decay via user specified half-life **W**: Has no chemical reactivity	**W:** Need to externally determine emissions from emission factor model for each area or volume source
Interchange/ Ramp	**S**:Needs site specific meteorological data - wind speed, direction, temperature and cloud cover; **W**: Does not include wind generation induced from traffic; requires morning temperature sounding	**S**: Can model a combination of area and volume source as line sources **W**: No specific features for ramps	**S:** May include nearby building or obstacle wake effect characterization; includes state of the science building wake algorithm (PRIME); surface roughness and ground reflectivity may vary for up to 12 wind directions **W**: Does not include options for specifying depressed source	**S:** Gaussian plume diffusion with numerical integration approach for area sources more accurate than finite-line area source algorithm; can use irregularly shaped (circles or polygon) area sources **W**: Does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	**W**: No traffic modeling capabilities	**W**: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for their associated heat flux	**S**: Has simple exponential decay via user specified half-life **W**: Has no chemical reactivity	**W:** Need to externally determine emissions from emission factor model for each area or volume source
Parking Area/ Travel Center/ Intermodal Facility	**S**:Needs site specific meteorological data - wind speed, direction, temperature and cloud cover; **W**: Requires morning temperature sounding	**S**: Can model as area and volume source with aspect ratio of up to 10:1	**S:** May include nearby building or obstacle wake effect characterization; includes state of the science building wake algorithm (PRIME); surface roughness and ground reflectivity may vary for up to 12 wind directions; **W**: Does not contain option for specifying parking facility	**S:** Gaussian plume diffusion with numerical integration approach for area sources more accurate than finite-line area source algorithm; can use irregularly shaped (circles or polygon) area sources **W**: No adjustment for vehicle heat flux effects on vertical dispersion	**S:** User can specify idle and transient at separate locations based on vehicle activity levels	**W**: No adjustment for the number of vehicles and their activity and for their associated heat flux	**S**: Has simple exponential decay via user specified half-life **W**: Has no chemical reactivity	**S:** Can specify emissions for each volume and area source based on activity levels and vehicle type **W:** Need to externally determine emissions from emission factor

Table 21. Air Quality Models—ISCST3: Relative Strength and Weaknesses (S/W) for Analysis of Air toxics from Transportation Projects (ICF International, NCHRP 25-25 Task 18)

Transportation Project	Meteorology	Geometry	Site Characterization	Dispersion Parameters	Traffic Modeling Capabilities	Interaction between Traffic and Met	Reactive Decay	Emission Linkages
Roadway Widening	**S**:Includes site specific meteorological data; **W**: Does not include wind generation induced from traffic	**S**: Can model a combination of area and volume source as line sources	**S:** May include nearby building or obstacle wake effect characterization; **W**: Does not include options for specifying at-grade, depressed, and bridge;	**S:** gaussian plume diffusion with numerical integration approach for area sources more accurate than finite-line area source algorithm **W**: does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	**W**: No traffic modeling capabilities	**W**: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for associated heat flux	**S**: has simple exponential decay via user specified half-life **W**: has no chemical reactivity	**W:** need to externally determine emissions from emission factor model for each area or volume source
HOV Lane Addition	**S**:Includes site specific meteorological data; **W**: Does not include wind generation induced from traffic	**S**: Can model a combination of area and volume source as line sources **W**: Does not consider lane restrictions	**S:** May include nearby building or obstacle wake effect characterization; **W**: Does not include options for specifying at-grade, depressed, and bridge;	**S:** gaussian plume diffusion with numerical integration approach for area sources more accurate than finite-line area source algorithm **W**: does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	**W**: No traffic modeling capabilities	**W**: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for associated heat flux	**S**: has simple exponential decay via user specified half-life **W**: has no chemical reactivity	**W:** need to externally determine emissions from emission factor model for each area or volume source
Roadway Intersection	**S**:Includes site specific meteorological data; **W**: Does not include wind generation induced from traffic	**S**: Can model a combination of area and volume source as line sources **W**: Does not consider intersection layout	**S:** May include nearby building or obstacle wake effect characterization; **W**: Does not include options for specifying at-grade, depressed, and bridge;	**S:** gaussian plume diffusion with numerical integration approach for area sources more accurate than finite-line area source algorithm **W**: does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	**W**: No traffic intersection queuing capabilities	**W**: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for associated heat flux	**S**: has simple exponential decay via user specified half-life **W**: has no chemical reactivity	**W:** need to externally determine emissions from emission factor model for each area or volume source
Interchange/ Ramp	**S**:Includes site specific meteorological data; **W**: Does not include wind generation induced from traffic	**S**: Can model a combination of area and volume source as line sources **W**: No specific features for ramps	**S:** May include nearby building or obstacle wake effect characterization; **W**: Does not include options for specifying at-grade, depressed, and bridge;	**S:** gaussian plume diffusion with numerical integration approach for area sources more accurate than finite-line area source algorithm **W**: does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	**W**: No traffic modeling capabilities	**W**: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for associated heat flux	**S**: has simple exponential decay via user specified half-life **W**: has no chemical reactivity	**W:** need to externally determine emissions from emission factor model for each area or volume source
Parking Area/ Travel Center/ Intermodal Facility	**S**:Includes site specific meteorological data;	**S**: Can model as area and volume source with aspect ratio of up to 10:1 **W**: No specific features for parking lots	**S:** May include nearby building or obstacle wake effect characterization; **W**: Does not contain option for specifying parking facility	**S:** gaussian plume diffusion with numerical integration approach for area sources more accurate than finite-line area source algorithm **W**: no adjustment for vehicle heat flux effects on vertical dispersion	**S:** User can specify idle and transient at separate locations based on vehicle activity levels	**W**: No adjustment for the number of vehicles and their activity and associated heat flux	**S**: has simple exponential decay via user specified half-life **W**: has no chemical reactivity	**S:** Can specify emissions for each volume and area source based on activity levels and vehicle type **W:** need to externally determine emissions from emission factor model for each area or volume source

Table 22. Air Quality Models—CALPUFF: Relative Strength and Weaknesses (S/W) for Analysis of Air toxics from Transportation Projects (ICF International, NCHRP 25-25 Task 18)

Transportation Project	Meteorology	Geometry	Site Characterization	Dispersion Parameters	Traffic Modeling Capabilities	Interaction between Traffic and Met	Reactive Decay	Emission Linkages
Roadway Widening	**S**:Needs site specific meteorological data - wind speed, direction, temperature, stability class, mixing height; **W**: Does not include wind generation induced from traffic	**S**: Can model a combination of area and volume source **W**: Line source algorithm not appropriate for mobile source	**S:** May include nearby building or obstacle wake effect characterization; surface roughness and albedo may vary if using gridded field option; **W**: Does not include options for specifying at-grade, depressed, and bridge	**S:** Gaussian puff diffusion with numerical integration approach for area sources; elongated puff-near field for more accurate simulation; dispersion coefficient may be based on similarity theory; **W**: Does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	**W**: No traffic modeling capabilities	**W**: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for associated heat flux	**S**: Has chemical transformati on for Sox and Nox emissions; or user specified diurnal cycle	**W:** Need to externally determine emissions from emission factor model for each area or volume source
HOV Lane Addition	**S**:Needs site specific meteorological data - wind speed, direction, temperature, stability class, mixing height; **W**: Does not include wind generation induced from traffic	**S**: Can model a combination of area and volume sources **W**: Does not consider lane restrictions; line source algorithm not appropriate for mobile source	**S:** May include nearby building or obstacle wake effect characterization; surface roughness and albedo may vary if using gridded field option; **W**: Does not include options for specifying at-grade, depressed, and bridge	**S:** Gaussian puff diffusion with numerical integration approach for area sources; elongated puff-near field for more accurate simulation; dispersion coefficient may be based on similarity theory; **W**: Does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	**W**: No traffic modeling capabilities	**W**: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for associated heat flux	**S**: Has chemical transformati on for Sox and Nox emissions; or user specified diurnal cycle	**W:** Need to externally determine emissions from emission factor model for each area or volume source
Roadway Intersection	**S**:Needs site specific meteorological data - wind speed, direction, temperature, stability class, mixing height; **W**: Does not include wind generation induced from traffic	**S**: Can model a combination of area and volume sources **W**: Does not consider intersection layout	**S:** May include nearby building or obstacle wake effect characterization; surface roughness and albedo may vary if using gridded field option; **W**: Does not include options for specifying at-grade, depressed, and bridge	**S:** Gaussian puff diffusion with numerical integration approach for area sources; elongated puff-near field for more accurate simulation; dispersion coefficient may be based on similarity theory; **W**: Does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	**W**: No traffic or intersection queuing capabilities	**W**: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for associated heat flux	**S**: Has chemical transformati on for Sox and Nox emissions; or user specified diurnal cycle	**W:** Need to externally determine emissions from emission factor model for each area or volume source
Interchange/ Ramp	**S**:Needs site specific meteorological data - wind speed, direction, temperature, stability class, mixing height; **W**: Does not include wind generation induced from traffic	**S**: Can model a combination of area and volume source **W**: No specific features for ramps; line source algorithm not appropriate for mobile source	**S:** May include nearby building or obstacle wake effect characterization; surface roughness and albedo may vary if using gridded field option; **W**: Does not include options for specifying at-grade, depressed, and bridge	**S:** Gaussian puff diffusion with numerical integration approach for area sources; elongated puff-near field for more accurate simulation; dispersion coefficient may be based on similarity theory; **W**: Does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	**W**: No traffic modeling capabilities	**W**: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for associated heat flux	**S**: Has chemical transformati on for Sox and Nox emissions; or user specified diurnal cycle	**W:** Need to externally determine emissions from emission factor model for each area or volume source; no modal emission factor
Parking Area/ Travel Center/ Interposal Facility	**S**:Needs site specific meteorological data - wind speed, direction, temperature, stability class, mixing height;	**S**: Can model as area and volume source with aspect ratio of up to 10:1 **W**: No specific features for parking lots	**S:** May include nearby building or obstacle wake effect characterization; surface roughness and albedo may vary if using gridded field option; **W**: Does not include options for specifying at-grade, depressed, and bridge	**S:** Gaussian puff diffusion with numerical integration approach for area sources; elongated puff-near field for more accurate simulation; dispersion coefficient may be based on similarity theory; **W**: No adjustment for vehicle heat flux effects on vertical dispersion	**S:** User can specify idle and transient at separate locations based on vehicle activity levels	**W**: No adjustment for the number of vehicles and their activity for the associated heat flux	**S**: Has chemical transformati on for Sox and Nox emissions; or user specified diurnal cycle	**S:** Can specify emissions for each volume and area source based on activity levels and vehicle type **W:** Need to externally determine emissions from emission factor model for each area or volume source; no modal emission factor

The information presented here builds upon the information provided in our identification of analytical tools available for air toxic assessment. These tables provide specific information on model strengths and weaknesses for nearly all transportation situations evaluated under NEPA. The identified strengths and weaknesses add to the transportation analyst's understanding of how these tools can be used in transportation MSAT assessments. In particular, information on model weaknesses may help the transportation analyst understand why a given model may not be suitable for use in an MSAT assessment. When considering the relative strengths and weaknesses of different models, the findings present a clearer picture of which modeling tools should be used in a given MSAT assessment. This information has been used in the section entitled, *Five Levels of Analyses for Air Toxic Assessment under NEPA*, to provide recommendations on the best modeling approaches for analyzing MSATs in the NEPA process. These findings are summarized here in the table below and presented again later in the report in Table 27.

Table 23. Best Available Air Quality Modeling Tools for use in Analyzing MSATs under NEPA (ICF International, NCHRP 25-25 Task 18)

Facility/Project Type	Primary Air Quality Model	Secondary Air Quality Model	Comments
Roadway Widening	CALINE4	CALINE3	
HOV Lane Addition	CALINE4	CALINE3	
Roadway Intersection	CAL3QHC(R)	HYROAD	With the release of the MOVES model HYROAD may be the preferred choice as the model can be directly linked to the modal emission factors.
Interchange/Ramp	CALINE4	CALINE3	Carefully consideration should be given to the emission factors under grade or acceleration environment.
Freight Terminal/ Intermodal Transfer Parking/ Travel Center/	AERMOD	ISC3	If facility is located where unusual meteorological conditions (fumigation, stagnation) occur then CALPUFF is the preferred model.

Health Impacts of Mobile Source Air Toxics and Current Range in Concentration

To assist the transportation analyst in assessing the relative impact of the transportation project versus current conditions, an assessment was performed for each MSAT documenting the potential health impacts and range of concentrations occurring throughout the U.S.

Health effects of MSATs may be divided into two categories: carcinogenic and chronic non-carcinogenic. Table 24 presents estimates of carcinogenic potency for 12 of the MSATs[8], as well as the weight of evidence and type of evidence. The carcinogenic potency estimates are taken preferentially from the EPA's Integrated Risk Information System (IRIS). If no estimate is available from IRIS, the next minimum risk level is obtained from the U.S. Department of Health and Human Services' Agency for Toxic Substances and Disease Registry (ATSDR). After that, the California Office of Environmental Health and Hazard Assessment (OEHHA) toxicity values are used. Finally, some toxicity values are taken from those developed by the EPA's Office of Air Quality Planning and Standards (OAQPS) for the National Air Toxics Assessment (NATA). Brief summaries of the weight of evidence and the basis for the carcinogenicity finding are also included in Table 25 from both IRIS and the International Agency for Research on Cancer (IARC).

[8] There is inadequate evidence in humans for the carcinogenicity of acrolein.

Table 24. Carcinogenic potency of MSATs (ICF International, NCHRP 25-25 Task 18)

Pollutant	Unit Risk Factor (URF) and 1 per million risk concentration	Classification and Evidence
Acetaldehyde	IRIS: 2.2e-6 $(\mu g/m^3)^{-1}$ 0.45 $\mu g/m^3$	IRIS: B2 (Probable human carcinogen based on sufficient evidence of carcinogenicity in animals[9]) IARC: 2B (Possible human carcinogen based on sufficient evidence in animals and inadequate evidence in humans)
Arsenic	IRIS: 4.3e-3$(\mu g/m^3)^{-1}$ 2.3e-4 $\mu g/m^3$	IRIS: A (Known human carcinogen, based on sufficient evidence from human data[10]) IARC: 1 (causally associated with cancer in humans)
Benzene	IRIS: 2.2e-6 to 7.8e-6 $(\mu g/m^3)^{-1}$ 0.13 to 0.45 $\mu g/m^3$	IRIS: A (Known human carcinogen for all routes of exposure based upon convincing human evidence[11] as well as supporting evidence from animal studies) IARC: 1 (causally associated with cancer in humans)
1,3-Butadiene	IRIS: 3e-5 $(\mu g/m^3)^{-1}$ 0.033 $\mu g/m^3$	IRIS: A (Known human carcinogen based on sufficient evidence of carcinogenicity in animals[12]) IARC: 2A (Probable human carcinogen)
Chromium, hexavalent	IRIS: 1.2e-2 $(\mu g/m^3)^{-1}$ 8.3e-5 $\mu g/m^3$	IRIS: A (Known human carcinogen by the inhalation route, based on studies of occupational exposure[13]) IARC: 1 (causally associated with cancer in humans)

[9] Based on increased incidence of nasal tumors in male and female rats and laryngeal tumors in male and female hamsters after inhalation exposure.

[10] Increased lung cancer mortality was observed in multiple human populations exposed primarily through inhalation. Also, increased mortality from multiple internal organ cancers (liver, kidney, lung, and bladder).

[11] Leukemia

[12] Supported by the total weight of evidence provided by the following: (1) sufficient evidence from epidemiologic studies of the majority of U.S. workers occupationally exposed, i.e. increased lymphohematopoietic cancers and a dose-response relationship for leukemias in polymer workers, (2) sufficient evidence in laboratory animal studies, i.e., tumors at multiple sites in mice and rats by inhalation, and (3) numerous studies consistently demonstrating that 1,3-butadiene is metabolized into genotoxic metabolites by experimental animals and humans

[13] Lung cancer

Pollutant	Unit Risk Factor (URF) and 1 per million risk concentration	Classification and Evidence
Diesel particles	OEHHA: 3e-4 $(\mu g/m^3)^{-1}$ 0.0033 $\mu g/m^3$	IRIS: likely to be carcinogenic to humans by inhalation supported by the following: (1) strong but less than sufficient evidence for a causal association between diesel exhaust exposure and increased lung cancer risk among workers in varied occupations where exposure to diesel exhaust occurs; (2) extensive supporting data including the demonstrated mutagenic and/or chromosomal effects of diesel exhaust and its organic constituents, and knowledge of the known mutagenic and/or carcinogenic activity of a number of individual organic compounds that adhere to the particles and are present in the diesel exhaust gases CARB: Calculations using the two studies of Garshick *et al.* (1987a, 1988) and the reanalyses of the individual data of the Garshick *et al.* (1988) cohort study provide a number of estimates of unit risk. The relative risks reported in these studies were related to estimates of the actual exposures to estimate potential cancer risks. Because of uncertainties in the actual workplace exposures, OEHHA developed a variety of exposure scenarios to bracket the possible exposures of interest.
Formaldehyde	IRIS: 1.3E-5 $(\mu g/m^3)^{-1}$ 0.08 $\mu g/m^3$	IRIS: B1 (probable human carcinogen based on adequate evidence for carcinogenicity in animals[14] and limited evidence in humans[15]) IARC: 2A (Probable human carcinogen)

[14] An increased incidence of nasal squamous cell carcinomas was observed in long-term inhalation studies in rats and in mice. The classification is supported by in vitro genotoxicity data and formaldehyde's structural relationships to other carcinogenic aldehydes such as acetaldehyde.

[15] Nine studies were reviewed that showed statistically significant associations between site-specific respiratory neoplasms and exposure to formaldehyde or formaldehyde-containing products.

Pollutant	Unit Risk Factor (URF) and 1 per million risk concentration	Classification and Evidence
Lead compounds	OEHHA: 1.2e-5 $(\mu g/m^3)^{-1}$ 0.0833 $\mu g/m^3$	IRIS: B2 (probable human carcinogen, based on sufficient evidence of carcinogenicity in animals[16]) IARC: 2B (Possibly carcinogenic to humans)
Methyl-tert-butyl ether (MTBE)	OEHHA: 2.6e-7 $(\mu g/m^3)^{-1}$ 3.85 $\mu g/m^3$	IARC: 3 (Not classifiable for human carcinogenicity)
Naphthalene	OEHHA: 3.4e-5 $(\mu g/m^3)^{-1}$ 0.029 $\mu g/m^3$	IRIS: C (Possible human carcinogen by inhalation, based on suggestive animal evidence[17]) IARC: 2B (Possibly carcinogenic to humans)
Nickel compounds	USEPA OAQPS: 1.6e-4 $(\mu g/m^3)^{-1}$ 0.00625 $\mu g/m^3$ (Conservatively assumes that 65% of emitted nickel is insoluble, and that all insoluble nickel is crystalline)	USEPA: A (Known human carcinogen, based on (1) increased risks of lung and nasal cancer in humans exposed to nickel refinery dust, most of which was believed to have been nickel subsulfide; (2) increased tumor incidences in animals by several routes of administration in several animal species and strains; and (3) positive results in genotoxicity assays form the basis for this classification) IARC: 2B (possibly carcinogenic to humans)
Polycyclic organic matter (POM)	USEPA OAQPS: 5.5e-5 $(\mu g/m^3)^{-1}$ 0.018 $\mu g/m^3$ (Total POM assumed to have a carcinogenic potency equal to 5% of that for pure benzo[a]pyrene, CARB: 1.1e-3)	USEPA: benzo[a]pyrene B2 (Probable human carcinogen based on sufficient evidence of carcinogenicity in animals) IARC: benzo[a]pyrene 2A (probable human carcinogen based on sufficient evidence for carcinogenicity in animals[18] and limited evidence in humans[19])

[16] Ten rat bioassays and one mouse assay have shown statistically significant increases in renal tumors with dietary and subcutaneous exposure to several soluble lead salts

[17] Observations of benign respiratory tumors and one carcinoma in female mice only exposed to naphthalene by inhalation

[18] Several types of malignant tumors have been induced in rodents by benzo[a]pyrene.

Table 25 presents the Reference Concentrations (RfCs) for chronic exposure and the target systems. For pollutants that have both carcinogenic and non-carcinogenic impacts, the 1 per million carcinogenic risk occurs at a lower concentration than the non-carcinogenic chronic RfC.

Table 25. Non-carcinogenic health effects of MSATs (ICF International, NCHRP 25-25 Task 18)

Pollutant	Chronic Reference Concentration ($\mu g/m^3$)	Target Systems
Acetaldehyde	9	Respiratory
Acrolein	0.02	Respiratory
Arsenic compounds	0.03 (OEHHA)	Developmental
Benzene	30	Immunological
1,3-Butadiene	2	Reproductive
Chromium, hexavalent	0.1	Respiratory
Diesel particles	5	Respiratory
Ethylbenzene	1000	Developmental
Formaldehyde	9.8 (ASTDR)	Respiratory
n-Hexane	200	Neurological, respiratory
Lead compounds	1.5 (USEPA OAQPS)	Developmental
Manganese compounds	0.05	Neurological
Mercury compounds	0.09 (OEHHA)	Neurological
Methyl-tert-butyl ether (MTBE)	3000	Liver, kidney, ocular
Naphthalene	3	Respiratory
Nickel compounds	0.065 (OEHHA)	Respiratory, immunological
Styrene	1000	Neurological
Toluene	400	Respiratory, neurological
Xylene	100	Neurological

Current Range in Concentrations

The most current assessment of nationwide MSAT concentrations is available through EPA's National Air Toxic Assessment (NATA) national scale assessment (http://www.epa.gov/ttn/atw/nata1999/ tables.html). This assessment modeled 1999 outdoor air concentrations at county level resolution. For those MSATs not modeled as part of NATA, observed 2005 concentrations from the EPA's AirData Reports

[19] Epidemiological evidence for human cancer from exposure to benzo[a]pyrene is found in studies of roofers, tar distillers, patent-fuel workers, and creosote-exposed brickmakers.

(http://www.epa.gov/air/data/geosel.html) were used to develop estimates of background level concentrations[20]. Figure 1 through Figure 38 present distributions of observed (2005) and modeled (1999) outdoor concentrations. Toxicity levels are also included in the figures (1 per million, 1 per 100,000 risk) for those pollutants with carcinogenic risk to provide perspective on the concentrations. For those pollutants with only non-cancer endpoints the RfC is provided. This information may be used in an analysis to identify current background level concentrations for a particular location.

The distributions of observed concentrations are composed of varied numbers of samples, ranging from 29 to 388. No observations were identified for diesel particles (diesel particles are difficult to distinguish from particles emitted by several other sources, and therefore cannot be directly characterized with current monitoring technology) or polycyclic organic matter (POM), both of which are complex mixtures of several compounds. Source receptor or apportionment studies[21] have identified annual average diesel PM concentrations ranging from 0.4 to 5.0 $\mu g/m^3$, depending upon the locations and source apportionment model (Frazer, et al., 2003; Kim et al., 2003; Kim and Hopke, 2004; Lewis et al., 2003; Manchester-Neesvig and Schauer, 2003; Maykut et al., 2003; Zheng et al., 2002). In the case of particle-bound arsenic, lead, manganese, and nickel, the observations are stratified by particle size: i.e., total suspended particles (TSP), particles with aerodynamic diameters of 10 microns or less (PM_{10}), or particles with aerodynamic diameters of 2.5 microns or less ($PM_{2.5}$).

[20] Note: One year of air monitoring data may be subject to significant meteorological variability.

[21] Receptor models are mathematical procedures for identifying and quantifying the sources of ambient air pollutants at a site (receptor), primarily on the basis of the concentrations of source-tracing chemical species measured at the receptor and generally without need of emissions inventories and meteorological data, the simpler approach (chemical mass balance) requires detailed information on the emission source chemical profiles of potential contributing sources and the corresponding chemical data from measurements made at a single ambient air sample. The more complex approach requires (multivariate approach) chemical measurements from hundreds of ambient air samples which are mathematically manipulated simultaneously, but without the need for the emission source chemical profiles; instead, they are generated from the ambient data themselves.

