NCHRP 25-25 TASK 70: ASSESSMENT OF QUANTITATIVE MOBILE SOURCE AIR TOXICS IN ENVIRONMENTAL DOCUMENTS

Requested by:

American Association of State Highway
and Transportation Officials (AASHTO)

Standing Committee on the Environment

Prepared by:

Cambridge Systematics, Inc.
Cambridge, MA

With:

Cambridge Environmental, Inc.
Sonoma Technology, Inc.

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final report

NCHRP 25-25 Task 70: Assessment of Quantitative Mobile Source Air Toxics in Environmental Documents

prepared for

National Cooperative Highway Research Program
Transportation Research Board
National Research Council

prepared by

Cambridge Systematics, Inc.
100 CambridgePark Drive, Suite 400
Cambridge, MA 02140

with

Cambridge Environmental, Inc.
Sonoma Technology, Inc.

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1.0 Introduction and Summary

■ 1.1 Project Overview

Mobile source air toxics (MSAT) are substances that are emitted from motor vehicle and other mobile source exhaust that have been identified as "hazardous air pollutants" with potential human health risks. Numerous MSATs have been identified with varying degrees of scientific knowledge and uncertainty over their health impacts. There currently are no regulations specifying either maximum levels of MSATs in vehicle exhaust, or maximum MSAT ambient concentrations. MSATs continue to be raised as concerns, however, in environmental impact studies for transportation projects. Responding to such concerns, the Federal Highway Administration (FHWA) has provided guidance on addressing MSATs in highway project environmental documentation prepared pursuant to the National Environmental Policy Act (NEPA).[1] The U.S. Environmental Protection Agency's (EPA) MOVES emission factor model expands the number of MSATs can be modeled, encompassing those that have been identified as being most significant. The Moving Ahead for Progress in the 21st Century Act (MAP-21) also provides for a study of mobile source air pollutants and associated health effects.[2]

This research project is intended to expand the base of knowledge regarding the MSAT impacts of transportation projects, and in particular, to provide additional information to help practitioners understand the degree of MSAT analysis that may be most warranted for transportation projects. The project provides information to help address the following key questions:

- Under what conditions might there be substantial differences in MSAT emissions among transportation project alternatives? Under what conditions might these result in significant differences in pollutant concentrations near the project?

- How might the MSAT effects of a project vary by type of project? How will this change over time as measures are phased in to reduce motor vehicle emissions?

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[1] Federal Highway Administration. "Interim Guidance Update on Mobile Source Air Toxic Analysis in NEPA." Memorandum from April Marchese, September 30, 2009.

[2] Sec. 2203(c), subsection "Air Quality and Congestion Mitigation Measure Outcomes Assessment Research."

- What are the key assumptions (emission rates, meteorological conditions, receptor locations, etc.) that affect changes in modeled pollutant concentrations in the vicinity of projects?

The research addressed these questions through the following tasks:

- In Task 1, recent environmental documents for transportation projects were examined to identify how MSATs have been treated (qualitative discussion, emissions modeling, dispersion modeling, and/or health risk assessment), and what the documents have found in terms of differences among project alternatives, timeframes, and geographic scales. Thirty projects were identified within the past five to 10 years for which MSAT emissions have been quantified, but dispersion modeling and analysis of localized concentrations was conducted for only a handful.

- In Task 2, two representative project types – a major highway widening and an intermodal freight terminal – were modeled to compare differences in MSAT impacts between project alternatives and over time, against background levels and identified health risk comparison levels for each pollutant. These two types of projects have been identified by FHWA as "category 3" projects – i.e., those which have the potential for meaningful differences among project alternatives, and should be more rigorously assessed for impacts (FHWA, 2009).

Different modeling techniques also were used in the case studies, with a line source model (CAL3QHC/r) traditionally used for transportation projects applied to the highway widening, and the more general AERMOD model applied to the intermodal freight terminal project using area source inputs. The case studies therefore provide insights into the relative strengths of each model.

1.2 Key Findings

Key findings are presented in relation to the questions posed above.

1. *Under what conditions might there be substantial differences in MSAT emissions among transportation project alternatives? Under what conditions might these result in significant differences in pollutant concentrations near the project?*

   - Major transportation project improvements have generally been found to generate modest impacts on total MSAT emissions and local MSAT concentrations, compared to no-project alternatives and broad trends associated with changing fleet emissions over time. Whether these impacts are positive or negative will depend upon the specific conditions of the project.
   - The impacts of transportation project alternatives on MSAT concentrations are generally fairly small relative to background levels of pollutants (5 to 15 percent in the case studies conducted for this research).

- While the impact of the project versus no-project alternative was small, the contribution of the local transportation source (project or no-project alternative) was on the same order of magnitude as current background levels for most pollutants.
- Current background pollutant concentrations across the U.S. for the evaluated pollutants typically exceed one-in-a million 70-year cancer risk levels, but are lower than one hundred-in-a-million cancer risk levels and other noncancer chronic health risk levels of concern for most pollutants. Adding the contribution from the local transportation source did not change whether any risk thresholds were exceeded in the case studies.
- The relative contribution of transportation sources (versus background) varies substantially by pollutant, with the highest relative impacts observed for diesel particulate matter and naphthalene.

2. *How might the MSAT effects of a project vary by type of project?*

   - The case studies focused on two types of projects that have previously been identified as leading to the most significant MSAT impacts of any transportation project: major highway expansions, and intermodal freight terminals. The case studies and limited review of environmental documentation found no reason to refute this, but also did not look at other types of projects.

3. *How will impacts change over time as measures are phased in to reduce motor vehicle emissions?*

   - The relative impacts of project alternatives will remain consistent over time. However, the absolute impacts (positive or negative) will become smaller as emission rates decrease due to cleaner vehicles and fuels. Decreases in MSAT emission rates of 50 to 90 percent or more will be observed by 2035, comparing to 2005 emission rates from on-road sources.
   - In nearly all cases modeled (as well as reviewed in environmental documentation), decreases in emissions per vehicle more than outweigh any increases in traffic over time periods of 10 to 25 years.

4. *What are the key assumptions that affect changes in modeled pollutant concentrations in the vicinity of projects?*

   - In the highway project case study examined here, intersections generated MSAT concentrations that were much higher than those modeled for highway mainlines. This was due primarily to closer proximity of receptors to vehicles at intersections, and secondarily to higher emission rates due to lower traffic speeds at intersections.
   - The intermodal freight terminal case study found the greatest pollutant concentrations to be directly adjacent to major roadways in the study area. The physical (site) design of such projects, and in particular the location of both on- and off-road emissions sources relative to nearby populations, will affect the relative impacts.

  - Meteorological conditions make a difference. In particular, an area that is characterized by generally light winds is estimated to have a traffic contribution to pollutant concentrations that is two to three times higher than an area where moderate to higher wind speeds are more prevalent.

There are numerous uncertainties inherent in any analysis of ambient pollutant concentrations, including assumptions about meteorological conditions, the spatial and temporal patterns of emissions, pollutant transport, secondary pollutant formation, averaging of daily conditions to represent annual exposure, the most appropriate location of receptors to represent human exposure, etc. Significant uncertainty also exists in relating pollutant concentrations to health risks. Modeling exercises such as presented in this research are intended to shed light on likely impacts but cannot fully overcome these uncertainties without considerable work scope and budget resources. Because of these uncertainties, additional research may be warranted to develop the type of comprehensive understanding necessary for the creation of a simplified screening process to address highway project MSATs.

2.0 MSAT Analysis in Published Environmental Documents

This section summarizes the findings of Task 1 of this project. One objective of this review was to provide information on how MSAT impacts have been estimated and reported in recent environmental documents, and the magnitude of those impacts. A second objective was to identify projects that could serve as a basis for modeling concentrations of MSATs under different project alternatives and other differing conditions.

■ 2.1 Overview of Identified Projects

Recent transportation project environmental documents that have addressed MSAT emissions were identified through discussions with project panel members, Internet searches, a review of literature sources, and the knowledge of the project team. The primary literature source identified was: "Air Quality Community of Practice Mobile Source Air Toxics State-of-the-Practice," Prepared for the American Association of State Highway and Transportation Officials (AASHTO), 2009.

A total of 30 projects were identified that have quantified MSAT emissions in their environmental analysis within the past five to 10 years. Of these, 21 had a signed record of decision (ROD), finding of no significant impact (FONSI), or Categorical Exclusion at the time of the review. (Having a signed ROD or FONSI was a criterion for using the project as a basis for the hypothetical projects to be modeled in Task 2.) This list is not necessarily a comprehensive list of all transportation environmental documents that have quantified MSAT emissions, but it probably includes most of the major transportation projects that have done so recently.

■ 2.2 Treatment of MSAT Emissions and Exposure

Table 2.1 identifies the project, sponsor agency, location, type of project, MSATs analyzed, method of analysis, and date that a ROD or FONSI was issued. Of the projects with a signed decision, only two estimated MSAT concentrations and exposure, and/or conducted a health risk assessment (HRA). The remaining projects only quantified MSAT emission levels. Of the 21 projects, four were freight intermodal terminals or port access roads, and the rest were highway projects, including six with managed lanes.

Most analyses included six key MSATs: benzene, 1,3-butadiene, formaldehyde, acetaldehyde, acrolein, and diesel particulate matter (DPM). Naphthalene and polycyclic organic matter (POM) were included with somewhat less frequency. The compounds analyzed are generally consistent with the seven compounds that EPA has identified as having significant contributions from mobile sources and also being among the national and regional-scale cancer risk drivers from their 1999 National Air Toxics Assessment (NATA).[3]

Part of the intent of Task 1 was to identify two or three projects that could serve as a hypothetical basis to model MSAT concentrations for different alternatives. One of the criteria for selecting these projects was to identify conditions that could lead to the largest MSAT changes. The research team used the change in DPM emissions (absolute and percent) between the no-project and project alternatives as an indicator for all MSATs. Table 2.2 shows the subset of projects from Table 2.1 that reported changes in DPM emissions of at least 0.1 tons per year between the project and no-project alternatives (either an increase or decrease), and provides more detail on the MSAT analysis and results. Findings can be summarized as follows:

- Some projects resulted in an increase in MSAT conditions for the project versus no-project alternative (usually due to higher traffic volumes), while others resulted in a decrease (usually due to higher traffic speeds that reduced emissions per vehicle).

- The relative difference between the no-project and project alternatives was nearly always small, on the order of 1 percent or less.

- The difference between alternatives also was very small compared to the change in emissions over time. In particular, a substantial decrease in emissions was generally observed for future years compared to a baseline or present year, due to the increasing stringency of vehicle emissions control standards and phase-in of lower-emission vehicles and fuels. Recently adopted standards for heavy-duty vehicles particularly affect the DPM emissions which are almost entirely from trucks.

From the projects listed in Table 2.2, two projects – the U.S. 36 highway corridor project in Denver and Boulder, Colorado, and the Detroit Intermodal Freight Terminal project in Detroit, Michigan – were selected as the basis for the hypothetical projects modeled in this research. These projects were considered representative of the respective type of project (highway widening, intermodal terminal), while showing among the largest impacts of the projects of each type.

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[3] http://www.epa.gov/ttn/atw/nata1999/.

Table 2.1 Environmental Documents Quantifying MSATs

			Type of Project				HAPs Analyzed								Analysis				ROD/FONSI Issued[a]	
Project Name	**Sponsor Agency**	**Geographic Location**	**Highway-Expansion**	**Highway – New**	**Intermodal Freight**	**HOV/HOT Lane**	**Benzene**	**Naphthalene**	**1,3 Butadiene**	**Formaldehyde**	**Acetaldehyde**	**Acrolein**	**DPM**	**POM**	**Emissions**	**Concentration**	**Exposure**	**HRA**	**Y/N**	**Date**
The Interstate 10 (San Bernardino Freeway/ El Monte Busway) HOT Lanes Project	CalTrans	Los Angeles County, CA	X			X	X		X	X	X	X	X		X				Y	4/1/2010
The Interstate 110 (Harbor Freeway/ Transitway) HOT Lanes Project	CalTrans	Los Angeles County, CA	X			X	X		X	X	X	X	X		X				Y	4/1/2010
I-5 HOV/Truck Lanes Project SR 14 to Parker Road	CalTrans	Los Angeles County, CA	X			X	X		X	X	X	X	X		X				Y	9/1/2009
Salmon Creek Interchange (I-205 and I-5)	WSDOT	Vancouver, WA	X				X		X	X	X	X	X		X				Y	3/1/2010
Tacoma/Pierce County HOV Program	WSDOT	Tacoma, WA	X			X	X		X	X	X	X	X		X				Y	1/1/2010
Detroit River International Crossing (DRIC)	Michigan DOT	Detroit, MI	X				X		X	X	X	X	X		X				Y	1/14/2009
I-5 Delta Park	Oregon DOT	Portland, OR	X				X		X				X		X				Y	12/1/2006
U.S. 36	CDOT	Denver, CO	X			X	X		X	X	X	X	X		X				Y	10/1/2009
Alaska Way Viaduct	WSDOT	Seattle, WA	X				X	X	X	X		X	X	X	X				Y	8/22/2011

[a] Information current as of November 2011.

Table 2.1 Environmental Documents Quantifying MSATs (continued)

			Type of Project				HAPs Analyzed							Analysis				ROD/FONSI Issued[a]	
Project Name	**Sponsor Agency**	**Geographic Location**	**Highway-Expansion**	**Highway – New**	**Intermodal Freight**	**HOV/HOT Lane**	**Benzene**	**Naphthalene**	**1,3 Butadiene**	**Formaldehyde**	**Acetaldehyde**	**Acrolein**	**DPM**	**POM**	**Emissions**	**Concentration**	**Exposure**	**HRA**	**Y/N**	**Date**
SR 520	WSDOT	Seattle, WA	X			X	X	X	X	X		X	X	X	X				Y	8/1/2011
I-405	WSDOT	Seattle, Washington	X				X	X	X	X		X	X		X				Y	5/10/2011
I-240 Widening	TNDOT	Memphis, Tennessee	X				X		X	X	X	X	X		X				Y	CatEx project
Intercounty Connector	Maryland DOT	Suburban Washington D.C.		X			X		X	X	X	X	X		X				Y	5/29/2006
Guam Hual Roads	DOD	Guam		X			X	X	X	X		X		X	X	X		X	Y	9/1/2010
Mountain View Corridor	Utah DOT	Salt Lake and Utah Counties		X			X		X	X	X	X	X		X	X			Y	11/17/2008
Circ-Williston	VTRANS	Williston, Vermont		X			X		X	X	X	X			X				Y	5/1/2011
North Spokane Corridor	WSDOT	Spokane, Washington		X			X	X	X	X		X	X	X	X				Y	2000
Birmingham Regional Intermodal Facility	FRA/FHWA	Birmingham, Alabama			X		X	X	X	X		X	X	X	X	X			Y	12/28/2010
Memphis Intermodal Facility	FRA	Rossville, Tennessee near Memphis			X		X	X	X	X		X	X	X	X				Y	12/20/2010
Schuyler-Heim Bridge Replacement and SR 47 Expressway Project	CalTrans	Port of Los Angeles/ Long Beach	X		X		X		X	X	X		X		X	X	X	X	Y	8/1/2009
Detroit Intermodal Freight Terminal	Michigan DOT	Detroit, Michigan			X		X		X	X	X	X	X		X				Y	4/22/2010

[a] Information current as of November 2011.

Table 2.1 Environmental Documents Quantifying MSATs (continued)

			Type of Project				HAPs Analyzed							Analysis				ROD/FONSI Issued[a]	
Project Name	**Sponsor Agency**	**Geographic Location**	**Highway-Expansion**	**Highway – New**	**Intermodal Freight**	**HOV/HOT Lane**	**Benzene**	**Naphthalene**	**1,3 Butadiene**	**Formaldehyde**	**Acetaldehyde**	**Acrolein**	**DPM**	**POM**	**Emissions**	**Concentration**	**Exposure**	**HRA**	**Y/N**	**Date**
Northwest I-75/575 HOV/BRT	Georgia DOT	Atlanta, Georgia	X			X	X		X	X	X	X	X		X				N	
Columbia River Crossing	ORDOT/ WSDOT	Portland, Oregon/ Vancouver, Washington	X				X	X	X	X		X	X		X	X			N	Expected late 2011
Zoo Interchange (I-94, I-894, and U.S. 45)	Wisconsin DOT	Milwaukee, Wisconsin	X				X		X	X	X	X	X		X				N	FEIS expected summer 2011
Gerald Desmond Bridge	CalTrans	Port of Los Angeles/ Long Beach	X		X		X		X	X	X	X	X		X	X	X	X	N	Final EIS July 2010
I-35 West Northbound Dynamically Priced Shoulder Lanes	Minnesota DOT	Minneapolis, Minnesota	X			X	X		X	X	X	X	X		X				?	
I-95/I-395 Bus/HOV/HOT Lane Project	Virginia DOT	Northern Virginia/ Washington D.C.	X			X	X		X	X	X	X	X		X				?	
Long Island Truck-Rail Intermodal Facility Project	NYSDOT	Long Island, New York			X		X		X	X	X	X	X		X				N	
Multiple Projects in Dallas/Fort Worth Area	NCTCOG	Dallas/Fort Worth, Texas																	N	

[a] Information current as of November 2011.

Table 2.2 MSAT Findings for a Sample of Major Projects

Project Name/ Location	Alternatives	Findings	MSAT differences
Alaskan Way Viaduct Seattle, Washington	2015 compared to 2030 for four alternatives (no-build viaduct closed, two tunnel, one elevated structure).	Build alternatives reduce MSATs slightly less than no-build. Localized MSAT concentration increases near tunnel portals, but localized decreases in other areas.	0.1 tons/year difference in DPM between no-build and highest build alternative.
U.S. 36 Corridor Boulder to Denver, Colorado[a]	2005 compared to 2035 for four alternative packages (no action, managed lanes/BRT, GP/HOV/BRT, Managed/Auxiliary/ BRT).	MSAT emissions increase for build packages when compared to no-build, mainly because of increased VMT.	8.6 tons/year difference in DPM between no-build and highest build alternative (note – we question the validity of this figure which is quite high compared to other studies).
SR 520: Bridge Replacement and HOV Program Seattle, Washington	2008 compared to 2030 for Two alternatives (no-build and build). Four other alternatives were not evaluated for MSATs.	MSAT emissions for build lower than no-build due to increased vehicle speeds (due to less congestion).	0.1 tons/year difference in DPM between build and no-build alternative.
Intercounty Connector Suburban Washington, D.C.	2000 Baseline compared to 2030 for three alternatives (no-build and 2 build corridors) within ICC study area. (Dispersion modeling for CO using CAL3QHC.)	MSAT emissions in 2030 are 67-92.5 percent lower than base year depending on MSAT and alternative. Both corridors reduce MSATs slightly less than no action.	Max is 10 percent difference between ICC Corridor 1 and 2 for most MSATs. DPM difference of 0.87 tons/year for ICC without surrounding network.
Mountain View Corridor Salt Lake and Utah Counties	Baseline compared to 2030 for five alternatives in Salt Lake County and seven alternatives in Utah County (no action plus several build with and without tolling).	MSAT emissions from alternatives are similar. MSAT emissions will decline over time in all cases, but will be somewhat higher with the project than without the project.	DPM difference of 1.37 tons per year compared to no-action for Salt Lake County. DPM difference of 0.29 tons/ year compared to no-action for Utah County.
North Spokane Corridor Spokane, Washington	2008 Baseline compared to 2030 for two alternatives (build and no-build).	MSAT emissions will decline over time in all cases, but will be somewhat higher with the project than without the project.	DPM difference of 0.26 tons/year between build and no-build.

Table 2.2 MSAT Findings for a Sample of Major Projects (continued)

Project Name/ Location	Alternatives	Findings	MSAT differences
Schuyler-Heim Bridge Replacement and SR 47 Expressway Project Los Angeles, California (Port of Los Angeles/ Long Beach)	2003 Baseline compared to 2015 and 2030 for three alternatives (no-build and two build). Dispersion modeling using AERMOD; health risk assessment conducted.	Virtually no difference in MSAT emissions among alternatives. HRA found varying levels of incremental cancer risk to varying number of people depending on alternative.	Max is 0.78 percent DPM difference between alternatives; all other MSATs have 0 percent difference.
Detroit Intermodal Freight Terminal Detroit, Michigan[a]	2004 baseline and 2025 for four alternatives analyzed (no-build, expand existing terminals, consolidate, composite). Terminals and surrounding roadways analyzed separately.	Significant MSAT emissions increases over no action; consolidate and composite alternatives slightly higher than expand for most MSATs.	Max is 14 percent acrolein difference between build alternatives. DPM difference of 0.53 tons/year between no-build and expand alternative.
Birmingham Regional Intermodal Facility Birmingham, Alabama	2015 for one alternative (new facility on preferred site location); Compared to countywide MSAT emissions. Dispersion modeling using AERMOD for $PM_{2.5}$ concentrations at nearby school and residences.	Very small increase in MSAT emissions in Jefferson County (0.0013 percent -0.1 percent). Max predicted impact on $PM_{2.5}$ concentrations <2 percent of annual NAAQS standard.	1.83 tons/year DPM emissions for the new facility.

[a] Project used as basis for case study.

3.0 Task 2 – Modeling Approach and Common Assumptions

3.1 Modeling Approach

In the case study portion of this research, two hypothetical projects were modeled in detail to examine MSAT concentrations in the vicinity of the project under different conditions. The goal was to use projects that might be expected to show substantial differences among project alternatives, and to examine the influence of other conditions on those differences. Two types of projects were selected from Table 2.2: a highway expansion project, and an intermodal freight terminal project.

Conditions that were varied in the analysis included:

- Project alternative (no-project versus one or more "build" alternatives that are substantially different);
- Evaluation year (current or baseline year, plus one or more forecast years through 2035);
- Traffic volumes, speeds/congestion levels, and composition (light versus heavy vehicles);
- Meteorology, including wind speeds and directions;
- Receptor locations (distance from affected facilities and orientation relative to wind); and
- Background concentrations.

Rather than modeling specific real-world projects in detail by either obtaining or carefully replicating the local inputs to the project analysis (e.g., vehicle fleet characteristics, temperature, topography), quasi-hypothetical projects were modeled using a mix of local and non-local inputs. Using real projects as a basis allowed the research team to use many existing data inputs (e.g., traffic changes, emission factors) that already were available from the environmental documentation, rather than recreating an analysis from scratch, allowing resources to be focused on dispersion modeling and sensitivity analysis. At the same time, the flexibility to use custom inputs minimized the need to collect new local data and allowed for testing a range of inputs representative of different conditions across the United States.

The study team conducted case studies for two hypothetical projects that were based on real projects in which MSAT emissions (but not project-related changes in concentrations) were modeled. To isolate the changes in MSAT concentrations associated with the project characteristics, common assumptions were used for meteorological inputs to the dispersion models and for MSAT background concentration levels. Comparison levels also were identified for each pollutant to provide a basis against which to compare whether pollutant levels and changes in these levels might be significant from a health risk perspective. These common assumptions are described in detail below.

3.2 Common Assumptions

Characteristics that are common to both case studies are discussed here. These include MSAT background concentrations and comparison levels, and the meteorological data sets used in the dispersion modeling.

MSAT Background Concentrations

Rather than using background concentrations specific to each project's location, representative background conditions were used, so as to make the study results more generally applicable. The EPA's 2005 National-scale Air Toxics Assessment (NATA) developed modeled background concentrations for the entire United States. These values were spatially averaged over census tracts. MSAT concentrations also are measured at various ambient air monitoring stations across the United States. These measurements were obtained from a search of the U.S. EPA's Air Quality System (AQS) via the AirData interface (http://www.epa.gov/aqspubl1/), downloaded for calendar year 2009 (the last complete year in the AirData system).

As part of the research for this project, the project team compared summary statistics for modeled and monitored pollutant concentrations and concluded that the use of modeled concentrations was a reasonable representation of conditions. In most cases, the average measured and modeled concentrations are of similar magnitude (within about a factor of two). Higher measured concentrations likely reflect the tendency to locate monitoring stations in highly urbanized areas (where air pollutant levels are greater). There is, however, a particularly striking difference for acrolein, for which the measured values are more than an order of magnitude greater than the modeled values. Problematically, the method typically used to measure acrolein is widely recognized to be unreliable, and thus it is not clear whether the modeled or measured values are of greater accuracy.

Two modeled background values were selected for each pollutant, as shown in Table 3.1: 1) the median concentration across all U.S. census tracts, and 2) the 95th percentile modeled value. The 95th percentile was selected to provide a "worse case" condition that might occur in areas with some of the highest ambient levels of air pollution. In both case studies, the background concentrations were not input directly into the dispersion model, but rather added to the output concentrations from the dispersion model that reflected the contributions of mobile sources. This allowed different background concentrations to be tested without rerunning the dispersion models. Since the modeling procedures used for this study did not account for secondary pollutant formation or other non-linear effects, the contribution of mobile sources at any given location would be independent of background concentrations.

Background levels are likely to decrease in the future as emissions from all sources (mobile and otherwise) decline due to increasingly stringent emission standards.[4] This research did not attempt to forecast future background levels, but rather used current background levels as a conservative point of comparison for the future year scenarios. With lower background levels, the relative (percent) contributions of the local transportation project, and the relative effect of the project versus no-project alternatives, will be greater, even though absolute impacts on pollutant concentrations will be the same.

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[4] See: Cook, R.; Strum, M.; Touma, J.S.; Palma, T.; Thurman, J.; Ensley, D.; Smith, R. (2007). "Inhalation exposure and risk from mobile source air toxics in future years." *Journal of Exposure Science and Environmental Epidemiology*, 17: 95-105. "For example, from 1999 to 2015 to 2030, national average total risk from mobile sources air toxics was projected to decreased from 12.4E-6 to 5.31E-6 to 5.52E-6. These projections do not include the MSAT2 rules or renewable fuel standards (RFS2)."

Table 3.1 MSAT Background Concentrations and Comparison Levels (ng/m^3)

	Background[a]		Comparison Levels	
Pollutant	Median	95th Percentile	Chronic Noncancer	70-Year Cancer 1 x 10^{-6} – 100 x 10^{-6}
Acetaldehyde	1,838	3,022	9,000[b]	500 – 50,000[b]
Acrolein	36	124	20[b]	n/a[b]
Benzene	933	2,305	30,000[b]	130 – 13,000[b,d]
1,3-Butadiene	58	159	2,000[b]	30 – 3000[b]
Formaldehyde	1,955	3,718	9,800[b]	80 – 8000[b]
Naphthalene	44	252	3000[b]	[c]
Diesel PM	531	2,912	5,000[b]	[c]

[a] U.S. EPA 2005 National-scale Air Toxics Assessment (NATA) www.epa.gov/ttn/atw/nata2005/tables.html, accessed January 2012.

[b] U.S. EPA. IRIS Toxicological Review and Summary Documents. U.S. Environmental Protection Agency, Washington, D.C., www.epa.gov/iris/, accessed June 2012.

[c] U.S. EPA has not established cancer risk thresholds for naphthalene or diesel PM. The California Environmental Protection Agency has set thresholds of 29 – 2,900 ng/m3 for naphthalene and 3.3 – 330 ng/m3 for diesel PM (see: "Technical Support Document for Cancer Potency Factors," Appendix A. California Environmental Protection Agency, Office of Environmental Health Hazard Assessment, Sacramento, CA, 2009.) California risk information for diesel PM is included here for reference given that, when California risk values are applied, diesel particulate matter accounts for over 80 percent of total excess cancer risk associated with all air toxics in the urban environment (see: "Multiple Air Toxics Exposure Study in the South Coast Air Basin: Final Report," South Coast Air Quality Management District, 2008.)

[d] Benzene values are the more conservative end of ranges provided by EPA. The ranges are 130 to 450 ng/m^3 for the 10^{-6} risk level, and 13,000 to 45,000 ng/m^3 for the 10^{-4} risk level.

Comparison Levels

"Comparison levels " were identified for each pollutant, so that both modeled concentrations and changes in concentrations could be compared against some benchmark of significance related to health effects. These levels are taken from published sources, primarily the U.S. EPA, providing levels of air pollutant concentrations that have been set as thresholds above which meaningful health impacts may occur. Thresholds are provided for chronic noncancer health risks, and for 70-year cancer risks, including one-in-a-million and one hundred-in-a million risk levels (i.e., the level above which at least one person in a million (1 x 10^{-6}), or 100 persons in a million (100 x 10^{-6}), might be expected to contract cancer). All of these levels correspond to the risk from long-term pollutant exposure (e.g., a multiyear period). Much higher exposure levels would be required to create health risks from short-term exposure (such as a peak hour or day).

The one-in-a million risk level is the low-end of the typical acceptable risk range of the Superfund program. Smaller risk levels are generally deemed insignificant by almost all regulatory bodies. Kocher and Hoffman (1991), in a detailed discussion, suggest one-in-a million as the de mimimis risk level.[5] An overall five-in-a-million residual risk level (the residual risk from EPA's mobile source control program, not considering diesel PM) is consistent with one-in-a million screening levels for individual MSATs as there are multiple MSATs that are potential carcinogens.