The 1999 modeled distributions are presented for all 66,300 U.S. Census tracts (labeled "total"), as well as for "urban" and "rural" stratifications (53,716 and 12,584 tracts, respectively). For several pollutants, the NATA study compared their model predictions to observed concentration at the same location and time period (i.e., acetaldehyde, benzene, formaldehyde, lead, manganese, and nickel). For those pollutants the figures below include the annual average model-to-monitor ratio found in the NATA study. In addition, the observed and modeled distributions for each pollutant are presented on the same page for comparison on an aggregate level. When comparing these distributions, the following points should be kept in mind:

- The observed values were measured in 2005 while the modeled values are estimates produced in 1999.
- The observed values represent distribution of the annual averages across multiple sites, parallel to the NATA results.
- The observed values in some cases come from small data sets, and in any case are neither geographically exhaustive (in contrast to the predictions) nor a probability sample. Rather, they are more likely to represent locations where high or moderate concentrations are expected.
- The modeled values for the particle-bound pollutants do not include re-entrained road dust or soil dust. Neglecting this contribution to concentrations would tend to lead to under-prediction.
- The modeled values for most of the pollutants (acrolein, arsenic, chromium VI, ethylbenzene, *n*-hexane, lead, manganese, MTBE, naphthalene, nickel, POM, styrene, and toluene) do not include background concentration estimates, which would reflect

natural sources or sources located farther than 50 km from the tract. Neglecting this contribution to concentrations would tend to lead to under-prediction.

Thus, even if the modeled values were perfectly accurate estimates, the observed and modeled distributions would not necessarily be expected to match exactly. In most cases the observed distributions are expected to be higher than the modeled distributions, although the modeled distributions might include some extreme values not covered by the smaller set of observed samples.

Another issue in the comparison of observed and modeled particle-bound pollutants is the question of what size fraction of observed concentrations is the proper basis of comparison. To the extent that emissions are combustion-related, they are probably composed primarily of PM_{10} and/or $PM_{2.5}$. Note that the model-to-monitor comparisons from the NATA study were based primarily on observed TSP.

Acetaldehyde

Figure 1 and Figure 2 present the observed and modeled concentration distributions of acetaldehyde, respectively. The modeled values include a component of acetaldehyde formed in the atmosphere from other pollutants (i.e., secondary formation), as well as an estimate of the background concentration. As noted in Figure 2, the NATA performance evaluation indicated that the modeled concentrations agreed well with the observed values in the same locations.

Both distributions exceed the 1 per 1,000,000 cancer risk level throughout. The distribution of modeled concentrations shows that relatively few locations have concentrations that exceed the 1 per 100,000 risk level: 212 Census tracts or 0.3%.

Figure 1. Observed Annual Average Concentrations of Acetaldehyde (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

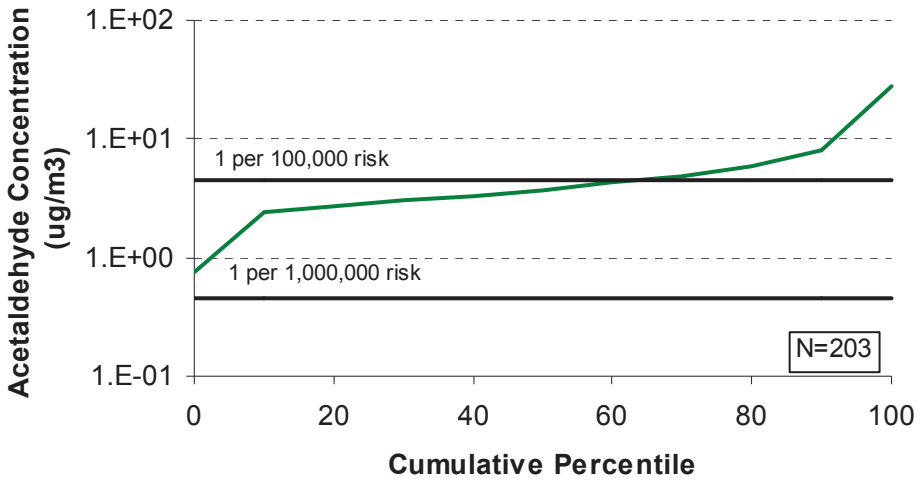
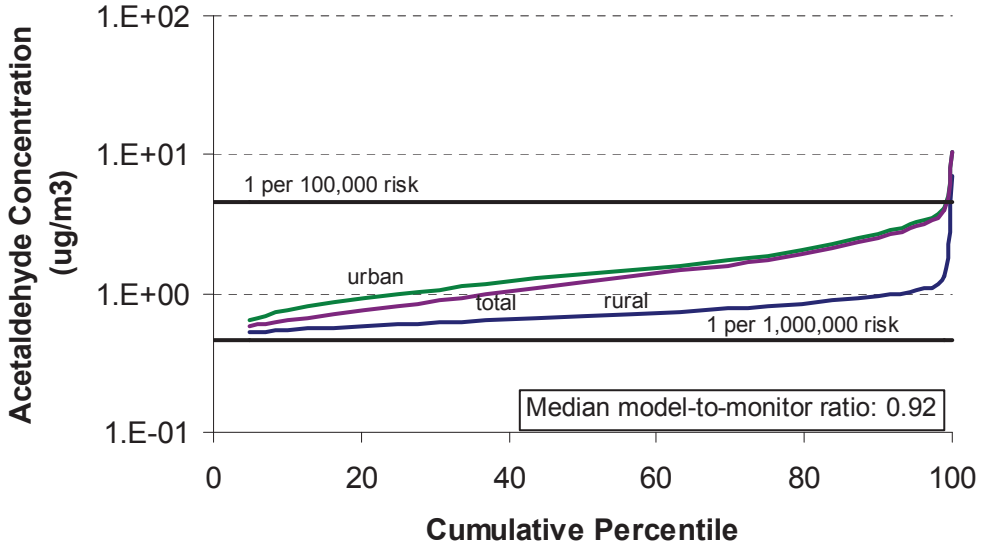


Figure 2. 1999 NATA Annual Average Concentration Estimates of Acetaldehyde (ICF International, NCHRP 25-25 Task 18)



Acrolein

Figure 3 and Figure 4 present the observed[22] and modeled concentration distributions of acrolein, respectively. As noted above, the modeled values do not include an estimate of the background concentration.

The observed concentration distribution exceeds the RfC (0.02 μg/m3) throughout. The modeled concentration distributions exceed the RfC for about 95% of urban tracts and about half of rural tracts.

[22] Note: The method used to measure acrolein is undergoing reevaluation it's likely that many of the sites used dinitropheynylhydrazine (DNPH)-coated cartridges. If so, they are likely an underestimate.

Figure 3. Observed Annual Average Concentrations of Acrolein (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

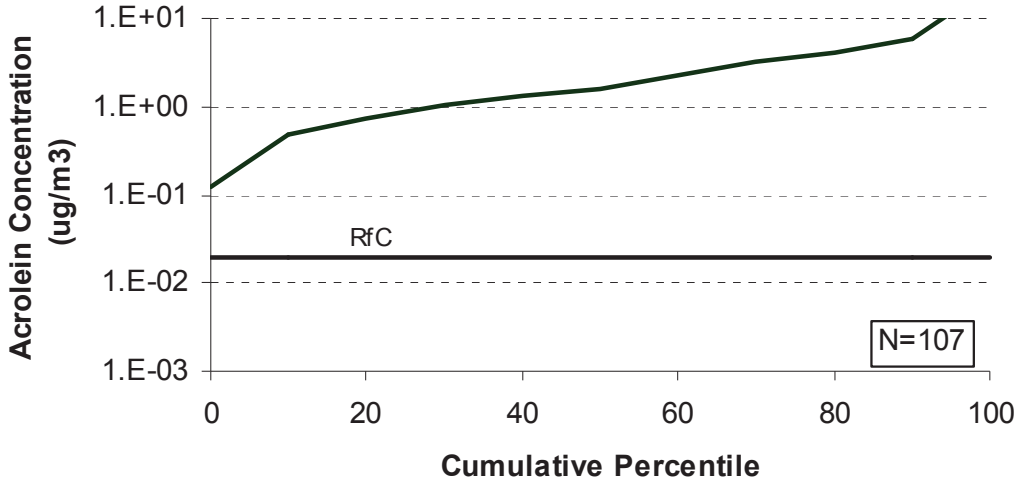
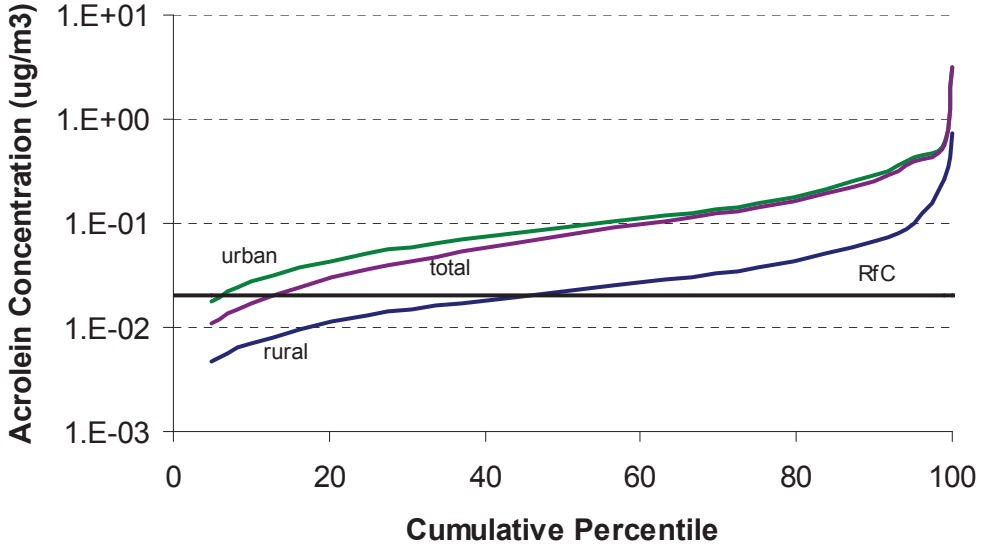


Figure 4. 1999 NATA Annual Average Concentration Estimates of Acrolein (ICF International, NCHRP 25-25 Task 18)



Arsenic

Figure 5 and Figure 6 present the observed and modeled concentration distributions of arsenic, respectively. The observed concentrations are stratified by particle size. As noted above, the modeled values do not include an estimate of the contribution from background concentrations or an estimate of the contribution from re-entrained road dust.

All the observed distributions exceed 1 per million cancer risk throughout. About 75% of the TSP observations, 20% of the PM10 observations, and 10% of the PM2.5 observations exceed the 1 per 100,000 cancer risk concentration. About 25% of the TSP observations exceed the 1 per 10,000 cancer risk concentration.

More than 20% of the modeled urban concentrations and almost 5% of the modeled rural concentrations exceed the 1 per 1,000,000 cancer risk concentration. About 1% of the modeled urban concentrations and 41 of the modeled rural concentrations exceed the 1 per 100,000 cancer risk concentration. Twenty-six modeled urban concentrations exceed the 1 per 10,000 cancer risk level.

Figure 5. Observed Annual Average Concentrations of Arsenic Compounds (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

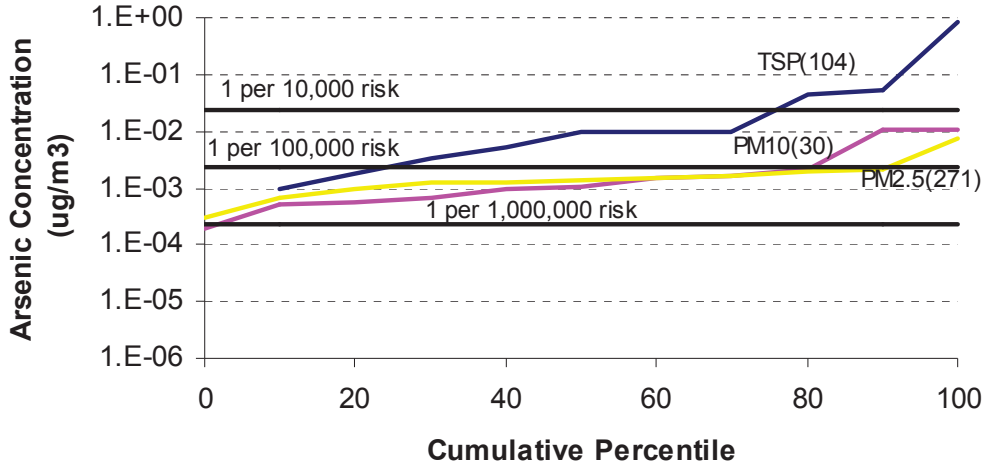
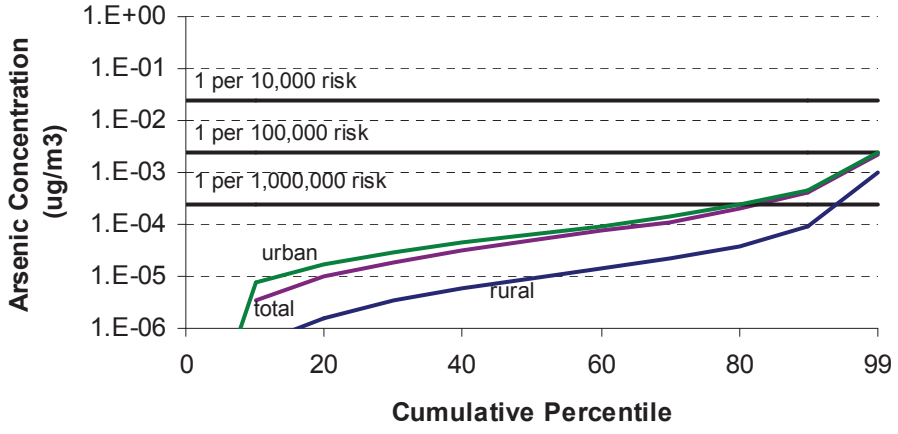


Figure 6. 1999 NATA Annual Average Concentration Estimates of Arsenic Compounds (ICF International, NCHRP 25-25 Task 18)



Benzene

Figure 7 and Figure 8 present the observed and modeled concentration distributions of benzene, respectively. The modeled values include an estimate of the background concentration. As noted in Figure 8, the NATA performance evaluation indicated that the modeled concentrations agreed well with the observed values in the same locations.

Both distributions exceed the 1 per 1,000,000 cancer risk level throughout. The upper segment (approximately 40%) of the observed distribution exceeds the 1 per 100,000 cancer risk level. About 55% of urban tracts but only about 3% of the rural tracts modeled were found to exceed the 1 per 100,000 cancer risk level.

Figure 7. Observed Annual Average Concentrations of Benzene (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

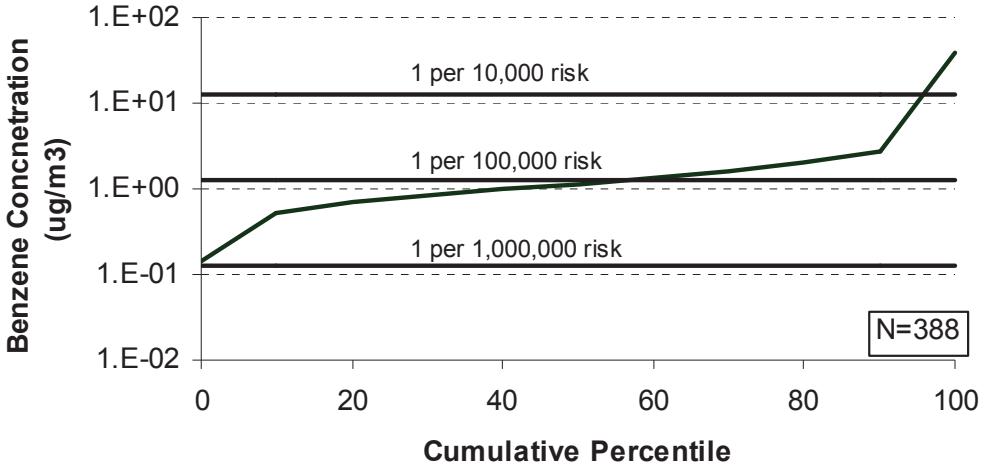
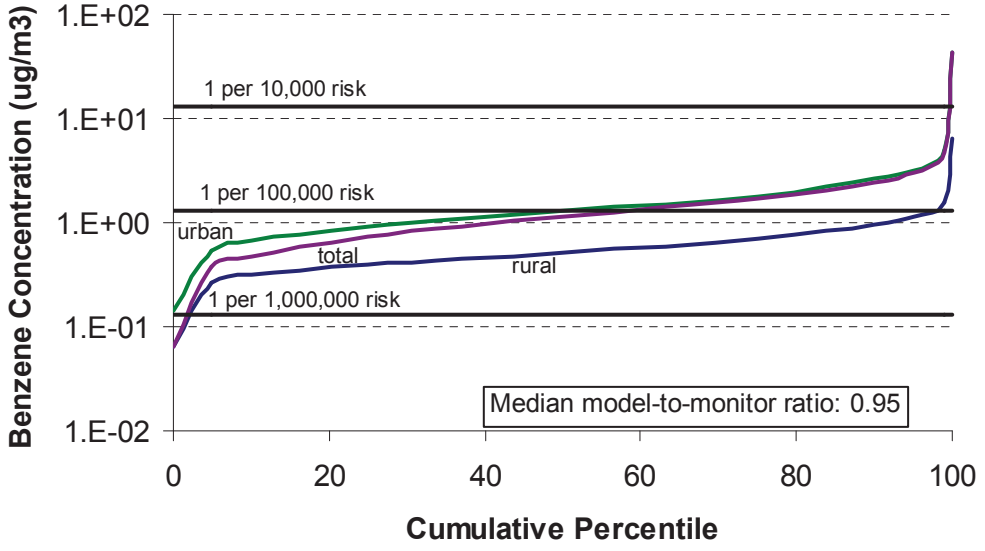


Figure 8. 1999 NATA Annual Average Concentration Estimates of Benzene (ICF International, NCHRP 25-25 Task 18)



1,3-Butadiene

Figure 9 and Figure 10 present the observed and modeled concentration distributions of 1,3-butadiene, respectively. The modeled values include an estimate of the background concentration.

The observed distribution shows exceedances of the 1 per 1,000,000 cancer risk level almost throughout, and exceedances of the 1 per 100,000 cancer risk level for approximately 15% of samples. The distribution of NATA predictions shows exceedances of the 1 per 1,000,000 cancer risk level for more than 90% of urban tracts and more than 20% of rural tracts, and exceedances of the 1 per 100,000 cancer risk level for about 10% of urban tracts and 51 rural tracts.

Figure 9. Observed Annual Average Concentrations of 1,3-Butadiene (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

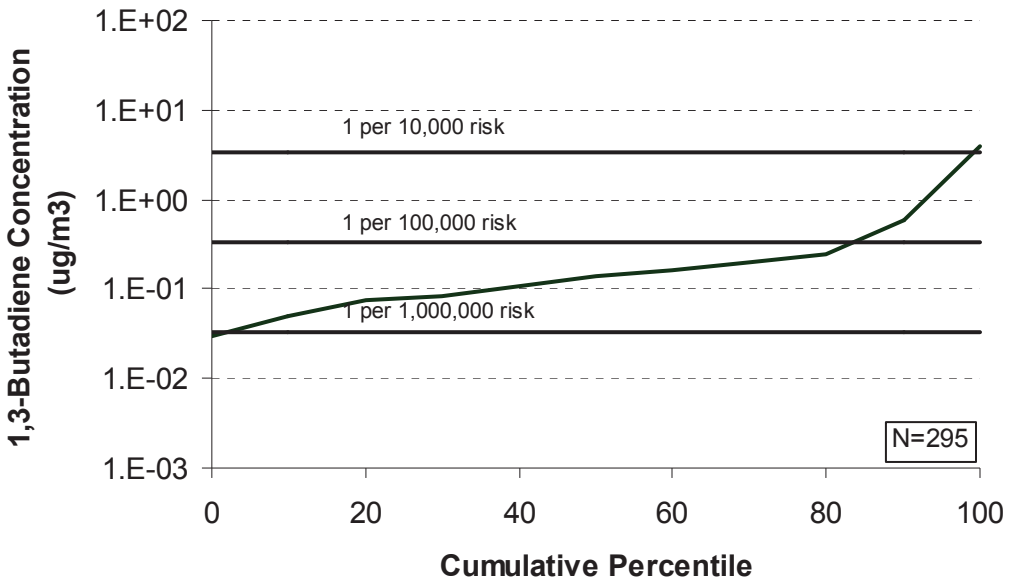
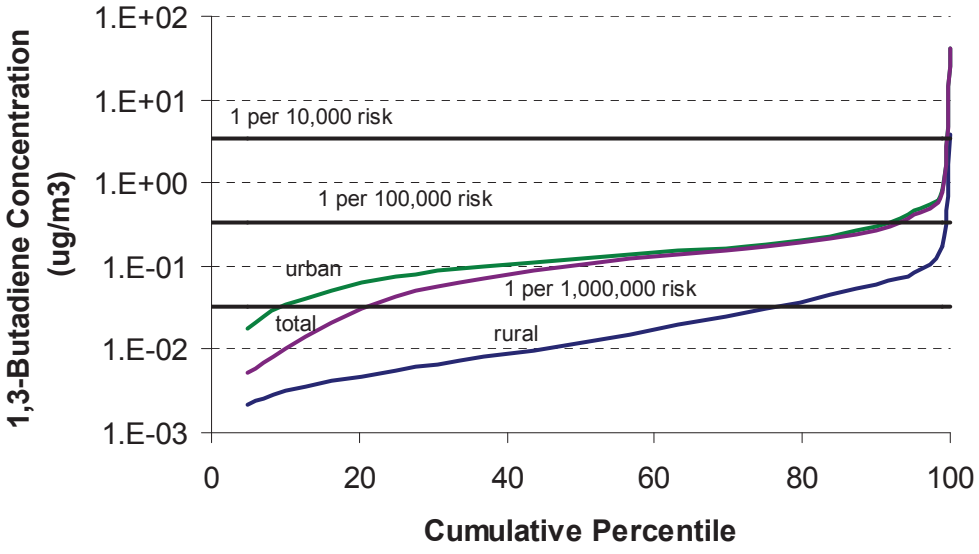


Figure 10. 1999 NATA Annual Average Concentration Estimates of 1,3-Butadiene (ICF International, NCHRP 25-25 Task 18)



Chromium, Hexavalent

Figure 11 and Figure 12 present the observed and modeled concentration distributions of hexavalent chromium, respectively. As noted above, the predictions do not include an estimate of background concentration contributions or an estimate of the contribution from re-entrained road dust. The observed distribution shows exceedances of the 1 per 1,000,000 cancer risk level for approximately 28% of the samples, and exceedances of the 1 per 100,000 cancer risk level for approximately 25% of samples. The distribution of NATA predictions shows exceedances of the 1 per 1,000,000 cancer risk level for more than 55% of urban tracts and about 17% of rural tracts, and exceedances of the 1 per 100,000 cancer risk level for more than 7% of urban tracts and almost 3% of rural tracts. The extreme upper end of the distribution includes 220 urban and 43 rural exceedances of the 1 per 1,000 cancer risk level.

Figure 11. Observed Annual Average Concentrations of Hexavalent Chromium (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

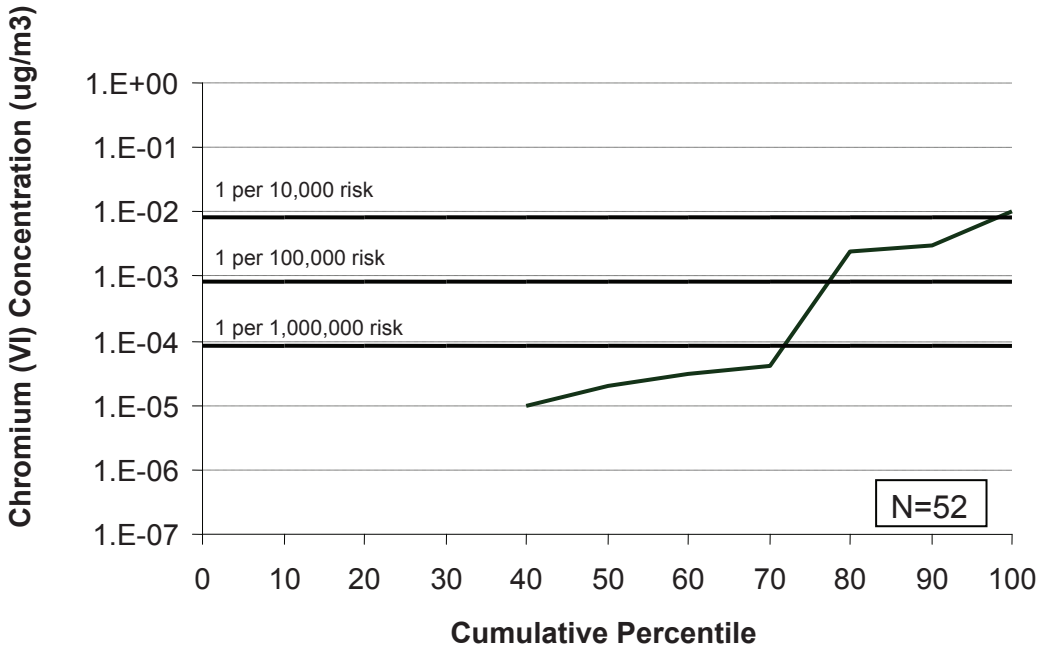
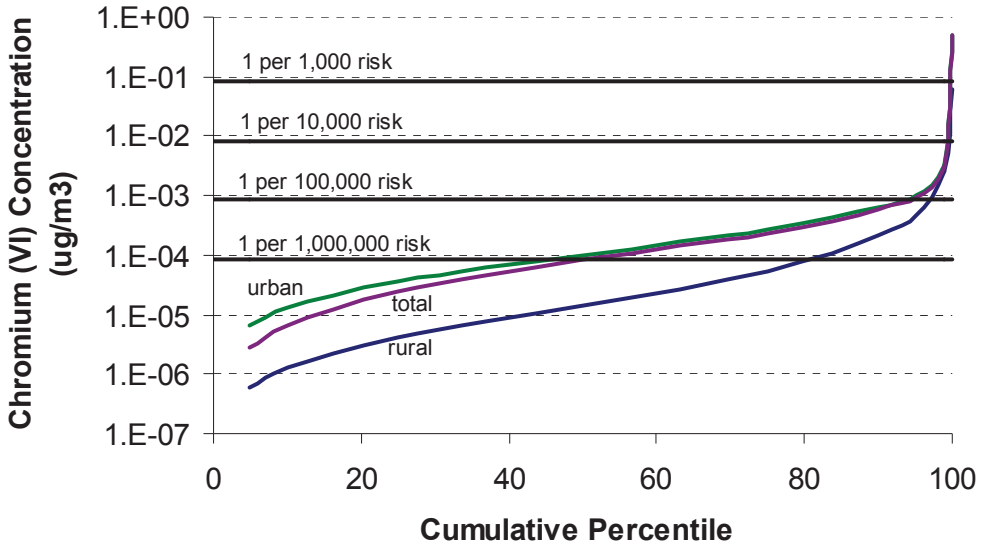


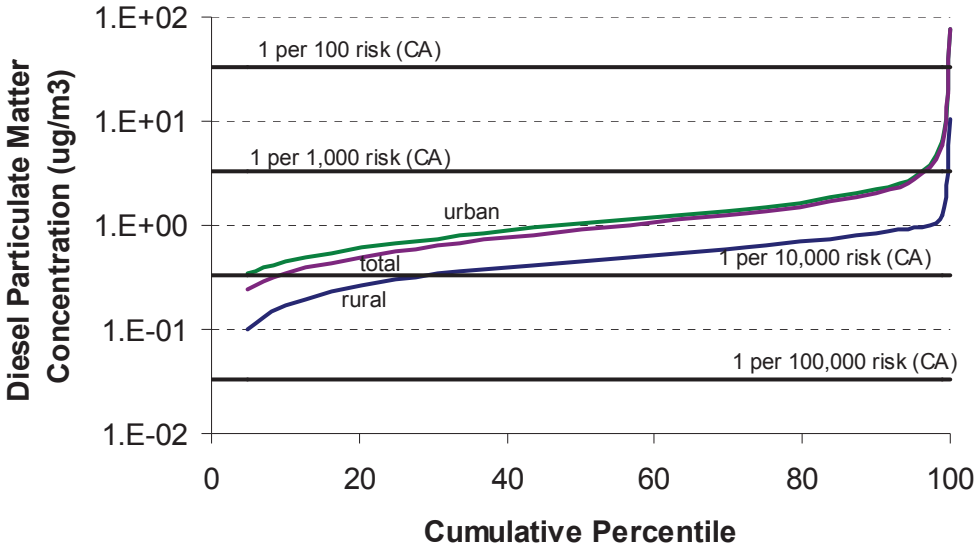
Figure 12. 1999 NATA Annual Average Concentration Estimates of Hexavalent Chromium (ICF International, NCHRP 25-25 Task 18)



Diesel Particles

Figure 13 presents the modeled concentration distribution of diesel particles for 1999. As noted above, no observed concentrations are available. The modeled values include background concentration contribution estimates from long-range transport, but do not include re-entrained road dust. The distribution shows that almost all tracts exceed the 1 per 100,000 cancer risk value based on California's OEHHA risk value (EPA does not currently have a risk value). About 95% of modeled urban concentrations and about 67% of modeled rural concentrations exceed the 1 per 10,000 cancer risk level. About 5% of modeled urban concentrations and 10 modeled rural concentrations exceed the 1 per 1,000 cancer risk level. Eight modeled urban concentrations exceed the 1 per 100 cancer risk level.

Figure 13: 1999 NATA annual average concentration estimates of Diesel Particulate Matter (ICF International, NCHRP 25-25 Task 18)



Ethylbenzene

Figure 14 and Figure 15 present the observed and modeled concentration distributions of ethylbenzene, respectively. As noted above, the modeled concentrations do not include an estimate of background concentrations. All measured and modeled concentrations are well below the RfC.

Figure 14. Observed Annual Average Concentrations of Ethylbenzene (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

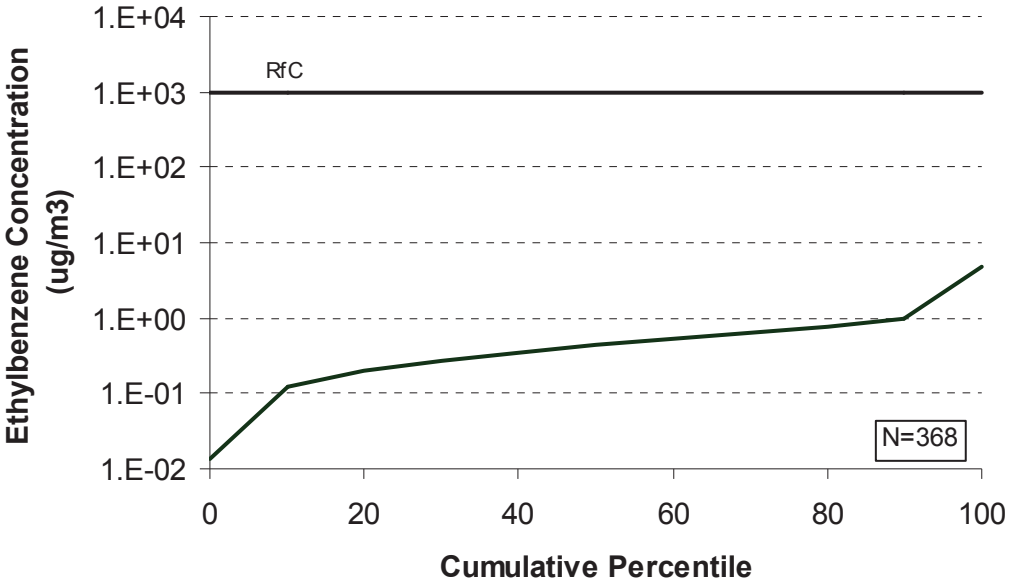
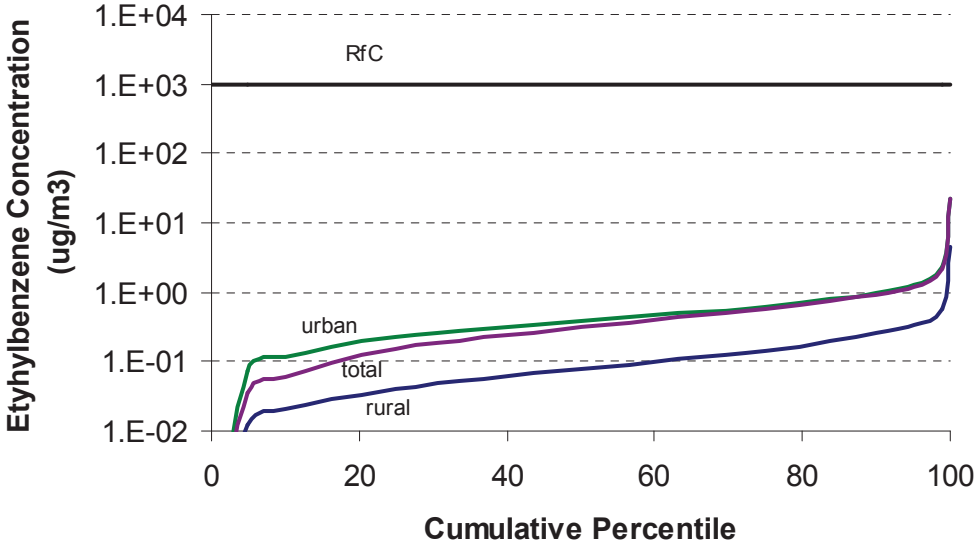


Figure 15. 1999 NATA Annual Average Concentration Estimates of Ethylbenzene (ICF International, NCHRP 25-25 Task 18)



Formaldehyde

Figure 16 and Figure 17 present the observed and modeled concentration distributions of formaldehyde, respectively. The modeled values include a component of formaldehyde formed in the atmosphere from other pollutants (i.e., secondary formation), as well as an estimate of the background concentration from natural sources and long-range transport. As noted in Figure 17, the NATA performance evaluation indicated that the modeled concentrations were generally somewhat lower than the observed values in the same locations. The underestimate may be due to missing emission sources, underestimates of secondary components, or underestimates of background concentrations.

The observed distribution shows exceedances of the RfC for about 10% of samples. (As noted above the RfC is lower than the 1 per million cancer risk concentration.) The distribution of predictions shows that relatively few locations have concentrations that exceed the reference concentrations: 54 census tracts or 0.08%.

Figure 16. Observed Annual Average Concentrations of Formaldehyde (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

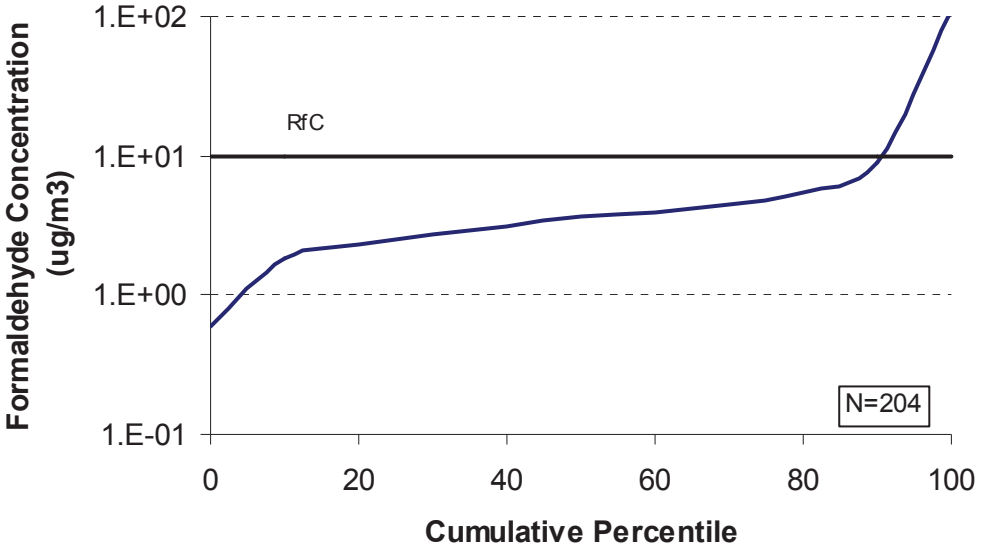
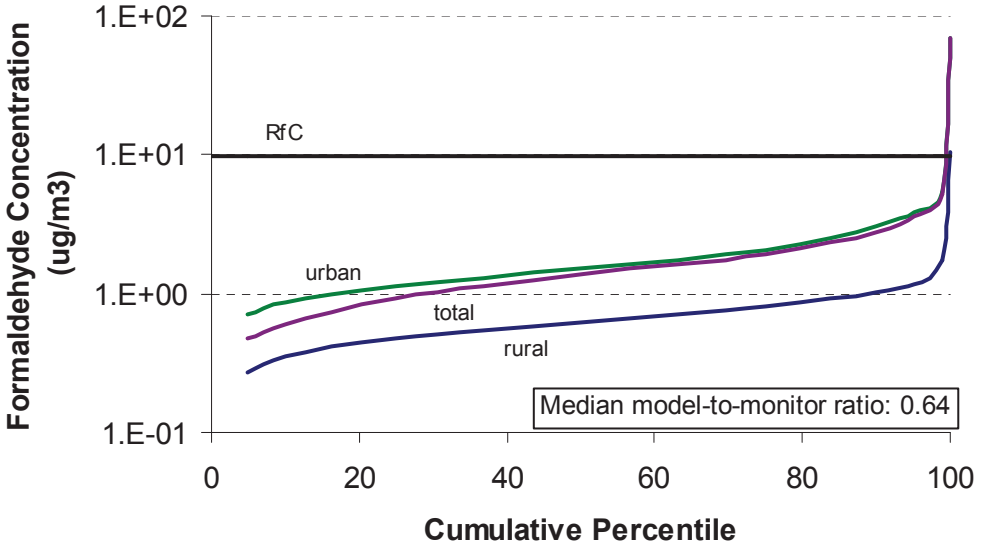


Figure 17. 1999 NATA Annual Average Concentration Estimates of Formaldehyde (ICF International, NCHRP 25-25 Task 18)



n-Hexane

Figure 18 and Figure 19 present the observed and modeled concentration distributions of n-Hexane, respectively. As noted above, the modeled concentrations do not include an estimate of background concentrations. All measured and modeled concentrations are well below the RfC.

Figure 18. Observed Annual Average Concentrations of n-Hexane (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

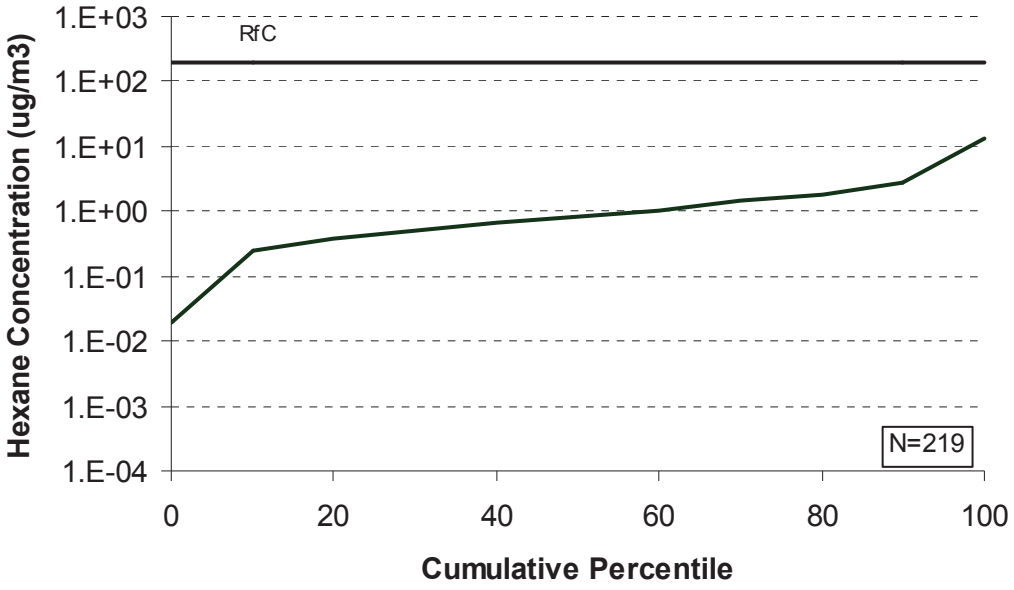
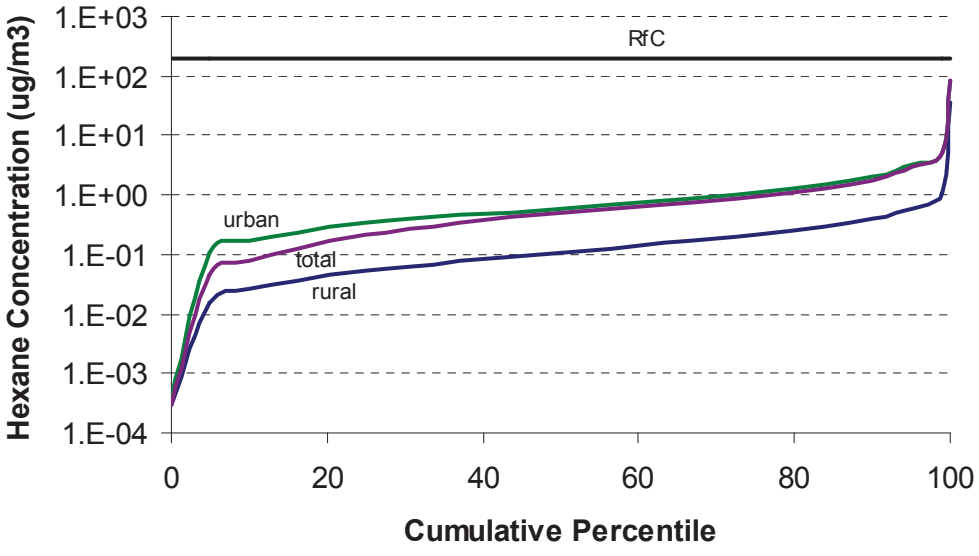


Figure 19. 1999 NATA Annual Average Concentration Estimates of n-Hexane (ICF International, NCHRP 25-25 Task 18)



Lead

Figure 20 and Figure 21 present the observed and modeled concentration distributions of lead, respectively. The observed concentrations are stratified by particle size. As noted above, the modeled values do not include an estimate of the contribution from background concentrations or an estimate of the contribution from re-entrained road dust.

The observed distributions of PM10-bound and PM2.5-bound lead are below the 1 per million cancer risk and RfC throughout. But about 25% of the TSP-bound lead observations exceed the 1 per million cancer risk. Two of the observations of TSP-bound lead (less than 1%) exceed the RfC. These two observations, as well as several others in the upper portion of the observed distribution, were made in the vicinity of the single remaining U.S. primary lead smelter.

About 10% of the modeled urban concentrations and about 5% of the modeled rural concentrations exceed the 1 per 1,000,000 cancer risk concentration. Only two urban tracts are modeled to have lead concentrations exceeding the RfC.

Figure 20. Observed Annual Average Concentrations of Lead Compounds (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

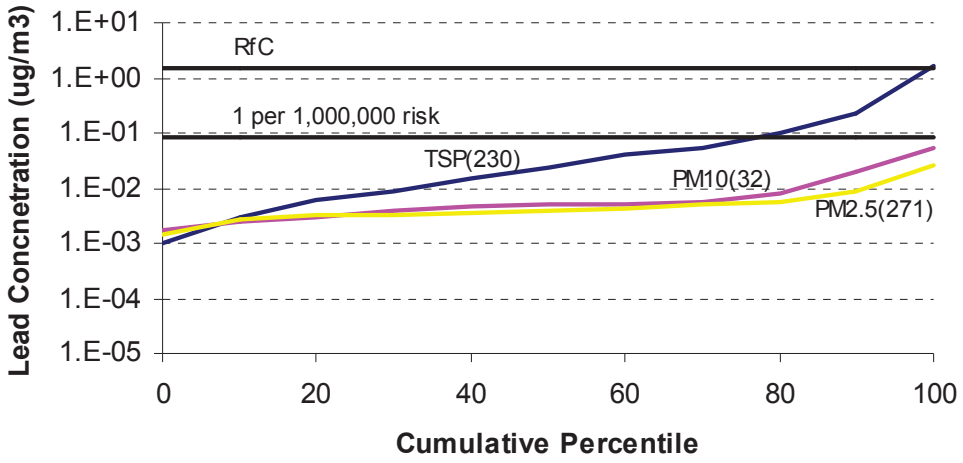
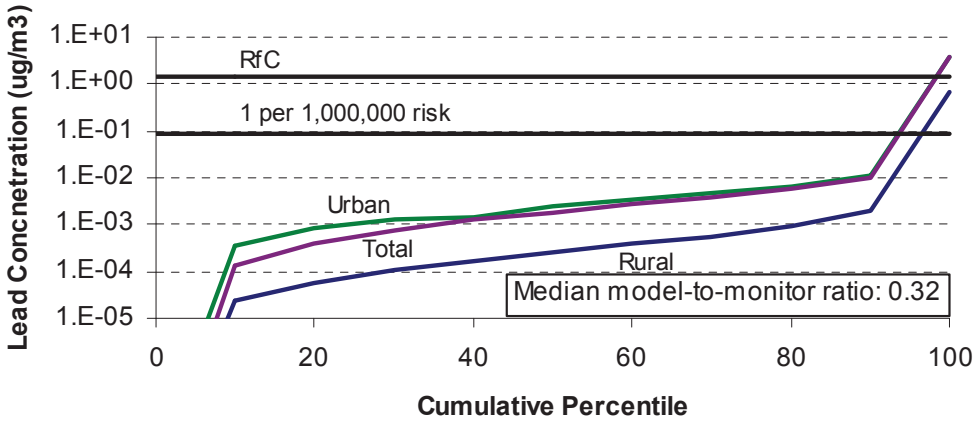


Figure 21. 1999 NATA Annual Average Concentration Estimates of Lead Compounds (ICF International, NCHRP 25-25 Task 18)



Manganese

Figure 22 and Figure 23 present the observed and modeled concentration distributions of manganese, respectively. The observed concentrations are stratified by particle size. As noted above, the modeled values do not include an estimate of the contribution from background concentrations or an estimate of the contribution from re-entrained road dust. As noted in Figure 23, the NATA performance evaluation indicated that the modeled concentrations were generally somewhat lower than the observed values in the same locations. This underestimate may be due the omission of background concentrations and re-entrained road dust contributions, other missing emission sources, and/or comparison of predictions to observed concentrations of a different size fraction.

About 25% of the TSP-bound manganese observations exceed the RfC, but only one observed PM10-bound manganese concentration (about 3%) and only one observed PM2.5-bound manganese concentration (less than 1%) exceed the RfC.