Meteorological Data Sets

Meteorological data sets from three locations were used in the case studies:

- A dataset from 1988 for Boulder, Colorado was used in Case Study Number 1;
- A dataset from 2007 for the Detroit City Airport in Michigan was used in Case Study Number 2, as downloaded from the Michigan Department of Environmental Quality web site; and
- Datasets from Anaheim, California (1981 for Case Study Number 1, 2005 for Case Study Number 2) were used as a comparison dataset in both case studies, as obtained from the South Coast Air Quality Management District web site.[6]

In each case, data were preprocessed by the regulatory agencies, and the model-ready.sfc and.pfl files downloaded (ISC format for Case Study Number 1, and AERMOD.sfc and.pfl files for Case Study Number 2). A single year of meteorological data was considered from each location.[7] Wind roses for the three data sets are provided in Figures 3.1 through 3.4 (wind roses were created with Lakes Environmental's WRPLOT View freeware program). The Boulder and Detroit data reflect a wide range of wind directions and speeds, along with a relatively high percentage of calm conditions (6 to 12 percent). In contrast, wind speeds are much lower for the Anaheim, California data set and exhibit a greater degree of channelization of winds from the southwest. The very low calms frequency of the

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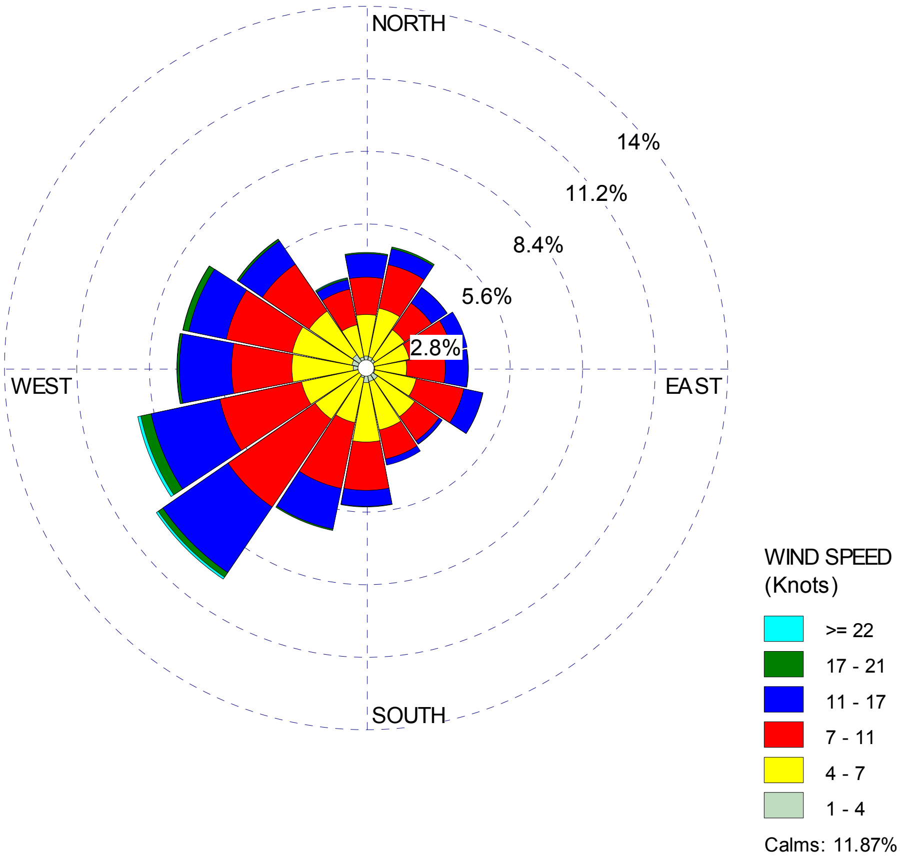
[5] Kocher, D.C. and Hoffman, F.O. (1991). "Regulating Environmental Carcinogens: Where do we Draw the Line?" *Environmental Science & Technology* 25: 1986-1989.

[6] Different datasets were obtained because of the need for compatibility between the dataset and the dispersion model used. The two datasets have very different calm frequency conditions that result from different meteorological data processors and/or improvements in the instrumentation – the later 2005 data set produced by AERMET is able to assign wind speeds to many of the hours considered calm in the 1981 data set.

[7] Regulatory applications typically require five-year periods when utilizing meteorological data from proximate airports. A single year was used in this study due to resource constraints.

Anaheim data used in Case Study Number 2 suggests a low threshold for the anemometer (or processing of 1-minute data). The Anaheim data were used to illustrate a "worst-case" scenario, since near-facility pollutant concentrations would be expected to be higher under low wind speed conditions.[8]

Figure 3.1 Boulder, Colorado Wind Rose



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[8] There is some debate over the best treatment of wind speeds, with some analysts suggesting that wind speeds of less than 1 m/s but higher than the response threshold of the instrument should be input as 1 m/s for steady-state Gaussian plume models, in order to avoid unrealistically high concentration predictions. When wind speeds below 1 m/s are considered by AERMOD as they were in this report's IFT case study number 2 (rather than being treated as calms), it is likely that higher concentrations are predicted. However, whether this is an appropriate treatment or not is subject to debate.

Figure 3.2 Detroit, Michigan (Airport) Wind Rose

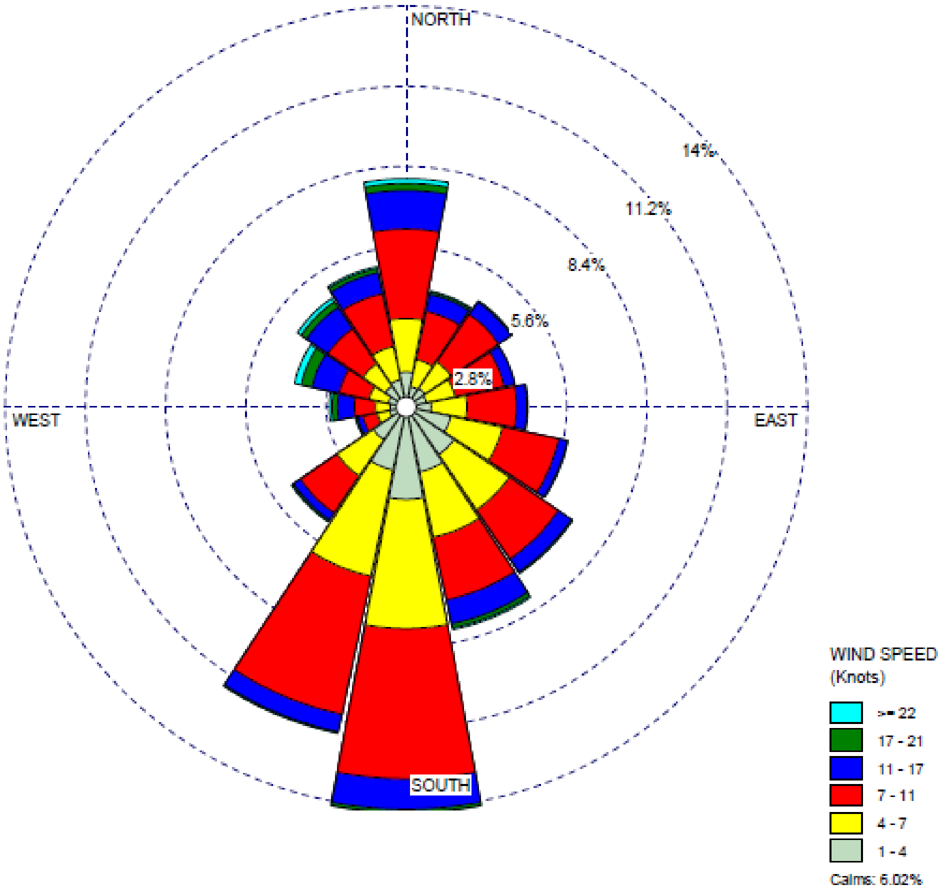


Figure 3.3 Anaheim, California Wind Rose (Case Study Number 1)

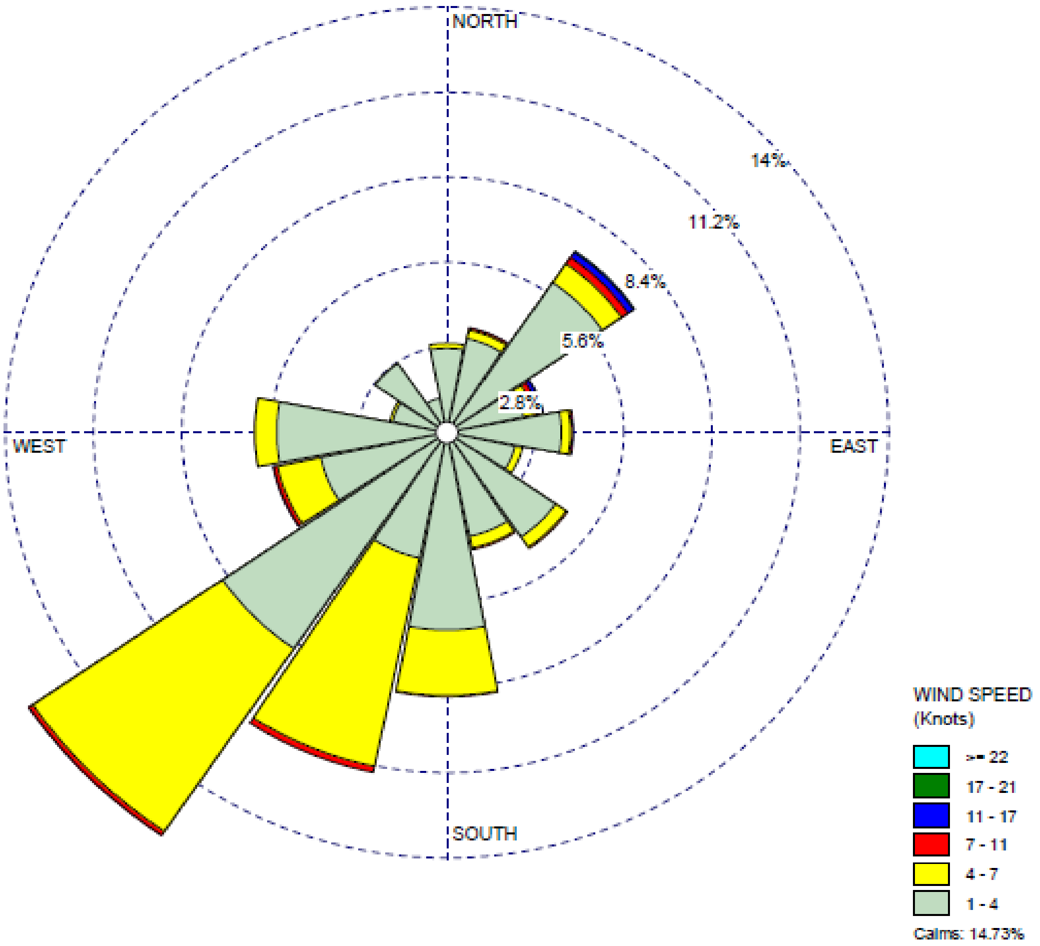
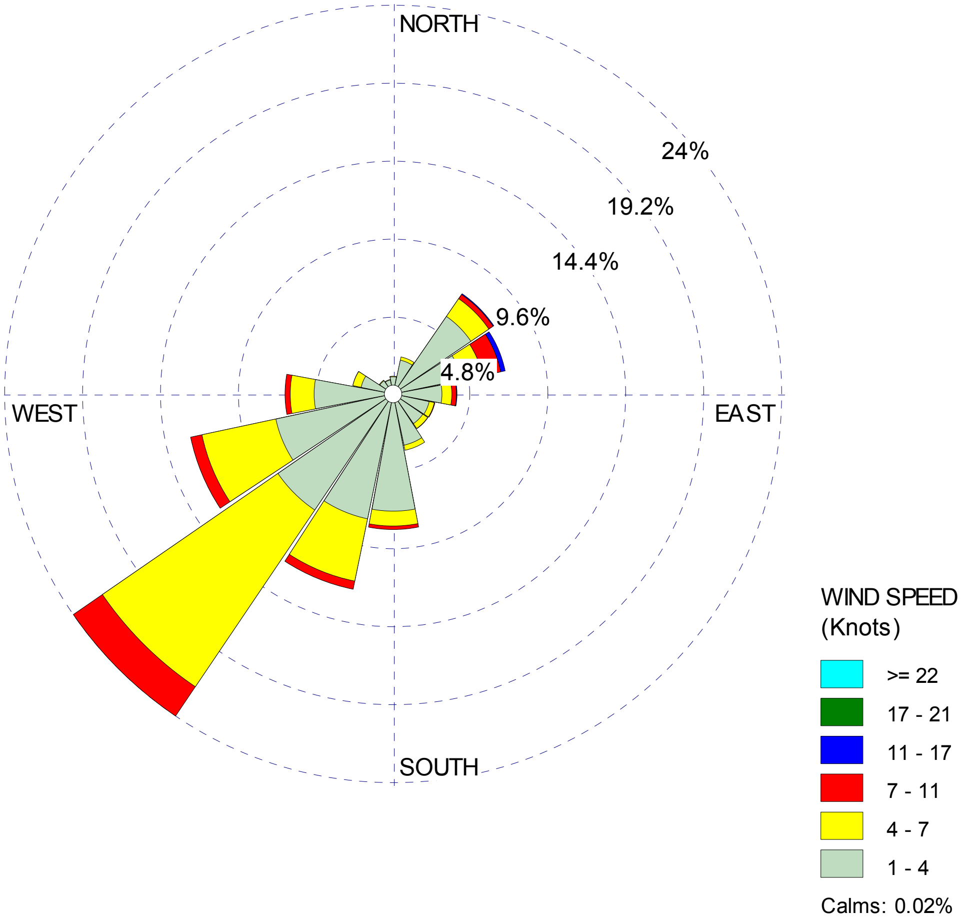


Figure 3.4 Anaheim, California Wind Rose (Case Study Number 2)

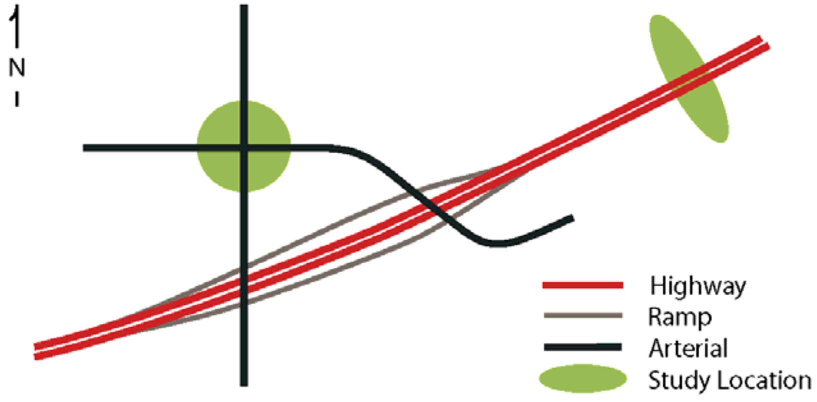


4.0 Case Study Number 1: Highway Expansion Project

4.1 Case Study Description

This case study conducted modeling to compare differences in MSAT concentrations among project alternatives for a highway expansion project. The CAL3QHC/r line-source dispersion model was used to examine pollutant concentrations near a freeway segment and the busiest intersection providing access to the freeway. The project in question would add capacity to the highway, including both general purpose and managed lanes, and results in a large increase in traffic volume on the highway. The geometry at adjacent intersections providing access to the highway is not altered by the project, but traffic speeds and volumes at these intersections vary slightly between project alternatives. A schematic representation of the intersection location relative to the highway is shown as Figure 4.1. The distance from the intersection to the mainline is about 900 feet.

Figure 4.1 Project Location Schematic



The case study is nominally based on the recent U.S. 36 Corridor project connecting Denver and Boulder, Colorado (CH2M Hill, 2009). For the sake of simulating realistic conditions, many aspects of the example derive from U.S. 36 project specifics and data. However, the case study is not intended to be an accurate portrayal of the project, as such an analysis would require detailed, intimate knowledge of the project. Rather, the case study uses information from the U.S. 36 project documentation along with other reasonable but unverified assumptions regarding model implementation and should not be considered an assessment of the project itself.

Lane, volume, and level of service (LOS) information for the mainline are provided in Tables 4.1 and 4.2. Geometry, volume and LOS information for the intersection are provided in Tables 4.3 and 4.4. The information shown in the tables documents the traffic volume increases on the highway, and variability between the build and no-build traffic characteristics at the adjacent intersection. The mainline and intersection study locations were analyzed in isolation from one another.

Table 4.1 Mainline Traffic Flows and Lane Geometry

Year/Alternative	Average Daily Traffic	Lanes	
		Westbound	Eastbound
2005	112,500	3 mixed flow lanes	2 mixed flow lanes 1 HOV lane
2035 No Action	141,800	Same as 2005	
2035 Preferred Alternative	180,500	3 mixed flow lanes 1 HOT lane	3 mixed flow lanes 1 HOT lane

Table 4.2 Mainline – Detailed Volume and LOS Information

Measure	Time Period	Lane Type	2003 Existing	2035 No-Build	2035 Build	2003 Existing	2035 No–Build	2035 Build
				Eastbound			Westbound	
Volume	Daily	General Purpose	53,880	65,900	89,500	56,580	71,700	78,100
		HOV/Managed Lane*	2,000	4,200	8,100	–	–	4,800
	AM Peak Hour	General Purpose	3,560	4,410	6,600	3,780	5,200	5,770
		HOV/ Managed Lane*	400	1,170	980	–	–	900
	PM Peak Hour	General Purpose	4,090	4,240	6,480	5,030	6,670	5,910
		HOV/ Managed. Lane*	100	–	610	–	–	630
Level of Service	AM Peak Hour	General Purpose	D	F	F	C	D	E
		HOV/ Managed Lane*	–	–	B	–	–	B
	PM Peak Hour	General Purpose	F	F	F	D	F	E
		HOV/ Managed Lane*	–	–	B	–	A	B

*HOV for the Existing and No-Build Scenario, Managed Lane for the Build Scenario

Table 4.3 Intersection Traffic Flows and Lane Geometry

Year/Alternative	Volume and Speed	Lanes
2005	AM Peak: 4,080 PM Peak: 6,950 Weighted Speed: 8.37 miles per hour.	**Northbound** 2 left turn pockets 2 through lanes 1 right turn pocket **Southbound** 2 left turn pockets 3 through lanes 1 right turn pocket **Westbound and Eastbound** Same as Southbound
2035 No Action	AM Peak: 8,330. PM Peak: 9,330 Weighted Speed: 6.69 miles per hour	
2035 Preferred Alternative	AM Peak: 8,500 PM Peak: 8,620 Weighted Speed: 7.13 miles per hour	

Table 4.4 Intersection – Detailed Volume and Speed Information

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR
Volume (vph)	895	855	160	980	600	260
Total Delay (s)	60.8	85	0.1	111.5	44.8	0.2
Link Distance (ft)	618.0	618.0	618.0	1,118.0	1,118.0	1,118.0
Free Flow Speed (mph)	15.0	30.0	9.0	15.0	30.0	9.0
Free Flow Travel Time (s)	28.1	14.0	46.8	50.8	25.4	84.7
Total Travel Time (s)	88.9	99.0	46.9	162.3	70.2	84.9
Estimated Speed (mph**)**	4.7	4.3	9.0	4.7	10.9	9.0
Lane Group	**NBL**	**NBT**	**NBR**	**SBL**	**SBT**	**SBR**
Volume (vph)	335	1,245	1,100	290	1,260	635
Total Delay (s)	134.8	79.5	5.4	133.6	105.4	0.9
Link Distance (ft)	540.0	540.0	540.0	691.0	691.0	691.0
Free Flow Speed (mph)	15.0	30.0	9.0	15.0	30.0	9.0
Free Flow Travel Time (s)	24.5	12.3	40.9	31.4	15.7	52.3
Total Travel Time (s)	159.3	91.8	46.3	165.0	121.1	53.2
Estimated Speed (mph)	2.3	4.0	8.0	2.9	3.9	8.8

Key: EB=Eastbound; WB=Westbound; NB=Northbound; SB=Southbound; L=Left; T=Through; R=Right

Pollutants considered in the highway expansion case study include:

- 1,3-butadiene;
- Acetaldehyde;
- Acrolein;
- Benzene;
- Formaldehyde;
- Napthalene; and
- Diesel particulate matter (PM_{10} from diesel vehicles was used as a surrogate).

The study focus is on chronic risk and therefore annual average concentrations were estimated for each pollutant. Findings from the case study explore the effect of location (relative to the highway or intersection), background concentration, analysis year, and the differences between the no-action and preferred alternatives.

Scenarios

The five scenarios modeled are summarized in Table 4.5. The No Action scenarios reflect existing roadway geometry and traffic forecasts that assumed no additional highway capacity. In the Preferred Alternative scenarios the highway is enlarged from six lanes to eight lanes (including an increase from one to two managed lanes). The additional capacity is reflected in the forecast traffic volumes.

The 2005 base year represents the existing condition; this serves a reference point to examine how emissions change over time with or without the highway expansion project. A long-term (2035) analysis was performed using the 2035 forecast traffic speeds and volumes both with and without the project, in conjunction with MOVES modeled emission rates for 2035. These scenarios allow identification of changes in concentrations resulting from likely long-term traffic increases, offset by significant reductions in emissions per vehicle due to fleet turnover meeting recent emissions standards. An additional set of scenarios was constructed using traffic volumes and speeds forecast for 2035, but with 2015 emission rates. These 2035 traffic/2015 emissions scenarios were included to reflect a "worst case" condition, assuming a large traffic increase in a short timeframe before the vehicle fleet has fully turned over to reflect the latest and most stringent emissions standards.

Table 4.5 Scenarios Modeled

Year / Project Alternative	Emission Factors	Goal of Comparison
2005/No Action	2005	Reference point
2035/No Action	2015	Test for project-related concentration change under "worst case" traffic and emission factors
2035/Preferred Alternative	2015	
2035/No Action	2035	Test for project-related concentration changes with 2035 emission factors
2035/Preferred Alternative	2035	

■ 4.2 Data and Methods

The CAL3QHC/r dispersion model was coupled with emission rates from MOVES2010a to estimate concentrations under five scenarios. CAL3QHC/r is a line-source model designed specifically for transportation analysis, and is commonly used to evaluate changes in pollutant concentrations near roadways and intersections. Since suitable emission factors were not available from the project documentation, the project team ran MOVES2010a with default inputs to develop speed-based emission factors that could be applied to the traffic volumes and speeds reported in the project environmental documentation. Traffic inputs for the intersection in a format suitable for input to CAL3QHC/r could not be readily obtained from the existing project documentation, so additional intersection analysis was conducted using Highway Capacity Manual (TRB, 2004) traffic operations methods using Synchro software. Inputs and outputs for the various scenarios modeled are provided in Appendix B.

Emission Factors

MOVES2010a was used to develop g/mile emission rates for use with the CAL3QHC/r model. Emission rates were based on average link speeds, which were determined based on information from the original project's environmental document. A county-level run rather than a project-level run was made because only average link speeds were available and project-level would only be used to take advantage of detailed drive cycle (operating mode distribution) information if it were available. Default inputs for Boulder County, Colorado were used. The emission factors represent the default weighting by source type (e.g., light versus heavy duty vehicles). All of the seven MSATs listed above were included in the MOVES runs. A separate MOVES run was conducted for each of three years and four seasons, resulting in 12 MOVES runs. Each MOVES run provided emission rates for each of the 24 hours of the day. Sample emission rates for each pollutant by year and speed bin are provided in Appendix A.

Application of CAL3QHC/r to estimate annual average concentrations requires much more traffic data than what is typically prepared for the traffic operations analysis in an environmental document. Specifically, traffic studies typically focus on the volume and resulting delay during the AM and PM peak periods of a typical day. The remaining 22 hours of the day and weekends are typically not modeled because there is typically not enough congestion to generate a significant impact on traffic operations. However, for emissions analysis, which is temperature dependent, it is necessary to estimate hourly traffic volumes for the entire day, and how weekdays compare to weekends. Hourly traffic distributions from continuous traffic count sensors on the mainline as documented in the environmental impact report (CH2M Hill, 2009) were used to estimate hourly traffic volumes at both the intersection and the mainline study locations. Emission rates reflecting each hour's temperature were then coupled with volume data for use in the CAL3QHC/r model.

Dispersion Modeling

Annual average concentrations were estimated at a variety of locations, referred to as receptors, using the CAL3QHC/r dispersion model. Each season was modeled separately to reflect the impact of temperature on the emission rates. The annual average concentrations were determined from the seasonal results. Samples of CAL3QHC/r output for the mainline and the intersection are provided in Appendix C.

The CAL3QHC/r model breaks each of the modeled roadway links into smaller segments oriented perpendicular to the wind field, and then assumes that the pollution concentration is reduced the further a receptor is from the centerline of the plume. The distribution of pollutant concentration relative to the plume center line has a Gaussian profile, and therefore this class of model is referred to as a Gaussian dispersion model. A conceptual image of the relationship between emissions and receptor concentrations is shown as Figure 4.2. The model is sensitive to the location of the receptors, the representation of the roadway links, and the wind-field/meteorological data set used. Each of these parameters for this study is documented below.

- **Receptors –** For the study intersection, receptors were positioned as shown in Figure 4.3. A total of 20 receptors were laid out: one at each corner and then at 250 and 500 feet from the corners on each leg of the intersection. All receptors were located 3 meters (10 feet) from the traveled way. [9] To model the mainline, six model receptors were used positioned along a line running perpendicular to the highway as shown in Figure 4.3 and 4.4. Receptors were located on each side of the highway 90, 125, and 150 feet from the highway centerline.

- **Roadways –** Roadways were modeled using an average speed method. Links away from the intersection were assumed to operate at the free flow speed. Within 500 feet of the intersection, movement-specific approach links (i.e., left, through, right) were used so that the average speed could reflect the approach-specific delay. This delay was determined from a traffic operations analysis using Highway Capacity Manual methods and Synchro software.

- **Wind Field –** Meteorological data sets from Boulder and Anaheim were used, as described in Section 3.0.