Figure 22. Observed Annual Average Concentrations of Manganese Compounds (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

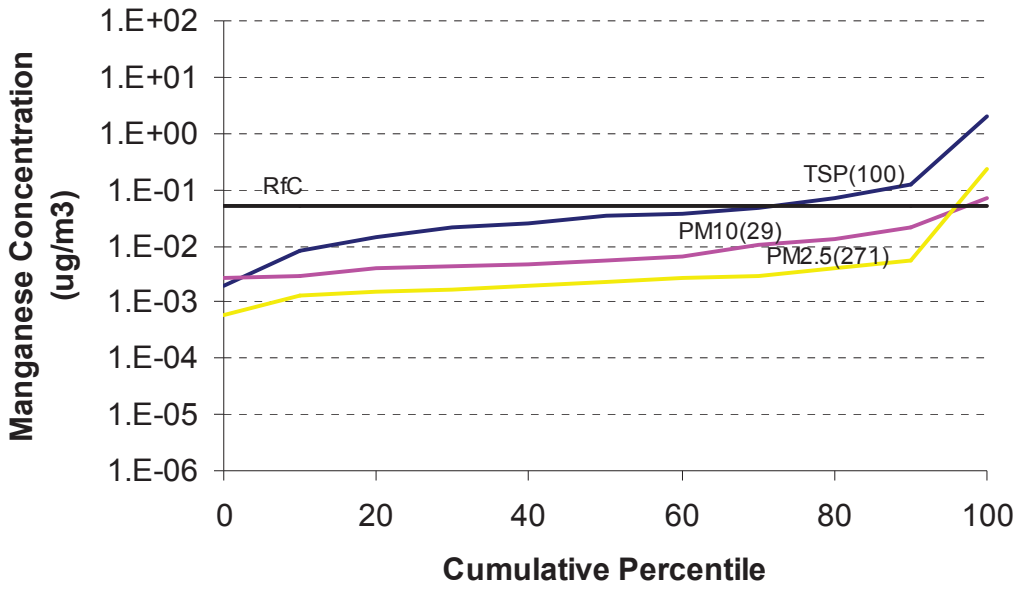
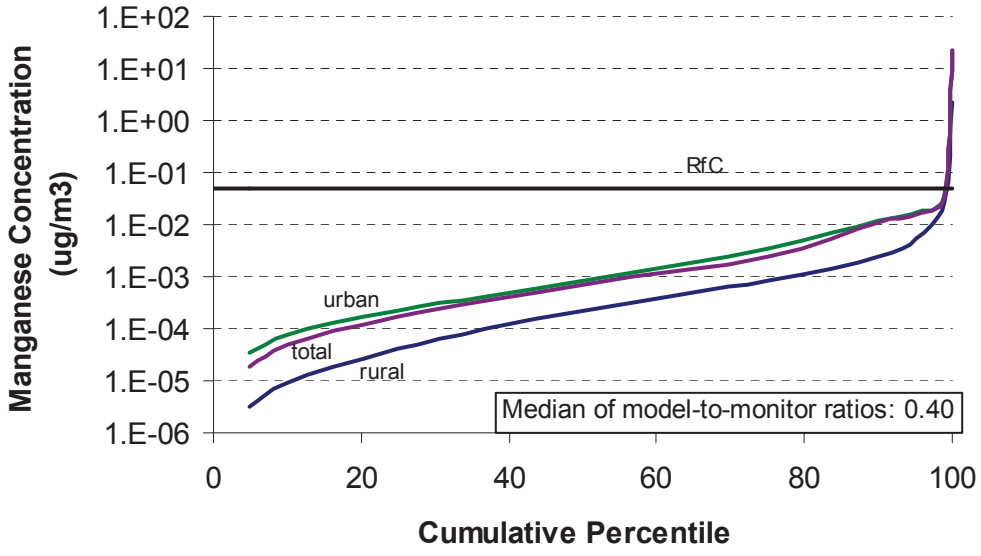


Figure 23. 1999 NATA Annual Average Concentration Estimates of Manganese Compounds (ICF International, NCHRP 25-25 Task 18)



Mercury

Figure 24 and Figure 25 present the observed and modeled concentration distributions of mercury, respectively. The observed concentrations are all $PM_{2.5}$-bound (few TSP-bound or PM_{10}-bound observations were identified.) with most, if not all measurements, made based on x-ray fluorescence (XRF). The modeled values include an estimated background concentration contribution, but not a contribution from re-entrained road dust.

The observed concentration distribution is below the RfC throughout, and only one modeled concentration exceeds the RfC. Note that for about 75% of the modeled concentrations more than 90% of the concentration estimate comes from the background concentration assumption.

Figure 24. Observed Annual Average Concentrations of Mercury Compounds (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

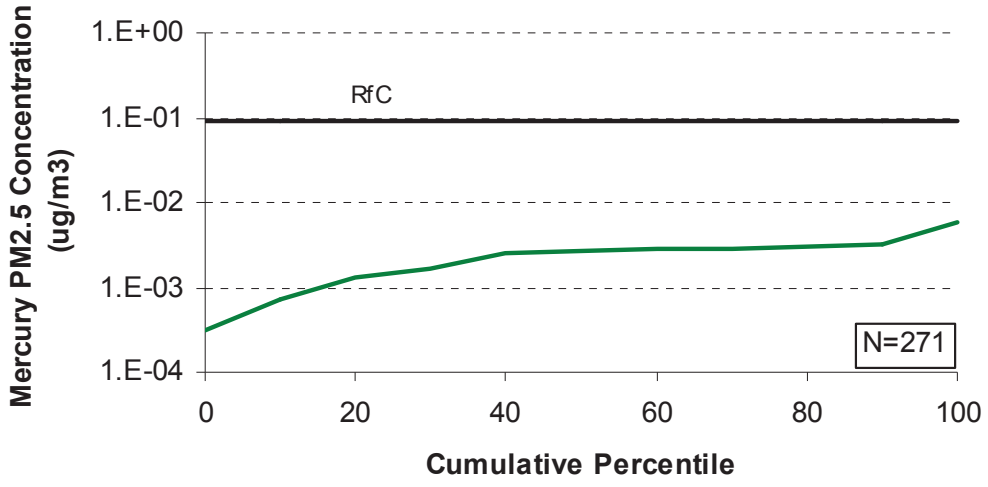
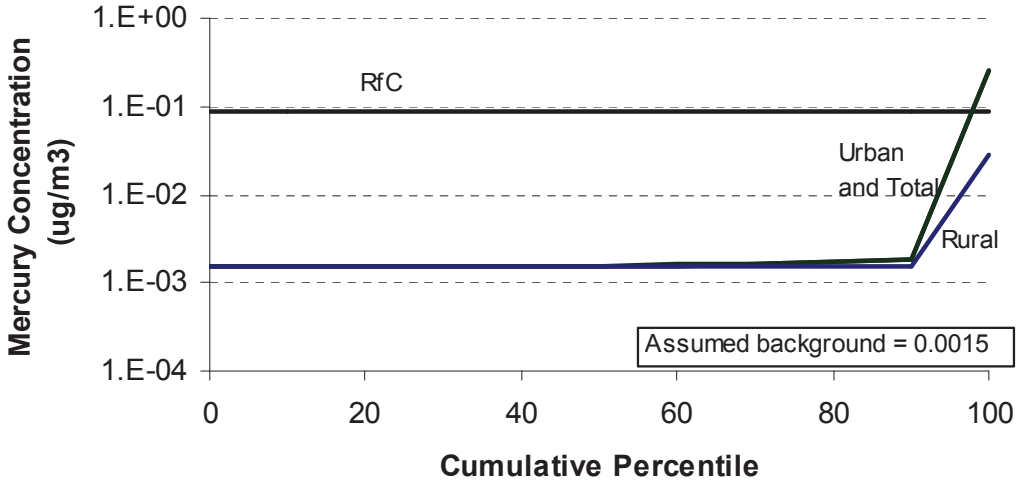


Figure 25. 1999 NATA Annual Average Concentration Estimates of Mercury Compounds (ICF International, NCHRP 25-25 Task 18)



Methyl-Tert-Butyl Ether (MTBE)

Figure 26 and Figure 27 present the observed and modeled concentration distributions of MTBE, respectively. The modeled concentrations do not include an estimated background concentration contribution.

Approximately 3% of the observed concentrations exceed the 1 per million cancer risk level. About 6% of the urban modeled concentrations, but only two rural modeled concentrations exceed the 1 per million cancer risk level.

Figure 26. Observed Annual Average Concentrations of Methyl-Tert-Butyl Ether (MTBE) (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

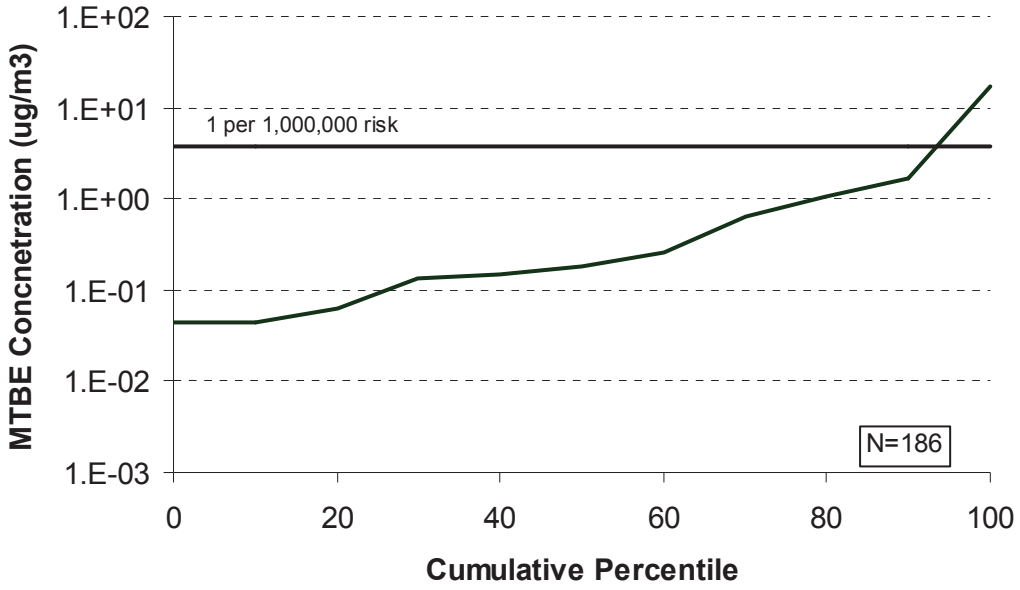
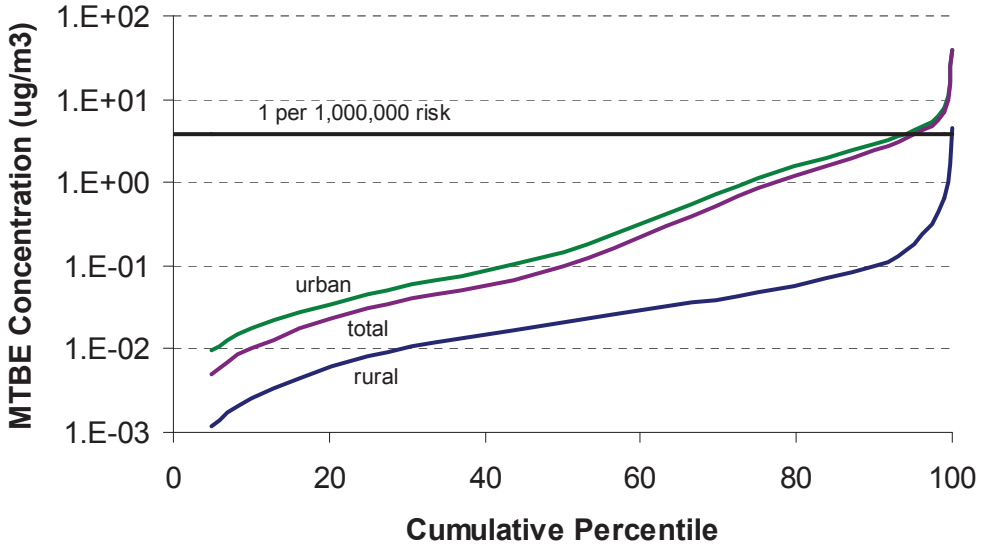


Figure 27. 1999 NATA Annual Average Concentration Estimates of Methyl-Tert-Butyl Ether (MTBE) (ICF International, NCHRP 25-25 Task 18)



Naphthalene

Figure 28 and Figure 29 present the observed and modeled concentration distributions of naphthalene, respectively. As noted above, the naphthalene predictions do not include an estimate of the contribution from background concentrations.

More the 85% of the observed naphthalene concentrations exceed the 1 per million cancer risk level, and more than 55% exceed 1 per 100,000 cancer risk level.

More than 75% of modeled urban concentrations and about 12% of modeled rural concentrations exceed the 1 per million cancer risk level. Almost 4% of modeled urban concentrations, but less than 1% of modeled rural concentrations (20 tracts), exceed the 1 per 100,000 cancer risk level.

Figure 28. Observed Annual Average Concentrations of Naphthalene (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

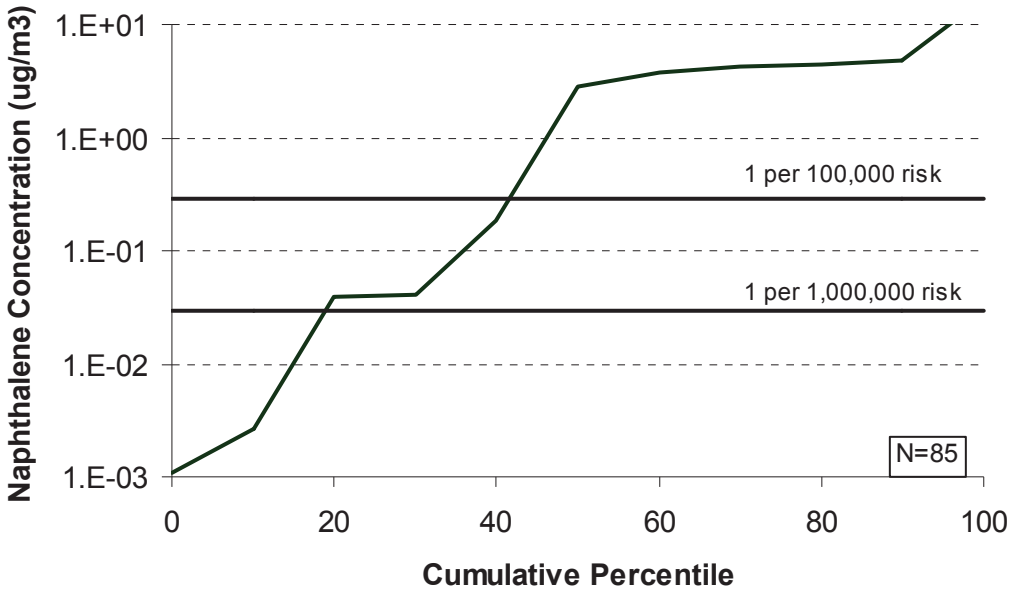
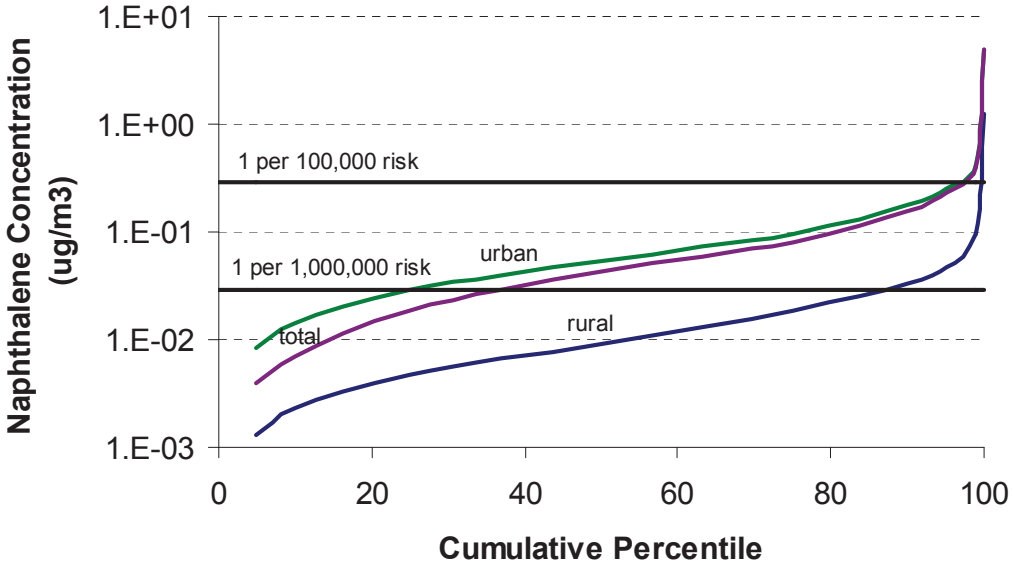


Figure 29. 1999 NATA Annual Average Concentration Estimates of Naphthalene (ICF International, NCHRP 25-25 Task 18)



Nickel

Figure 30 and Figure 31 present the observed and modeled concentration distributions of nickel, respectively. The observed concentrations are stratified by particle size. As noted above, the modeled values do not include an estimate of the contribution from background concentrations or an estimate of the contribution from re-entrained road dust. As noted in Figure 31, the NATA performance evaluation indicated that the modeled concentrations were generally somewhat lower than the observed values in the same locations. This underestimate may be due to the omission of background concentrations and re-entrained road dust contributions, other missing emission sources, and/or comparison of predictions to observed concentrations of a different size fraction.

About 38% of the observed TSP-bound nickel concentrations exceed the 1 per million cancer risk concentration, and about 8% exceed the 1 per 100,000 cancer risk level. About 3% of the observed PM10-bound and about 3% of observed PM2.5-bound nickel concentrations exceed the 1 per million cancer risk.

More than 6% of modeled urban concentrations and about 1.5% of modeled rural concentrations exceed the 1 per million cancer risk level. Less than 1% of modeled urban concentrations (239 tracts) and only seven modeled rural concentrations exceed the 1 per 100,000 cancer risk level.

Figure 30. Observed Annual Average Concentrations of Nickel Compounds (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

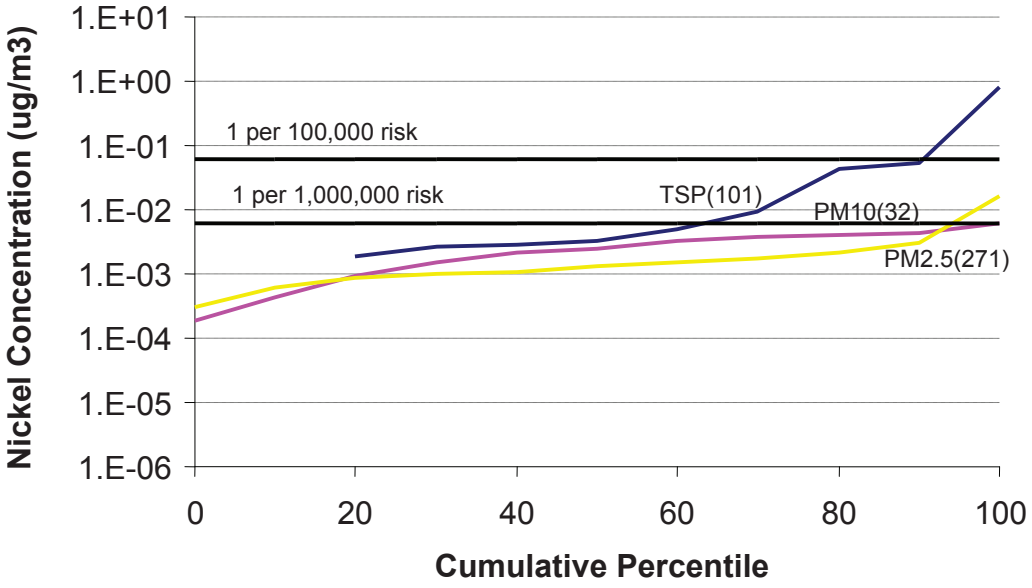
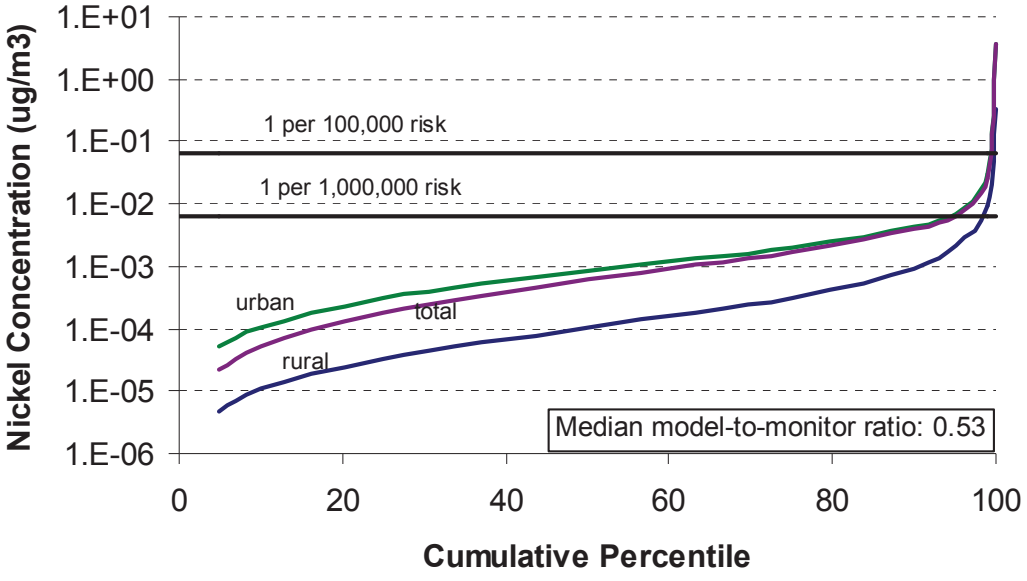


Figure 31. 1999 NATA Annual Average Concentration Estimates of Nickel Compounds (ICF International, NCHRP 25-25 Task 18)

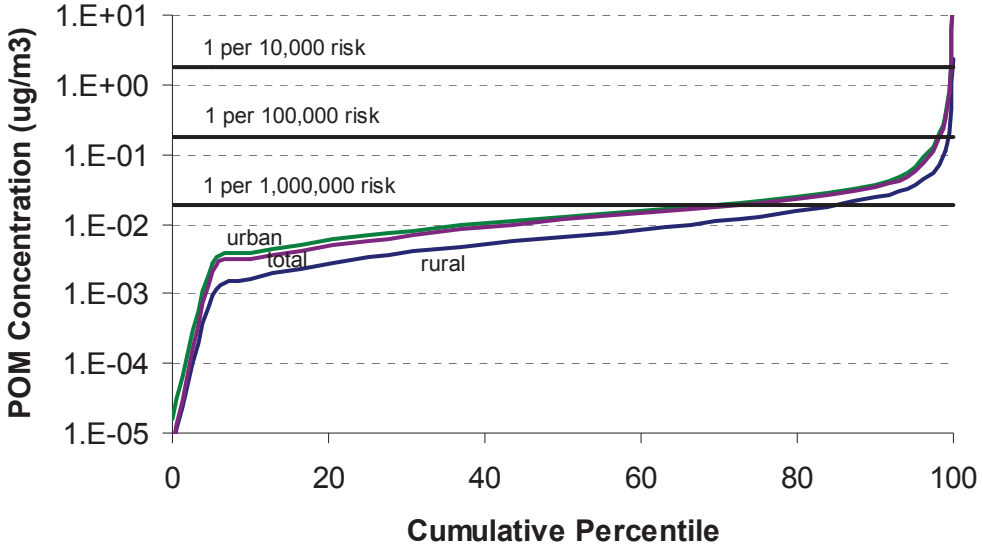


Polycyclic Organic Matter (POM)

Figure 32 presents the modeled concentration distributions of POM in 1999. As noted above, no observed concentrations were identified. The modeled values do not include an estimate of background concentration contributions.

More than 30% of modeled urban concentrations and more than 14% of modeled rural concentrations exceed the 1 per million cancer risk level. About 2% of modeled urban concentrations and 60 modeled rural concentrations exceed the 1 per 100,000 cancer risk level. Only 14 modeled urban concentrations and four modeled rural concentrations exceed the 1 per 10,000 cancer risk levels.

Figure 32. 1999 NATA Annual Average Concentration Estimates of Polycyclic Organic Compounds (POM) (ICF International, NCHRP 25-25 Task 18)



Styrene

Figure 33 and Figure 34 present the observed and modeled concentration distributions of styrene, respectively. As noted above, the modeled values do not include an estimate of the contribution from background concentrations. All measured and modeled concentrations are well below the RfC.