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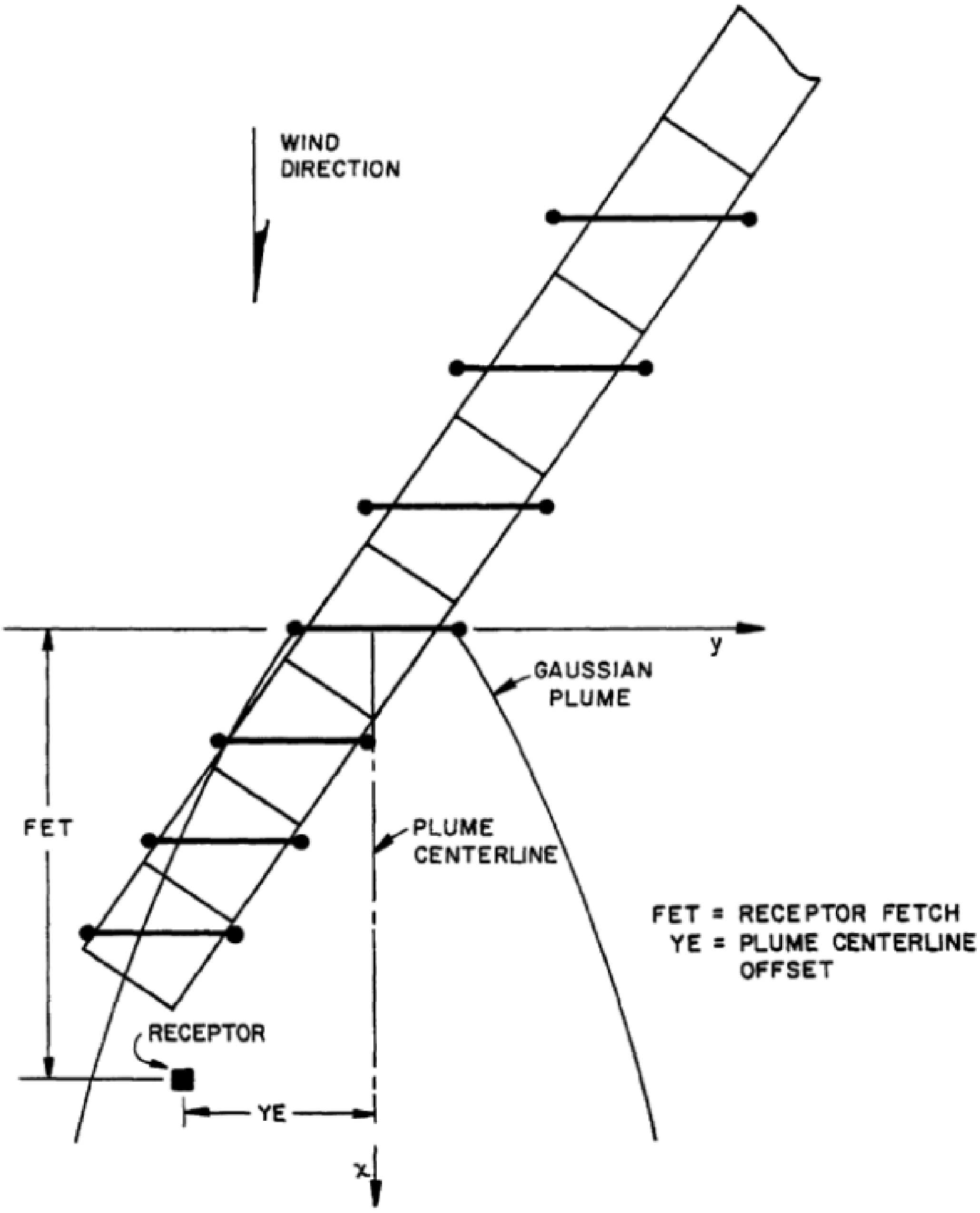
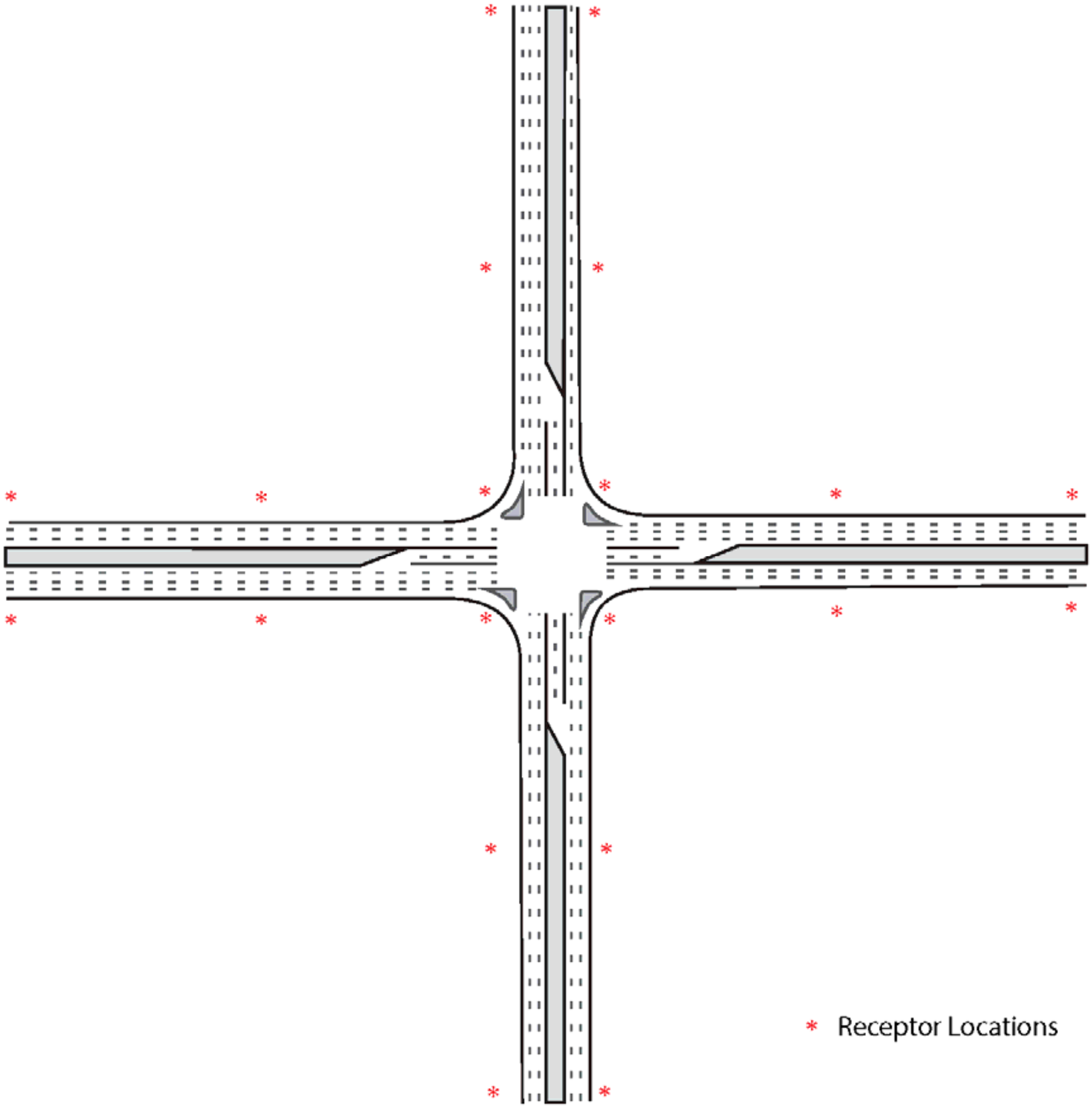
[9] The 3 m receptor distance reflects the concentration in the "mixing zone" above and surrounding the traveled way. See: [9] Niemeier, Debbie A., Douglas S. Eisinger, Tom P. Kear, Daniel P.Y. Chang, Yu Meng (1997). *Transportation Project-Level Carbon Monoxide Protocol* (Research Report UCD-ITS-RR-97-21). Institute of Transportation Studies, University of California, Davis.

Figure 4.2 Conceptual CAL3QHC/r Application of Gaussian Plume Model



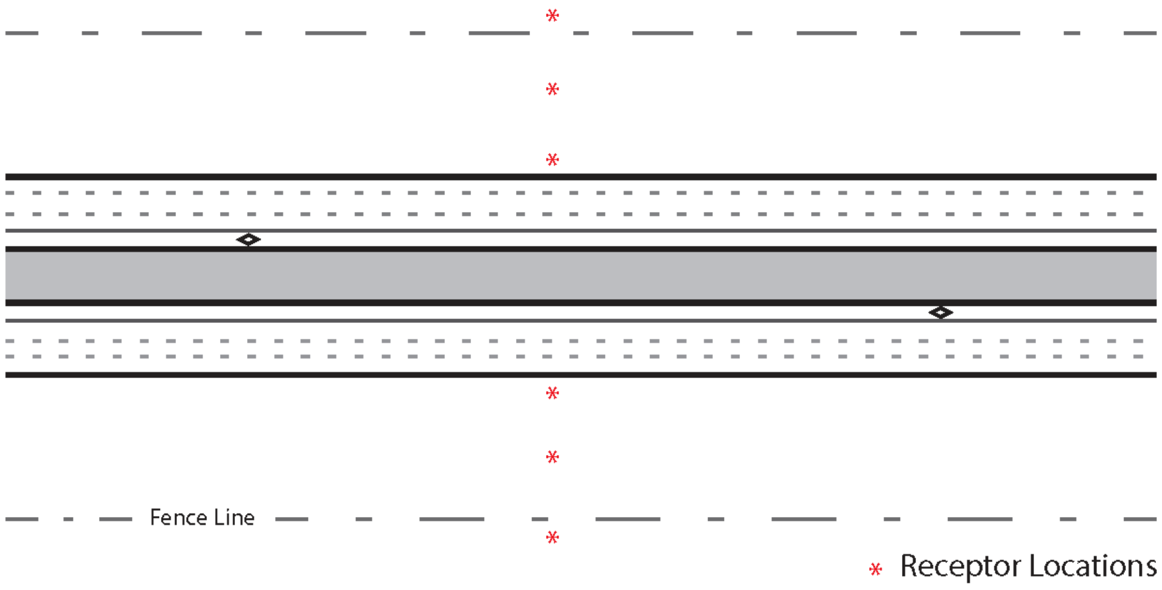
Source: CALINE4 User Guide.

Figure 4.3 Receptor Locations: Intersection[a]



[a] At intersection with 3-meter setback; 250 and 500 feet from intersection.

Figure 4.4 Receptor Locations: Mainline[a]



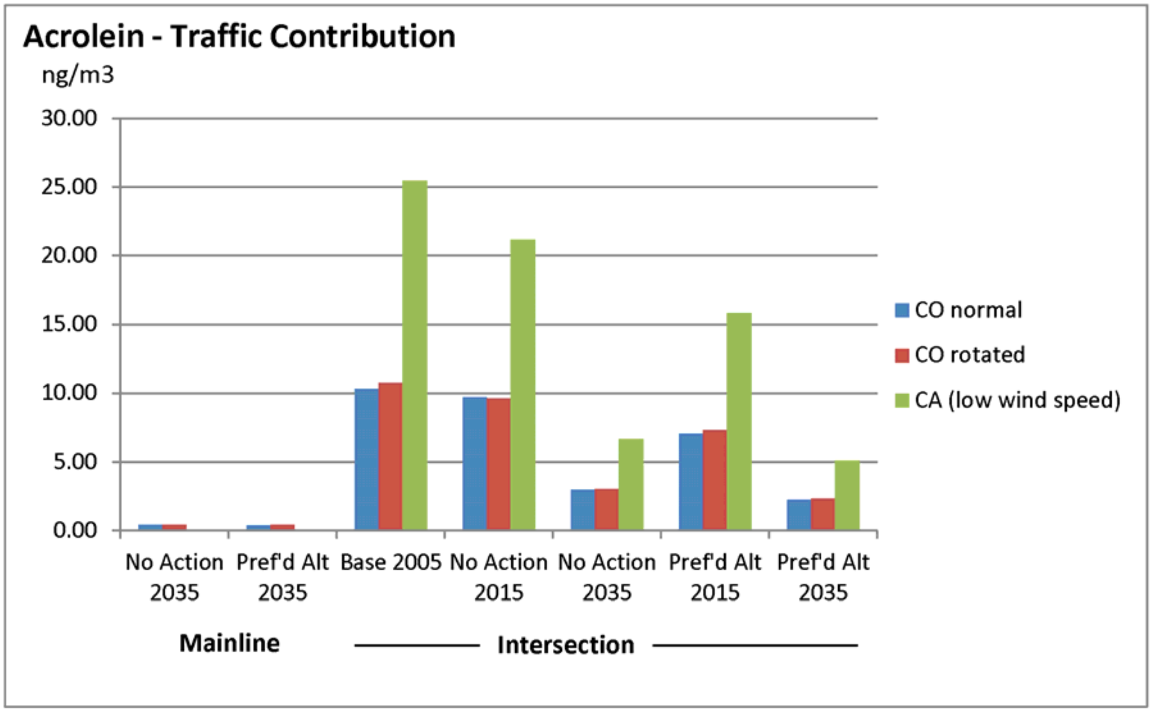
[a] Located 90, 120, and 180 feet from centerline of highway.

4.3 Modeling Results

The results of the CAL3QHC/r analysis are presented in graphical format in Figures 4.5 through 4.15 and described below.

The first series of figures illustrates the effect of the study location (intersection versus mainline), receptor location, and wind field. Figure 4.5 contrasts the highest estimated concentrations between the intersection and the mainline for the meteorological data (wind-field data) sets used. Concentrations shown do not include any contribution from the ambient background so that the effect of the project is not obscured. The wind field data used includes the Colorado wind-field; the Colorado wind-field rotated 90 degrees as a check on the effect of project orientation; and the lower wind speed California data. Generally, the remainder of the results presented will focus on the intersection, using the California wind-field data where the largest project impacts are observed. Acrolein is depicted in Figure 4.5 as an example, with additional pollutants presented later.

Figure 4.5 Effect of Study Location and Wind Field



The effect of receptor location, specifically proximity to the traveled way, is shown in Figure 4.6 for the mainline and Figure 4.7 for the intersection. For the mainline, the closest receptor to the traveled way on the predominantly downwind side of the highway is expected to experience the highest annual average pollutant concentrations related to the traffic. At the intersection, the highest concentrations occur at the corner receptors. These receptors are closest to the contributions from two adjacent legs of the intersection, and are close to the congested approach links where there tends to be higher emitting traffic activity. Because of the relatively consistent pattern in the concentrations, results presented will be limited to the locations with the highest predicted concentrations.

Figure 4.6 Effect of Receptor Location (Mainline)

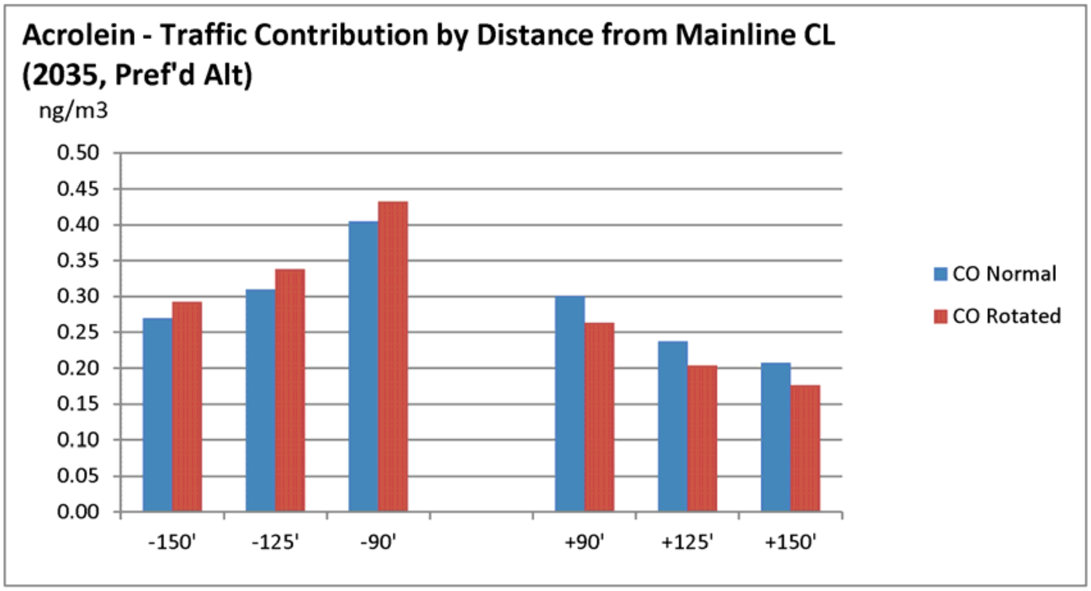
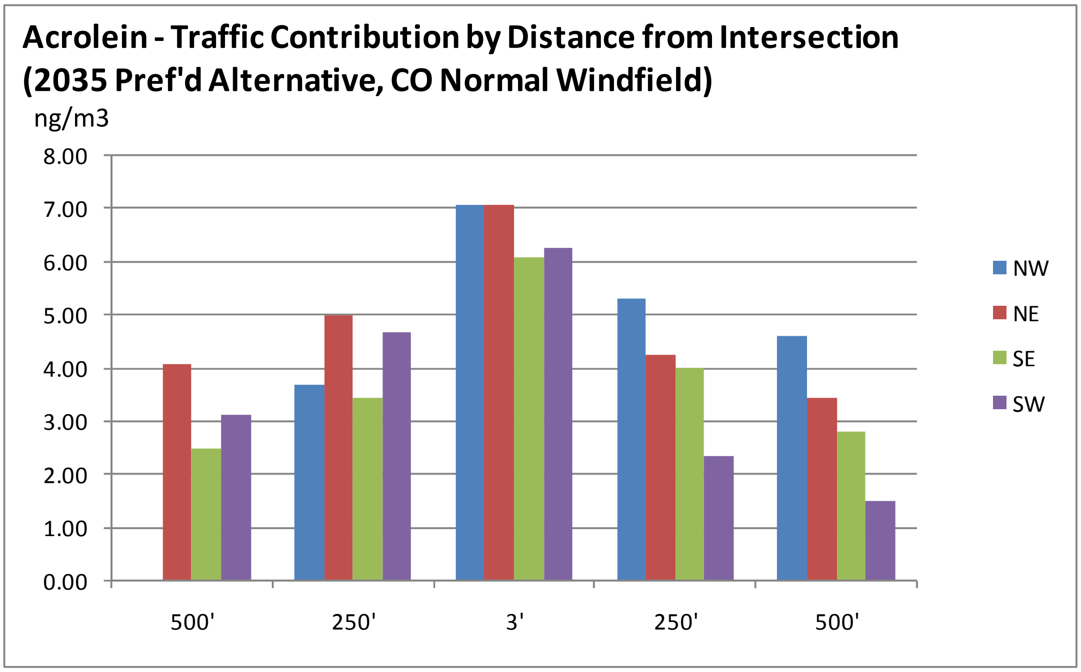


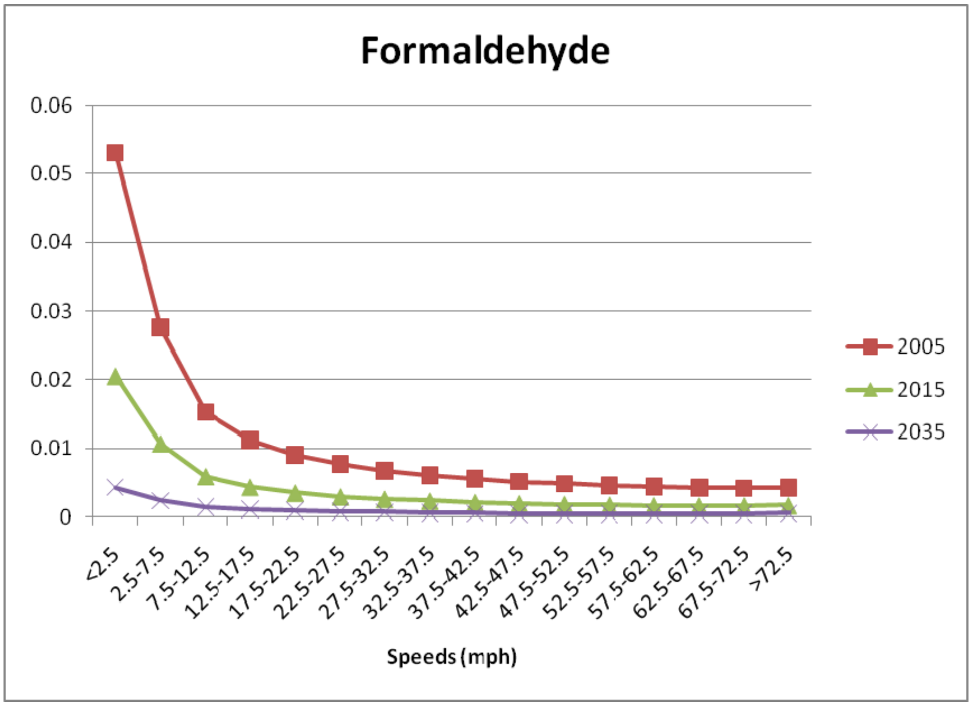
Figure 4.7 Effect of Receptor Location (Intersection)[a]



There are several patterns in the results that are much easier to understand within the context of how emission rates vary over 2005, 2015, 2035, and how emissions are affected by the vehicle activity. Figure 4.8 presents these relationships for formaldehyde; other pollutants have similar trends. See Appendix A for emission rates for all pollutants, including a comparison of the ratio of 2015 and 2035 to 2005 emissions.

- Emissions are higher under stop-and-go driving conditions, which result in higher levels of vehicle-specific power (VSP) and lower link speeds. The weighted average speeds through the intersection were in the 5 to 10 mile-per-hour range, which in part explains the higher predicted concentrations at the intersection versus the mainline. (The intersection receptors also are closer to traffic than the mainline receptors.)
- There is a dramatic decline in the emissions from the vehicle fleet over time, which means that the estimated 2035 concentrations are less than the 2005 concentrations, even when large increases in traffic volume occur. Emissions in 2015 also are substantially lower than in 2005.

Figure 4.8 Example of Influence of Speed and Year on Emission Rates (g/mi)

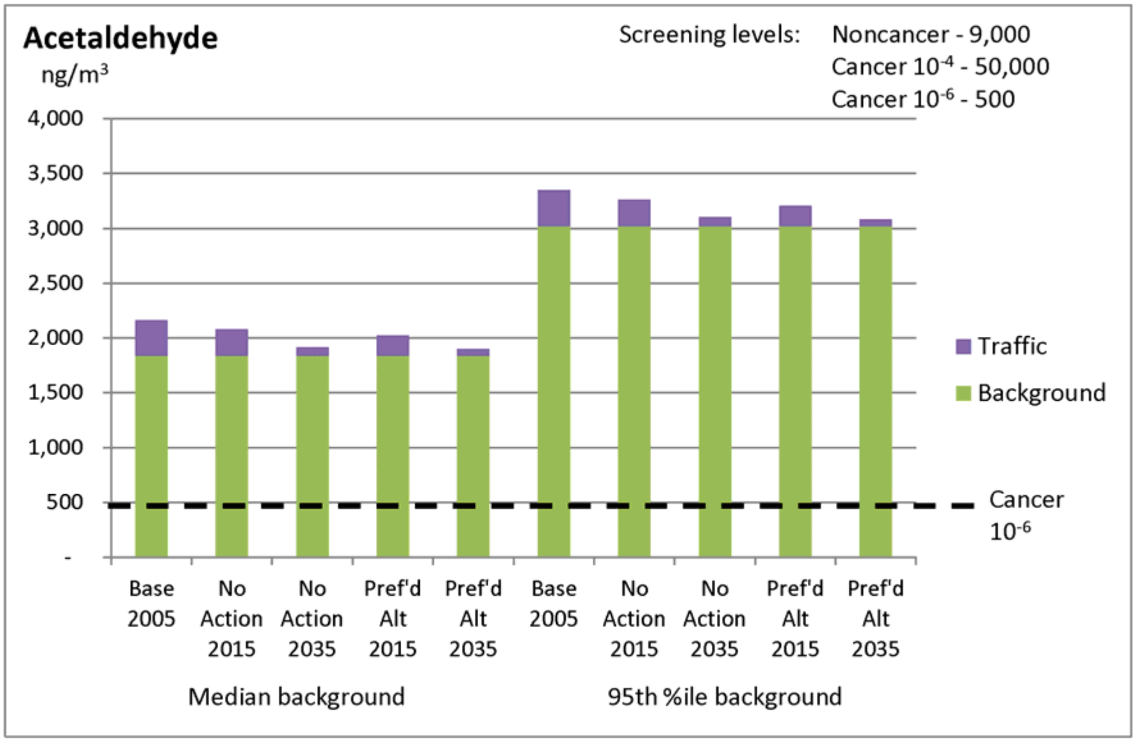


The next series of figures (Figures 4.9 to 4.15) presents the results for each pollutant from the intersection modeling, using the California wind field data. Numerical results are shown in Table 4.4 following these figures. The figures show the results for each scenario on top of the median and 95th percentile background concentrations (see Section 3.0).

The intersection's contributions for acetaldehyde (Figure 4.9) are smaller than the one in a million cancer screening level and smaller than the noncancer screening level. When combined with the estimated background concentration levels, risk would exceed one in a million for cancer, but the majority of that risk is associated with the background concentration level.

For both the preferred alternative and the no action alternative, acetaldehyde concentrations drop over time. This relationship holds true for all pollutants except naphthalene, for which future emission rates decrease relatively less than for other pollutants. The preferred alternative has lower concentrations than the no action alternative, for any given year. Again, this is true for all pollutants except naphthalene, where the unusual shape of the speed-emissions curve leads to a slight increase in emissions under the preferred alternative.

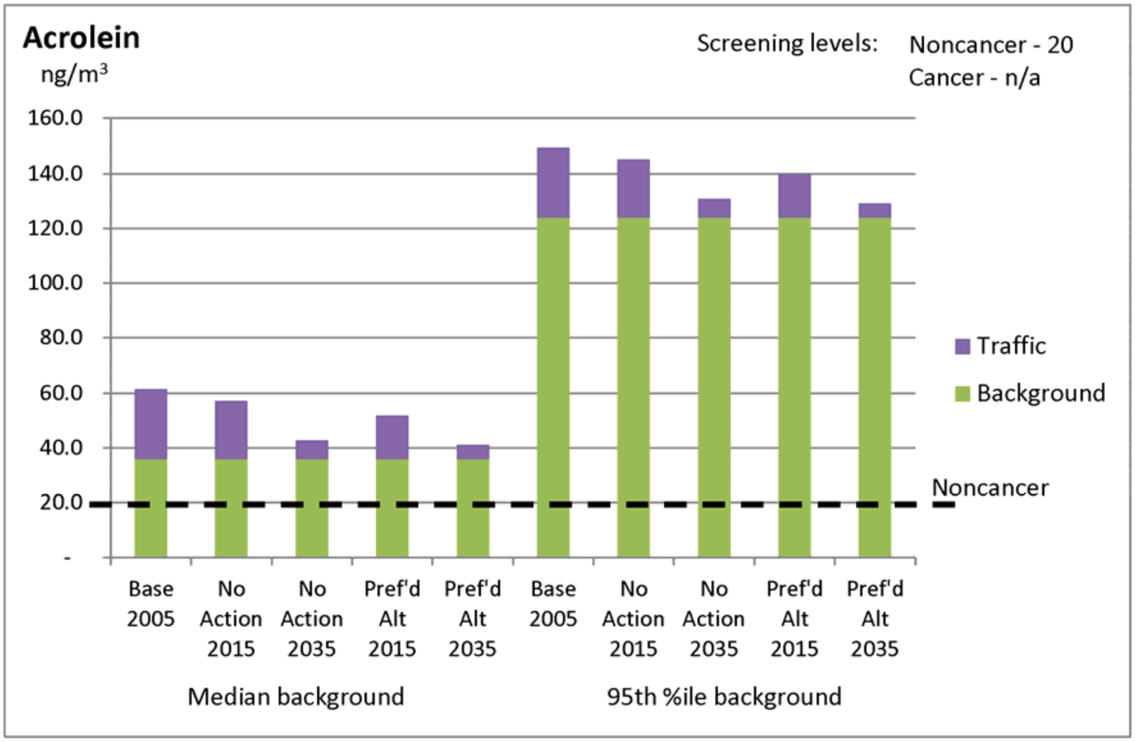
Figure 4.9 Intersection Results: Acetaldehyde



The 2005 acrolein contribution from traffic (Figure 4.10) is on par with the noncancer screening level, but future project contributions are all below the noncancer screening level. Considered with the background concentrations, the noncancer screening threshold is exceeded. Acrolein is not considered a human carcinogen, so there is no cancer screening threshold.

For both the preferred alternative and the no action alternative, acrolein concentrations drop over time. The preferred alternative also has lower concentrations than the no action alternative, for any given year.

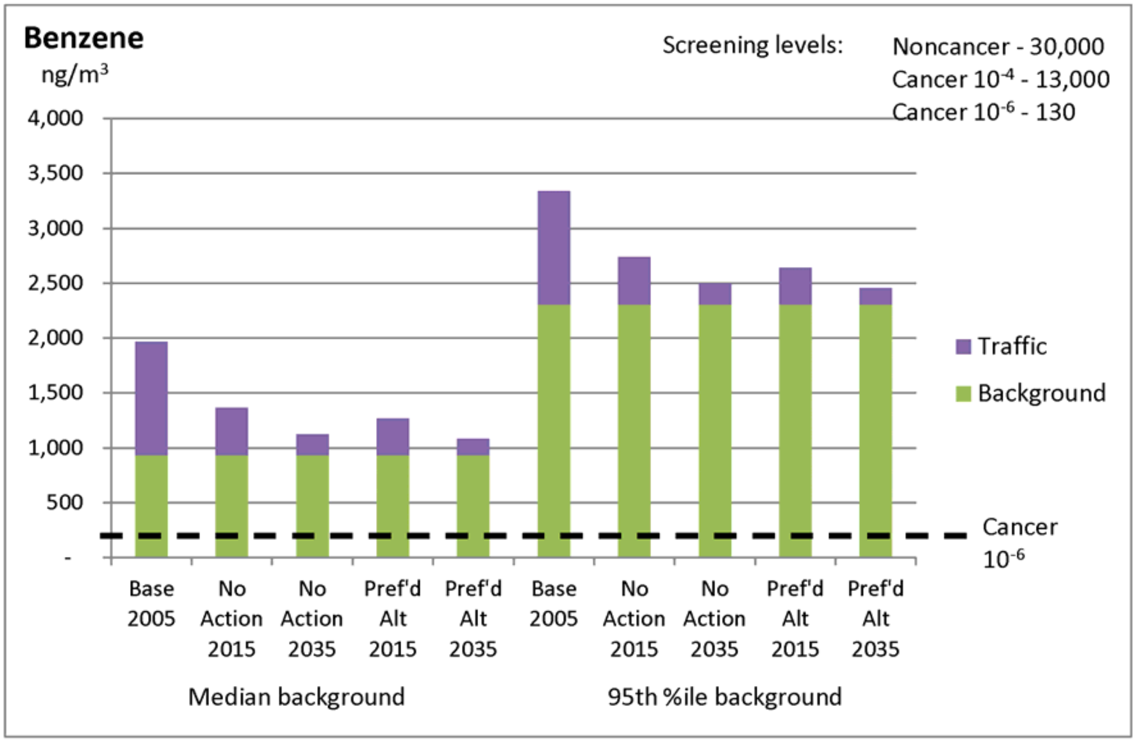
Figure 4.10 Intersection Results: Acrolein



Estimated benzene concentrations (Figure 4.11) in 2005 and 2015 exceed the one in one million cancer screening threshold with or without the background concentration. The hundred-in-a-million cancer screening threshold is not exceeded, and the noncancer screening threshold is not exceeded under any condition.

For both the preferred alternative and the no action alternative, benzene concentrations drop over time. The preferred alternative has lower concentrations than the no action alternative, for any given year.

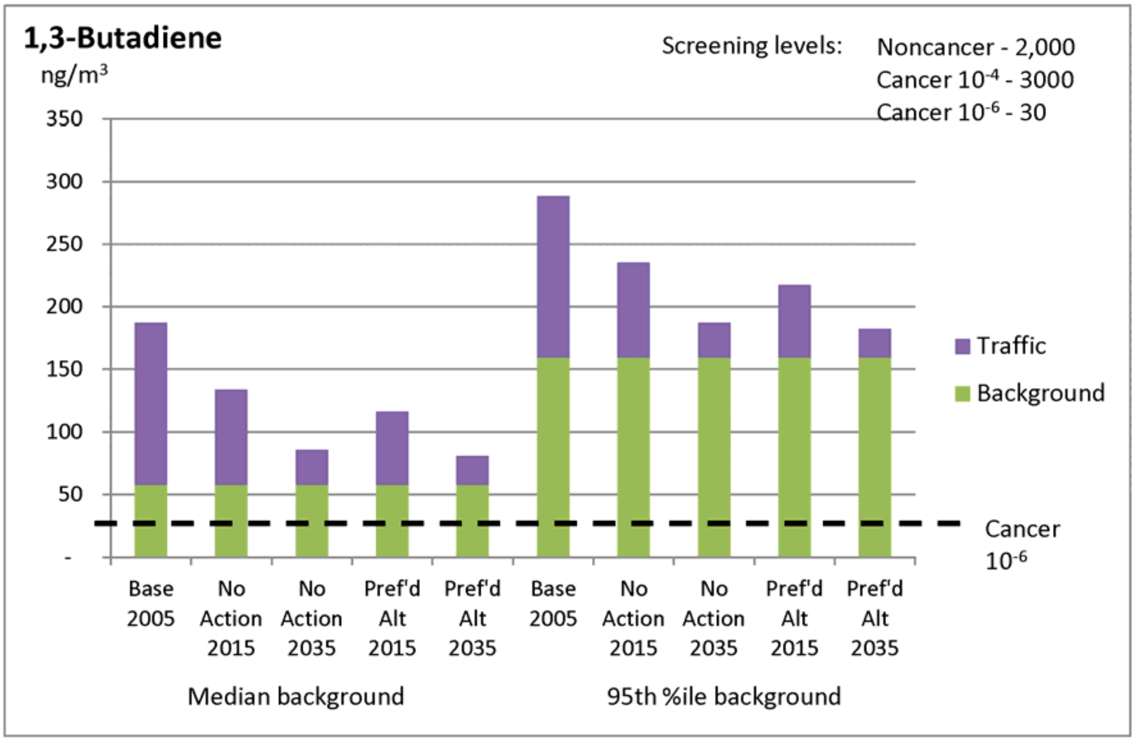
Figure 4.11 Intersection Results: Benzene



The same pattern seen with formaldehyde holds true for 1,3-butadiene (Figure 4.12), although with 1,3-butadiene the project contribution relative to the background contribution tends to be more significant. One in a million cancer screening thresholds are exceeded, but hundred-in-a-million and noncancer thresholds are not exceeded.

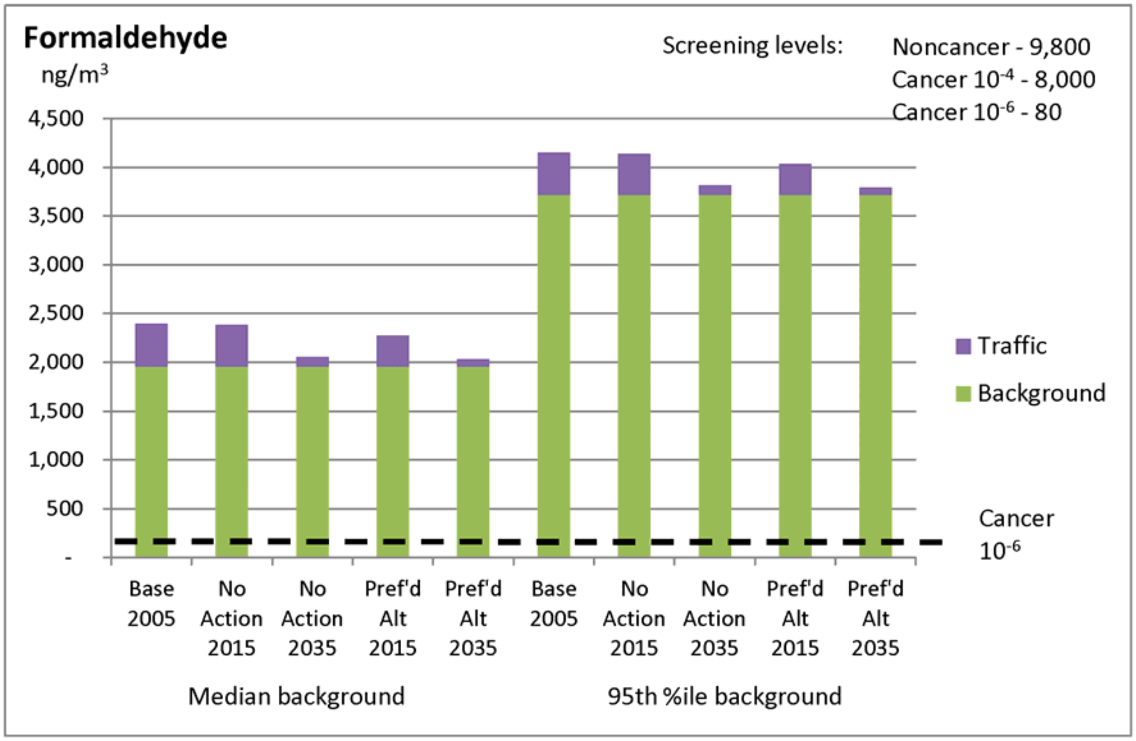
For both the preferred alternative and the no action alternative, 1,3-butadiene concentrations drop over time. The preferred alternative has lower concentrations than the no action alternative, for any given year.

Figure 4.12 Intersection Results: 1,3-butadiene



The intersection contribution to formaldehyde concentration (Figure 4.13) exceeds the one-in-a-million risk level in both 2005 and 2015, but not 2035. As noted for most of the other pollutants, the preferred alternative reduces formaldehyde concentrations associated with the intersection. The contribution of background concentrations to the risk associated with formaldehyde also is larger than the contribution from the intersection.

Figure 4.13 Intersection Results: Formaldehyde

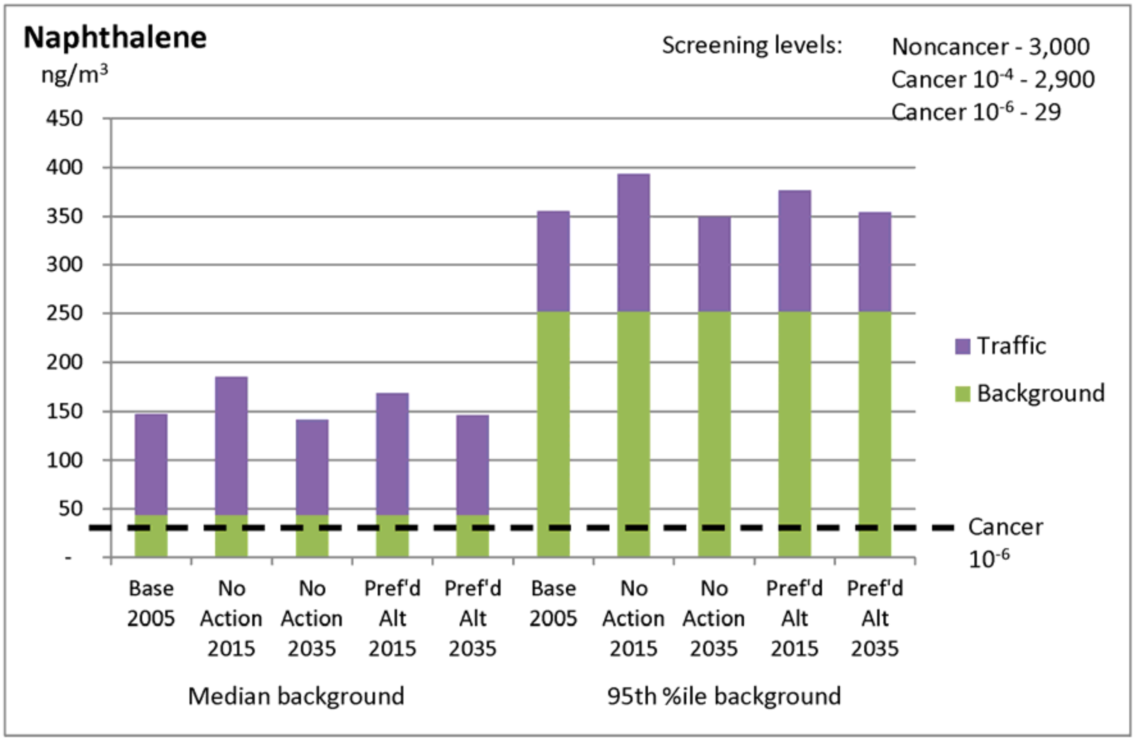


The pattern of predicted concentrations for naphthalene differs from the patterns of other pollutants in two ways (Figure 4.14).

First, the intersection's estimated contribution to the nearby concentration of naphthalene grows from 2005 the 2015, and the 2035 concentration estimate is only slightly below the 2005 concentration estimate. This is because naphthalene emissions are not anticipated to drop as quickly as the emissions of other MSATs; in fact the traffic growth from 2005 to 2035 essentially cancels out the emission reduction benefits of lower emitting vehicles.

Second, for 2035 the preferred alternative is anticipated to result in a slightly higher concentration of naphthalene at the intersection than what is expected to occur under the no action alternative. This results from the fact that the modeled variation in naphthalene emissions as a function of speed is slightly different than that of most the other pollutants.

Figure 4.14 Intersection Results: Naphthalene



Estimated concentrations for diesel particulate matter (Figure 4.15) have several notable attributes. With 95th percentile background concentrations the 2005 scenario was close to, but did not exceed, the noncancer screening threshold.

There are no Federal carcinogenic risk factors for diesel particulate matter. However, California has an extremely high carcinogenic risk factor associated with diesel particulate matter that results in a one in a million risk of cancer with a lifetime exposure to concentrations of only 3.3 ng per cubic meter of diesel particulate matter. To put this in perspective, the 95th percentile background concentration would have a risk approaching the hundred-in-a-million risk level. California's approach has not been accepted by several other jurisdictions that have considered the issue, and the California risk factors are often used as a reference point but not a constraint when they are discussed in MSAT analysis outside of California.

For both the preferred alternative and the no action alternative, diesel particulate matter concentrations drop over time. The preferred alternative has lower concentrations than the no action alternative, for any given year.

Figure 4.15 Intersection Results: Diesel Particulate Matter

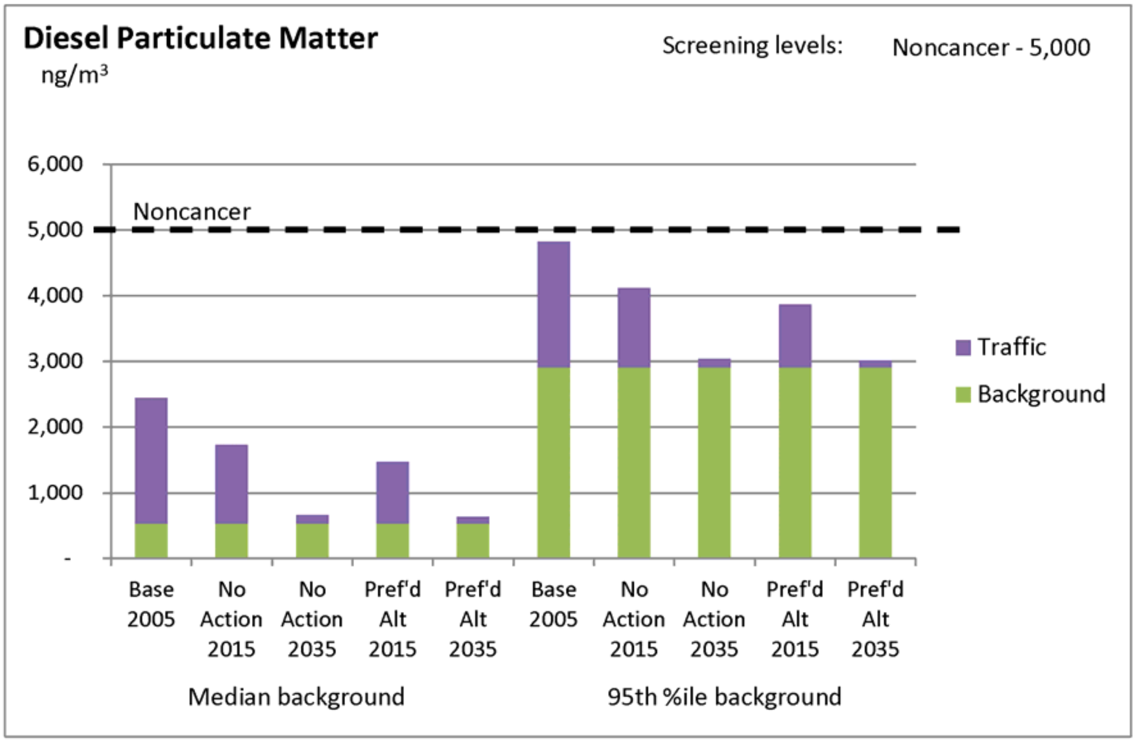


Table 4.6 presents numerical results for the intersection analysis, including the background concentration (median and 95th percentile), incremental concentration attributable to the traffic source modeled under each alternative, traffic source as a percent of total concentration at median background, change in total concentration for the Preferred Alternative versus No Action, and percent change (Preferred – No Action) at the median background. This table represents the change in annual average pollutant concentrations at the receptor with the maximum modeled contribution from traffic for each project (i.e., directly adjacent to the intersection). Negative values represent a decrease in pollutant concentrations under the Preferred Alternative. With 2015 emission factors, the relative change from the project is 15 percent or less of median conditions. With 2035 emission factors, the change for all pollutants between the Preferred and No Action alternatives is less than 6 percent.

Table 4.7 shows the contribution of traffic to total air pollutant concentrations in 2035 for the No Action and Preferred Alternative, at the current-day background levels, with the local meteorological data. Traffic contributes less than 4 percent for any pollutant except for naphthalene, for which it contributes 30 percent under the No Action alternative. (Inconsistencies in processing of diesel P.M. data for the mainline compared with other pollutants were discovered too late to correct so this pollutant is not shown in this table.)

For some pollutants, there is a small increase between the No Action and Preferred Alternative scenarios, and for others there is a small decrease. The change in total concentrations between the No Action and Preferred Alternative is less than 0.1 percent for all pollutants shown. While there was a significant traffic increase for the Preferred Alternative (about 180,000 versus 140,000 vehicles per day), there we also saw a significant improvement in traffic flow, especially for the managed lanes (which operate at level of service B in the peak periods), which appears to offset the traffic volume increase.

The mainline analysis was not conducted using 2015 emission factors due to the decision to focus on the intersection analysis where the most significant contributions of traffic to local pollutant concentrations was observed. Using the methodology applied in this case study for the intersection (2035 traffic conditions with 2015 emission factors), the percent contributions of traffic shown in Table 4.7 would be higher in 2015 in proportion to 2015 versus 2035 emission factors (see Appendix A).

Table 4.6 Contribution of Traffic and Change in Pollutant Concentrations for Preferred Alternative versus No Action (Intersection)

Scenario/ Year	Acetal-dehyde	Acrolein	Benzene	1,3-Buta-diene	Formal-dehyde	Naph-thalene	Diesel PM
Background Concentrations (ng/m3)							
Median	1,838	36.0	933	58	1,955	44	531
95th Percentile	3,022	124.0	2,305	159	3,718	252	2,912
Incremental Contribution from Traffic Source (ng/m3)							
Base 2005	327	25.5	1,035	129	437	103	1,912
No Action 2015	242	21.2	434	76	426	142	1,199
No Action 2035	79	6.7	192	28	99	98	127
Pref'd Alt 2015	183	15.8	336	58	318	125	947
Pref'd Alt 2035	62	5.1	151	23	76	102	100
Traffic Source as Percent of Total at Median Background							
Base 2005	15%	41%	53%	69%	18%	70%	78%
No Action 2015	12%	37%	32%	57%	18%	76%	69%
No Action 2035	4%	16%	17%	32%	5%	69%	19%
Pref'd Alt 2015	9%	31%	26%	50%	14%	74%	64%
Pref'd Alt 2035	3%	12%	14%	28%	4%	70%	16%
Preferred Alternative Versus No Action (Change in total concentration, ng/m3)							
2015	-58	-5.3	-99	-18	-107	-17	-253
2035	-17	-1.6	-41	-5	-23	5	-27
Preferred Alternative Versus No Action (Percent change in total concentration at median background)							
2015	-3%	-9%	-7%	-13%	-5%	-9%	-15%
2035	-1%	-4%	-4%	-6%	-1%	3%	-4%

Table 4.7 Traffic Contribution to Pollutant Concentrations on Mainline (2035, Colorado Normal Windfield) [a]

	Acetal-dehyde	Acrolein	Benzene	1,3-Buta-diene	Formal-dehyde	Naph-thalene
Background Concentrations (ng/m3)						
Median	1,838	36.0	933	58	1,955	44
95th Percentile	3,022	124.0	2,305	159	3,718	252
Incremental Contribution of Traffic at Maximum Receptor – Mainline (ng/m3)						
No Action	6.46	0.40	15.31	2.30	7.72	18.98
Preferred Alternative	6.53	0.39	15.47	2.31	7.76	18.94
Percent Contribution of Traffic to Total – Preferred Alternative						
2035	0.4%	1.1%	1.6%	3.8%	0.4%	30.1%
Preferred Alternative Versus No Action: % Change in Total Concentration (at Median Background)						
2035	0.004%	-0.027%	0.017%	0.030%	0.002%	-0.064%

[a] Due to data processing issues discovered late in the analysis process, findings for diesel PM consistent with other pollutants in this table are not available.

4.4 Discussion

The highway expansion case study considered a freeway where the preferred alternative is anticipated to increase traffic by nearly 30 percent, and an intersection where the preferred alternative is anticipated to cause relatively minor changes in traffic but slight improvements in speed and delay. Average annual concentrations of key MSATs near the roadway and intersection were modeled. There are a number of insights that can be drawn from the case study:

- Intersections are much more likely to generate higher levels of MSATs at receptor locations than highway mainlines, due to more likely proximity of people to vehicles (receptors placed closer to the roadway), and to higher emission rates due to lower traffic speeds and idling at intersections.

- Modeled concentrations drop rapidly over time under both the project and no-project alternatives for most pollutants as emissions per vehicle decrease in the future. These emissions decreases more than offset the effects of projected significant increases in traffic volumes, for most pollutants under most conditions.

- In this particular situation, the project alternative at the intersection resulted in slightly lower concentrations than the no-action alternative, due to different traffic patterns. On the mainline, the project alternative resulted in small changes in concentrations relative to the no-action alternative (some increases and some decreases), as improved traffic flow roughly offset increased traffic volumes. The overall contribution of traffic was small compared to at the intersection – changing concentrations of all pollutants by less than four percent except for naphthalene (diesel P.M. results are not available). Different projects will have different effects (either positive or negative) depending upon the specific traffic impacts.

- The relative contribution of traffic (versus background) varies substantially by pollutant in this case study. Traffic has the lowest relative impacts for acetaldehyde and formaldehyde, and the highest relative impacts for diesel particulate matter and naphthalene. Note that the relative contributions of traffic to pollutants may depend upon the mix of heavy versus light duty vehicles in the study area. In this study, the MOVES default vehicle mix was used.
- Meteorology (specifically, wind field) makes a difference. An area that is characterized by generally light winds was estimated to have a traffic contribution to pollutant concentrations that is two to three times *higher* than an area where moderate to higher wind speeds are more prevalent. However, rotating the wind field by 90 degrees did not make a significant difference in modeled average annual concentrations.
- The receptor locations selected for this analysis were conservative (i.e., closer to the roadway than would be expected to represent long-term human exposure), and therefore chronic exposure impacts on human populations will almost certainly be lower than modeled.
- A note about running CAL3QHC/r also is relevant. The model was not originally designed to account for seasonal variation in emission rates (for example, related to seasonal fuel specifications and temperature profiles). To use the model in conjunction with MOVES output, multiple model runs need to be performed (one for each season) and the results weighted together to arrive at annual average concentration estimates.

■ 4.5 References

CH2M Hill (2009). *U.S. 36 Corridor Final Environmental Impact Statement/Final Section 4(f) Evaluation: Air Quality Technical Report Addendum.*

Transportation Research Board (2004). *Highway Capacity Manual.* National Academy of Sciences, Washington, D.C.

5.0 Intermodal Freight Terminal

5.1 Case Study Description

The second case study considers an intermodal freight terminal (IFT) as a commonly proposed transportation project. IFTs are characterized as the transfer point of shipped goods from one mode of transportation to another. A typical example is the transfer of containers from rail systems to truck transport.

In contrast to the highway expansion project in Case Study Number 1, IFTs include "off-road" operations over larger areas not confined to just well-defined roads, lanes, and traffic considerations. The CAL3QHC/r model applied in Case Study Number 1 is not well-suited to considering rail yard and container handling sources, which often emit pollutants diffusely over wide areas. The AERMOD system, the U.S. EPA's guideline model for Clean Air Act air permitting applications, is increasingly being recommended by regulatory authorities for transportation projects (U.S. EPA, 2004; U.S. EPA, 2010). A prime advantage of AERMOD is its ability to consider area source emissions. Consequently, AERMOD is used for the IFT example.

The IFT example is nominally based on the recent Detroit Intermodal Freight Terminal (DIFT) project. For the sake of simulating realistic conditions, many aspects of the example derive from DIFT project specifics and data. However, the IFT example is not intended to be an accurate portrayal of the DIFT, as such an analysis would require detailed, intimate knowledge of the project. Rather, the IFT example uses information from the DIFT documentation along with reasonable but unverified assumptions regarding model implementation. As an example, emissions estimates for various MSATs are taken as aggregate totals from the DIFT project reports, but are assigned spatially and temporally according to professional judgment without project-specific details on patterns of use, operating hour constraints, etc.

Project Description and Scenarios Considered

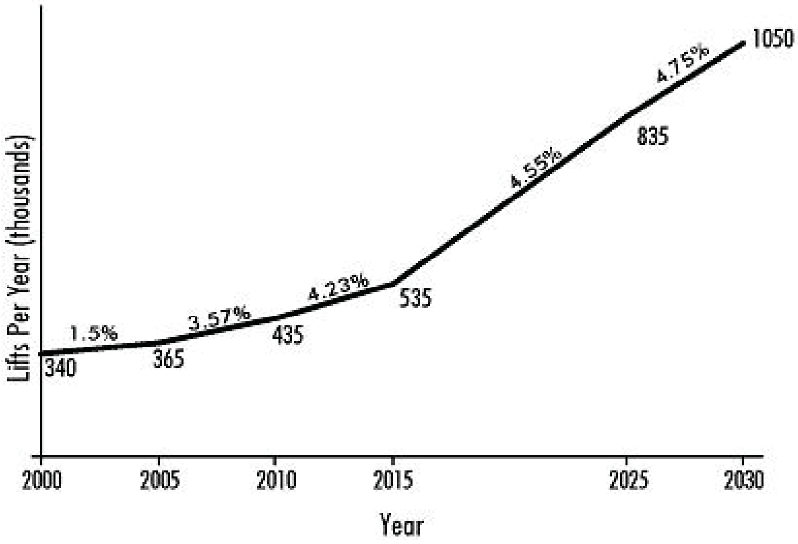
The case study project is a systematic examination of intermodal activities in an urban area. There are presently multiple intermodal operations that occur across this area at rail yards owned and operated by different carriers. Intermodal volume is projected to roughly triple from 2005 to 2030 (Figure 5.1). The project systematically examined various alternatives to accommodate this growth. The Livernois-Junction Terminal, the largest of the intermodal facilities, served as a principal focus (Figure 5.2). The Preferred Alternative for the year 2025 involves consolidating much of the intermodal activity at the Livernois-Junction Terminal through expansion and enhancement of the facility.

Focusing the IFT example on the Livernois-Junction Terminal, three scenarios are considered for the MSAT modeling analysis:

- The 2004 baseline condition;
- A 2025 No Action alternative based on unregulated growth; and
- The 2025 Preferred Action alternative focused on consolidated development.

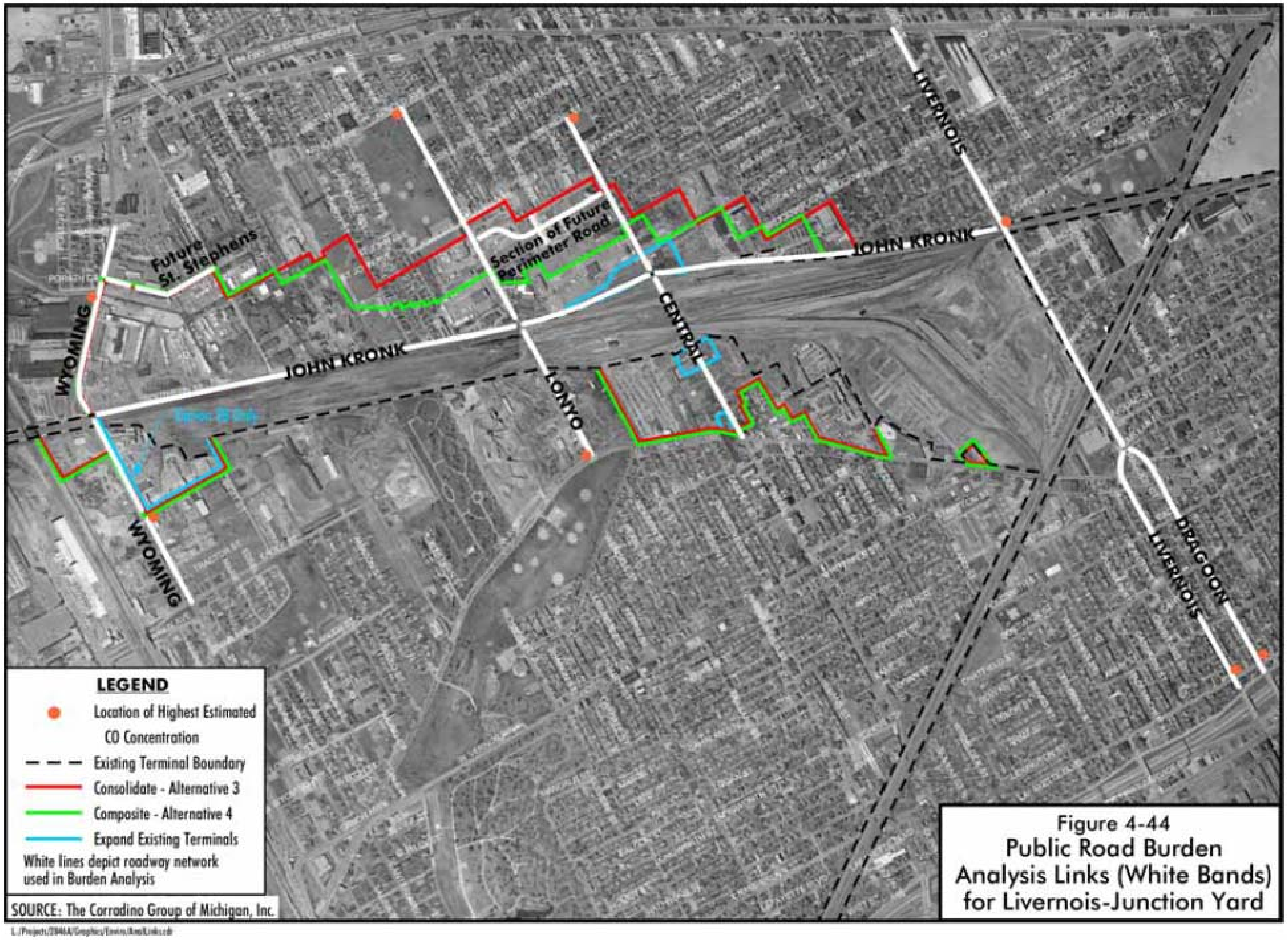
The project study also considers the intermediate 2015 time period, but since emissions for these scenarios are incomplete, they are not included in the IFT example.

Figure 5.1 Projected Growth in Intermodal Activity for the Detroit Area



Source: Michigan DOT, 2010.

Figure 5.2 Livernois-Junction Yard Boundaries for Various Development Alternatives



Source: Michigan DOT (2009).

Boundary of the Preferred Alternative depicted in red (consolidation). Affected surface roads indicated in white.

■ 5.2 Data and Modeling Approach

Emissions Data

The DIFT project environmental analysis developed MSAT emissions for sources both on the intermodal facility and over public roadways in the vicinity of the project. Emissions are taken from the DIFT spreadsheets made available as part of project documentation (Corradino Group, 2004). DIFT emissions are based on U.S. EPA emission factor methodology. Vehicular emissions are based on the U.S. EPA's MOBILE6 model, and diesel engine emissions derive from U.S. EPA emission factors and emission standards for new engines.[10] MSATs considered are acetaldehyde, acrolein, benzene, 1,3-butadiene, formaldehyde, and diesel particulate matter. EPA's MOVES model predicts very divergent results compared to MOBILE6.2; use of updated emission factors would change the absolute levels of on-road source pollutants found in the case study and may change the relative contribution of different source types. However the overall conclusions should not be substantially affected.

Overall MSAT emissions for the three project scenarios are depicted in Figures 5.3 through 5.8. Color coding is used in these figures to differentiate the following emission sources:

- Yellow reflects emissions from traffic on local roads (outside of the intermodal facility), with bright and dull colors differentiating gasoline and diesel engine emissions;
- Red reflects emissions at the intermodal gate areas;
- Blue indicates emissions associated with container handling equipment;
- Green indicates emissions from locomotives; and
- Orange corresponds to industrial emissions on the intermodal property not associated with intermodal operations (applicable to the Baseline and No Action scenarios).