Figure 33. Observed Annual Average Concentrations of Styrene (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

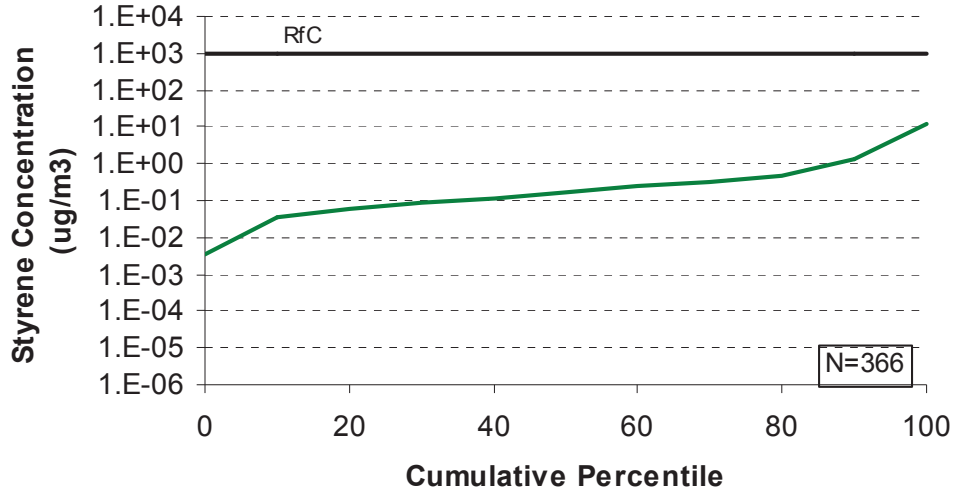
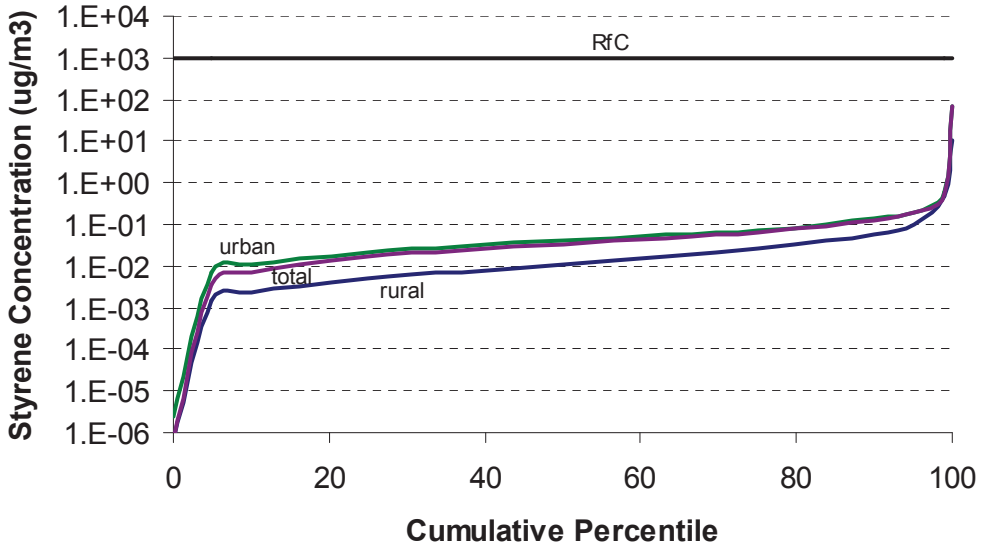


Figure 34. 1999 NATA Annual Average Concentration Estimates of Styrene (ICF International, NCHRP 25-25 Task 18)



Toluene

Figure 35 and Figure 36 present the observed and modeled concentration distributions of toluene, respectively. As noted above, the modeled values do not include an estimate of the contribution from background concentrations. All measured and modeled concentrations are well below the RfC.

Figure 35. Observed Annual Average Concentrations of Toluene (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

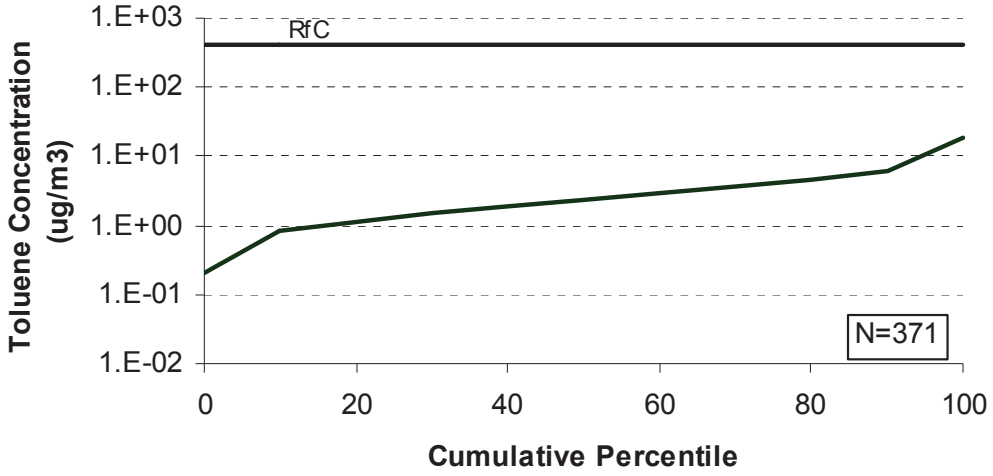
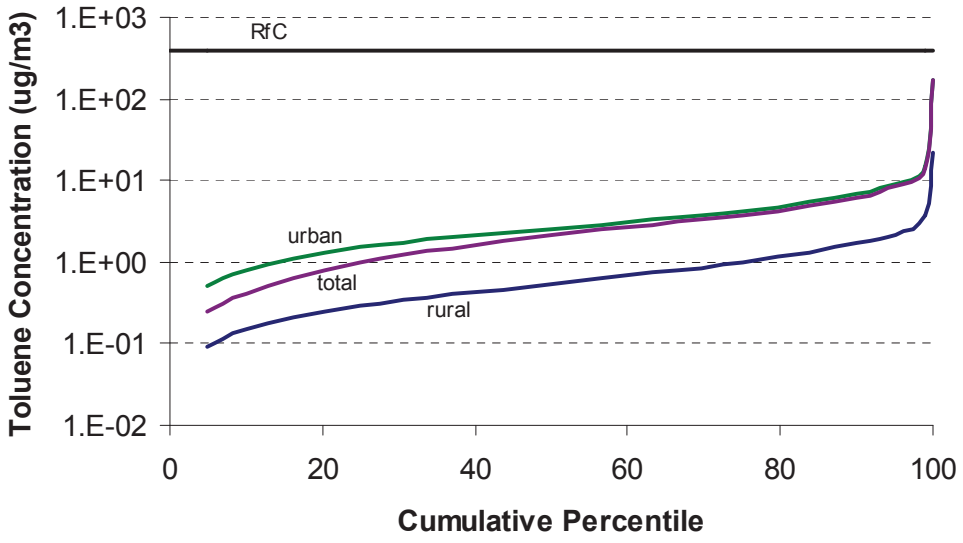


Figure 36. 1999 NATA Annual Average Concentration Estimates of Toluene (ICF International, NCHRP 25-25 Task 18)



Xylene

Figure 37 and Figure 38 present the observed and modeled concentration distributions of xylene, respectively. The modeled values include an estimate of the contribution from background concentrations. All measured and modeled concentrations are well below the RfC.

Figure 37. Observed Annual Average Concentrations of Xylene (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

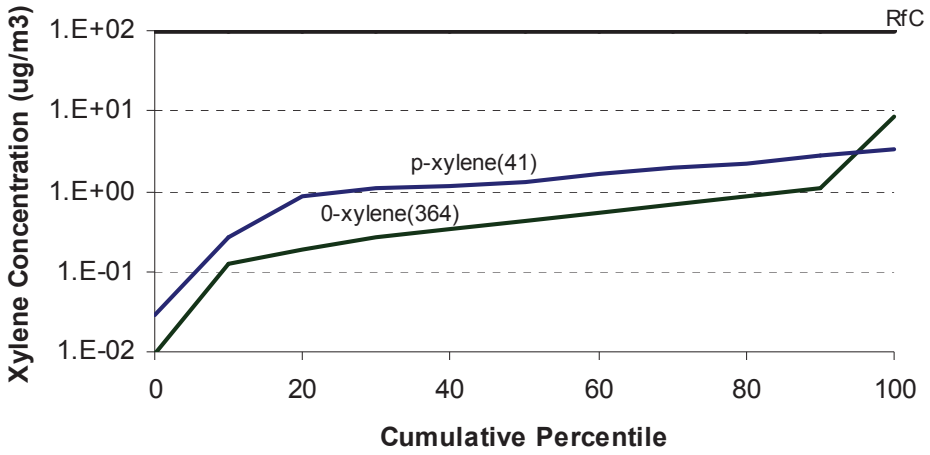
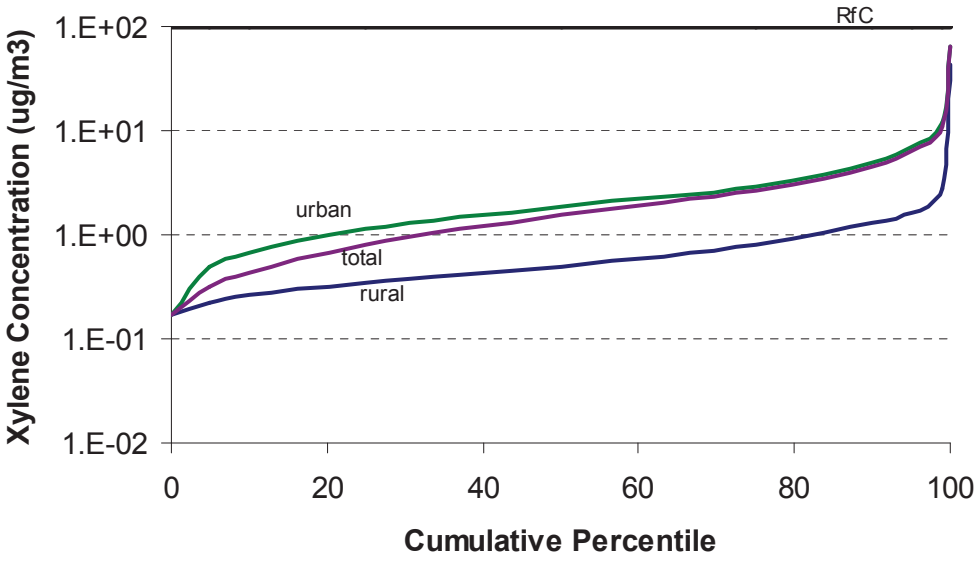


Figure 38. 1999 NATA Annual Average Concentration Estimates of Xylene (ICF International, NCHRP 25-25 Task 18)



Summary

The spatial patterns of observed and modeled concentrations suggest that the following pollutants are of widespread concern with respect to potential health impacts.

- Acetaldehyde
- Acrolein
- Arsenic
- Benzene
- 1,3-Butadiene
- Diesel particles
- Naphthalene

The findings suggest that the following pollutants are of concern in some areas with respect to potential health impacts.

- Chromium, hexavalent
- Formaldehyde
- Lead
- Manganese
- Methyl-tert-butyl ether (MTBE)
- Nickel
- Polycyclic Organic Matter (POM)

Estimating Background Pollutant Concentrations for Environmental Assessment

During environmental impact assessment of potential projects, estimation of background pollutant concentrations may be based on either pollutant measurements or air dispersion modeling.

The optimal approach is local monitoring of the pollutants of interest. For MSATs the appropriate monitoring duration is at least one year, since monitoring of shorter duration can be biased due to seasonal patterns in ambient concentrations.

Use of monitoring data from the EPA's AirData Reports is a cost-effective alternative to expensive local monitoring, if data are available at a nearby location. Each monitor has a designated scale of representation as follows:

- Microscale, representative of several to 100 m
- Middle scale, representative of 100 to 500 m
- Neighborhood scale, representative of 0.5 to 4 km
- Urban scale, representative of 4 to 50 km

If no representative monitoring data are available, NATA model predictions can be used. As noted above, NATA model predictions are available for every U.S. Census tract for 1999, and are scheduled to be available for 2002 when a new round of modeling is completed in 2007[23].

Recommended Procedures for Analyzing MSAT

Recommendations have been developed on how to select and apply the best available models and associated techniques for MSAT impact assessment in the NEPA process. The approach uses both policy and technical considerations to determine the need and

[23] EPA intends to have available by mid-2007 NATA-like assessment tools that can be used to estimate future year background concentrations. It is also possible that some states may develop an estimate of future background concentrations and these could potentially be used in an analysis.

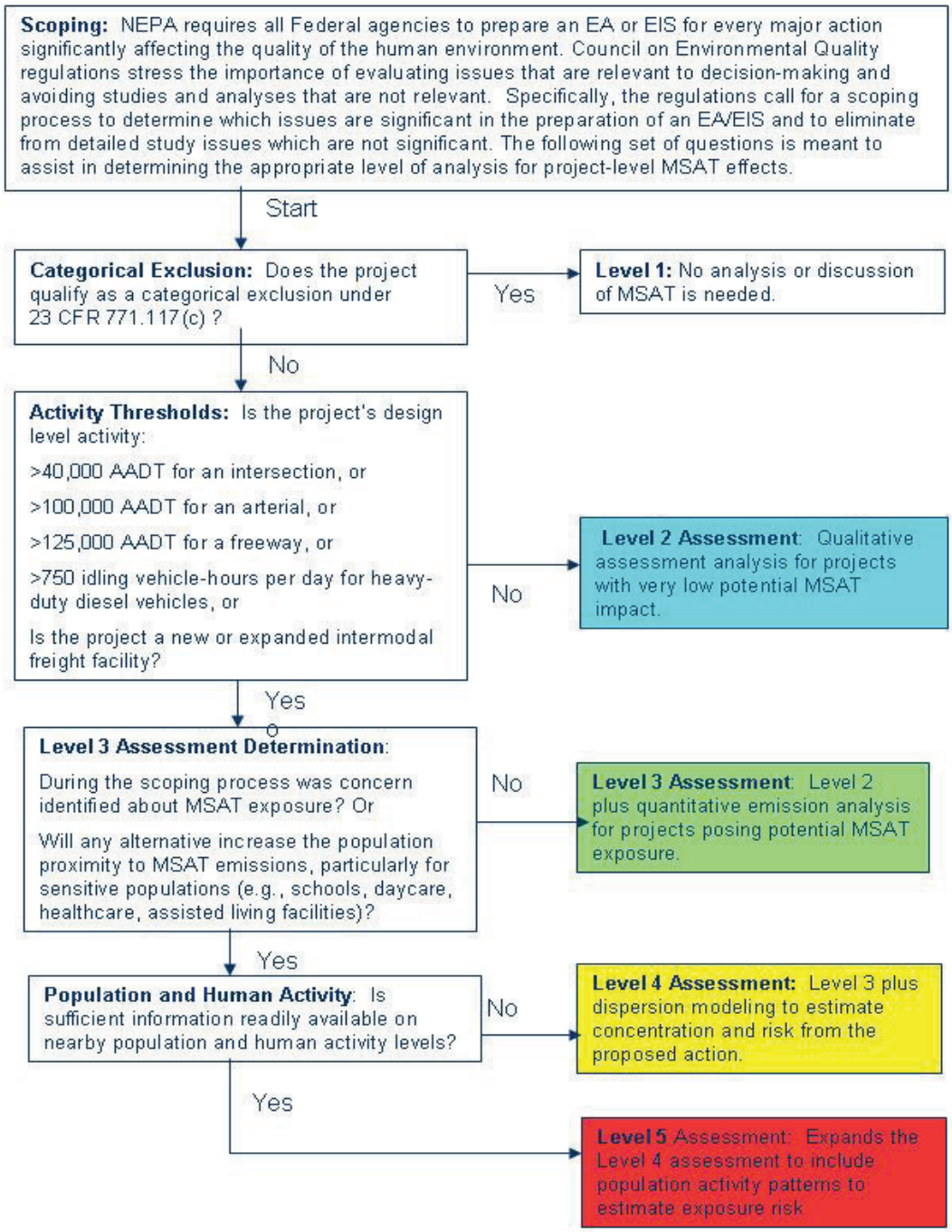
appropriateness for conducting a MSAT assessment. A set of policy and technical questions have been developed, and responses to these questions should guide the transportation analyst in determining the appropriate level of analysis under NEPA.

The set of policy-related questions help identify the appropriate level of analysis based on information about the scope of the project, its likely impact to the community, and the general public's level of concern. Coupled with the policy-related questions are technical questions which identify the appropriate level of technical analysis based on health risk considerations. This combined set of questions fully scope the transportation project, with the policy questions identifying the appropriate level of analysis and the technical questions addressing the technical feasibility of the desired policy-level analysis. Based on these considerations five analysis levels were identified with each level of analysis balancing the need for an increased level of analysis due to the projects potential for risk with the increased level of effort to conduct the analysis.

The full set of questions appears in Figure 39. The first level of analysis requires no review; subsequent levels require increasingly more data and analysis to demonstrate the projects potential MSAT impact. The first level of analysis identifies whether the project has either a categorical exclusion under 23 CFR 771.117(c). At the second level, a qualitative analysis is recommended. This level of analysis is applicable when there is little chance for increased air toxic exposure or the uncertainty is so large that quantitative assessment is unlikely to convey any useful information to the reader of the NEPA document. The third level of analysis develops a quantitative estimate of emissions for the proposed action. The fourth level of analysis expands upon the emission analysis by including dispersion modeling to estimate concentration and risk toxicity. The fifth level of analysis incorporates population activity patterns to estimate exposure risk.

A detailed discussion is presented for each level of analysis in the following section.

Figure 39. Recommendation Flowchart (ICF International, NCHRP 25-25 Task 18)



Five Levels of Analyses for Air Toxic Assessment under NEPA

Level 1—Air Toxic Risk Assessment

To reach this level of assessment the proposed project must be categorically excluded under 23 CFR 771.117(c), in which case no analysis or discussion of MSATs is needed. However, supporting documentation should show that the project qualifies as a categorical exclusion and/or exemption. In addition, the project should document the basis for the determination that no meaningful air-related impacts occur as a result of the project based on a brief description of the factors considered to support this conclusion.

Level 2—Qualitative Air Toxic Assessment

It is anticipated that many of the more typical transportation projects will fall into this analysis category. The types of projects that will typically be found in this level of analysis are projects which improve operations without substantially adding new capacity and therefore are anticipated to have very low potential impact. Examples include: freeway widening projects where increased volume remains below the screening threshold level of 125,000 AADT in the design year; new interchanges where a new arterial segment is built to connect to an existing highway and the project's traffic volume remains below the 100,000 AADT design year threshold screening level; and a new interchange project developed to serve a new residential development where the project's traffic volume is below the screening threshold level of 40,000AADT in the design year. Appendix C provides a detailed discussion on the development of these health risk-based screening thresholds from analysis of the key risk drivers.

EPA has identified some 21 hazardous air pollutants as mobile source air toxics (66 CFR 17235). Based on EPA's 1996 NATA National Scale Assessment (http://www.epa.gov/ttn/atw/

nata/natsaov.html) a set of six MSAT's were identified as mobile source air toxics of greatest concern and have been referred to as the priority MSATs. The six MSATs originally identified are:

- Benzene
- Diesel PM and organic gases
- 1,3 butadiene
- Acrolein
- Formaldehyde
- Acetaldehyde

The analysis at this level and all other levels will focus the assessment on these same six MSATs.

The *primary steps* for this analysis are described as follows:

1) Qualitatively describe how the project will affect traffic volume, speed, and vehicle mix for each proposed alternative. These three parameters have effects on total MSAT emissions. Use information based on latest emission factor model and studies. See the discussion on Level 2 Recommended Tools for current best available approach. For each of the priority MSATs, discuss how these three parameters are affected by the project action and alternatives.

2) Describe how the project alternatives may alter current and projected traffic patterns in the vicinity of the project. The project may lead to traffic increases in some locations and decreases in other locations. Traffic pattern changes may also impact exposure distance, especially to sensitive receptors.

3) Summarize and tally the expected changes for each of the four parameters (traffic volume, speed, vehicle mix, traffic pattern) for each project alternative. Based on the number of changes, compare the various alternatives to inform decision makers which of the alternatives has the least likely impact. Note that while the changes for

each parameter are not necessarily equal in terms of their change to MSAT emissions for each project alternative, this comparison will convey useful information on the likely direction of change (no change/increase/decrease), particularly at the local level.

4) Obtain background concentrations for the location or model predictions from the most recent NATA (see discussion under Level 2 Recommended Tools section) for the particular county where the project is located, unless local site-specific data are available. The NATA data may be expressed as a range of concentrations using information on the project setting as a discriminating value. This information will provide an assessment of the likely current situation at the location of the project. See discussion on the MSAT Emission Trends in the Level 2 Recommend Tools Section.

5) Summarize the current state or regional emission trends for MSATs, if available; otherwise summarize the current national emissions trends for MSATs as discuss applicability to the project. This discussion should compare state, regional, or national trends for MSATs relative to the project's proposed completion date within the near term (5 years), mid-term (10-15 years) and project life (25-30 years). The discussion should identify that the national overall trend is downward through 2015, even with increasing VMT due to fuel regulations and engine technologies regulations, but that the proposed action or alternative may slow the downward trend (depending upon the project-specific change in VMT, fleet mix, and speed). See discussion on MSAT Emission Trends in the Level 2 Recommend Tools Section.

6) Conclusion: Discuss the likely range in current background concentrations and estimate future background[24] concentrations for the project setting using the information gathered in Step 4 and 5 above. Statements can then be made that because of the conservative assumptions and screening analysis done under the NCHRP 25-25, Task 18 study, this type of project has low potential to result in a toxic hotspot. Also, because the study is not foreseen to have any potential adverse impacts, no discussion is needed on the current science of air toxic assessment.

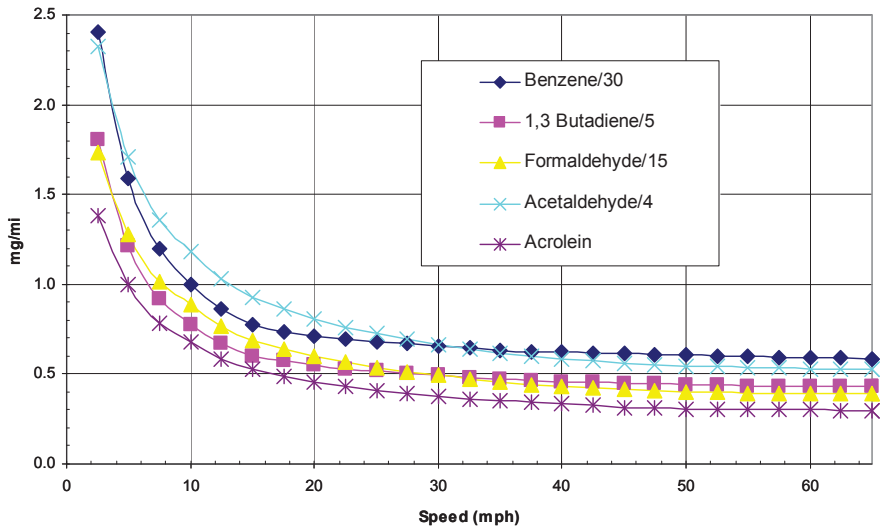
Level 2 Recommended Tools

- **Methods for Estimating Emission Direction for Key Parameters**. For the speed and fleet mix parameters, the latest available emission factor model should be used to show how priority MSAT emissions change with these parameters. This information will then form the basis for discussion of the change in MSATs resulting from the proposed action.
  - **Speed.** Currently, the best available tool for estimating emission factors for MSATs is from EPA's MOBILE6.2 model. The information available is suitable for estimating the likely change in direction as result of the proposed action. In an analysis done by FHWA (Tang et al., 2003), priority MSAT emission rates were determined as a function of speeds for freeways (Figure 40) and arterials (Figure 41). If the proposed action changes the speed on the facility then the figure(s) below can be used to estimate the relative change in MSAT emissions.[25]

[24] EPA intends to have available by mid-2007 NATA-like assessment tools that can be used to estimate future year background concentrations. It is also possible that some states may develop an estimate of future background concentrations and these could potentially be used in an analysis.

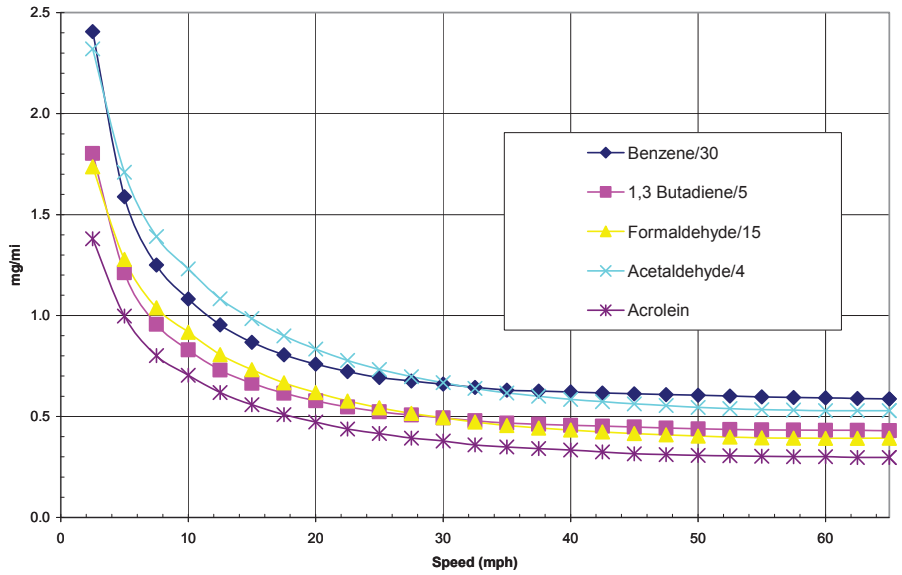
[25] Appendix D contains the specific values output by MOBILE6.2 as used in Figures 40-44 these can be used to better quantify the relative change from a proposed action.

Figure 40. Freeway Facility Speed Effects on MSATs (ICF International, NCHRP 25-25 Task 18)



Note: Based on application of MOBILE6.2 with national default in calendar year 2010. Diesel PM not shown as reported as constant with speed. Fuel RVP set to 8.5 pounds per square inch (psi). Min/Max temperatures of 88.0 °F and 100.0 °F and benzene fuel content of 1.5%. To display MSATs on same graph the true emission factor has been scaled, the true emission factor is equal to the value in the graph multiplied by the denominator. For example, the true benzene emission rate at 10 mph is (1.0*30) = 30 mg/mi.

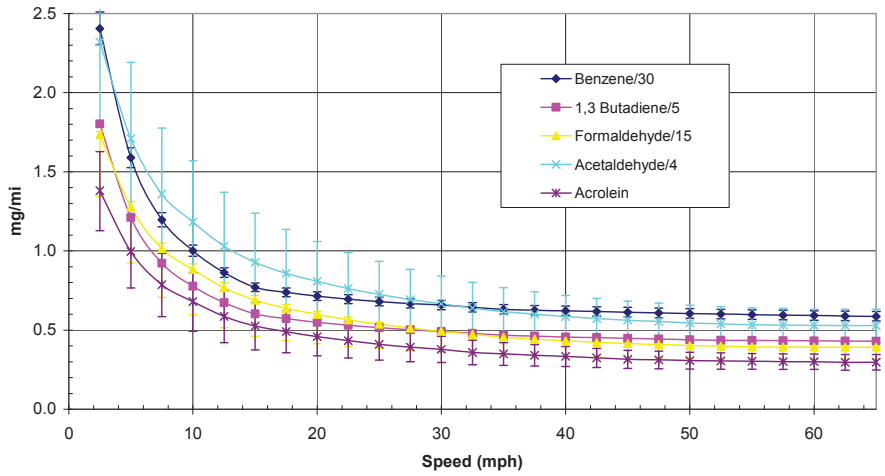
Figure 41. Arterial Facility Speed Effects on MSATs (ICF International, NCHRP 25-25 Task 18)



Note: Based on application of MOBILE6.2 with national default in calendar year 2010. Diesel PM not shown as reported as constant wth speed. Fuel RVP was set at 8.5 pounds per square inch (psi). Min/Max temperatures of 88.0 degrees Fahrenheit and 100.0 degrees Fahrenheit and benzene fuel content of 1.5%. To display MSATs on same graph the true emission factor has been scaled, the true emission factor is equal to the value in the graph multiplied by the denominator. For example, the true benzene emission rate at 52.5 mph is (0.6*30) = 18 mg/mi.

– **Fleet mix.** Similar to speed effects, the best available tool for estimating changes in fleet mix on MSAT emissions is to apply EPA's MOBILE6.2 emission factor model. The information available is suitable for estimating the likely direction of the change in MSAT emissions as result of the proposed action. As was done for speed effects, the priority MSAT emission rates were modeled as a function of speeds for freeways (Figure 42) and arterials (Figure 43) along with an upper and lower bound for the heavy-duty diesel vehicles fractions of 2 and 15 percent. Changes in fleet mix have the potential to impact MSAT emissions. If the proposed action changes the HDDV fraction for the facility then the figure(s) below can be used to estimate the relative change in the MSAT emissions.

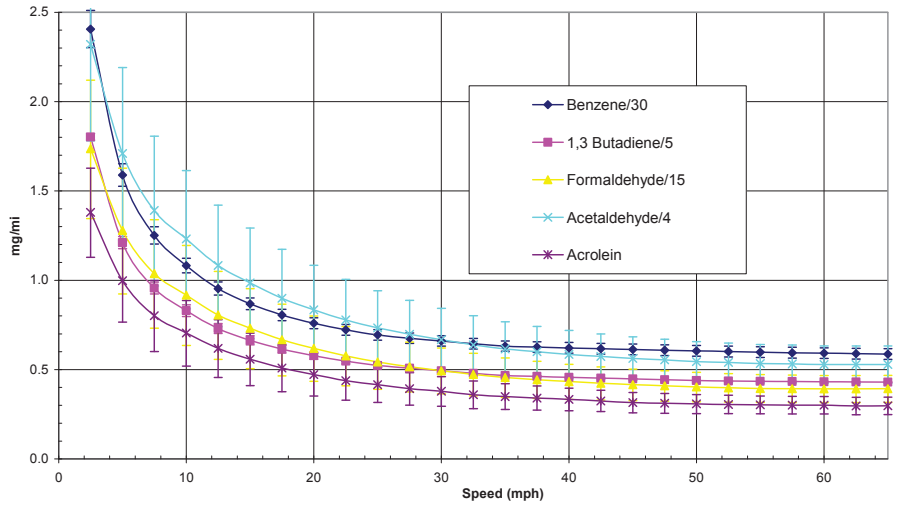
Figure 42. Freeway Facility Speed and Fleet Mix Effects on MSAT Emission Factors (ICF International, NCHRP 25-25 Task 18)



Note: Error bars show change relative to default fleet (8.5% HDDV) for 2% HDDV and 15% HDDV. Benzene is highest with 2% HDDV. All other MSATs are higher with greater HDDV percentage except butadiene which is higher with 15% HDDV at low speeds and then crosses at 47.5 mph to have higher concentrations with lower (2%) HDDV at higher speeds. To display MSATs on same graph the true emission factor has been scaled, the true emission factor is equal to the value in the graph multiplied by the denominator. For example, the true benzene emission rate at 10 mph is (1.0*30) = 30 mg/mi.

Figure 43. Arterial Facility Speed and Fleet Mix Effects on MSAT Emission Factors (ICF International, NCHRP 25-25 Task 18)

(Ranges Based on 2% and 15% HDDV Fleet Mix)



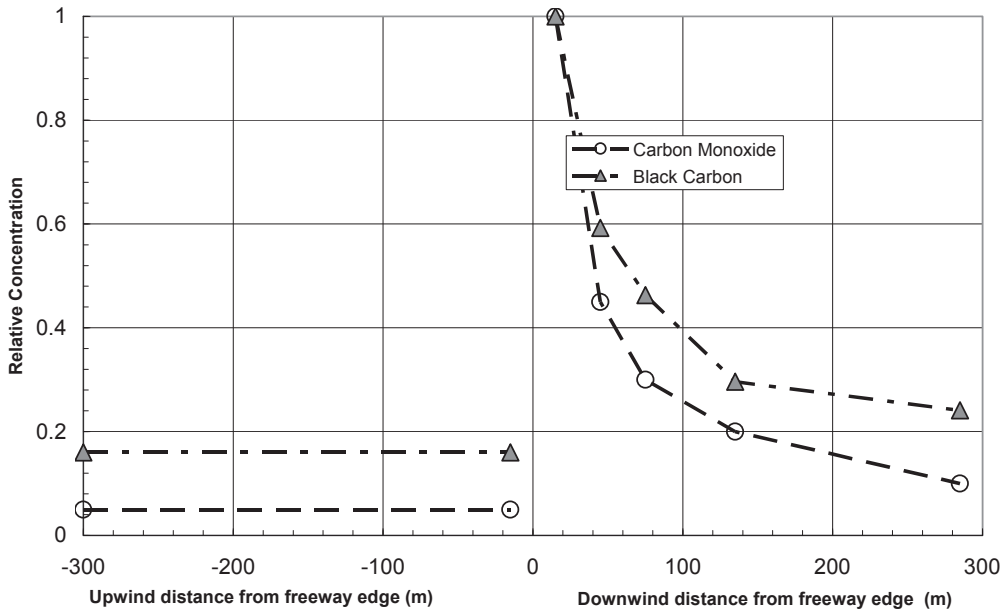
Note: Error bars show change relative to default fleet (8.5% HDDV) for 2% HDDV and 15% HDDV. Benzene is highest with 2% HDDV. All other MSATs are higher with greater HDDV percentage except butadiene which is higher with 15% HDDV at low speeds and then crosses at 47.5 mph to have higher concentrations with lower (2%) HDDV at higher speeds. To display MSATs on same graph the true emission factor has been scaled, the true emission factor is equal to the value in the graph multiplied by the denominator. For example, the true benzene emission rate at 52.5 mph is (0.6*30) = 18 mg/mi.

The other parameters can be characterized as follows:

- **Traffic volume.** As a first order estimate, emissions of MSAT vary linearly with volume; i.e., doubling the traffic volume will double the emissions, assuming no limitation imposed by capacity.

- **Distance curve.** If the proposed action changes the relative distance between the roadway and the location of exposed individuals (exposure distance) then Figure 44 can be used as a conservative estimate of the potential increase or decrease in MSAT exposure. The figure shows the relative change in pollutant concentration as a function of downwind distance. The black carbon measurement can be used as a close approximation for diesel PM and the carbon monoxide as a surrogate for the other gas-phase priority MSATs.

Figure 44. Relative Carbon Monoxide and Black Carbon Concentrations vs. Downwind Distance (ICF International, NCHRP 25-25 Task 18)



Notes: Based on measurements collected during the daytime (May-July 2001) adjacent to the 30-m wide I-405 freeway by Zhu, Hinds, Kim and Sioutas (2002). Traffic density ranged from 140 to 250 vehicles per minute. Wind direction were consistently perpendicular to the freeway at 1-2 m/s. Less than 5% of vehicles were heavy-duty diesel trucks.

- **Background Concentrations.** An estimate should be made of the background MSAT concentration at the proposed location of the transportation project. This estimate will provide a reviewer with useful information on the likely air toxic concentration in the vicinity of the proposed project. Because it is cost prohibitive to conduct air toxic monitoring at all locations in the U.S.[26]., EPA has assessed the current conditions at the census tract level through air quality modeling. This assessment is known as the National Air Toxic Assessment—National Scale Assessment (NATA-NSA). The most current results of its national-scale assessment were released in February 2006 based on a 1999 emissions inventory. The assessment identifies the concentration for each priority MSAT (as well as many other MSATs) as a distribution with values reported at the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles for each county in the U.S. The transportation analyst can then select the appropriate percentile to use for the estimated mobile background concentration based on a local understanding of the county-level emission densities. For locations where this information is not known or unavailable, a GIS spatial analysis of census tract block group population density can be used as a surrogate for estimating the emission density distribution within the county to determine the appropriate percentile ranking.

- **Mobile Source Air Toxics Emissions Trends**. EPA is the lead federal agency for administering the Clean Air Act and has certain responsibilities regarding the health effects of MSATs. EPA issued a Final Rule on Controlling Emissions of Hazardous Air Pollutants from Mobile Sources, 66 FR 17229 (March 29, 2001). This rule was issued under the authority in Section 202 of the Clean Air Act. In this rule, EPA

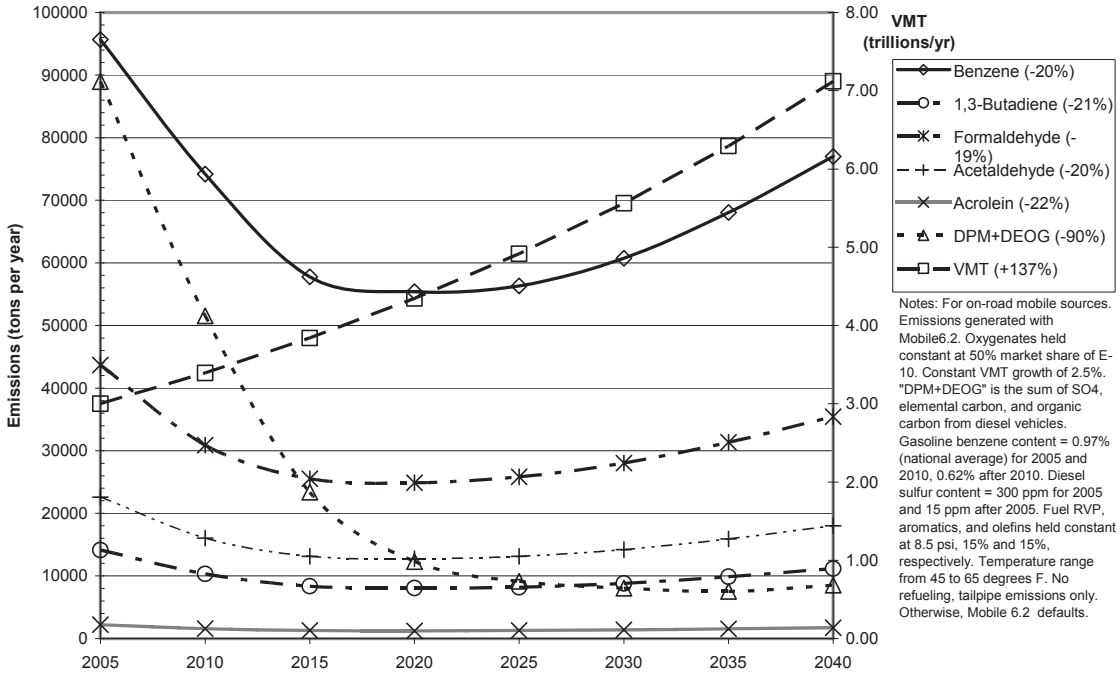
[26] In some circumstances it may be possible to use ambient monitoring data for background concentration. This data can be obtained from AirData website (http://www.epa.gov/air/data/index.html)

examined the impacts of existing and newly promulgated mobile source control programs, including its reformulated gasoline (RFG) program, its national low emission vehicle (NLEV) standards, its Tier 2 motor vehicle emissions standards and gasoline sulfur control requirements, and its proposed heavy duty engine and vehicle standards, and on-highway sulfur control requirements for diesel fuel. The rule established toxics emissions performance standards for gasoline refiners and committed to additional rulemaking to evaluate the need for and feasibility of additional controls. On February 9, 2007, EPA issued new rules to reduce hazardous air pollutants from mobile sources. The new standards would significantly lower emissions of benzene and other air toxics by: (1) lowering benzene content in gasoline; (2) reducing exhaust emissions from passenger vehicles operated at cold temperatures (under 75 degrees F); and (3) reducing emissions that evaporate from, and permeate through, portable gasoline containers (note that this last proposed measure does not directly affect on-road emissions of MSATs).

Based on these regulations, in the near-term (between 2005 and 2010—see Figure 45) there are projected reductions in on-highway emissions of acrolein, benzene, formaldehyde, 1,3-butadiene, and acetaldehyde of 22 percent to 30 percent, and on-highway reductions of diesel PM emissions of 42 percent, even with a 13 percent increase in VMT. The highest emissions reduction projections occur in the mid-term (between 2005 and 2020), where projected on-highway emissions reductions of acrolein, benzene, formaldehyde, 1,3-butadiene, and acetaldehyde are 40 percent to 42 percent, and projected reductions for on-highway diesel PM emissions are 74 percent, even with a 28 percent increase in VMT. However, the long-term emissions

reduction projections show smaller decreases for the gas-only air toxics as the increase in VMT overtakes the regulatory reductions. Between 2005 and 2040 on-highway emissions of acrolein, benzene, formaldehyde, 1,3-butadiene, and acetaldehyde are projected to decrease between 19 percent to 22 percent, but on-highway diesel PM emissions are projected to fall by 90 percent, even with a 138 percent increase in VMT as shown in Figure 45.

Figure 45. U.S. Annual Vehicle Miles Traveled (VMT) vs. Mobile Source Air Toxics (MSAT) Emissions (2005–2040) (ICF International, NCHRP 25-25 Task 18)



Level 3—Quantitative Emissions Assessment

This type of analysis will use the available information on the proposed action and alternatives in conjunction with the best available emission factors to quantitatively estimate the impact for MSAT emissions. The projects that fall into this category have shown a high potential for MSAT emissions to concentrate at high enough levels to be of potential concern. The type of projects that would fall into this category would include major intermodal freight facilities and highway projects which add or create new capacity above the 125,000 AADT for interstates, 100,000 AADT for arterials, or 40,000 AADT for intersections.

The analysis should focus on the priority MSAT emissions, as these are the most likely principal contributors to any significant increase in heath risk. The analysis of the proposed action and its alternatives will provide decision makers with information that discriminates between project alternatives as well as information on the relative impact of the action in comparison with existing air toxic concentrations.

The *primary steps* for this analysis are described as follows:

1) Quantitatively assess the change in transportation-related parameters which result from the proposed action and alternatives. These include how the project and the alternatives will affect traffic volume, speed, and vehicle fleet mix. Of these parameters, speed and vehicle fleet mix can be used in the most currently available emission factor model to provide reliable estimate of changes in MSAT emissions between alternatives. See the discussion on the Level 3 Recommended Tools for further information on application of this approach. For each of the priority MSATs, discuss how these three parameters are affected by the project action and alternatives.

2) Assess how the project may alter current traffic patterns in the vicinity of the project. Traffic may increase in some locations and decrease in other locations. Traffic pattern changes may also impact exposure distance, especially to sensitive receptors.

3) For each alternative, quantitatively summarize the expected change in MSAT emissions. This will provide decision makers with the ability to compare the relative differences in emissions impacts between the various alternatives.

4) Obtain background concentrations for the location or model predictions from the most recent NATA for the particular county where the project is located. This data may be expressed as a range of concentrations using information on the project setting as a discriminating value. This information will provide an assessment of the likely current situation at the location of the project. See discussion on the MSAT Emission Trends in Level 3 Recommend Tools Section.

5) Summarize the current national emission trends for MSATs. This discussion should compare national trends for MSAT emissions relative to the project's proposed completion date with the near term (5 years), mid-term (10-15 years) and project life (25-30 year). The discussion should identify that the trend is downward through 2015, even with increasing VMT due to fuel regulations and engine technologies regulations, but that the proposed action of alternative will likely slow the downward trend (depending upon project specific change in VMT, fleet mix, speed). See discussion on the MSAT Emission Trends (2005-2040) in Level 3 Recommend Tools section.

6) Conclusion: Discuss the likely range in current background concentrations and estimate future background[27] concentrations for the project setting from the information gathered in Step 4 and 5 above. Identify the air toxic emissions associated with the project relative to the no action and various action alternatives. Because this project has a high potential to result in a local toxic hotspot, the analysis should include a discussion on the limitations of currently available tools for assessing the health impacts from MSAT emission changes. This is a requirement under Council of Environmental Quality (CEQ), which implements NEPA regulations (40 CFR 1502.22(b)). See discussion on the *Unavailable Information for Project Specific MSAT Impact Analysis* in the Level 3 Recommended Tools Section.

Level 3 Recommended Tools

- **Methods for Estimating Emissions for Key Parameters**. For the speed and fleet mix parameters, the latest available emission factor model should be used to show how emissions of priority MSATs change with these parameters. This information will then form the basis for discussion of the change in MSATs with respect to the proposed action.
  - **Speed**. Currently, the best available tool for estimating emission factors for MSATs is EPA's MOBILE6.2 emission factor model. While the model has limitations in estimating emissions for a particular vehicle for a particular speed, it can provide a reliable approach for comparing emissions under proposed project alternatives. In most cases the decision maker will want information on how

[27] EPA intends to have available by mid-2007 NATA-like assessment tools that can be used to estimate future year background concentrations. It is also possible that some states may develop an estimate of future background concentrations and these could potentially be used in an analysis.

projected emissions vary between the proposed action and alternatives. In providing this estimate, average speed information from the proposed action provides suitable information for comparing project alternatives. EPA anticipates releasing a new mobile emission factor model called **MO**tor **V**ehicle **E**mission **S**imulator (MOVES) in 2007 suitable for estimating modal emissions at the project level specific to varying locations within the project. Until the release of MOVES, the assessment should be made through the use of average speeds for each proposed project alternative.

– **Fleet mix**. Here again, the best tool currently available for estimating emission factor changes as a result of fleet mix changes is EPA's MOBILE6.2 emission factor model. While the basis of the model is somewhat limited to older technologies, most of the MSAT emission changes are associated with VOC emissions, and the model has incorporated more recent engine emission reduction technology making it suitable for assessing project alternatives. Until MOVES becomes available the assessment should be made using the appropriate fleet mix as an input for MOBILE6.2 for each project alternative.

- **Background Concentrations.** An estimate should be made of the background MSAT concentrations at the proposed location of the transportation project. This will provide a reviewer useful information on the likely air toxic concentration in the vicinity of the proposed project. If available, local near-site monitoring data should be used to estimate background concentrations[28]. However, because it is cost prohibitive to conduct air toxic monitoring at all locations in the U.S., EPA has assessed the current

[28] In some circumstances it may be possible to use ambient monitoring data for background concentration. This data can be obtained from AirData website (http://www.epa.gov/air/data/index.html)

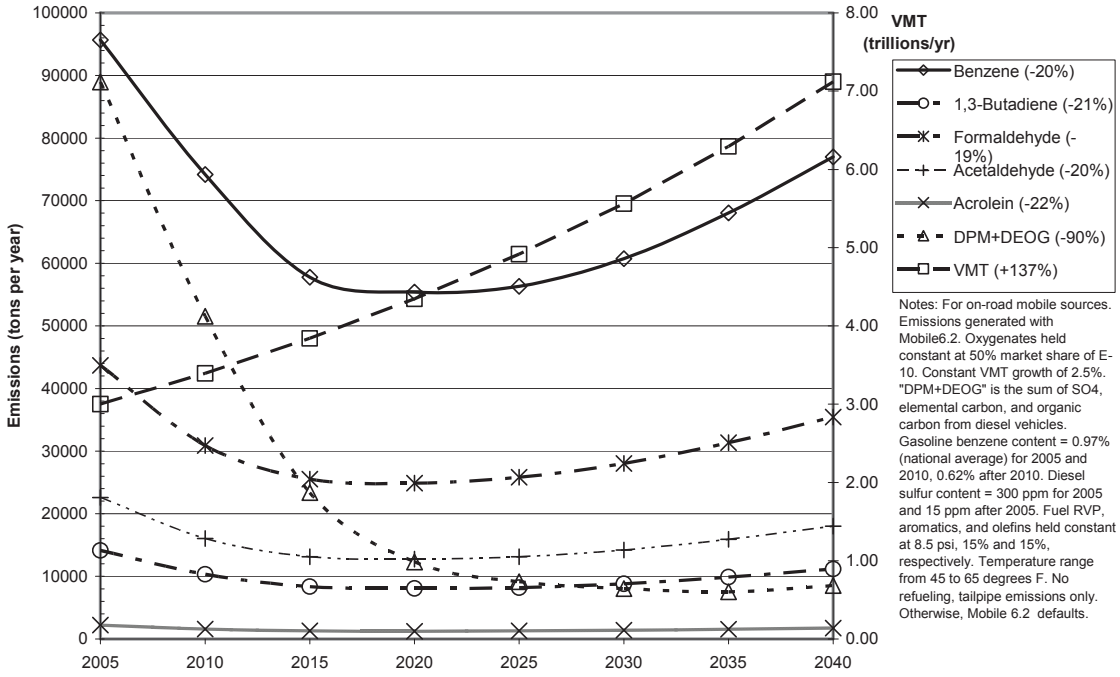
conditions at the census tract level through air quality modeling. This assessment is known as the National Air Toxic Assessment—National Scale Assessment (NATA-NSA). The most current results of its national-scale assessment were released in February 2006 based on a 1999 emission inventory. The assessment identifies the concentration for each priority MSAT (as well as many other MSATs) as a distribution with values reported at the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentile for each county in the U.S. The transportation analyst can then select the appropriate percentile to use for the estimated background concentration based on a local understanding of the county-level emission densities. For locations where this information is not known or unavailable, a GIS spatial analysis of census tract block group population density can be used as a surrogate for estimating the emission density distribution within the county to determine the appropriate percentile ranking.

- **Mobile Source Air Toxics Emissions Trends.** EPA is the lead federal agency for administering the Clean Air Act and has certain responsibilities regarding the health effects of MSATs. EPA issued a Final Rule on Controlling Emissions of Hazardous Air Pollutants from Mobile Sources, 66 FR 17229 (March 29, 2001). This rule was issued under the authority in Section 202 of the Clean Air Act. In this rule, EPA examined the impacts of existing and newly promulgated mobile source control programs, including its reformulated gasoline (RFG) program, its national low emission vehicle (NLEV) standards, its Tier 2 motor vehicle emissions standards and gasoline sulfur control requirements, and its proposed heavy duty engine and vehicle standards and on-highway sulfur control requirements for diesel fuel. The rule established toxics emissions performance standards for gasoline refiners and

committed to additional rulemaking to evaluate the need for and feasibility of additional controls. In February 7, 2007, EPA issued new rules to reduce hazardous air pollutants from mobile sources. The new standards would significantly lower emissions of benzene and other air toxics by: (1) lowering benzene content in gasoline; (2) reducing exhaust emissions from passenger vehicles operated at cold temperatures (under 75 degrees F); and (3) reducing emissions that evaporate from, and permeate through, portable gasoline containers (gas cans, note that this last measure does not directly affect on-road emission of MSATs).