Emissions from each source, as reported in the project spreadsheets, are assumed to be evenly distributed (both spatially and temporally) within the respective source areas as shown. A more detailed modeling exercise could consider variances in the spatial distribution of emissions within each source area, as well as variations by time of day.

Traffic emissions on local roads account for the bulk of emissions of benzene and 1,3-butadiene, as well as a substantial portion of the aggregate emissions for other MSATs.

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[10] The locomotive emission factors are for Tier 0 (1973-2001) line-haul locomotives. Toxics emission factors are from the 1999 National Emissions Inventory, Appendix C (Corradino Group, 2004).

Intermodal sources are of greatest importance for emissions of diesel particulate matter. For all MSATs, emissions for the 2025 scenarios are lower than those of the 2004 baseline, and the decreases projected over time are greater in magnitude than differences between the 2025 No Action and Preferred Alternative scenarios. The most substantial decreases from 2004 to 2025 are expected for diesel particulate matter emissions. Examining the 2025 scenarios, the higher aggregate emissions vary among MSATs for the No Action and Preferred Alternative scenarios, but differences are generally small.

Traffic emissions on local roads are spread unevenly. Figure 5.9 indicates the road network and distributions of traffic emissions. Figures 5.10 and 5.11 show examples of the distribution of pollutants by roadway segment for the No Action and Preferred Alternative; distributions for other pollutants are generally similar. Livernois Avenue, a major thoroughfare, handles the greatest level of traffic. It is worthy to note the projected decreases in emissions on Livernois Avenue between the 2025 No Action and Preferred Alternative scenarios, which result in part from redirection of the intermodal facility traffic to a greater number of gates.

Figure 5.3 Emissions of Benzene by Source

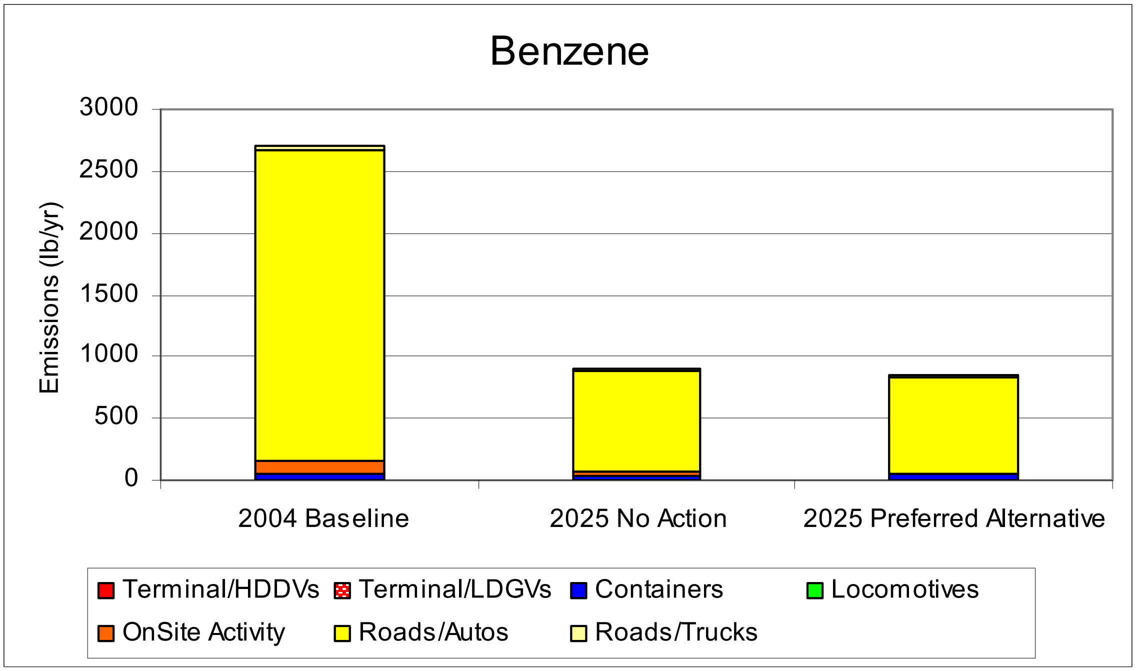
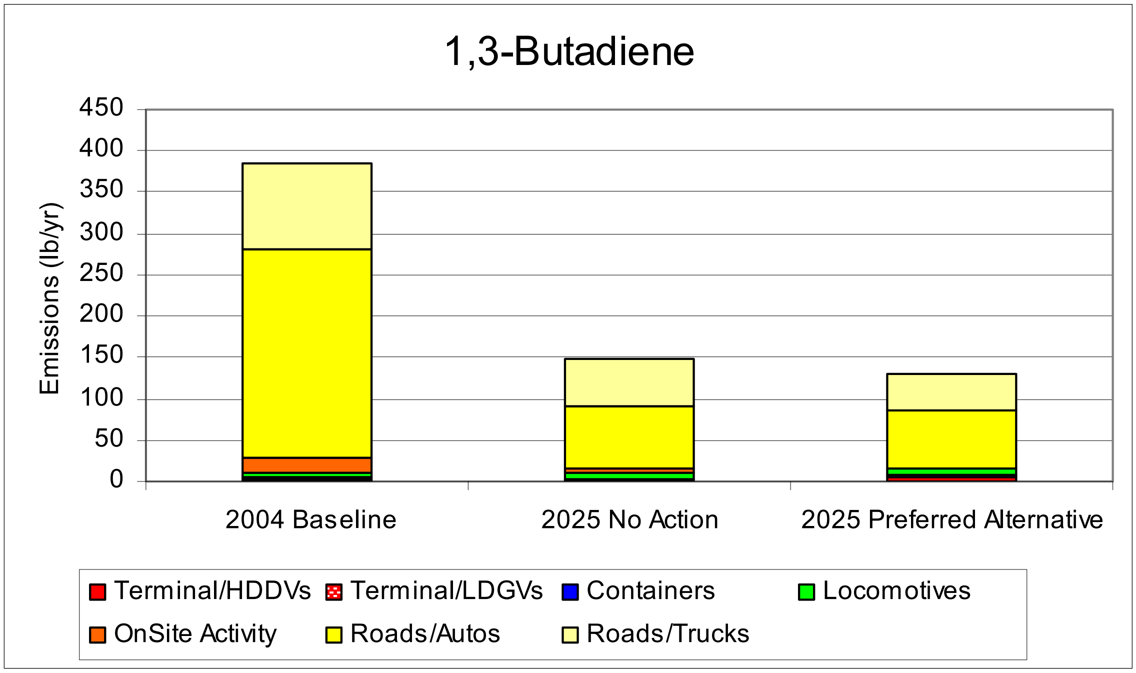


Figure 5.4 Emissions of 1,3-Butadiene by Source



Source: Corradino Group, 2004.

Figure 5.5 Emissions of Formaldehyde by Source

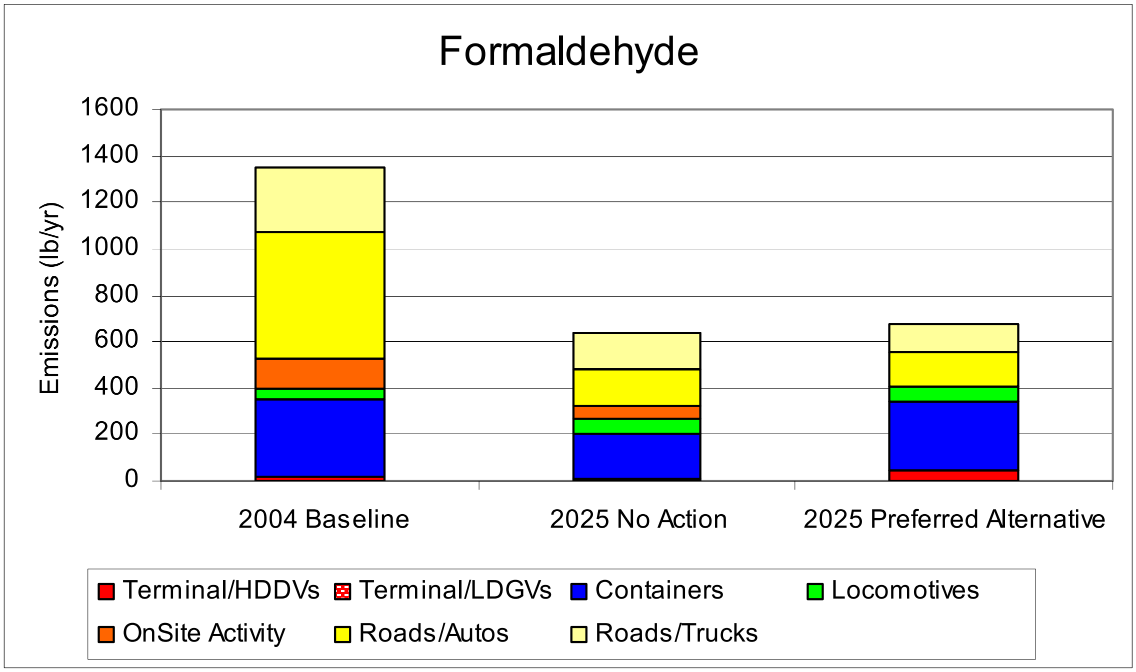
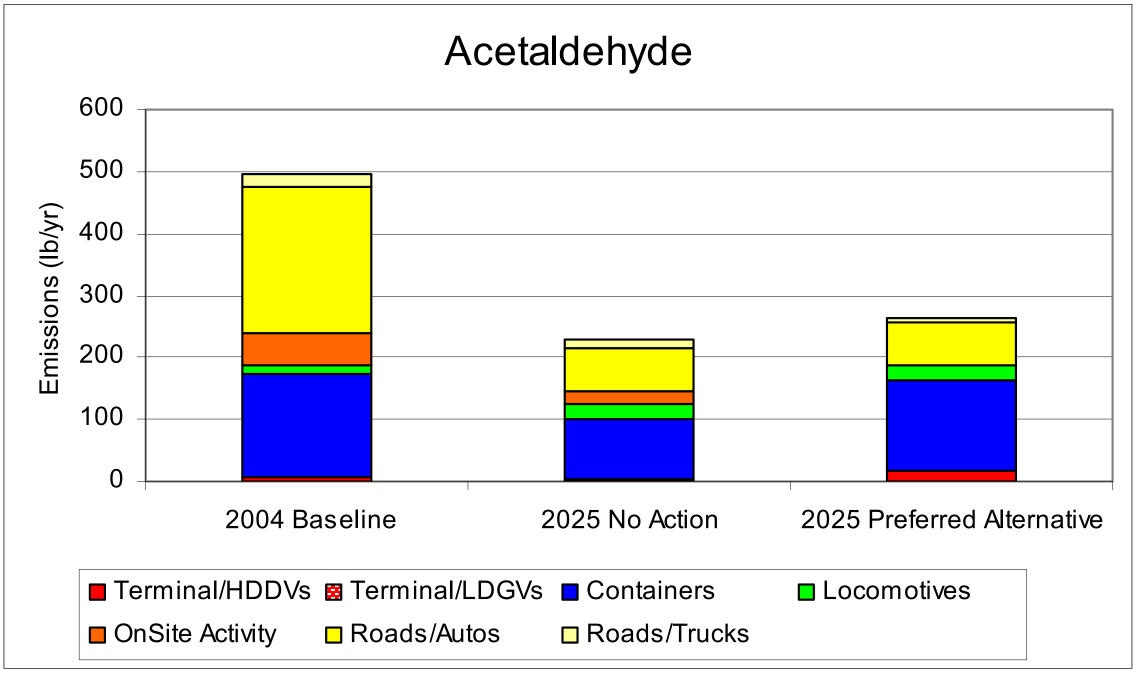


Figure 5.6 Emissions of Acetaldehyde by Source



Source: Corradino Group, 2004.

Figure 5.7 Emissions of Acrolein by Source

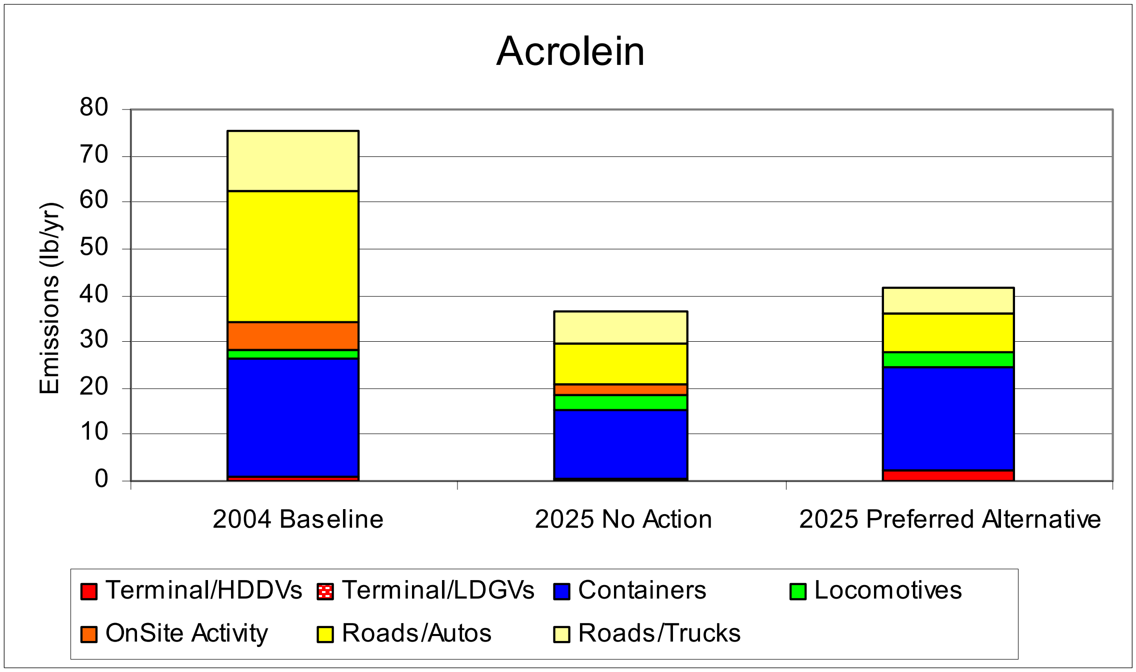
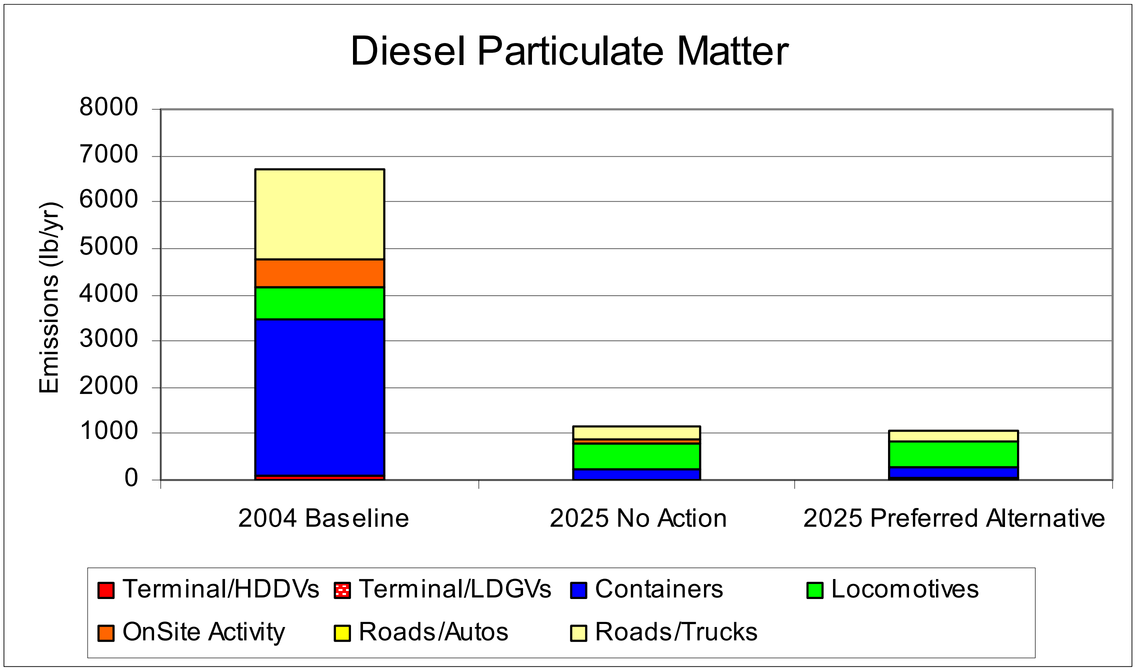
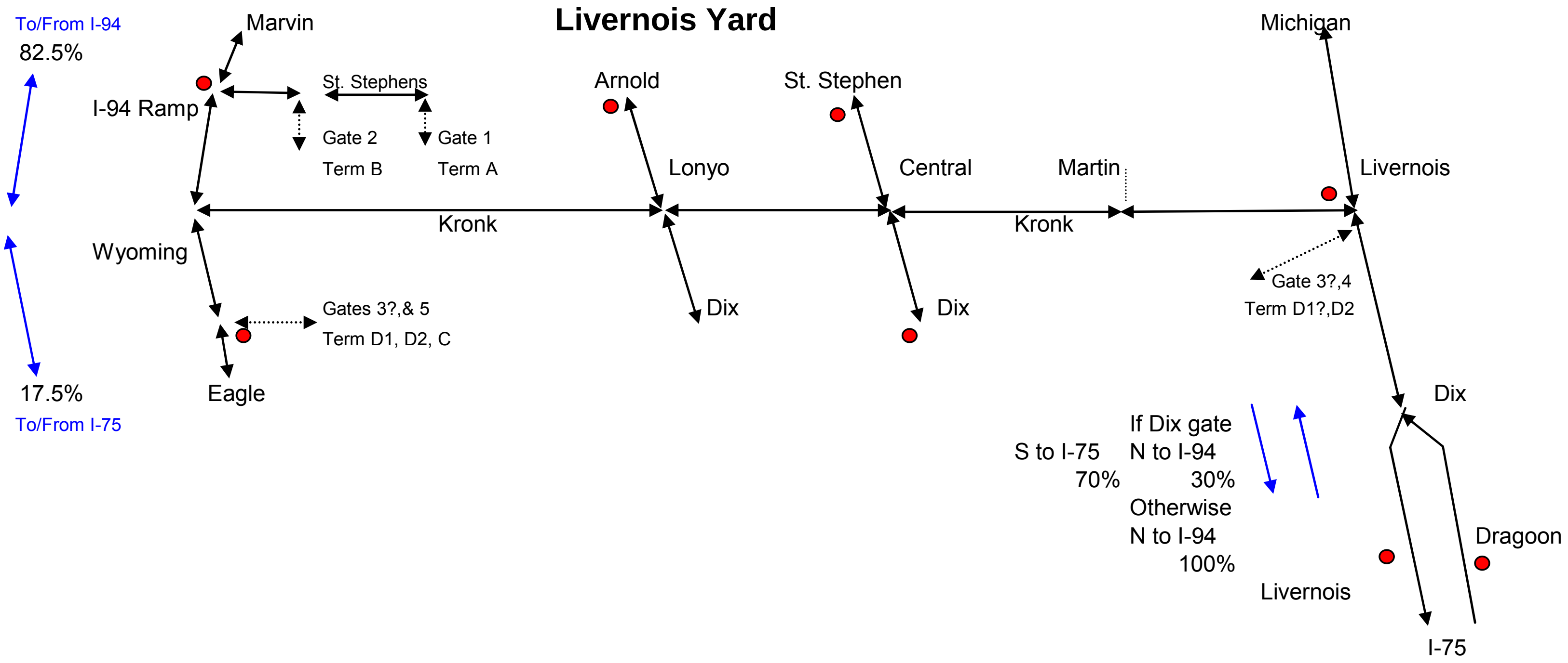


Figure 5.8 Emissions of Diesel Particulate Matter by Source



Source: Corradino Group, 2004.

Figure 5.9 Schematic of Local Roadways



Note: The red dots indicate intersections for which the project considered CO hot spot analysis. The blue lines and associated percentages reflect the assumed access frequencies of truck access routes to/from major highways within the analysis area.

Figure 5.10 Roadway Acrolein Emissions by Road Segment

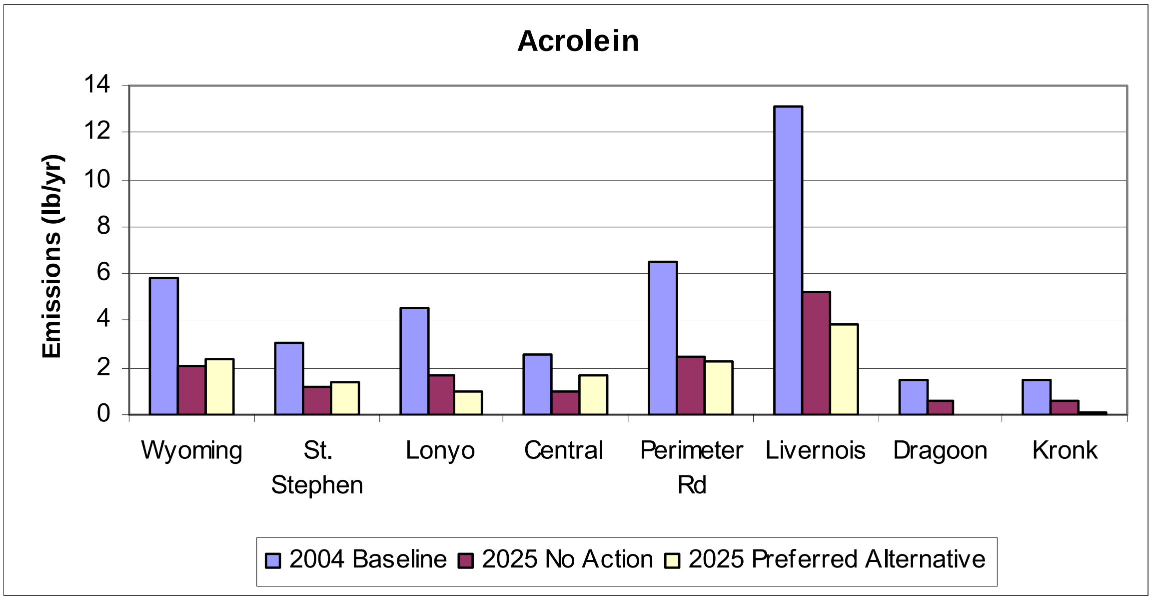
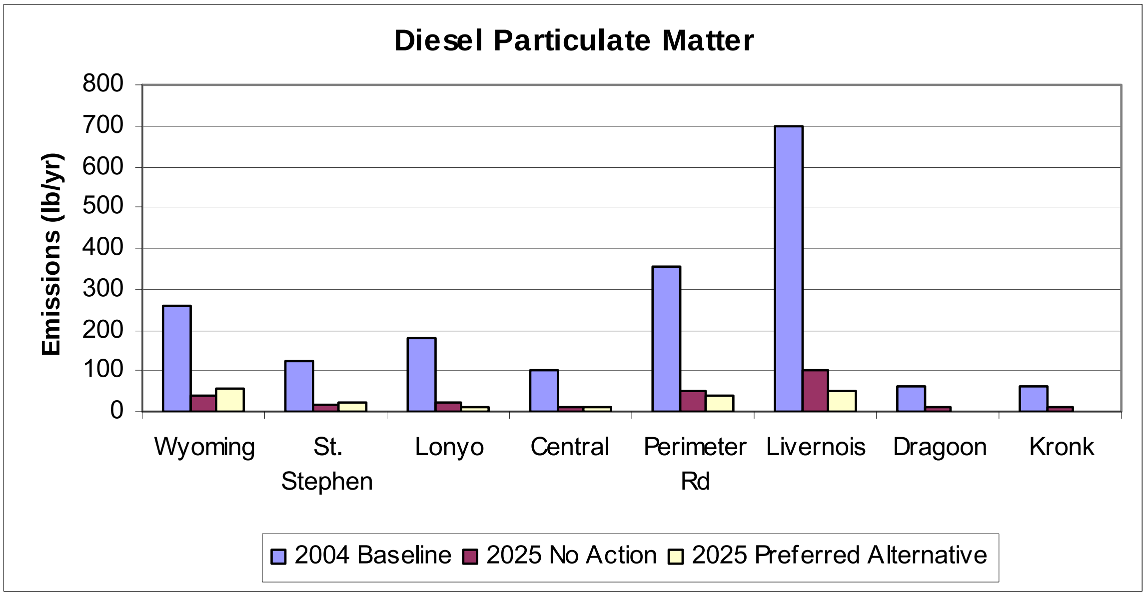


Figure 5.11 Roadway DPM Emissions by Road Segment



Impact Analysis and Study Area

Compliance with Clean Air Act regulations is typically focused on identifying the highest concentrations of pollutants that will occur at any location at or beyond the project "fenceline," irrespective of land use and demographic patterns. Since MSATs are not subject to National Ambient Air Quality Standards, fenceline compliance is not necessarily required. Additionally, it may be useful for decision-making to have knowledge of how greater communities at large are affected by project emissions. As such, the IFT example is oriented toward population-based impacts, as facilitated by AERMOD's ability to examine grids of receptor locations.[11]

A study area was arbitrarily defined to surround the intermodal facility and also encompass the local traffic emissions considered in the project analysis. The blue outline on Figures 5.12 and 5.13 indicates the study area definition, judged to include the locations likely to be most significantly affected by emissions from the IFT facility.

Residential locations, based on present development patterns, were identified throughout the localized study area surrounding the facility. A regular grid of receptors spaced at 50 m was overlaid on an aerial photograph in Google Earth software. Geographic coordinates (latitude and longitude) were converted from UTM coordinates using the U.S. Army's Corpscon software assuming essential equivalence between NAD83 and WGS84 data. Locations on the grid within existing residential development were retained as receptor locations for modeling, resulting in a total of 2,509 locations within the study area receptor network. Defined in this manner, model predictions can be interpreted to estimate population-weighted exposures, and peak concentrations near sources can be evaluated against average levels predicted over the modeling domain. Residential receptor locations are indicated on Figures 5.12 and 5.13 by the dark green dots. In general, there is some buffer distance between the IFT facility and residential locations, but in certain areas (particularly at the eastern boundary along Livernois Avenue), residences are quite close to the IFT.

Different project-specific decisions could be made when examining population-weighted risks. A complete exposure analysis would consider all locations at which people may spend time working, playing, shopping, etc., and the impacts at these locations would need to be weighted by the frequency of time spent at these locations. This may include activity locations (such as schools, workplaces, hospitals, etc.) that may be located in non-residential areas. The development of population-weighted exposure metrics also may involve policy decisions (e.g., the acceptability of tradeoffs in involuntary risks resulting from a project) and all assumptions in such an analysis should be clearly documented.