Based on these regulations, in the near-term (between 2005 and 2010) there are projected reductions in on-highway emissions of acrolein, benzene, formaldehyde, 1,3-butadiene, and acetaldehyde of 22 percent to 30 percent (see Figure 46), and on-highway reductions of diesel PM emissions of 42 percent, even with a 13 percent increase in VMT. The highest emissions reduction projections occur in the mid-term (between 2005 and 2020), where projected on-highway emissions reductions of acrolein, benzene, formaldehyde, 1,3-butadiene, and acetaldehyde are 40 percent to 42 percent, and projected reductions for on-highway diesel PM emissions are 74 percent, even with a 28 percent increase in VMT. However, the long-term emissions reduction projections show smaller decreases for the gas-only air toxics as the increase in VMT overtakes the regulatory reductions. Between 2005 and 2040 on-highway emissions of acrolein, benzene, formaldehyde, 1,3-butadiene, and acetaldehyde are projected to decrease between 19 percent to 22 percent, but on-highway diesel PM emissions are projected to fall by 90 percent, even with a 138 percent increase in VMT as shown in Figure 46.

Figure 46. U.S. Annual Vehicle Miles Traveled (VMT) vs. Mobile Source Air Toxics (MSAT) Emissions (2005-2040) (ICF International, NCHRP 25-25 Task 18)



Unavailable Information for Project-Specific MSAT Impact Analysis. Available technical tools have limitations in their ability to assess project-specific health impacts from the emissions changes associated with project alternatives. Due to these limitations, the following discussion should be included in accordance with CEQ regulations (40 CFR 1502.22(b)) regarding incomplete or unavailable information.

- **Information That is Incomplete**. At this level of assessment, evaluating the environmental and health impacts from MSATs on a proposed highway project involves emissions modeling in order to compare emissions between different alternatives. This assessment entails specific issues of concern regarding limitations with emission factor estimation methodology.

- **Emissions.** The current EPA tool used to estimate MSAT emissions from motor vehicles, MOBILE6.2, is not sensitive to vehicle speed for a specific location, but is considered to give reliable estimates using average speed over a trip, and hence is more appropriate for estimating emissions on a regional basis. This means that MOBILE6.2 has more limited capabilities to estimate emission factors for a specific operating condition for a specific facility type. Because of this limitation, MOBILE6.2 is less certain in estimating emission effects for a local assessment than for a region wide or corridor study. For diesel particulate matter, MOBILE6.2 emission factors do not change with vehicle speed, although the other MSAT emission rates do vary with speed as expected. Also, the basis for the emissions rates used in MOBILE6.2 for both diesel particulate matter and MSATs are based on a limited number of vehicle test engines built in the early 1990s. These issues are being addressed in the EPA's new emission factor model, MOVES. However in the interim,

these limitations do not prevent an emission analysis from being conducted as the model still produces a reasonable understanding of how a project will affect MSAT emissions, particularly for the larger scale projects which are considered under this level of analysis. MOBILE6.2's limitations reduce the certainty regarding MSAT emissions projections, but remain an adequate tool for projecting emissions trends and for conducting comparative emission analyses between project alternatives.

Summary of Existing Scientific Evidence Relevant to Evaluating the Adverse Impacts of MSATs. Research on the health impacts of MSATs has been ongoing for over twenty years. For different MSATs, there are a variety of studies showing either statistically associated adverse health outcomes through epidemiological studies and/or animal studies (typically rats) which demonstrate adverse health outcomes. Research on long-duration low exposure studies is on-going. Further, model-based and empirical studies have confirmed that spatial detail is important in characterizing the air toxic impacts of transportation sources (Zhang et al., 2005; McConnell, et al., 2006).

The EPA, as well as state agencies, has assessed the risks associated with emissions of priority MSATs. The EPA's Integrated Risk Information System (IRIS) is a database of human health effects that may result from exposure to various substances found in the environment. The IRIS database is located at http://www.epa.gov/iris. The toxicity information for the priority MSATs is identified in the IRIS database and summarized for cancer-causing potential based on a "weight of evidence characterization for carcinogenicity." The following bullets present a summary of the agency's most current evaluations of the potential cancer-related hazards for the five chemicals and the diesel particulate matter mixture. The IRIS web site should be reviewed during preparation of the NEPA document to see if updates have been made to this information.

- **Benzene** is characterized as a *known human carcinogen* based upon convincing human evidence as well as supporting evidence from animal studies. This is EPA's strongest statement on scientific evidence to support carcinogenic risk association. Both epidemiologic studies and case studies provide clear evidence of a causal association between exposure to benzene and leukemia as well as blood disorders, anemia and Hodgkin's lymphoma. These human data are supported by animal studies. The animal data add to the argument that exposure to benzene increases the risk of cancer in multiple species at multiple organ sites (blood cells, oral and nasal, liver, stomach, lung, ovary, and mammary gland). Recent evidence supports the viewpoint that there are likely multiple mechanistic pathways leading to cancer. A range of 2.2×10^{-6} to 7.8×10^{-6} is the estimated increase in the lifetime cancer risk of an individual who is exposed for a lifetime to 1 $\mu g/m^3$ benzene in air.

- **1, 3-butadiene** is characterized as *carcinogenic to humans* by inhalation. The characterization is supported by the total weight of evidence provided by: (1) sufficient evidence from epidemiologic studies of the majority of U.S. workers occupationally exposed to 1,3-butadiene; (2) sufficient evidence in laboratory animal studies showing that 1,3-butadiene causes tumors at multiple sites in mice and rats by inhalation; and (3) numerous studies consistently demonstrating that 1, 3-butadiene is metabolized by experimental animals and humans. The inhalation cancer risk of 3×10^{-5} is the increase in the lifetime cancer risk of an individual who is exposed for a lifetime to 1 $\mu g/m^3$ 1,3 butadiene in air.

- The potential carcinogenicity of **acrolein** cannot be determined because the existing data are inadequate for an assessment of human carcinogenic potential for either the oral or inhalation route of exposure.

- **Formaldehyde** is a *probable human carcinogen,* based on limited evidence in humans, and sufficient evidence in animals. Human data include nine studies that show statistically significant associations between site-specific abnormal growth of tissue in the respiratory system and exposure to formaldehyde or formaldehyde-containing products. Animal studies have shown an increased incidence of nasal cell carcinomas in long-term inhalation studies in rats and in mice. The inhalation cancer risk of 1.3×10^{-5} is the increase in the lifetime cancer risk of an individual who is exposed for a lifetime to 1 $\mu g/m^3$ formaldehyde in air.

- **Acetaldehyde** is a *probable human carcinogen* based on increased incidence of nasal tumors in male and female rats and laryngeal tumors in male and female hamsters after inhalation exposure. Inadequate evidence is available from human epidemiological studies. The inhalation cancer risk of 2.2×10^{-6} is the increase in the lifetime cancer risk of an individual who is exposed for a lifetime to 1 $\mu g/m^3$ acetaldehyde in air.

- **Diesel exhaust** (DE) is *likely to be human carcinogenic* though inhalation from environmental exposures. The characterization is supported by the total weight of evidence provided by: (1) strong but less than sufficient evidence for a causal association between DE exposure and increased lung cancer risk among workers in varied occupations where exposure to DE occurs; (2) extensive supporting data demonstrating mutagenic and/or chromosomal effects of DE and its organic constituents; and (3)

evidence of carcinogenicity of DPM and the associated organic compounds in rats and mice by other routes of exposure (dermal, tracheal, and just beneath the skin). Diesel exhaust is the combination of diesel particulate matter and diesel exhaust organic gases. No quantitative inhalation cancer risk value has been established by EPA at this time, as available data are considered too uncertain for a confident quantitative dose-response analysis and subsequent derivation of cancer unit risk for DE.

The priority MSATs also have chronic non-cancer health issues. Again, information is available from IRIS which describes the agency's most current understanding of health impacts from chronic exposures. To characterize the health impacts health researchers have developed the inhalation Reference Concentration (RfC) which is based on the assumption that thresholds exist for certain toxic effects such as cellular necrosis. The inhalation RfC considers toxic effects for both the respiratory system and for effects peripheral to the respiratory system. It is generally expressed as a concentration. The RfC is an estimate, with uncertainty (both plus and minus) typically spanning an order of magnitude, of the daily inhalation exposure of the human population, including sensitive subgroups, that is likely to be without an appreciable risk of a negative effect during a lifetime of exposure. The following bullets present a summary of EPA's most current evaluations of the potential chronic (non-cancer) hazards associated with the five chemicals and the diesel particulate matter mixture. (The IRIS web site should be reviewed during preparation of the NEPA document to see if updates have been made to this information.)

- **Benzene.** The inhalation RfC considers toxic effects for both the respiratory system and for effects peripheral to the respiratory system. Benzene was found to decrease lymphocyte blood count. The overall confidence in this RfC assessment is medium with an RfC of 30 $\mu g/m^3$.

- **1,3-butadiene.** The most critical effect from chronic inhalation exposure was ovarian atrophy in female mice and testicular atrophy in male mice. The overall confidence in the assessment is medium with an RfC of 2.0 $\mu g/m^3$.
- **Acrolein.** Exposure has found to impair lung function as well as entail nasal effects. The overall confidence in this RfC assessment is medium with an RfC of 2×10^{-2} $\mu g/m^3$.
- **Formaldehyde.** Insufficient data upon which to develop an RfC.
- **Acetaldehyde.** The most critical effect from chronic inhalation exposure was degeneration of olfactory tissue. The overall confidence in the assessment is low with an RfC of 9.0 $\mu g/m^3$.
- **Diesel exhaust (DE).** Has chronic respiratory effects and is the principal non-cancer hazard to humans from DE exposure. Prolonged exposures may also impair pulmonary function and could produce symptoms, such as cough, phlegm, and chronic bronchitis. Respiratory effects are considered the "critical effect" for the derivation of a chronic RfC for DE. The overall confidence level in the RfC is considered medium in a range of low to high confidence with an RfC of 5.0 $\mu g/m^3$.

There have been other studies that address MSAT health impacts in proximity to roadways. The Health Effects Institute, a non-profit organization funded approximately equally by EPA and the worldwide motor vehicle industry, is conducting research on improving the understanding of: diesel exhaust and associated impact on carcinogenicity and non cancer endpoints; atmospheric transformation of diesel emissions; occupational exposures to aldehydes, 1,3 butadiene, multiple air toxics as well as studies on traffic-related exposures at toxic hotspots; respiratory impairment; and significance of toxic secondary emissions. In addition HEI is embarking on a study of the

emissions from the latest diesel engine technology designed to meet EPA's 2007 exhaust PM emission standards for heavy duty diesel trucks. After peer review and publication these studies will be available to EPA and will be used as needed to update or revise the agency's best understanding of the possible adverse human health impacts. This should be viewed as a continuing effort to better understand the association between exposure and health effects.

California's Office of Environmental Health Hazard Assessment (OEHHA) has made cancer risk assessments following procedures generally similar to those used by EPA. The approach uses both animal and human data, when available, as part of the dose-response assessment. The approaches have been peer reviewed by advisory committee of scientists from outside California's State government (the California Air Resources Board's Scientific Review Panel) using a formalized process. Table 26 provides a comparison between MSAT cancer risk values developed by OEHHA and by EPA in IRIS. Some of the differences are due to California's use of more recent studies which the state has reviewed and used in their assessment, superseding EPA information. This is the case for both 1,3-butadiene and formaldehyde. California is working to harmonize the findings as part of the recommendations made by California's Risk Assessment Advisory Committee (RAAC) regarding harmonization within Cal/EPA and with U.S. EPA.

Table 26. Comparison of Priority Mobile Source Air Toxic Cancer Unit Risk Values—California Based Toxic Air Containment Program and Corresponding US EPA IRIS Cancer (ICF International, NCHRP 25-25 Task 18)

Unit Risk Values*				
Chemical	**California Hot Spots Unit Risk**	**(µg/m3)$^{-1}$**	**IRIS Unit Risk (µg/m3)$^{-1}$**	**HS/IRIS Ratio**
Acetaldehyde	TAC	2.7 E-6	2.2 E-6	1.2
Acrolein		N/A	N/A	N/A
Benzene	TAC	2.9 E-5	7.8 E-6	3.7
1,3-Butadiene	TAC	1.7 E-4	3.0 E-5	5.7
Diesel Exhaust	TAC	3.0 E-4	N/A	N/A
Formaldehyde	TAC	6.0 E-6	1.3 E-5	0.5

N/A—Not available; insufficient information upon which to base a risk value
TAC—California Toxic Air Contaminant Program
* *Upper end unit risk values if range is given, as of 1 June 2006*

In addition to cancer risks, California has also developed reference concentration levels (RfC) following procedures documented in California's Air Toxics Hot Spots Program Risk Assessment Guidelines, Part III: *The Determination of Chronic Reference Exposure Levels for Airborne Toxicants,* which presents a method for deriving inhalation exposure levels to protect the public from a lifetime of exposure to hazardous airborne substances. The guidelines incorporate many of the EPA's procedural recommendations. The values for the priority MSATs are given in Table 27 below. The concentration for diesel PM is the same as the value listed in EPA's IRIS and the value for acrolein is three times higher. With the exception of acrolein, for which no unit risk values is available, these concentrations are much higher than a value triggering a one in a million cancer risk.

Table 27. Comparison of Priority Mobile Source Air Toxic Chronic Reference Concentration Levels with California Reference Concentration Levels (ICF International, NCHRP 25-25 Task 18)

	Reference Concentration Level*			
Chemical	**California RfC**	**(µg/m3)**	**IRIS RfC (µg/m3)**	**CA/IRIS Ratio**
Acetaldehyde	TAC	9.0	9.0	1.0
Acrolein	TAC	0.06	0.02	3.0
Benzene	TAC	60	30	2.0
1,3-Butadiene	TAC	20	2	10.0
Diesel Exhaust	TAC	5.0	5.0	1.0
Formaldehyde	TAC	3.0	N/A	N/A

TAC—California Toxic Air Contaminant Program
N/A—Not available; insufficient information upon which to discern a reference concentration level

Some recent studies have reported that proximity to roadways is related to adverse health outcomes—particularly respiratory problems (John Hopkins School of Public Health, 2004). Many of these studies have been published in peer reviewed journal articles and have shown a strong association between elevated MSAT concentrations and roadway proximity and, in a number of cases, with adverse health outcomes—particularly for sensitive subpopulations. While these studies are retrospective, they are suggestive of the linkages between MSAT emissions and the motor vehicle activity projected for this level of analysis and indicate that adverse health impacts may be possible.

While no one study is definitive, these studies in aggregate are suggestive that reasonable scientific evidence is available that indicates an adverse impact may occur as a result of MSAT emissions, particularly at locations in close proximity to concentrated motor vehicle activity. Based on the current understanding and potential for adverse effects, it appears that a prudent course of action is to provide an estimate of the potential emission changes under a proposed action given the existing evidence to support the possibility of an adverse health outcome.

Relevance of Incomplete Information to Evaluating Reasonably Foreseeable Significant Adverse Impacts on the Human Environment and Evaluation of Impacts Based Upon Research Methods Generally Accepted in the Scientific Community. Because of the limitations in currently available emission models as discussed earlier, a quantitative assessment of the effects of air toxic emissions is not recommended at this time for relatively small projects. Tools are available that allow reasonable emissions change estimates to compare alternatives under larger projects. The amount of MSAT emissions from each of the project alternatives can be predicted with enough accuracy to provide useful information to decision makers and the general public for better understanding of the project's impact. Projections may be more reliable

for certain MSATs (e.g., benzene) than other MSATs (diesel particulate matter). (As noted above, the current emissions model is not recommended for use as an emissions analysis tool for smaller projects.) Therefore, smaller projects are not of sufficient size to determine if they have "significant adverse impacts on the human environment." However, if the project is of sufficient size and/or proximity of exposure is increased then an evaluation of the emission impacts is a reasonable method based on supporting scientific methods and understanding and available information for estimating MSAT emissions.

Level 4—Quantitative Air Toxic Risk Assessment

This assessment will follow the same procedures as outlined in the Level 3 analysis, but will involve additional air quality modeling of ambient pollutant concentrations to provide the reviewer with a better perspective on the relative impact of the increased air toxic risk of the proposed project relative to existing air toxic risk. The analysis will use the available information on the proposed action and its alternatives in conjunction with the best available emission factors to quantitatively estimate the impact on MSAT emissions, and then conduct dispersion modeling and assess the cumulative air toxic risk for the proposed action. The projects that fall into this category have not only shown a high potential for MSAT emissions to concentrate at high enough levels to be of potential concern, but have been raised as a public concern during the scoping process.

The analysis should focus on the priority MSATs, as these are the most likely principal contributors to any significant increase in exposure. The analysis of the proposed action and its alternatives will provide decision makers with information to discriminate between project alternatives as well as information on the relative impact of the action in comparison with existing air toxic concentrations.

The *primary steps* for this analysis will follow the same steps discussed under the Level 3 analysis, but with expanded capabilities to address the spatial risk assessment aspects through air quality modeling. The *primary steps* are described as follows:

1) Quantitatively assess the change in transportation-related parameters which will result from the proposed action and alternatives. These include how the project and the alternatives will affect traffic volume, speed, and vehicle fleet mix. Of these parameters, speed and vehicle fleet mix can be used in the most currently available emission factor model to produce reliable estimates of differences in project-level emissions between alternatives. See the discussion on Level 4 Recommended Tools for the methodology of conducting this analysis. For each of the priority MSATs, discuss how these three parameters are affected by the project action and alternatives.

2) Assess how the project may alter current and future traffic patterns in the vicinity of the project. The project may lead to increased traffic in some locations and decreased traffic in other locations. Traffic pattern changes may also impact exposure distance, especially to sensitive receptors.

3) For each alternative, quantitatively summarize the expected change in emissions and conduct air quality modeling to assess cancer risk, providing information on the maximum exposed individual, sensitive receptors and population-weighted risk. This analysis will provide decision makers with information on the relative differences in terms of cancer risk between the various alternatives.

4) Obtain background MSAT concentrations for the location using the most recent NATA National Scale Assessment Study for the particular county where the project is located and the land use setting. This data may be expressed as a range of concentrations using information on the project setting as a discriminating value. This information will provide an assessment of the likely current situation at the location of the project setting.

5) Summarize the current national emission trends for MSATs. This discussion should compare national trends for MSATs relative to the project's proposed completion date with the near term (5 years), mid-term (10-15 years) and project life (25-30 year). The discussion should identify that the national overall trend is downward through 2015, even with increasing VMT due to fuel regulations and engine technologies regulations, but that the proposed action of alternative will likely slow the downward trend (depending upon project specific change in VMT, fleet mix, speed). See discussion on the MSAT Emission Trends (2005-2040) in the Level 4 Recommend Tools Section.

6) Conduct air quality modeling for the project using an appropriate air quality model. Project emissions should be spatially and temporally allocated. The model should use the best available meteorology data that reasonably characterize the project location. Careful attention should be placed on the selection of locations where concentrations are to be modeled (receptor locations). These should include both sensitive receptor locations as well as locations to where the public may have potential access. The receptors should have their project-related risk determined from the combined concentration and risk for each priority MSAT. The aggregate

risk for the project is the sum of the risk from each of the priority MSATs. A discussion should be developed that summarizes the increase in risk associated with the project and alternatives. See discussion on the *Use of Air Quality Models to Estimate Impacts* in the Level 4 Recommend Tools Section.

7) Conclusion: Discuss the likely range in current background risk and estimate future background[29] for the project setting from the information gathered in Step 4 and 5 above. Identify the risk impact associated with the project relative to the no action and various action alternatives. Because this project has a high potential to result in a local toxic hotspot, discussion should be developed on the limitations of the currently available tools for assessing the risk impact. This is a requirement under Council of Environmental Quality (CEQ, which implements NEPA) regulations (40 CFR 1502.22(b)). See discussion on the *Unavailable Information for Project Specific MSAT Impact Analysis* in the Level 4 Recommended Tools Section.

Level 4 Recommended Tools

- **Methods for Estimating Emissions for Key Parameters.** For the speed and fleet mix parameters, the latest available emission factor model should be used to show how priority MSAT emissions change with these parameters. This information will then form the basis for discussion of the change in MSATs under the proposed action and alternatives.
  - **Speed**. Currently the best available tool for estimating emission factors for MSATs is EPA's MOBILE6.2 emission factor model. While the model has

[29] EPA intends to have available by mid-2007 NATA-like assessment tools that can be used to estimate future year background concentrations. It is also possible that some states may develop an estimate of future background concentrations and these could potentially be used in an analysis.

limitations in estimating emissions for a particular vehicle for a particular speed, it can provide a reliable approach for comparing emissions under proposed project alternatives. In most cases the decision maker will want information on how projected emissions vary between the proposed action and alternatives. In providing this estimated average speed[30] information from the proposed action provides suitable information for comparing project alternatives. EPA anticipates releasing a new mobile emission factor model called **MO**tor **V**ehicle **E**mission **S**imulator (MOVES) in 2007 suitable for estimating modal emissions at the project level specific to varying locations within the project. Until the release of MOVES, the assessment should be made through the use of average speeds for each proposed project alternative.

– **Fleet mix**. Here again, the best available current tool for estimating emission factor changes as a result of fleet mix changes from the proposed action is by using EPA's MOBILE6.2 emission factor model. While the basis of the model is somewhat limited to older technologies, most MSAT emission changes are associated with VOC emissions, and the model has incorporated more recent engine emission reduction technology making it suitable for assessing project alternatives. Until MOVES becomes available, the assessment should be made using the appropriate fleet mix as a MOBILE6.2 input for each project alternative.

- **Background Concentrations**. An estimate should be made of the background MSAT concentration at the proposed location of the transportation project. This will provide a reviewer with useful information on the likely air toxic concentration in the vicinity

[30] Note that estimates of speeds are subject to significant uncertainty at high level of service which affects the size of emission impact of a proposed action and alternatives.

of the proposed project. Ideally, local site-specific ambient monitoring data are available[31]. However, because it is cost prohibitive to conduct air toxic monitoring at all locations in the U.S., EPA has assessed the current conditions at the census tract level through air quality modeling. This assessment is known as the National Air Toxic Assessment—National Scale Assessment (NATA-NSA). The most current results of its national-scale assessment were released in February 2006 based on a 1999 emissions inventory. The assessment identifies the concentration for each priority MSAT (as well as many other MSATs) as a distribution with values reported at the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentile for each county in the U.S. In the absence of site-specific ambient monitoring data, the transportation analyst can select the appropriate percentile to use for the estimated background concentration based on a local understanding of the county-level emission densities. For locations where this is not known or unavailable, a GIS spatial analysis of census tract block group population density can be used as a surrogate for estimating the emission density distribution within the county to determine the appropriate percentile ranking.