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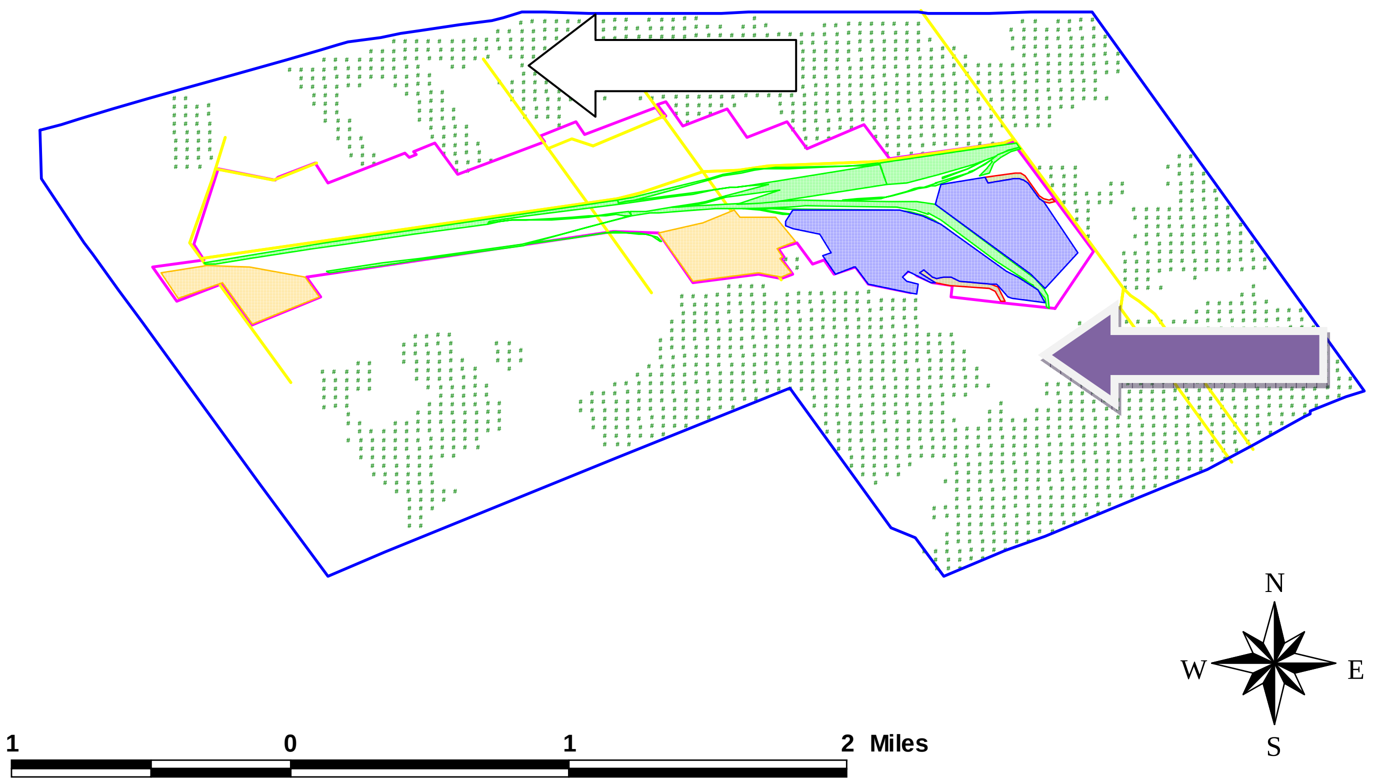
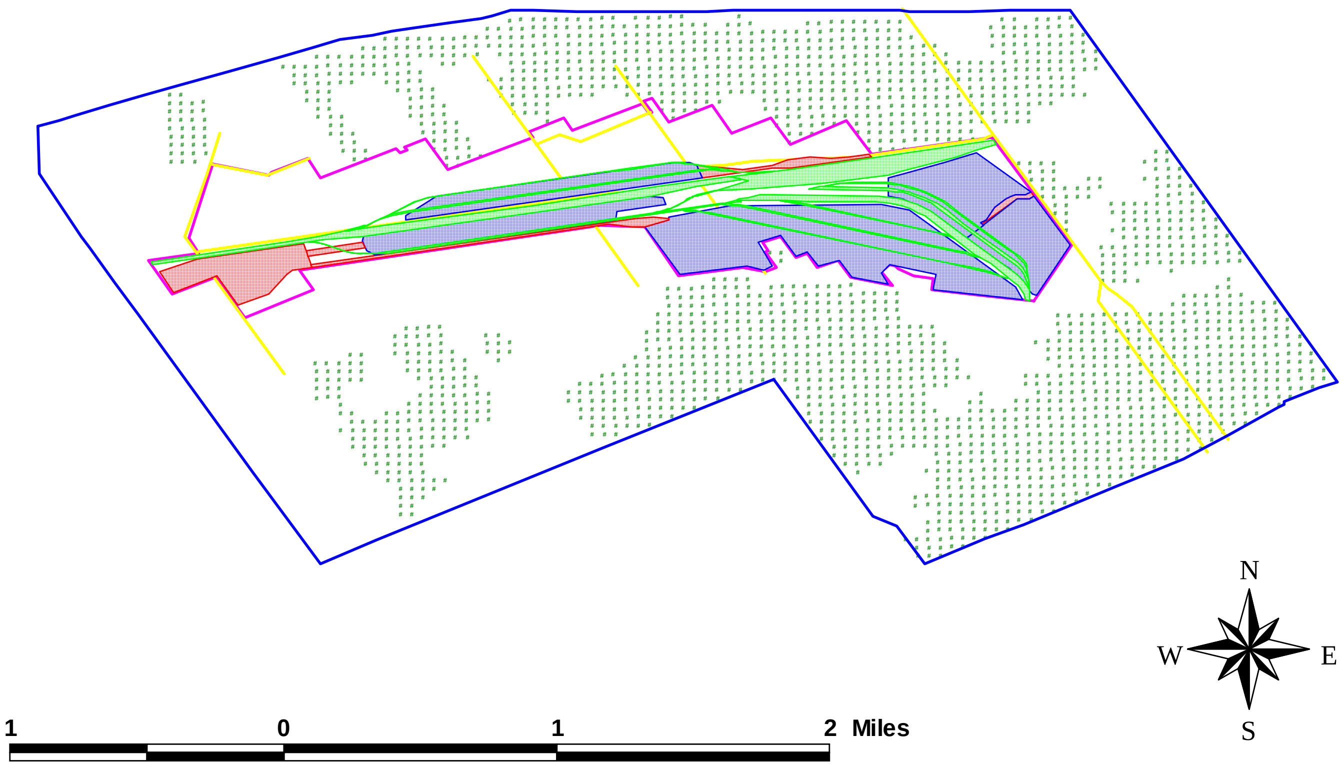
[11] EPA's hotspot guidance was not rigorously followed in the AERMOD analysis of the IFT example, due mainly to the exploration of exposure for residential areas. The example's modeling techniques are, however, relatively easy to extend to a hot spot analysis. Required steps would include modeling at all off-site locations (at which National Ambient Air Quality Standards would apply), refinement of receptor grids near the project boundary (including tight receptor spacing on the order of 10 m to refine steep concentration gradients), consideration of temporal (hourly and seasonal) variability in emissions, and use of a full five year meteorological data set for the off-site (airport) data source.

Figure 5.12 Study Area for the 2004 Baseline and 2025 No Action Scenarios



Residential receptor locations are indicated by dark green dots. The blue outline defines the study area. The fuchsia outline indicates the boundary of the model DIFT project. Yellow lines indicate surface roads and traffic sources. Red hatched areas indicate gate areas. Blue hatched areas indicate intermodal operations. Green hatched areas indicate rail lines. Orange hatched areas indicate non-IFT industrial activities.

Figure 5.13 Study Area for the 2025 Preferred Alternative Scenario



Residential receptor locations are indicated by dark green dots. The blue outline defines the study area. The fuchsia outline indicates the boundary of the model DIFT project. Yellow lines indicate surface roads and traffic sources. Red hatched areas indicate gate areas. Blue hatched areas indicate intermodal operations. Green hatched areas indicate rail lines.

Modeling Definition of Emission Sources

MSAT emissions were assigned to various emission sources based on geographic locations and known and/or anticipated patterns of use. Locations for the 2004 Baseline and 2025 No Action scenarios were made using interpreted land use from current aerial photography within the Google Earth software program. Locations for the Preferred Alternative were interpreted from a DIFT project map inserted as a base map into Google Earth. Source areas were created as irregular polygons within the Google Earth mapping tools. Geographic coordinates (latitude and longitude) were extracted from the resulting Google Earth.kml files and converted to UTM coordinates (for use within AERMOD input files) using the U.S. Army's Corpscon program. Figure 5.12 (2004 Baseline and 2025 No Action scenarios) and Figures 5.13 (2025 Preferred Alternative scenario) indicate emission source locations. Emissions from the IFT example were assigned to specific emission polygons according to the following color coding (consistent with Figures 5.3 through 5.8):

- Yellow lines (in actuality very slim polygons) represent local road traffic emissions;
- Red polygons correspond to intermodal gate areas;
- Blue polygons correspond to container handling areas;
- Green polygons reflect locations of rail lines (with multiple parallel tracks surrounded by individual polygons); and
- Orange polygons cover areas of apparent industrial activity (applicable to the Baseline and No Action scenarios) not associated with intermodal operations.

Preliminary testing was conducted to evaluate methods of modeling emissions from roadways. AERMOD is not specifically oriented toward roadway sources. AERMOD documentation (U.S. EPA, 2004) recommends approximating roadways as a series of adjacent volume sources, but representation by area sources also is possible. The volume source approach dates back to a period when area sources were not available in the older ISC models, although it does have advantages such as the incorporation of plume meander. AERMOD continues the volume source method by placing virtual point sources upwind to simulate an appropriate degree of dispersion upon reaching the actual emission locations. In contrast, area sources are represented as a series of finite line sources perpendicular to the wind, using an iteration scheme to determine the number sufficient to achieve convergence and accuracy. The original AERMOD user's manual suggested that the aspect ratio of area sources (length to width) be no greater than 10. The current version will give warnings for aspect ratios greater than 100; AERMOD Change Bulletin number 3 notes that "The upper limit of aspect ratio for stable performance of the numerical integration algorithm for area sources has not been fully tested and documented, and may vary depending on the specifics of the application."

Options to model roadway emissions were evaluated in comparative AERMOD simulations using a year of meteorological data and a sample source configuration and receptor network. Three potential source configurations were considered:

- A "Split Area" simulation in which 40 individual area sources were used to represent the roadway network such that the aspect ratio of all area sources was less than 10;
- A "Sparse Area" simulation in which only six elongated area sources were used to represent the roadway network, with source aspect ratios as high as 140; and
- A "Volume" simulation in which 602 individual volume sources were used to represent the roadways (with the number determined by the need to keep the length and width of the volume sources equal).

Similar results were found in all cases. The "Split Area" and "Sparse Area" simulations yielded essentially identical results, indicating that aspect ratios need not be limited to less than 10, and that there is no advantage to breaking long roadway segments into multiple sources. Results of the "Volume" and "Split Area" simulations correlated well with some level of scatter, with the "Volume" simulation predicting slightly lower concentrations on average. The scatter is likely induced by the superposition of the individual plumes of the individual volume sources; better agreement would likely be reached by using a larger number of smaller volume sources. Given the similarity of results for the three configurations, computational requirement is a more significant consideration. The "Sparse Area" simulation was quickest, and the "Split Area" simulation was slowest. Consequently, the "Sparse Area" simulation method was deemed most advantageous due to its faster simulation time.

AERMOD's AREAPOLY source option was used to represent all emission sources. Additional assumptions necessary to specify source emissions include:

- Constant (with time) and uniform (with space) emissions over the area sources;
- Constant widths for the roadway sources based on interpretation of aerial photography;
- Emission height of 1.5 meters for the roadway sources and 3 meters for the intermodal sources based on estimates of initial turbulent mixing zones; and
- Initial dispersion parameter σ_{z0} equal to the source height divided by 2.15, per the recommendation of AERMOD (U.S. EPA, 2004).

Meteorological Data

AERMOD considers hourly meteorological data. Two different meteorological data sets were considered in the IFT example, consistent with Case Study Number 1. These included data for the Detroit City Airport and for Southern California as described in Section 3.0. The Detroit City Airport data reflect a wide range of wind directions and speeds, along with a relatively high percentage of calm conditions (about 12 percent). In contrast, wind speeds are much lower for the Anaheim, California data set and exhibit a greater degree of channelization of winds from the southwest. Because processed meteorological data are utilized, it was not necessary to exercise the AERMET and

AERSURFACE preprocessors within the example application, as these steps were undertaken by the regulatory authorities supplying the data.

Terrain Data and Receptor Elevations

Consistent with local topography, flat terrain is assumed for the IFT example. Concentrations were predicted at ground-level at each receptor location. The presence of significant terrain elevations in actual modeling applications might require use of the AERMAP preprocessor to determine receptor elevations. However, it is not clear that terrain elevations have an important bearing with respect to area source emissions in AERMOD, and applications are likely to focus on locations close to facility emissions (where receptor and source area elevations are similar). Hence, flat terrain simulations are likely to suffice in most applications.

AERMOD Simulation Methods

Source groups were assembled in the AERMOD simulation runs according to the DIFT emissions availability (Corradino Group, 2004). Four source groups were used for the intermodal sources (gate area traffic, container handling, locomotives, and non-intermodal industrial activity), and 18 source groups were assembled for the traffic emissions on local roads (in congruence with emission estimates). Many source groups comprised multiple individual area sources such that the total number of individual area sources numbered 32 for the 18 road/traffic source groups, 29 for the five intermodal source groups for the 2004 Baseline and 2025 No Action scenarios, and 32 for the four intermodal source groups for the 2025 Preferred Alternative (which includes no non-intermodal industrial activity). Unit emission rates of 1 g/s were used in modeling each individual source group. Since area sources use an emissions density as input, the 1 g/s emission rate was divided by the total area of the individual sources to derive an emission rate in units of g/s-m^2 for use by AERMOD.

Results of the AERMOD simulations were imported into spreadsheets and multiplied by source- and MSAT-specific emission rates to derive estimates of MSAT concentrations across the receptor network.

■ 5.3 Modeling Results

Predicted MSAT concentrations for the IFT simulations are summarized in a series of tables and figures:

- Table 5. through 5.6 (one for each MSAT) provide statistical summaries of the predicted concentrations across the receptor network;

- Figures 5.14 through 5.19 (one for each MSAT) depict the maximum predicted incremental concentrations with respect to ambient background levels and risk-based concentration benchmarks;

- Figures 5.20 through 5.25 (representative pairs of plots shown for benzene, acrolein, and DPM) depict spatial patterns of the predicted concentrations across the study area receptor network for the two meteorological data simulations;

- Figures 5.26 through 5.28 (representative plots shown for benzene, acrolein, and DPM) depict spatial patterns of the differences in concentrations that would result in 2025 from implementation of the Preferred Alternative (compared with the No Action alternative); and

- Figure 5.29 (representative plots shown for DPM) indicate the emission sources responsible for overall incremental concentrations at worst-case and average receptor locations. For most other pollutants, the relative contribution of offsite roads versus other sources is even more predominant.

- Figure 5.30 presents the source impacts for the receptor that experienced the greatest *increase* in concentrations between the No Action and Preferred Alternative scenarios (0.006 $\mu g/m^3$ based on the Detroit meteorological data), and Figure 5.31 presents the source impacts for the receptor that experienced the greatest *decrease* (0.002 $\mu g/m^3$). Locomotives and containers provide the greatest contribution to the increase in 2025.

Some general observations and remarks, focusing on diesel particulate matter as the primary MSAT of interest at IFT facilities, include:

- The highest incremental concentrations are predicted for diesel particulate matter and benzene, and the lowest incremental concentrations for acrolein;

- Incremental concentration impacts at worst-case receptor locations are 1) more than an order of magnitude greater than average impacts across the receptor network and 2) also considerably greater than the 95th percentile values across the receptor network;

- Predicted incremental concentration values are two to three times greater for the low wind Anaheim meteorological data;

- Increases in MSAT concentrations, when added to background, do not lead to exceedances of any non-cancer risk-based concentrations or 10^{-4} cancer risk levels, but 10^{-6} cancer risk levels are exceeded for benzene, 1,3-butadiene, formaldehyde, and acetaldehyde (including background levels);[12]

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[12] California's unit risk factor for diesel particulate matter is not included in the development of the risk-based concentrations, as discussed in the conclusions.

- Predicted incremental MSAT concentrations are largest for the 2004 Baseline scenario, while lower but similar increments are predicted for the 2025 No Action and Preferred Alternative scenarios;

- Maximum predicted incremental concentrations due to IFT emissions are comparable to or greater than background levels for several MSATs, most notably diesel particulate matter;

- Predicted MSAT concentrations are generally highest to the east of the IFT facility, and the importance of roadway/traffic emissions are apparent for all MSATs compared with IFT-specific sources;

- In the 2025 timeframe, MSAT concentrations are predicted to increase by small levels at some locations, but decrease at others, due to implementation of the Preferred Alternative, with decreases tending to be of greater magnitude;

- In this example, decreases in MSAT concentrations in 2025 along the eastern boundary of the IFT are created by the Preferred Alternative due to a shifting of emissions toward the central and western portions of the facility, thus compensating for higher level of intermodal activity; and

- Traffic/off-site road emissions account for almost all of the concentration estimates for benzene and 1,3-butadiene, as well as large fractions for the other MSATs, with intermodal sources contributing most significantly for diesel particulate matter.

Table 5.1 Predicted Concentrations of Benzene in Ambient Air ($\mu g/m^3$)

Scenario	Met Data	Maximum	Average	Median	95th Percentile
2004 Baseline	Detroit	1.13	0.06	0.04	0.19
2025 No Action	Detroit	0.37	0.02	0.01	0.06
2025 Preferred Alternative	Detroit	0.36	0.02	0.01	0.06
2004 Baseline	Anaheim	2.84	0.16	0.10	0.50
2025 No Action	Anaheim	0.94	0.05	0.03	0.16
2025 Preferred Alternative	Anaheim	0.90	0.05	0.03	0.15
Scenario	Met Data	Maximum	Average	Median	95th Percentile
2004 Baseline	Detroit	1.13	0.06	0.04	0.19

Table 5.2 Predicted Concentrations of 1,3-Butadiene in Ambient Air (μg/m^3)

Scenario	Met Data	Maximum	Average	Median	95th Percentile
2004 Baseline	Detroit	0.116	0.006	0.004	0.020
2025 No Action	Detroit	0.038	0.002	0.001	0.006
2025 Preferred Alternative	Detroit	0.034	0.002	0.001	0.005
2004 Baseline	Anaheim	0.292	0.017	0.011	0.051
2025 No Action	Anaheim	0.095	0.006	0.004	0.016
2025 Preferred Alternative	Anaheim	0.086	0.005	0.003	0.014
2025 Preferred Alternative	Anaheim	0.086	0.005	0.003	0.014

Table 5.3 Predicted Concentrations of Formaldehyde in Ambient Air (μg/m^3)

Scenario	Met Data	Maximum	Average	Median	95th Percentile
2004 Baseline	Detroit	0.403	0.023	0.015	0.068
2025 No Action	Detroit	0.160	0.010	0.006	0.028
2025 Preferred Alternative	Detroit	0.128	0.008	0.006	0.023
2004 Baseline	Anaheim	1.015	0.065	0.045	0.177
2025 No Action	Anaheim	0.404	0.028	0.019	0.073
2025 Preferred Alternative	Anaheim	0.324	0.024	0.017	0.064

Table 5.1 Predicted Concentrations of Acetaldehyde in Ambient Air (µg/m³)

Scenario	Met Data	Maximum	Average	Median	95th Percentile
2004 Baseline	Detroit	0.174	0.010	0.006	0.030
2025 No Action	Detroit	0.068	0.004	0.003	0.012
2025 Preferred Alternative	Detroit	0.056	0.004	0.003	0.010
2004 Baseline	Anaheim	0.438	0.028	0.020	0.077
2025 No Action	Anaheim	0.172	0.012	0.008	0.031
2025 Preferred Alternative	Anaheim	0.142	0.011	0.007	0.028

Table 5.2 Predicted Concentrations of Acrolein in Ambient Air (µg/m³)

Scenario	Met Data	Maximum	Average	Median	95th Percentile
2004 Baseline	Detroit	0.02	0.001	0.0008	0.003
2025 No Action	Detroit	0.008	0.0005	0.0003	0.001
2025 Preferred Alternative	Detroit	0.007	0.0005	0.0003	0.001
2004 Baseline	Anaheim	0.05	0.003	0.002	0.009
2025 No Action	Anaheim	0.02	0.002	0.001	0.004
2025 Preferred Alternative	Anaheim	0.02	0.001	0.001	0.004

Table 5.3 Predicted Concentrations of Diesel Particulate Matter in Ambient Air (µg/m³)

Scenario	Met Data	Maximum	Average	Median	95th Percentile
2004 Baseline	Detroit	1.19	0.08	0.05	0.22
2025 No Action	Detroit	0.16	0.01	0.009	0.04
2025 Preferred Alternative	Detroit	0.11	0.01	0.007	0.03
2004 Baseline	Anaheim	3.10	0.24	0.16	0.65
2025 No Action	Anaheim	0.42	0.04	0.03	0.11
2025 Preferred Alternative	Anaheim	0.27	0.03	0.02	0.09

Figure 5.14 Maximum Predicted Concentrations: Benzene

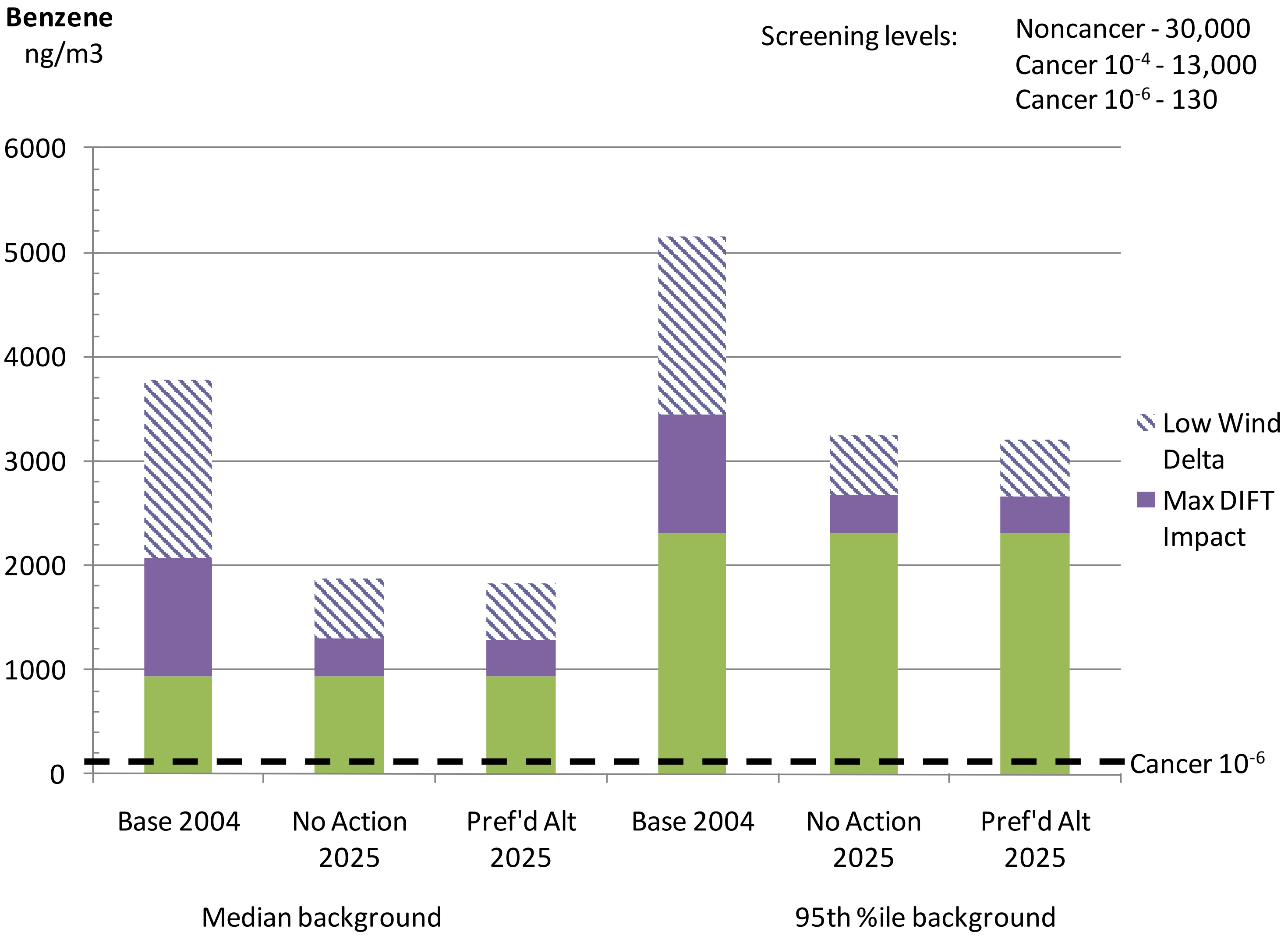


Figure 5.15 Maximum Predicted Concentrations: 1,3-Butadiene

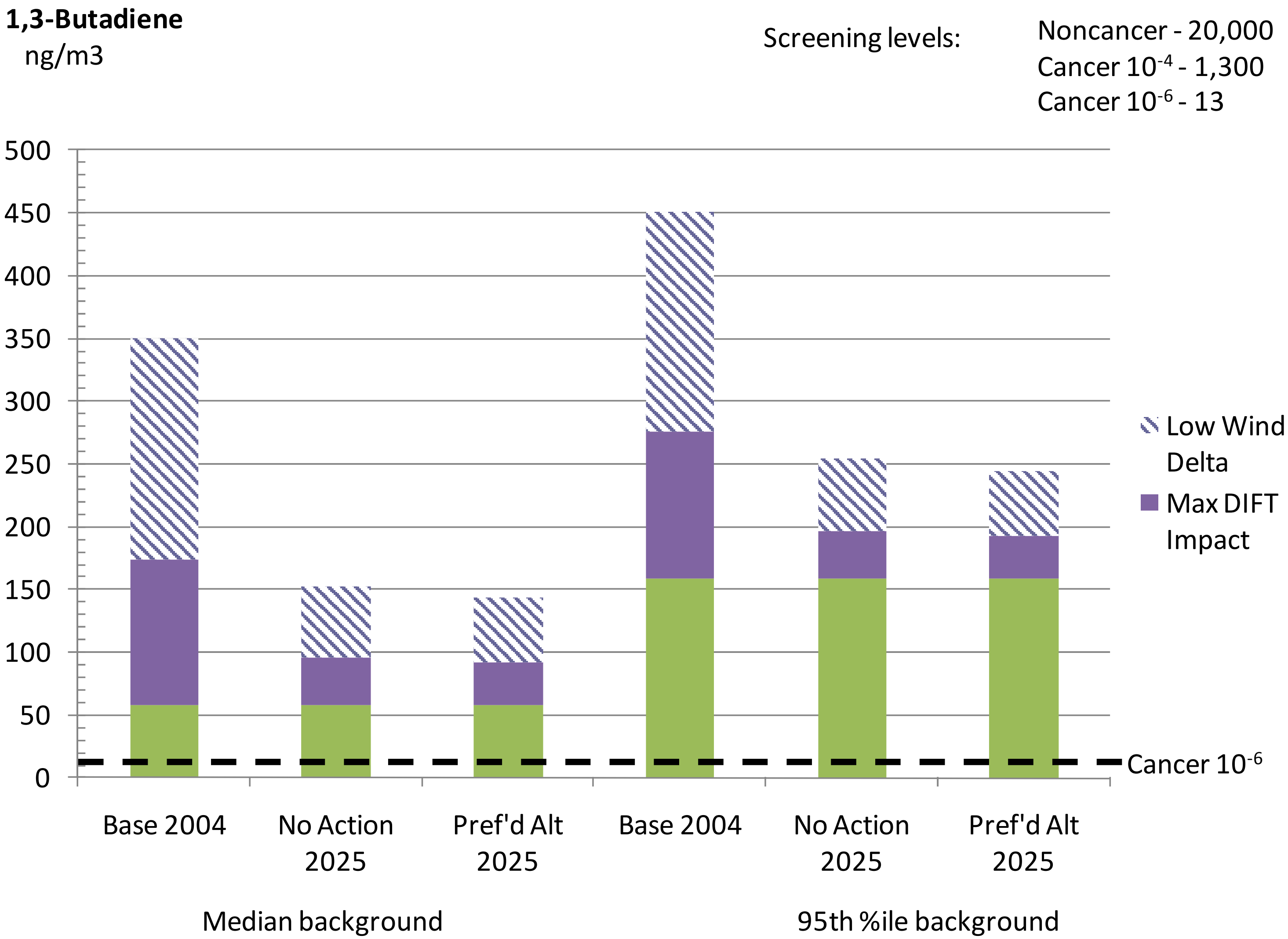


Figure 5.16 Maximum Predicted Concentrations: Formaldehyde

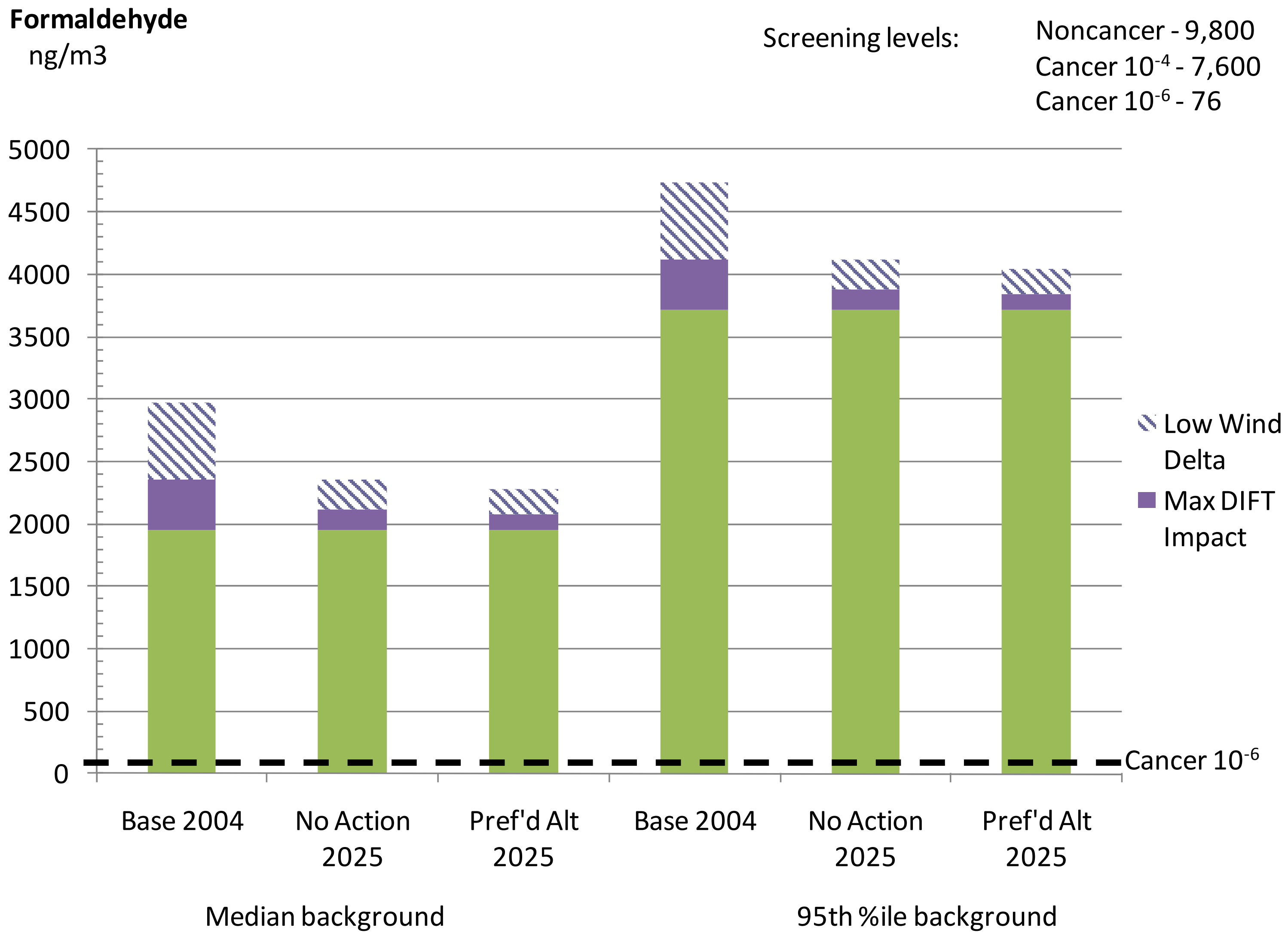


Figure 5.17 Maximum Predicted Concentrations: Acetaldehyde

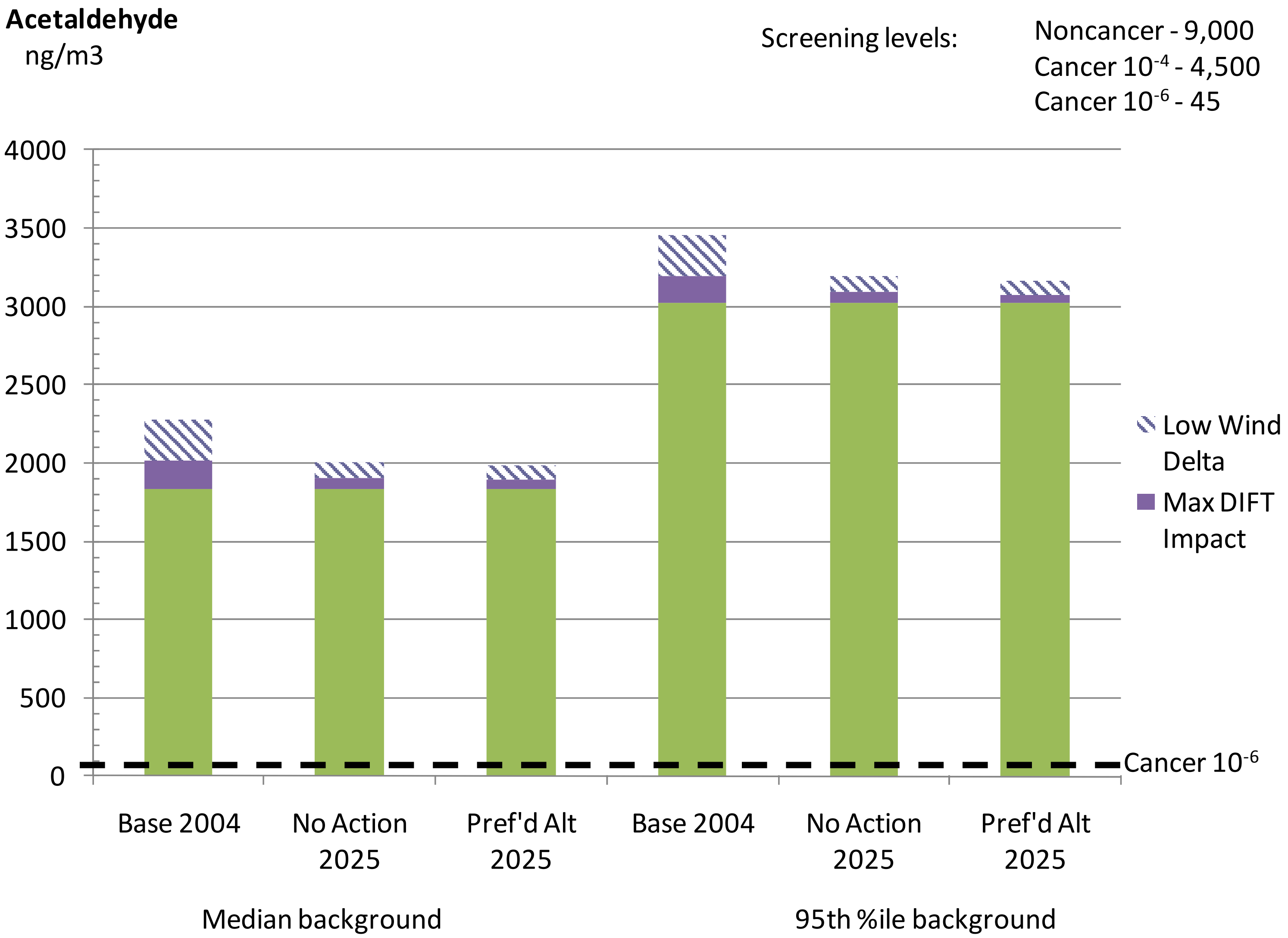


Figure 5.18 Maximum Predicted Concentrations: Acrolein

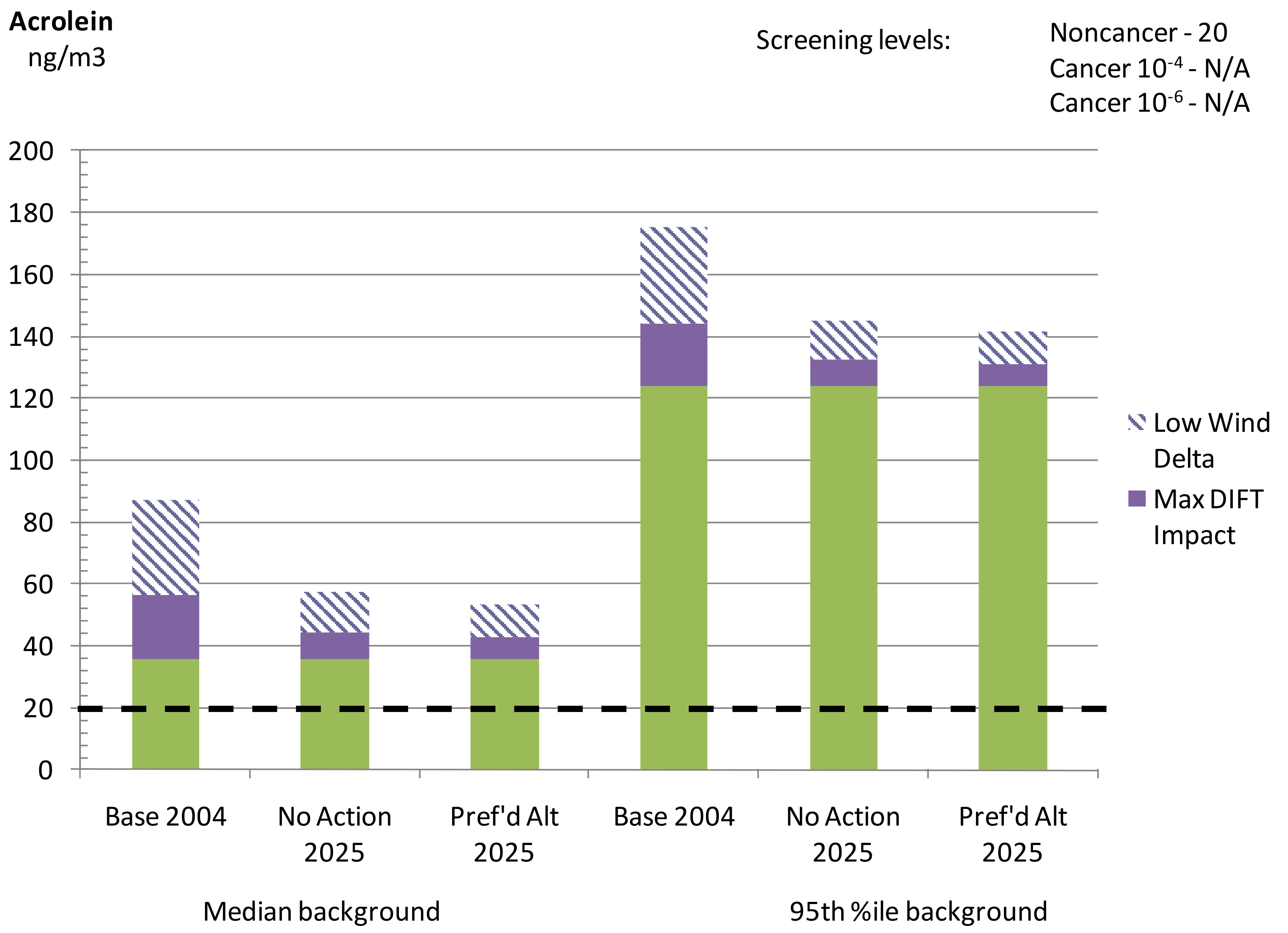


Figure 5.19 Maximum Predicted Concentrations: Diesel Particulate Matter

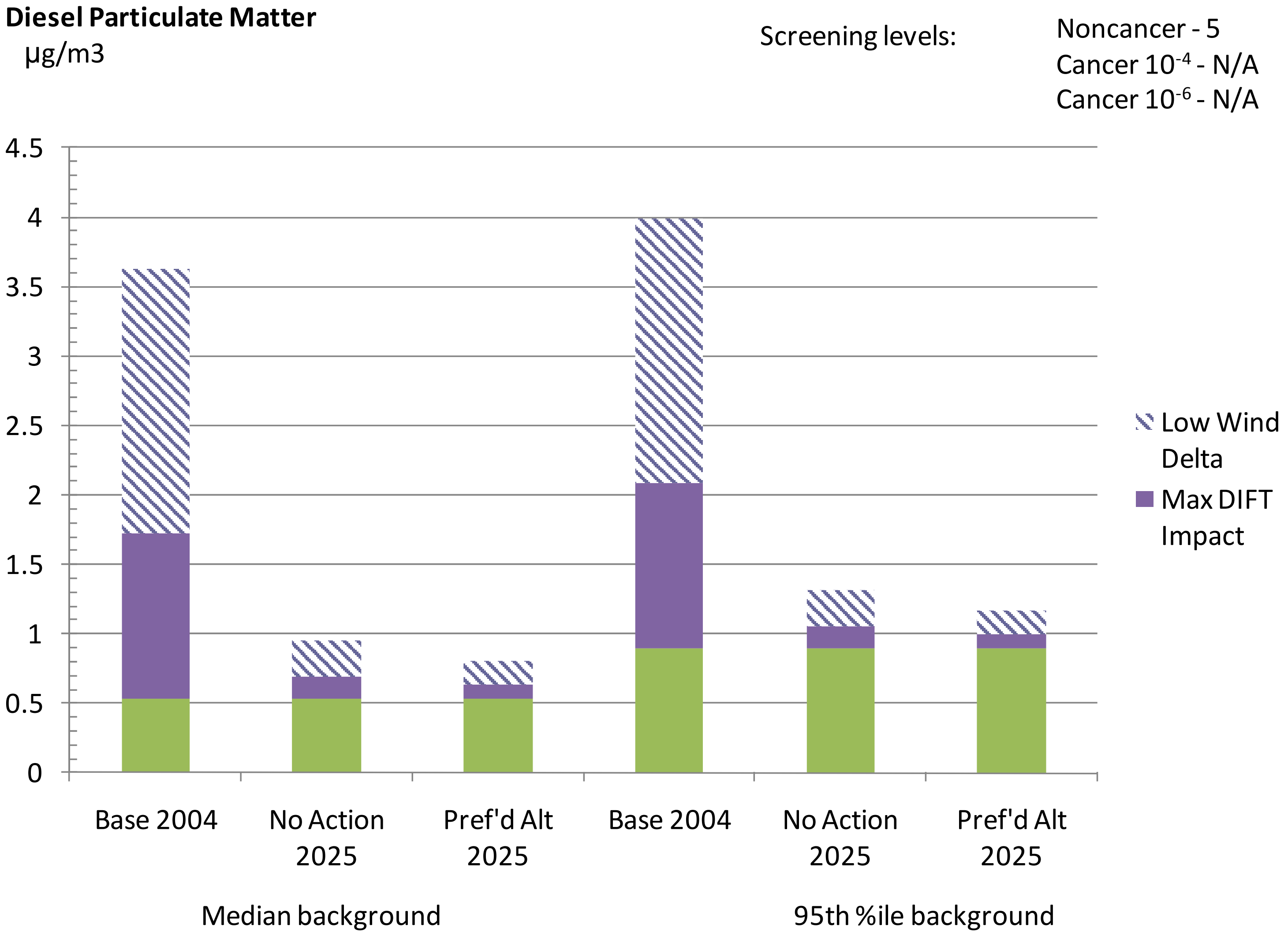


Figure 5.20 Predicted Incremental Concentrations of Benzene (in µg/m³): Detroit Meteorological Data

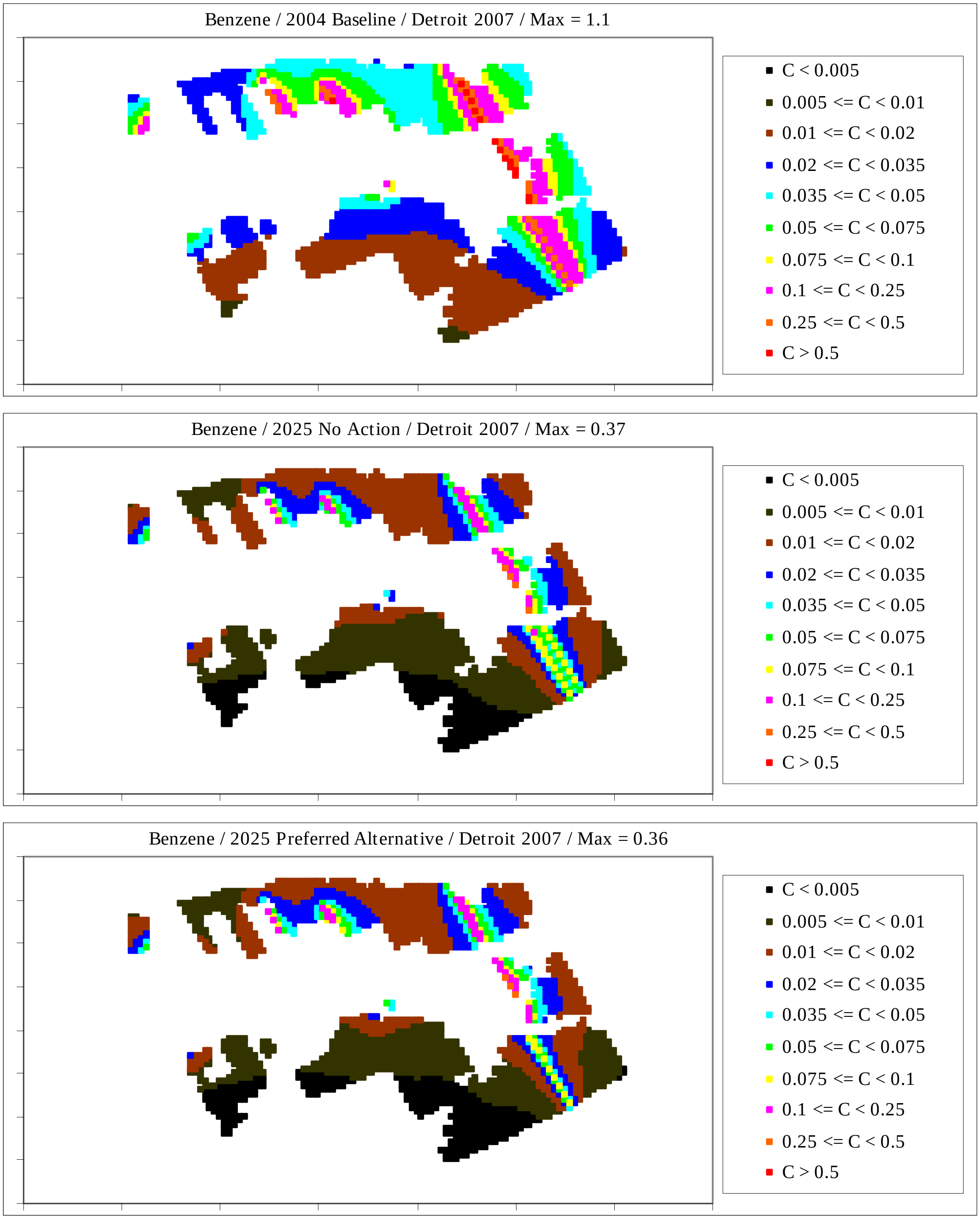


Figure 5.21 Predicted Incremental Concentrations of Benzene (in µg/m³): Anaheim Meteorological Data

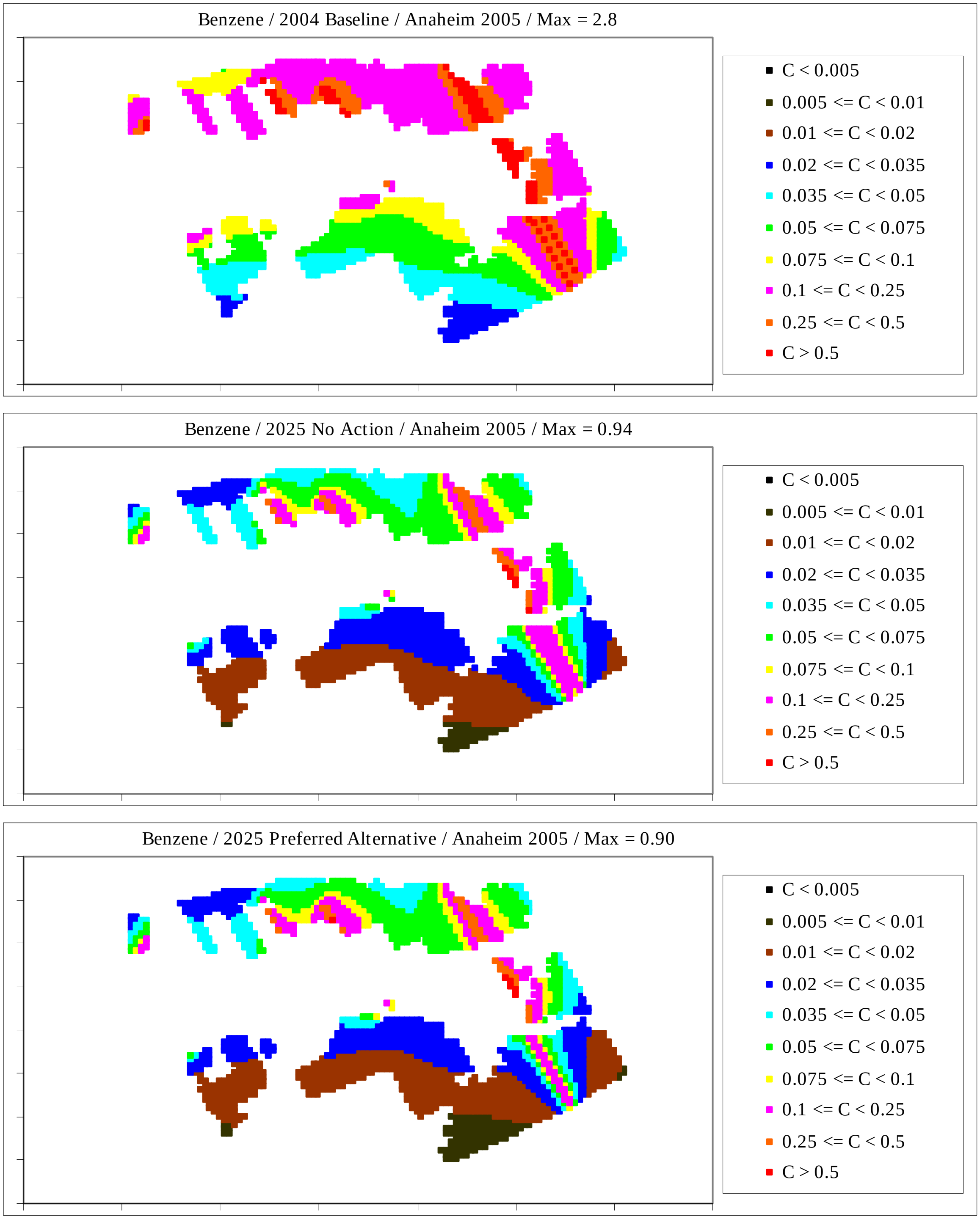
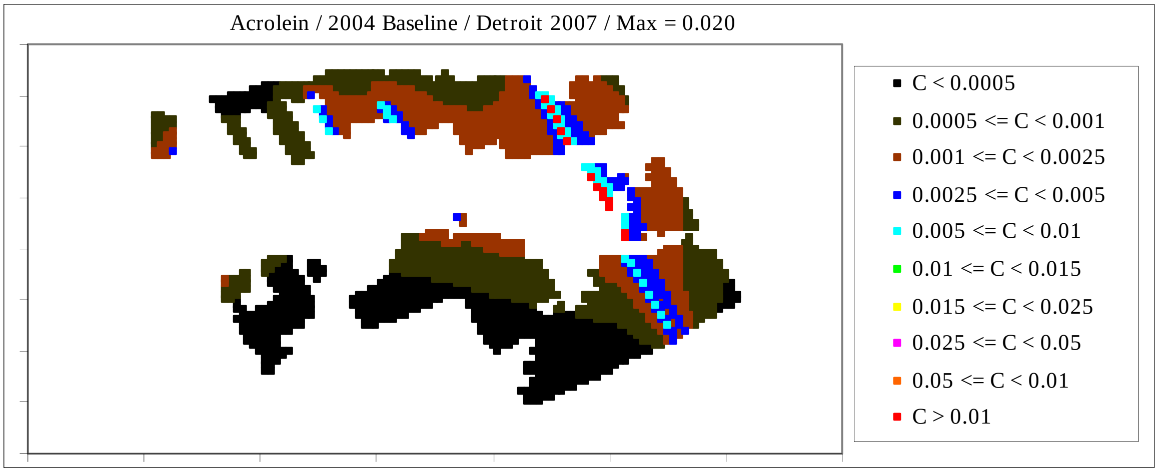
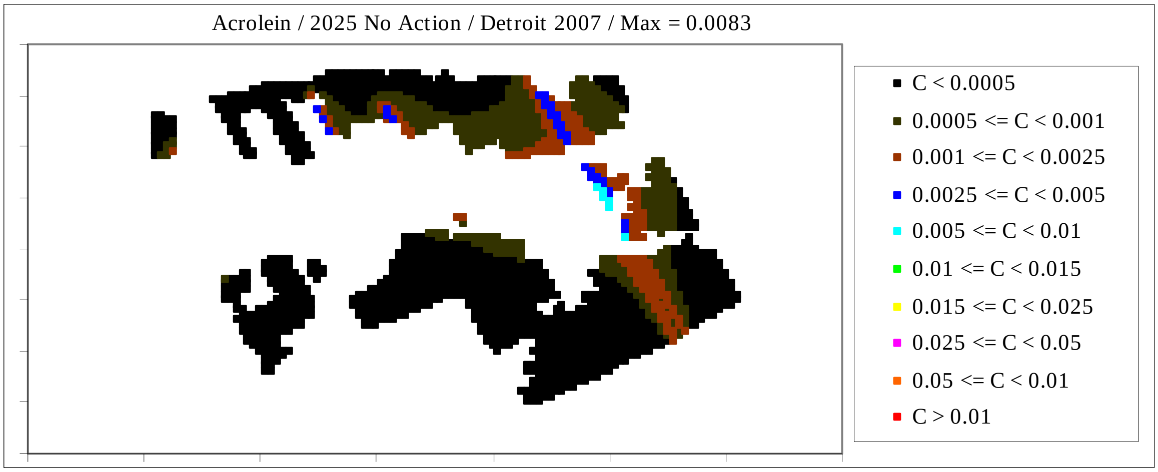


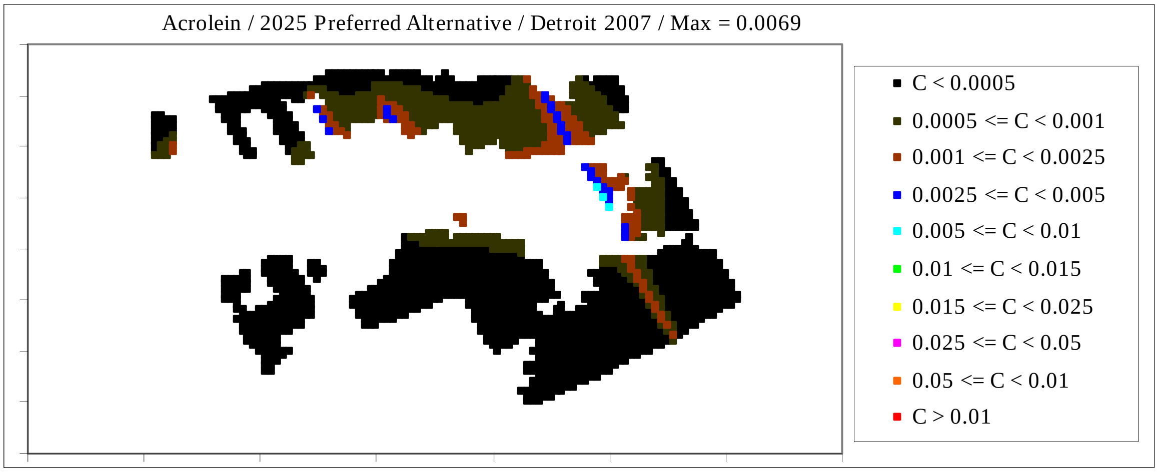
Figure 5.22 Predicted Incremental Concentrations of Acrolein (in µg/m³): Detroit Meteorological Data



Acrolein / 2004 Baseline / Detroit 2007 / Max = 0.020



Acrolein / 2025 No Action / Detroit 2007 / Max = 0.0083



Acrolein / 2025 Preferred Alternative / Detroit 2007 / Max = 0.0069

Figure 5.23 Predicted Incremental Concentrations of Acrolein (in µg/m³): Anaheim Meteorological Data

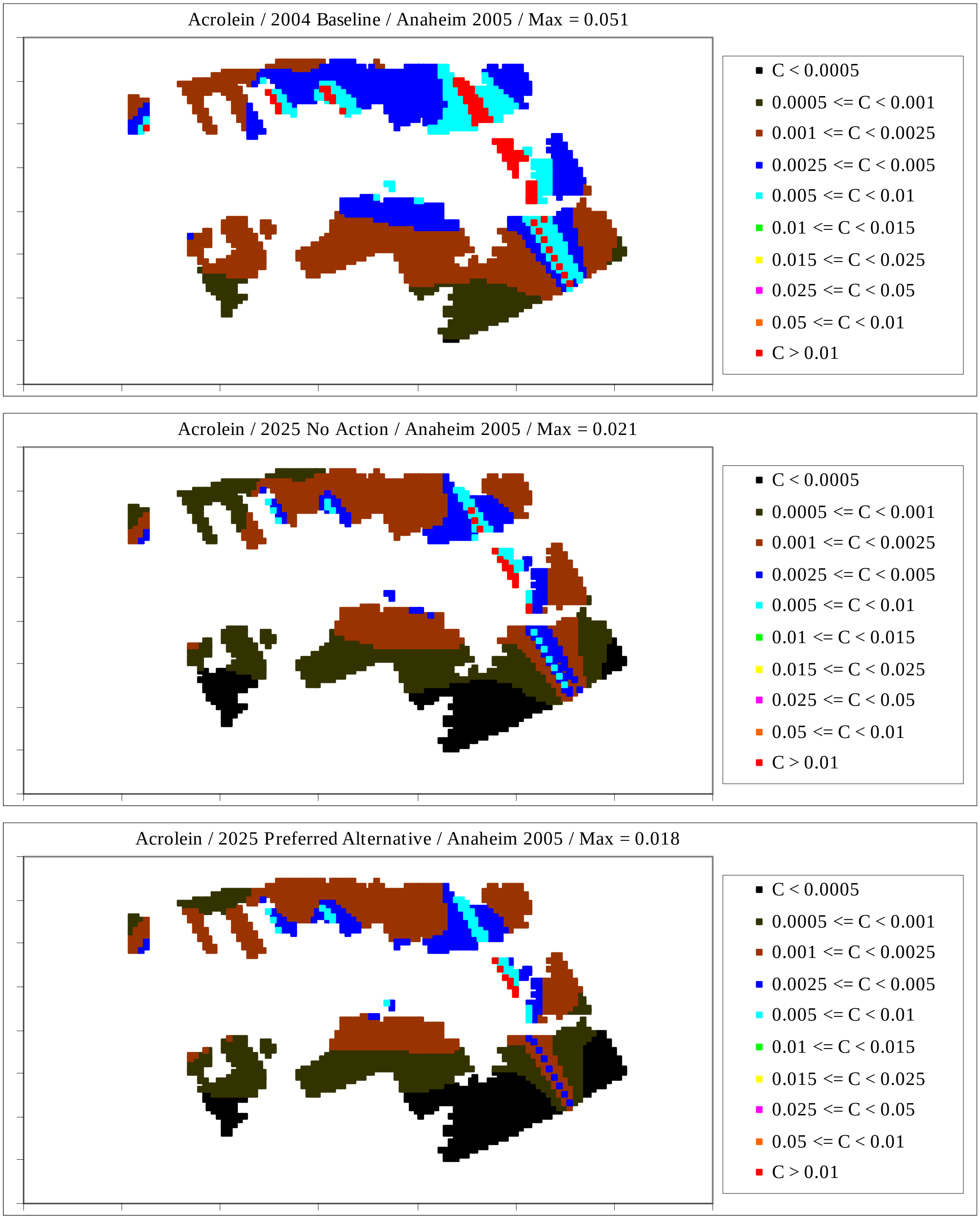


Figure 5.24 Predicted Incremental Concentrations of DPM (in µg/m³): Detroit Meteorological Data