- **Mobile Source Air Toxics Emissions Trends**. EPA is the lead federal agency for administering the Clean Air Act and has certain responsibilities regarding the health effects of MSATs. EPA issued a Final Rule on Controlling Emissions of Hazardous Air Pollutants from Mobile Sources, 66 FR 17229 (March 29, 2001). This rule was issued under the authority in Section 202 of the Clean Air Act. In this rule, EPA examined the impacts of existing and newly promulgated mobile source control programs, including its reformulated gasoline (RFG) program, its national low

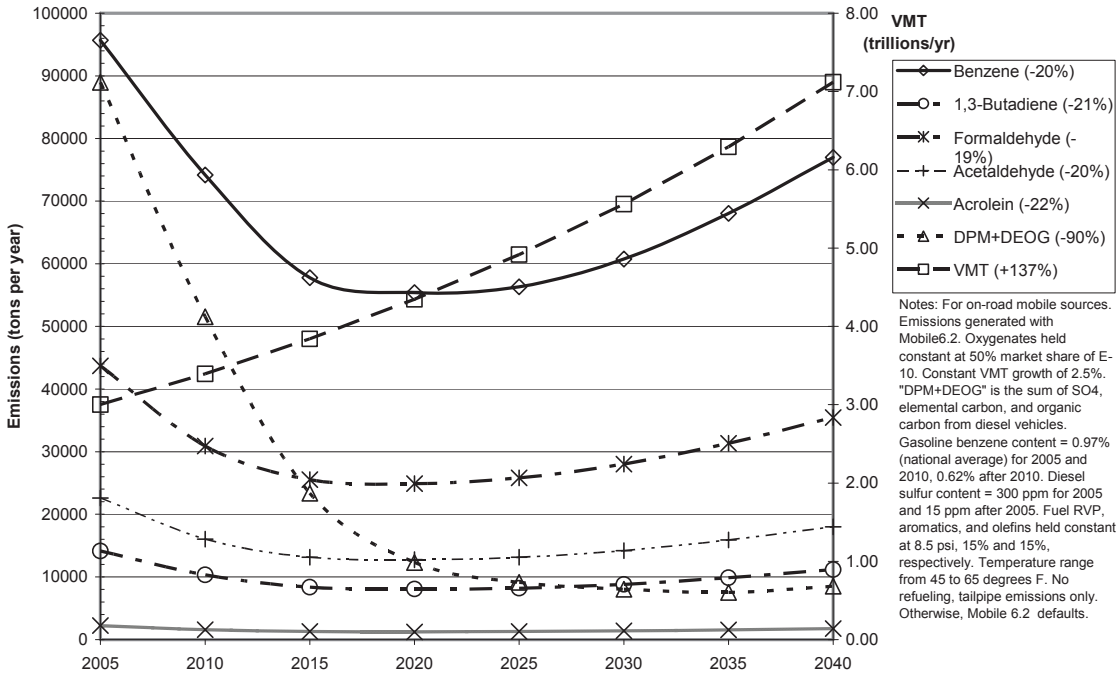
[31] In some circumstances it may be possible to use ambient monitoring data for background concentration. This data can be obtained from AirData website (http://www.epa.gov/air/data/index.html)

emission vehicle (NLEV) standards, its Tier 2 motor vehicle emissions standards and gasoline sulfur control requirements, and its proposed heavy duty engine and vehicle standards and on-highway sulfur control requirements for diesel fuel. The rule established toxic emissions performance standards for gasoline refiners and committed to additional rulemaking to evaluate the need for and feasibility of additional controls. On February 9, 2007, EPA issued a final rule to reduce hazardous air pollutants from mobile sources. The new standards would significantly lower emissions of benzene and other air toxics by: (1) lowering benzene content in gasoline; (2) reducing exhaust emissions from passenger vehicles operated at cold temperatures (under 75 degrees F); and (3) reducing emissions that evaporate from, and permeate through, portable gasoline containers (this last proposed measure does not directly affect on-road emission of MSATs).

Based on these regulations, in the near-term (between 2005 and 2010) there are projected reductions in on-highway emissions of acrolein, benzene, formaldehyde, 1,3-butadiene, and acetaldehyde of 22 percent to 30 percent, and on-highway reductions of diesel PM emissions of 42 percent, even with a 13 percent increase in VMT (see Figure 47). The highest emissions reduction projections occur in the mid-term (between 2005 and 2020), where projected on-highway emissions reductions of acrolein, benzene, formaldehyde, 1,3-butadiene, and acetaldehyde are 40 percent to 42 percent, and projected reductions for on-highway diesel PM emissions are 74 percent, even with a 28 percent increase in VMT. However, the long-term emissions reduction projections show smaller decreases for the gas-only air toxics as the increase in VMT overtakes the regulatory reductions. Between 2005 and 2040 on-highway emissions of acrolein,

benzene, formaldehyde, 1,3-butadiene, and acetaldehyde are projected to decrease between 19 percent to 22 percent, but on-highway diesel PM emissions are projected to fall by 90 percent, even with a 138 percent increase in VMT as shown in Figure 47.

Figure 47. U.S. Annual Vehicle Miles Traveled (VMT) vs. Mobile Source Air Toxics (MSAT) Emissions (2005–2040) (ICF International, NCHRP 25-25 Task 18)



- **Use of Air Quality Dispersion Models to Estimate Impact**. To estimate ambient concentrations for project-level assessments, air dispersion models have been routinely used in air quality assessments. Recommendations are provided in Table 28 on the most appropriate air quality model to use for air toxic risk assessment based on an understanding of the current models' strengths and weaknesses in transportation settings.

Table 28. Best Available Air Quality Modeling Tools for use in Analyzing MSATs under NEPA (ICF International, NCHRP 25-25 Task 18)

Facility/Project Type	Primary Air Quality Model	Secondary Air Quality Model	Comments
Roadway Widening	CALINE4	CALINE3	
HOV Lane Addition	CALINE4	CALINE3	
Roadway Intersection	CAL3QHC(R)	HYROAD	With the release of the MOVES model HYROAD may be the preferred choice as the model can be directly linked to the modal emission factors.
Interchange/Ramp	CALINE4	CALINE3	Carefully consideration should be given to the emission factors under grade or acceleration environment.
Freight Terminal/ Intermodal Transfer Parking/ Travel Center/	AERMOD	ISC3	If facility is located where unusual meteorological conditions (fumigation, stagnation) occur then CALPUFF is the preferred model.

These air quality models require the usual representative meteorological data consisting of wind speed, wind direction, and atmospheric stability and are coupled with the emission factors, as described earlier, from the MOBILE6.2 model. For air toxics applications, consideration should be given to reactive decay for the chemically active MSAT species[32]. For the priority MSATs, the following first-order reactive decay rates should be assigned:

- 1,3 butadiene: half-life 3 hours (Howard, 1989)
- Primary formaldehyde: half-life 12 hours (Howard, 1989)
- Primary acetaldehyde: half-life 15 hours (CARB, 2001)
- Primary acrolein: half-life 12 hours (Howard, 1989)

The remaining priority MSAT pollutants can be considered chemically inert.

In applying the air quality models the analyst should place receptors (locations where modeled concentrations are determined) at the nearest public access points. This would include locations such as sidewalks and yards of residential housing. Receptors should also be placed at sensitive locations such as schools, daycare centers, nursing homes or assisted living facilities. These sensitive subpopulations may be of more concern than the general population. Receptor locations should remain the same between the action and no action alternative to enable the determination of the proposed project impact. However, some types of projects (e.g., roadway widening) may bring the receptor closer to the roadway and associated emissions. In this case the receptors for the proposed action should be placed at the closest reasonable distance from the proposed roadway and compared with the receptors from the no action.

[32] The effect of chemical reactivity in the near roadway environment is small. For the most reactive pollutant, 1,3 butadiene, the decrease in ambient concentration under low wind speed conditions (0.5 ms^{-1}) at 400-m from the roadway would reduce the ambient concentration level by only 5% percent.

- **Use of Toxicity Weighted Risk Assessment**. In order to determine the cancer risk from the proposed project the modeled air concentrations at each receptor location for each priority MSAT must be multiplied by their individual unit risk level. While each MSAT does not target the same organ, a conservative approach is to assume that they do so that the sum of the risks from each MSAT is the maximum increased cancer risk. The receptor location which has the highest risk should be identified as the maximum individual cancer risk.

Unavailable Information for Project-Specific MSAT Impact Analysis. Available technical tools have limitations in their ability to assess project-specific health impacts from the emission changes associated with project alternatives. Due to these limitations, the following discussion should be included in accordance with CEQ regulations (40 CFR 1502.22(b)) regarding incomplete or unavailable information:

- **Information That Is Incomplete.** At this level of assessment, evaluating the environmental and health impacts from MSATs on a proposed highway project involves emissions and pollutant concentration modeling in order to compare emissions and air quality between different alternatives. This assessment raises some specific issues of concern regarding limitations with emission factor and air quality model estimation methodology.
  - **Emissions.** The current EPA tool to estimate MSAT emissions from motor vehicles, MOBILE6.2, is not sensitive to vehicle speed for a specific location, but is considered to give reliable estimates using average speed over a trip, and hence is more appropriate for estimating emissions on a regional basis. This means that MOBILE6.2 has limited capability to estimate emission factors for a specific

operating condition for a specific facility type. Because of this limitation, MOBILE6.2 is less certain in estimating emission effects for a local assessment than for a region wide or corridor study. For diesel particulate matter, MOBILE6.2 emission factors do not change with vehicle speed, although the other MSAT emission rates do vary with speed as expected. Also, the basis for the emissions rates used in MOBILE6.2 for both diesel particulate matter and MSATs are based on a limited number of vehicle test engines built in the early 1990s. These issues are being addressed in the EPA's new emission factor model, MOVES. However in the interim, these limitations do not prevent an emission analysis from being conducted as the model still represents a reasonable understanding of how a project will affect MSAT emissions, particularly for the larger scale projects which are considered under this level of analysis. These limitations reduce the certainty of MOBILE6.2 MSAT emissions projections, but remain an adequate tool for projecting emissions trends and for conducting comparative emission analyses between project alternatives.

– **Air Quality Models.** Historically model performance studies of air quality models have found observed and model concentrations to generally be within a factor of two or better. However, many of these performance evaluation studies focused on short-term (24-hour or less) averaging periods. Modeling evaluation studies for longer averaging periods (1-year) have generally shown better model performance. Recent modeling studies for air toxic assessment have found that improved bottom-up emissions inventories have produced improved model performances and found model results often within the range of the uncertainty of

the observations. Further, air quality models used in transportation assessments have been shown to be sensitive to key parameters such as VMT and source/receptor distances, making them a useful tool for assessing relative impacts between project alternatives even in light of the incomplete information on mobile source emission behavior.

Summary of Existing Scientific Evidence Relevant to Evaluating the Adverse Impacts of MSATs. Research on the health impacts of MSATs has been ongoing for over twenty years. For different MSATs, there are a variety of studies showing either statistically associated adverse health outcomes through epidemiological studies and/or animal studies (typically rats) which demonstrate adverse health outcomes. Research on long-duration low exposure studies is on-going.

The EPA, as well as state agencies, has assessed the risks associated with emissions of priority MSATs. The EPA's Integrated Risk Information System (IRIS) is a database of human health effects that may result from exposure to various substances found in the environment. The IRIS database is located at http://www.epa.gov/iris. The toxicity information for the six prioritized MSATs is identified in the IRIS database and summarized for cancer-causing potential based on a "weight of evidence characterization for carcinogenicity." The following bullets present a summary of EPA's most current evaluations of the potential cancer-related hazards for the five chemicals and the diesel particulate matter mixture. (The IRIS web site should be reviewed during preparation of the NEPA document to see if updates have been made to this information.)

- **Benzene** is characterized as a *known human carcinogen* based upon convincing human evidence as well as supporting evidence from animal studies. This is EPA's strongest statement on scientific evidence to support carcinogenic risk association.

Both epidemiologic studies and case studies provide clear evidence of a causal association between exposure to benzene and leukemia as well as blood disorders, anemia and Hodgkin's lymphoma. These human data are supported by animal studies. The animal data add to the argument that exposure to benzene increases the risk of cancer in multiple species at multiple organ sites (blood cells, oral and nasal, liver, stomach, lung, ovary, and mammary gland). Recent evidence supports the viewpoint that there are likely multiple mechanistic pathways leading to cancer. A range of 2.2×10^{-6} to 7.8×10^{-6} is the estimated increase in the lifetime cancer risk of an individual who is exposed for a lifetime to 1 $\mu g/m^3$ benzene in air.

- **1, 3-butadiene** is characterized as *known carcinogenic to humans* by inhalation. The characterization is supported by the total weight of evidence provided by: (1) sufficient evidence from epidemiologic studies of the majority of U.S. workers occupationally exposed to 1,3-butadiene; (2) sufficient evidence in laboratory animal studies showing that 1,3-butadiene causes tumors at multiple sites in mice and rats by inhalation; and (3) numerous studies consistently demonstrating that 1, 3-butadiene is metabolized by experimental animals and humans. The inhalation cancer risk of 3×10^{-5} is the increase in the lifetime cancer risk of an individual who is exposed for a lifetime to 1 $\mu g/m^3$ 1,3 butadiene in air.
- The potential carcinogenicity of **acrolein** cannot be determined because the existing data are inadequate for an assessment of human carcinogenic potential for either the oral or inhalation route of exposure.
- **Formaldehyde** is a *probable human carcinogen*, based on limited evidence in humans, and sufficient evidence in animals. Human data include nine studies that

show statistically significant associations between site-specific abnormal growth of tissue in the respiratory system and exposure to formaldehyde or formaldehyde-containing products. Animal studies have shown an increased incidence of nasal cell carcinomas in long-term inhalation studies in rats and in mice. The inhalation cancer risk of 1.3×10^{-5} is the increase in the lifetime cancer risk of an individual who is exposed for a lifetime to 1 $\mu g/m^3$ formaldehyde in air.

- **Acetaldehyde** is a *probable human carcinogen* based on increased incidence of nasal tumors in male and female rats and laryngeal tumors in male and female hamsters after inhalation exposure. Inadequate evidence is available from human epidemiological studies. The inhalation cancer risk of 2.2×10^{-6} is the increase in the lifetime cancer risk of an individual who is exposed for a lifetime to 1 $\mu g/m^3$ acetaldehyde in air.
- **Diesel exhaust** (DE) is *likely to be human carcinogenic* though inhalation from environmental exposures. The characterization is supported by the total weight of evidence provided by: (1) strong but less than sufficient evidence for a causal association between DE exposure and increased lung cancer risk among workers in varied occupations where exposure to DE occurs; (2) extensive supporting data demonstrating mutagenic and/or chromosomal effects of DE and its organic constituents; and (3) evidence of carcinogenicity of DPM and the associated organic compounds in rats and mice by other routes of exposure (dermal, tracheal, and just beneath the skin). Diesel exhaust is the combination of diesel particulate matter and diesel exhaust organic gases. No quantitative inhalation cancer risk value has been established by EPA at this time, as available data are considered too uncertain for a confident quantitative dose-response analysis and subsequent derivation of cancer unit risk for DE.

The priority MSATs also have chronic non-cancer health issues. Again, information is available from IRIS which describes the EPA's most current understanding of health impacts from chronic exposures. To characterize the health impacts health researchers have developed the inhalation Reference Concentration (RfC) which is based on the assumption that thresholds exist for certain toxic effects such as cellular necrosis. The inhalation RfC considers toxic effects for both the respiratory system and for effects peripheral to the respiratory system. It is generally expressed as a concentration. The RfC is an estimate, with uncertainty (both plus and minus) typically spanning an order of magnitude, of the daily inhalation exposure of the human population, including sensitive subgroups, that is likely to be without an appreciable risk of a negative effect during a lifetime of exposure. The following bullets present a summary of EPA's most current evaluations of the potential chronic (non-cancer) hazards associated with the five chemicals and the diesel particulate matter mixture. (The IRIS web site should be reviewed during preparation of the NEPA document to see if updates have been made to this information.)

- **Benzene.** The inhalation RfC considers toxic effects for both the respiratory system and for effects peripheral to the respiratory system. Benzene was found to decrease lymphocyte blood count. The overall confidence in this RfC assessment is medium with an RfC of 30 $\mu g/m^3$.

- **1,3-Butadiene.** The most critical effect from chronic inhalation exposure was ovarian atrophy in female mice and testicular atrophy in male mice. The overall confidence in the assessment is medium with an RfC of 2.0 $\mu g/m^3$.

- **Acroleins.** Exposure has found to impair lung function as well as nasal effects. The overall confidence in this RfC assessment is medium with an RfC of 2×10^{-2} $\mu g/m^3$.

- **Formaldehyde.** Insufficient data upon which to develop an RfC.

- **Acetaldehyde. T**he most critical effect from chronic inhalation exposure was degeneration of olfactory tissue. The overall confidence in the assessment is low with an RfC of 9.0 $\mu g/m^3$.

- **Diesel Exhaust (DE).** Has chronic respiratory effects and is the principal non-cancer hazard to humans from DE exposure. Prolonged exposures may also impair pulmonary function and could produce symptoms, such as cough, phlegm, and chronic bronchitis. Respiratory effects are considered the "critical effect" for the derivation of a chronic RfC for DE. The overall confidence level in the RfC is considered medium in a range of low to high confidence with an RfC of 5.0 $\mu g/m^3$.

There have been other studies that address MSAT health impacts in proximity to roadways. The Health Effects Institute, a non-profit organization funded by EPA, FHWA, the Coordinating Research Council, and engine manufacturers is providing research funding for studies focused on better understanding of: diesel exhaust and associated impact on asthma and respiratory inflammation; atmospheric transformation of diesel emissions; occupational exposures to aldehydes, 1,3 butadiene, and multiple air toxics as well as studies on traffic-related exposures at toxic hotspots; respiratory impairment; and significance of toxic secondary emissions. In addition HEI is embarking on a study of the emissions from the latest diesel engine technology designed to meet EPA's 2007 exhaust PM emission standards for heavy duty diesel trucks. After peer review and publication these studies will be available to IRIS and will be used to update or revise the agency's best understanding of the possible adverse human health impact. This should be viewed as a continuing effort to better understand the association between exposure and health effects.

California's Office of Environmental Health Hazard Assessment (OEHHA) has made cancer risk assessments following procedures generally similar to those used by the EPA. The approach uses both animal and human data, when available, as part of the dose-response assessment. The approaches have been peer reviewed by advisory committee of scientists from outside California's State government (the California Air Resources Board's Scientific Review Panel) using a formalized process. Table 29 provides a comparison between MSAT cancer risk values developed by OEHHA and by EPA in IRIS. Some of the differences are due to California's use of more recent studies which the state has reviewed and used in their assessment, superseding EPA information. This is the case for both 1,3-butadiene and formaldehyde. California is working to harmonize the findings as part of the recommendations made by California's Risk Assessment Advisory Committee (RAAC) regarding harmonization within Cal/EPA and with U.S. EPA.

Table 29. Comparison of Priority Mobile Source Air Toxic Cancer Unit Risk Values—California Based Toxic Air Containment Program and Corresponding US EPA IRIS Cancer (ICF International, NCHRP 25-25 Task 18)

Unit Risk Values*				
Chemical	**California Hot Spots Unit Risk**	**(µg/m3)$^{-1}$**	**IRIS Unit Risk (µg/m3)$^{-1}$**	**HS/IRIS Ratio**
Acetaldehyde	TAC	2.7 E-6	2.2 E-6	1.2
Acrolein		N/A	N/A	N/A
Benzene	TAC	2.9 E-5	7.8 E-6	3.7
1,3-Butadiene	TAC	1.7 E-4	3.0 E-5	5.7
Diesel Exhaust	TAC	3.0 E-4	N/A	N/A
Formaldehyde	TAC	6.0 E-6	1.3 E-5	0.5

N/A—Not available; insufficient information upon which to base a risk value
TAC—California Toxic Air Contaminant Program
* *Upper end unit risk values if range is given, as of 1 June 2006*

In addition to cancer risks, California has also developed reference concentration levels (RfC) following procedures documented in California's Air Toxics Hot Spots Program Risk Assessment Guidelines, Part III: *The Determination of Chronic Reference Exposure Levels for Airborne Toxicants,* which presents a method for deriving inhalation exposure levels to protect the public from a lifetime of exposure to hazardous airborne substances. The guidelines incorporate many of the EPA's procedural recommendations. The values for the priority MSATs are given in Table 30 below. The concentration for diesel PM is the same as the value listed in EPA's IRIS and the value for acrolein is three times higher. With the exception of acrolein, for which no unit risk values is available, these concentrations are much higher than a value triggering a one in a million cancer risk.

Table 30. Comparison of Priority Mobile Source Air Toxic Chronic Reference Concentration Levels with California Reference Concentration Levels (ICF International, NCHRP 25-25 Task 18)

Reference Concentration Level*				
Chemical	**California RfC**		**IRIS RfC**	**CA/IRIS Ratio**
		(µg/m3)	**(µg/m3)**	
Acetaldehyde	TAC	9.0	9.0	1.0
Acrolein	TAC	0.06	0.02	3.0
Benzene	TAC	60	30	2.0
1,3-Butadiene	TAC	20	2	10.0
Diesel Exhaust	TAC	5.0	5.0	1.0
Formaldehyde	TAC	3.0	N/A	N/A

TAC—California Toxic Air Contaminant Program
N/A—Not available; insufficient information upon which to discern a reference concentration level

Some recent studies have reported that proximity to roadways is related to adverse health outcomes—particularly respiratory problems (John Hopkins School of Public Health, 2004). Many of these studies have been published in peer reviewed journal articles and have shown a strong association between elevated MSAT concentrations and roadway proximity and, in a number of cases, with adverse health outcomes—particularly for sensitive subpopulations. While these studies are retrospective, they are suggestive of the linkages between MSAT emissions and the motor vehicle activity projected for this level of analysis and indicate that adverse health impacts may be possible.

While no one study is definitive, these studies in aggregate are suggestive that reasonable scientific evidence is available that indicates an adverse impact may occur as a result of MSAT emissions, particularly at locations in close proximity to concentrated motor vehicle activity. Based on the current understanding and potential for adverse effects, it appears that a prudent course of action is to provide an estimate of the potential emission changes under a proposed action given the existing evidence to support the possibility of an adverse health outcome.

Relevance of Incomplete Information to Evaluating Reasonably Foreseeable Significant Adverse Impacts on the Human Environment and Evaluation Of Impacts Based Upon Research Methods Generally Accepted In The Scientific Community. Because of the limitations in currently available emission models as discussed above, a quantitative assessment of the air toxic emissions cannot be made for relatively small projects. Tools are available that allow reasonable emissions change estimates to be developed to compare alternatives under larger projects. The amount of MSAT emissions from each of the project alternatives can be predicted with enough accuracy to provide useful information to decision makers and the general public for better understanding of the project's impact. Projections may be more reliable for

certain MSATs (e.g., benzene) than other MSATs (diesel particulate matter). (As noted above, the current emissions models are not capable of serving as a meaningful emissions analysis tool for smaller projects.) Therefore, smaller projects are not of sufficient size to determine if they have "significant adverse impacts on the human environment." However, if the project is of sufficient size and/or proximity of exposure is increased then an evaluation of the emission impacts is a reasonable method based on supporting scientific methods and understanding and available information for estimating MSAT emissions.

Level 5—Quantitative Exposure Assessment

This assessment will follow the same procedures as outlined in the Level 4 analysis, but will add an additional component following the air dispersion modeling that incorporates exposure assessment techniques. This analysis will provide the reviewer more information as to the population exposed to the increased risk. The analysis will still use the available information on the proposed action and its alternatives in conjunction with the best available emission factors to quantitatively estimate the impact for MSAT emissions and then conduct dispersion modeling for the proposed action. The projects that fall into this category have not only shown a high potential for MSAT emissions to concentrate at high enough levels to be of potential concern, but have been raised as a public concern during the scoping process, as well as having sufficient local information available on nearby population and human activity levels to conduct the exposure assessment.

Exposure Assessment. Exposure models combine information about the geographic pattern of pollutant concentrations (typically from an air dispersion model) with information about population activities. In exposure model applications the receptor is a person, population subgroup, or specific area. The simplest models estimate inhalation exposure using ambient

concentrations (monitored or modeled) and residential population distributions, with the implicit assumption that the populace is outside at home at all times. This assumption may bias exposure estimates for certain population cohorts, particularly for air toxics that exhibit strong diurnal concentration patterns, and/or in cases where indoor concentrations are considerably lower than outdoor concentrations[33].

More complete models combine concentration data with time-activity data. Activity profiles specify a schedule of movements among specified locations (e.g., indoors at home, outdoors at a neighborhood park) and activities (e.g., sleeping, walking the dog) for an individual over a period of time. Specified locations where the activities take place are generally referred to as microenvironments. A microenvironment is a location within which the pollutant concentration is assumed to be uniform at any time interval, although it may vary over time and may vary with the associated activity.

Risk characterization combines the results of the dose-response assessment with the exposure assessment to estimate the likelihood of adverse effects occurring. For carcinogens, the results may be characterized in several different ways. Examples are the average risk to the population as a whole, the average risk to various subsets defined by residential location or other demographic factor, or the number of people subject to an individual risk level above a given threshold. For chronic and acute effects, the risk is typically characterized by the number of people exposed above the concentrations that exceed the threshold.

The overall objective for this level of assessment is to develop a refined estimate of exposure by taking into account the different concentrations in different locations (or microenvironments) in which people in the project area interact with the MSATs. Results from

[33] Note that these cases are exceptions to most situations.