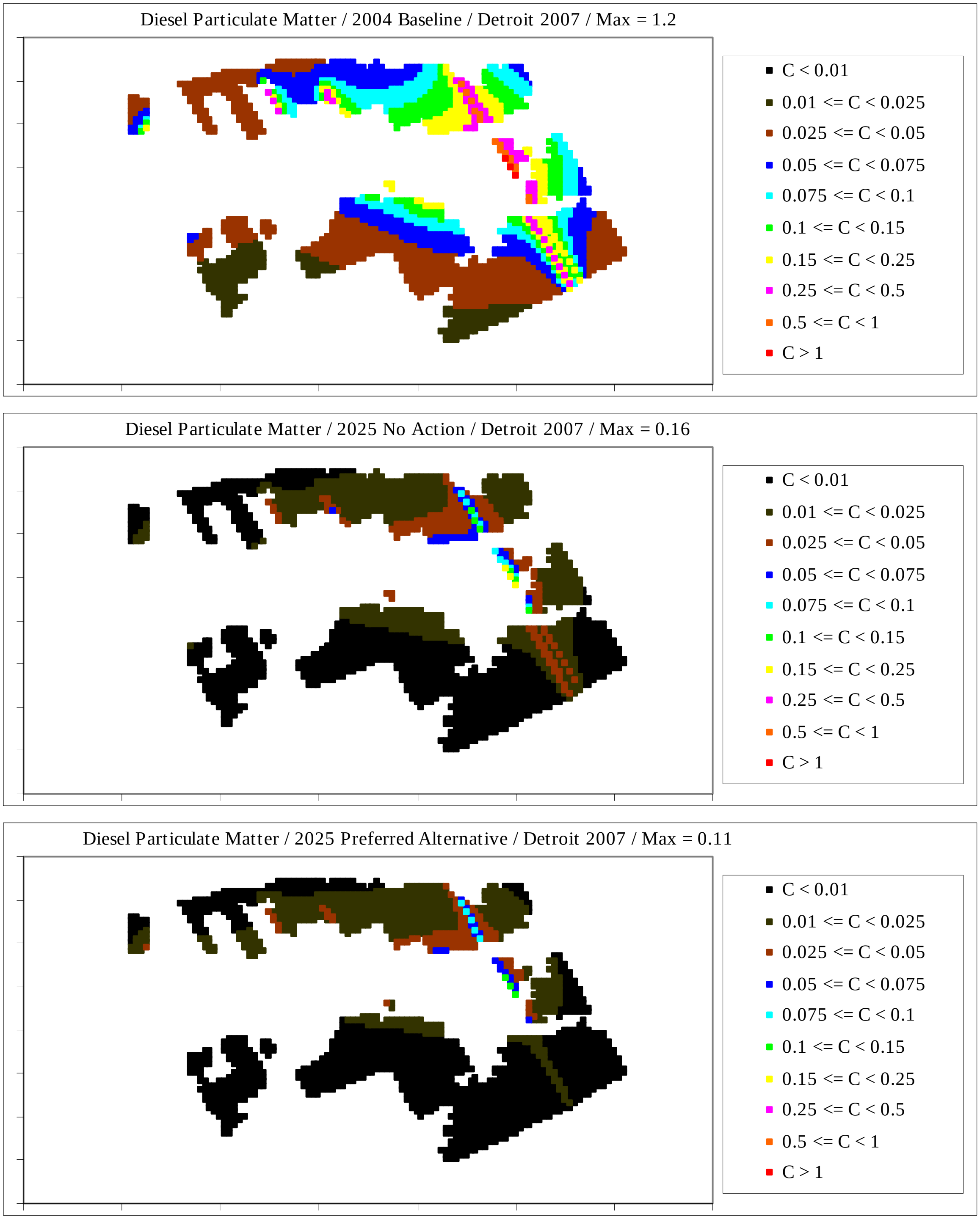


Figure 5.25 Predicted Incremental Concentrations of DPM (in µg/m³): Anaheim Meteorological Data

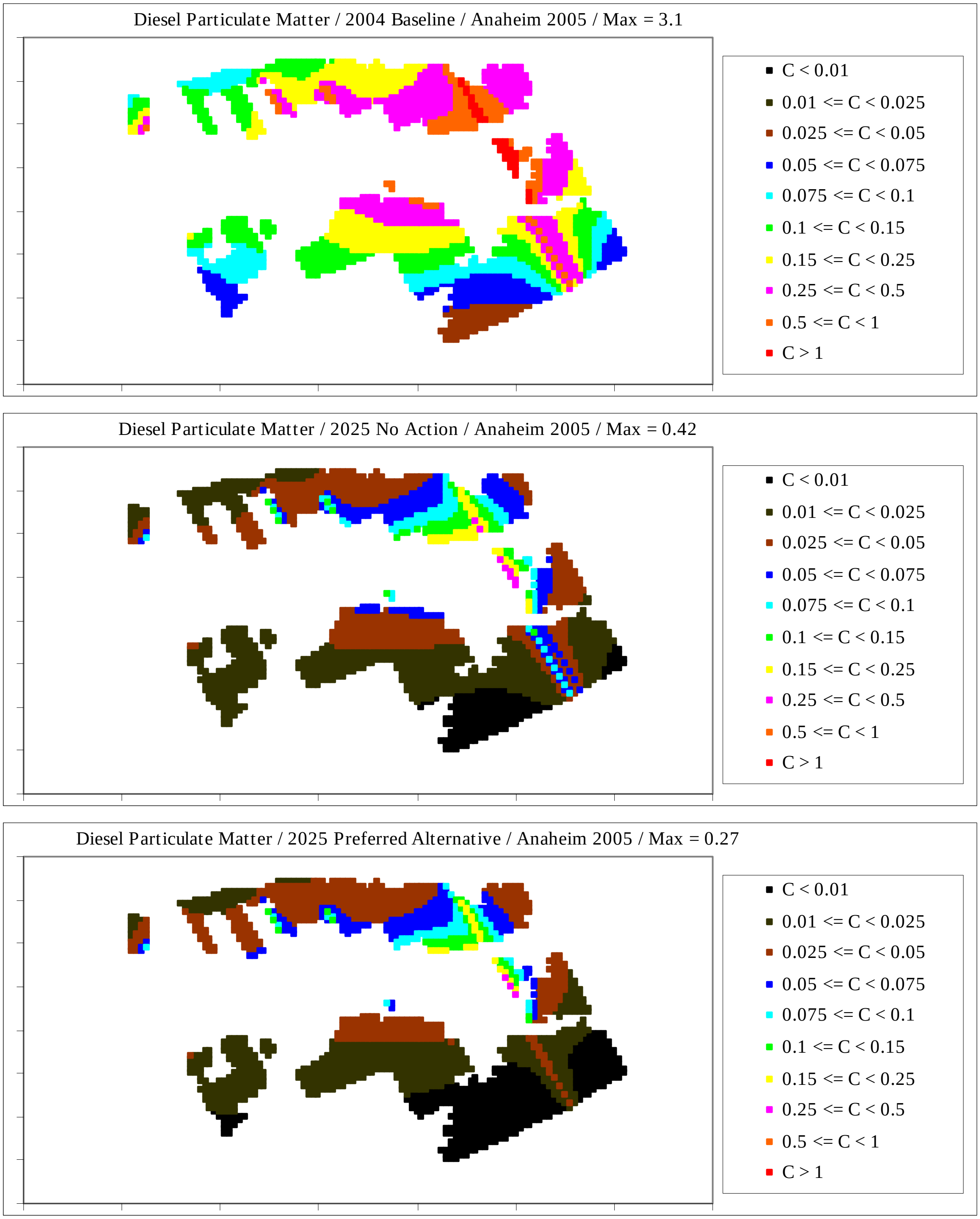
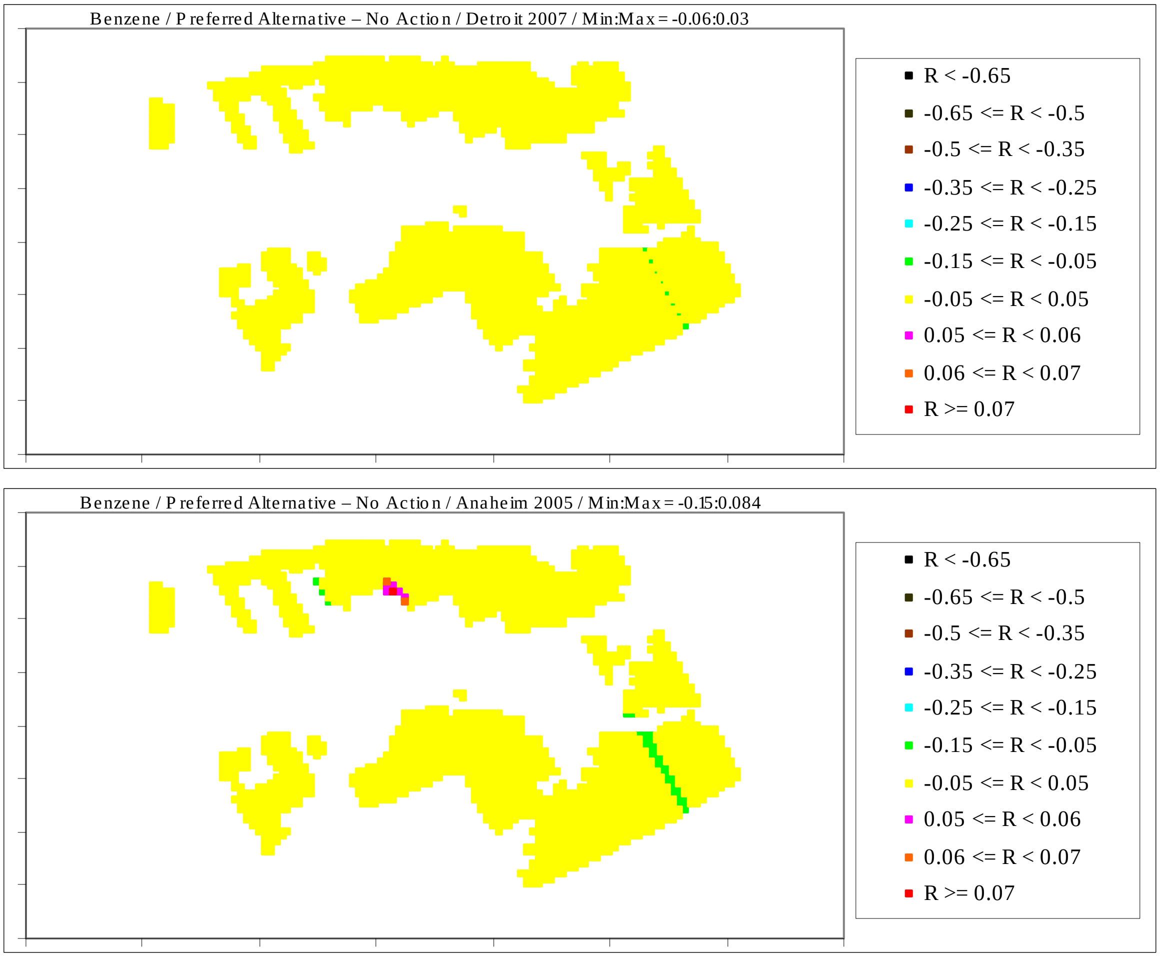
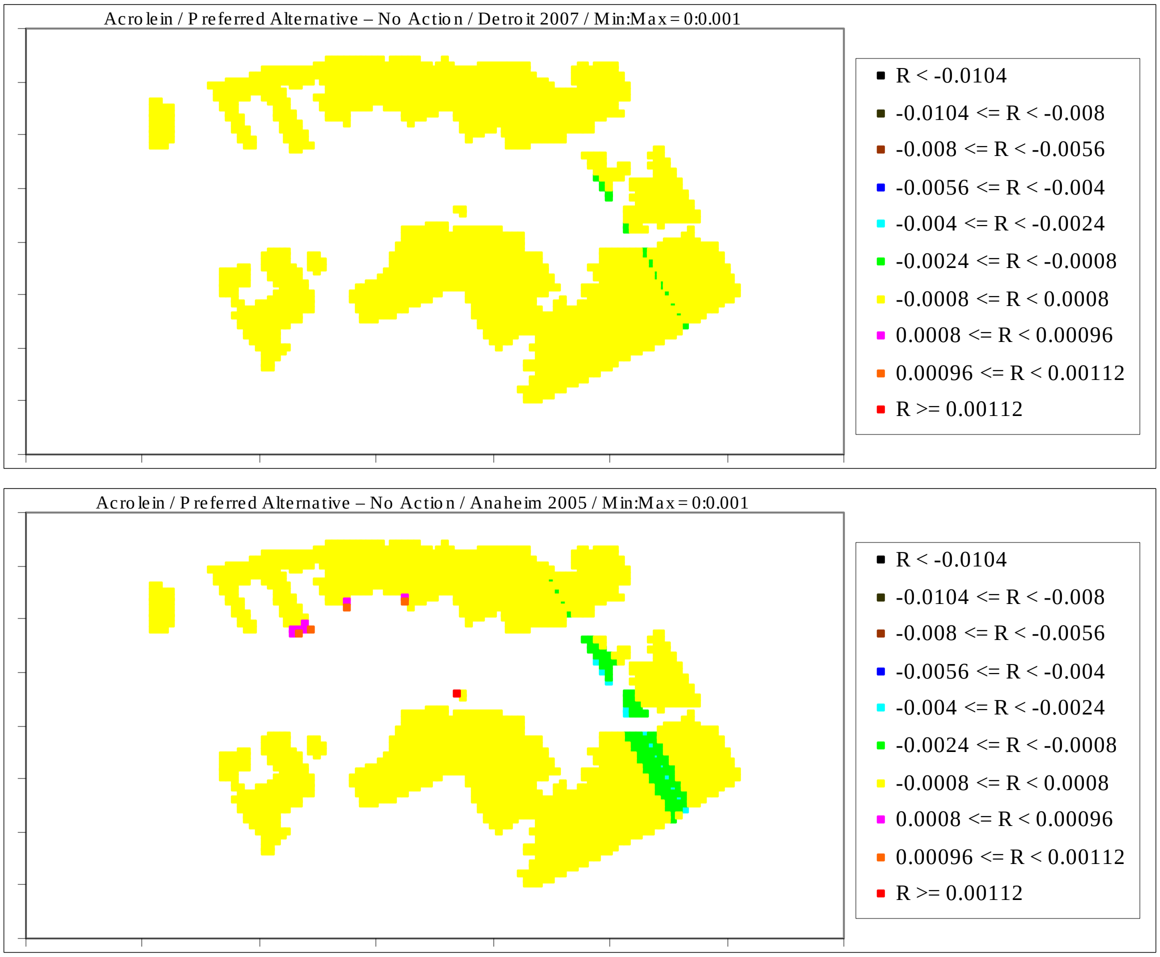


Figure 5.26 Differences in Predicted Incremental Concentrations of Benzene (in µg/m^3) Between the Preferred and No Action Scenarios in 2025



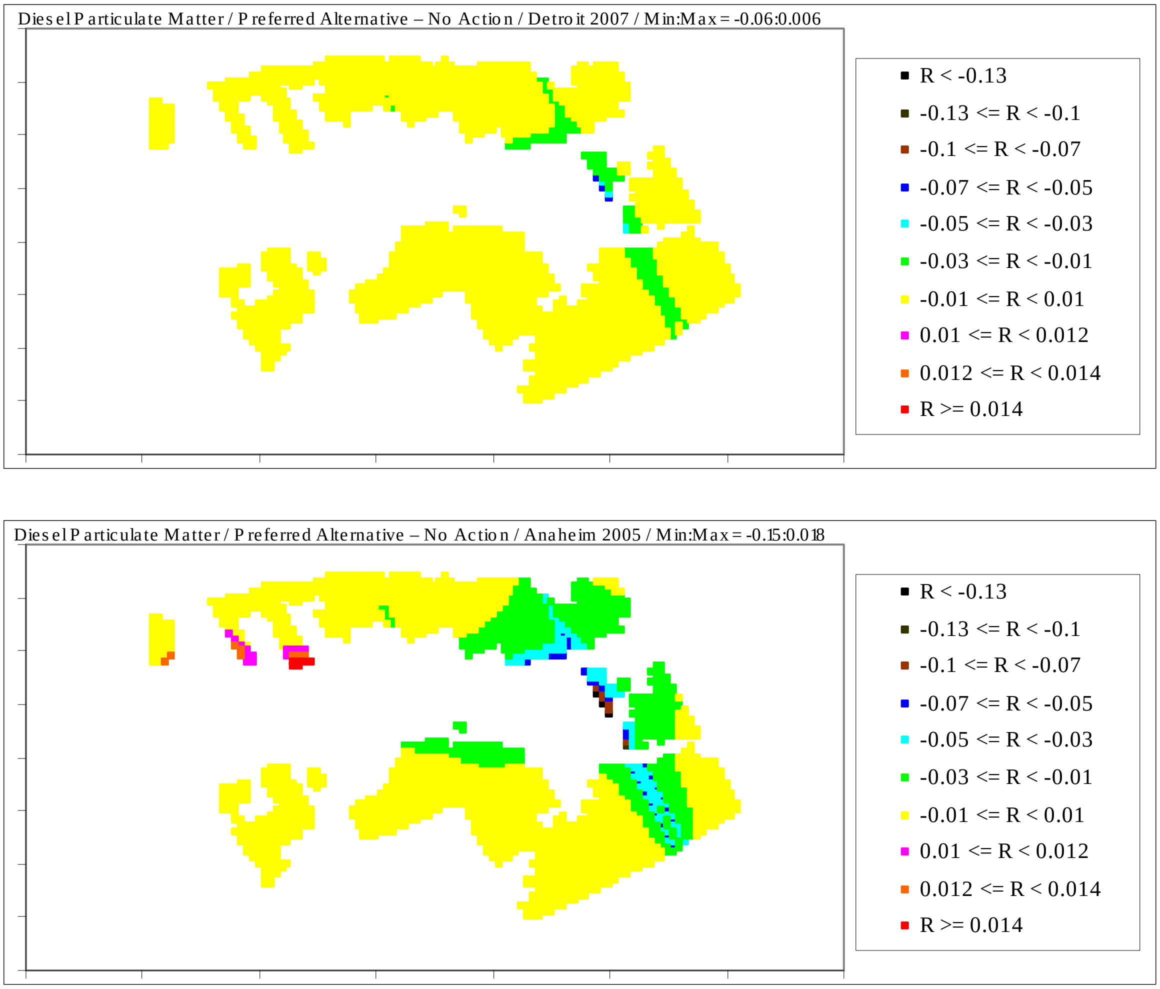
Positive values indicate higher concentrations for the Preferred Alternative, and negative values lower concentrations.

Figure 5.27 Differences in Predicted Incremental Concentrations of Acrolein (in µg/m³) Between the Preferred and No Action Scenarios in 2025



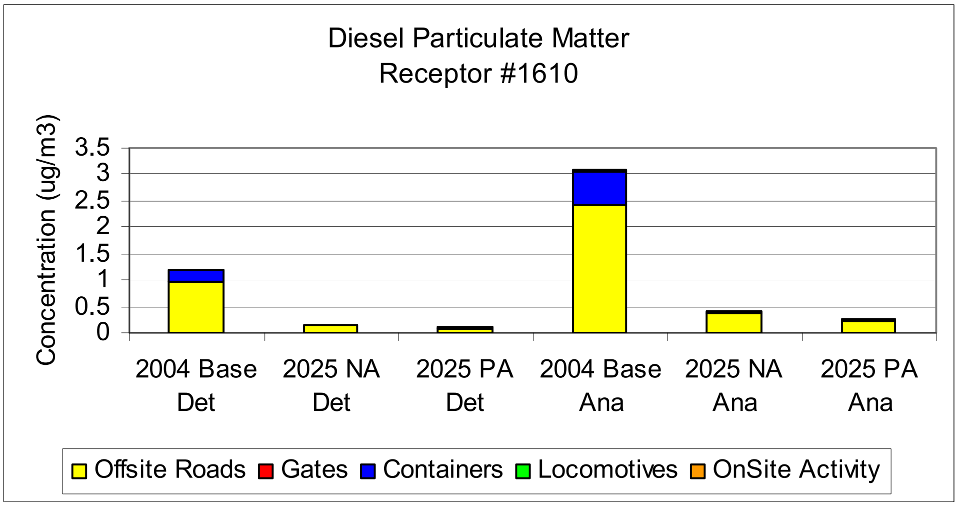
Positive values indicate higher concentrations for the Preferred Alternative, and negative values lower concentrations.

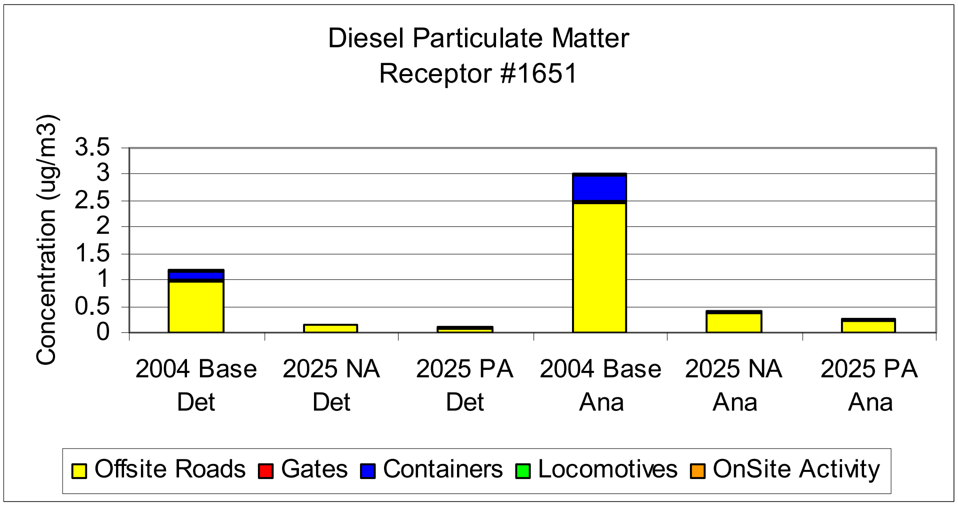
Figure 5.28 Differences in Predicted Incremental Concentrations of DPM (in µg/m³) Between the Preferred and No Action Scenarios in 2025



Positive values indicate higher concentrations for the Preferred Alternative, and negative values lower concentrations.

Figure 5.29 Predicted Incremental Concentrations of DPM (in µg/m³) at Two Most Highly Impacted Receptors and Average





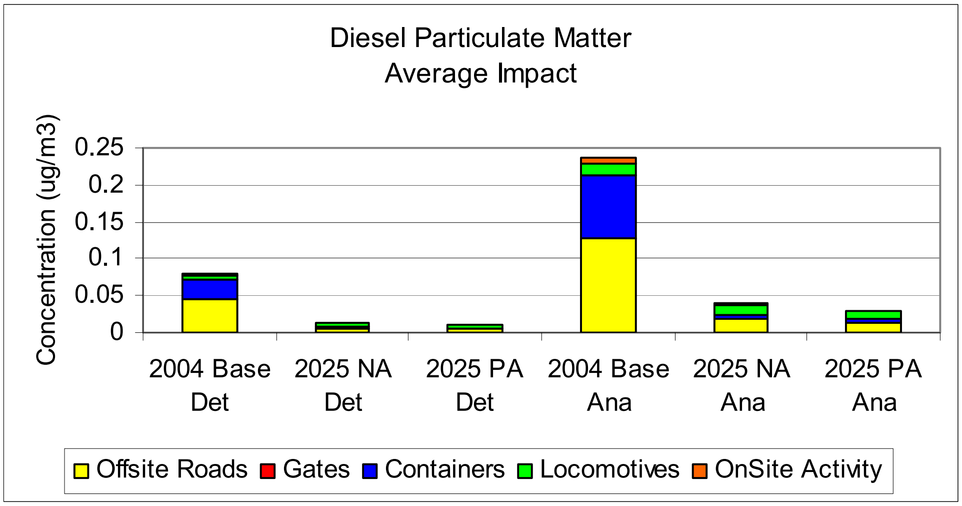


Figure 5.30 Source Impacts for Receptor with Greatest Increase in Concentrations from No Action to Preferred Alternative

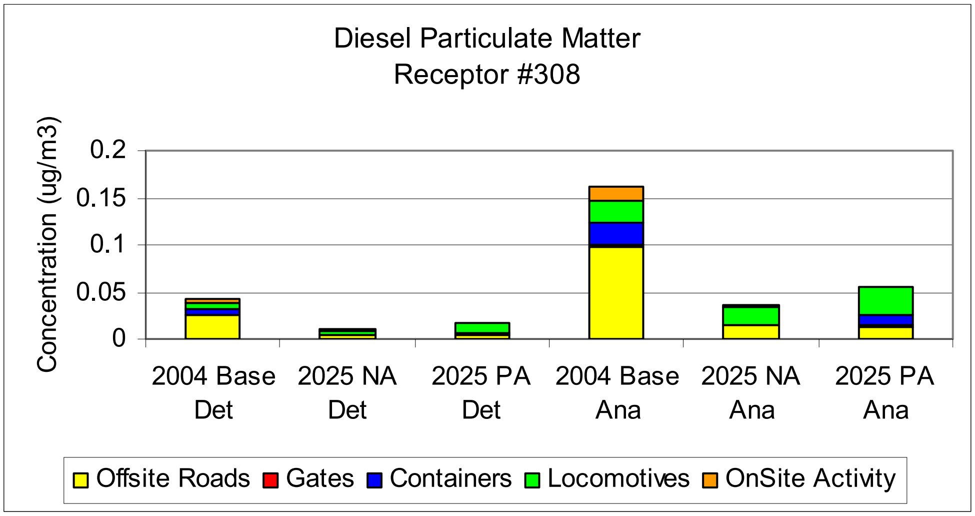
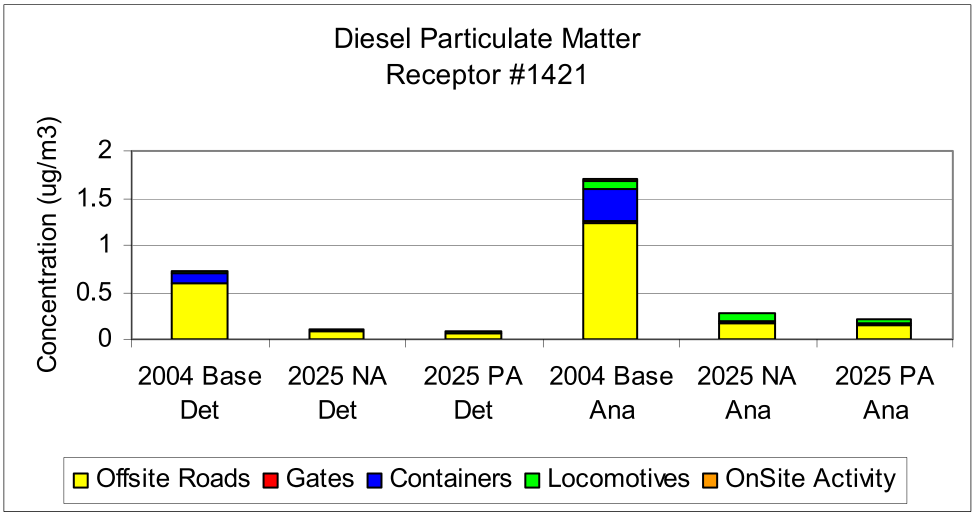


Figure 5.31 Source Impacts for Receptor with Greatest Decrease in Concentrations from No Action to Preferred Alternative



Comparisons of IFT Example Impacts with Similar Projects

Figure 5.32 compares predictions of maximum incremental diesel particulate matter concentrations to similar values estimated in risk assessments of various railyards in California. The latter estimates are derived from reports downloaded from the California Air Resources Board web site (http://www.arb.ca.gov/railyard/hra/hra.htm), with diesel particulate matter increments back-calculated from the Maximum Individual Cancer Risk (MICR) estimates[13] based on the most-affected actual residential locations. The California railyard projects were conducted over a period ranging from 2004 to 2008, and hence are roughly comparable with the timeframe of the 2004 baseline analysis for the IFT.

The modeled IFT increments are comparable to those found in the California studies, many of which include intermodal operations. The IFT example increments tend toward the higher end of the California studies, probably because of the location of the worst-case impacts just to the east of the IFT facility, while many of the California railyards have greater buffer distances to residential locations.

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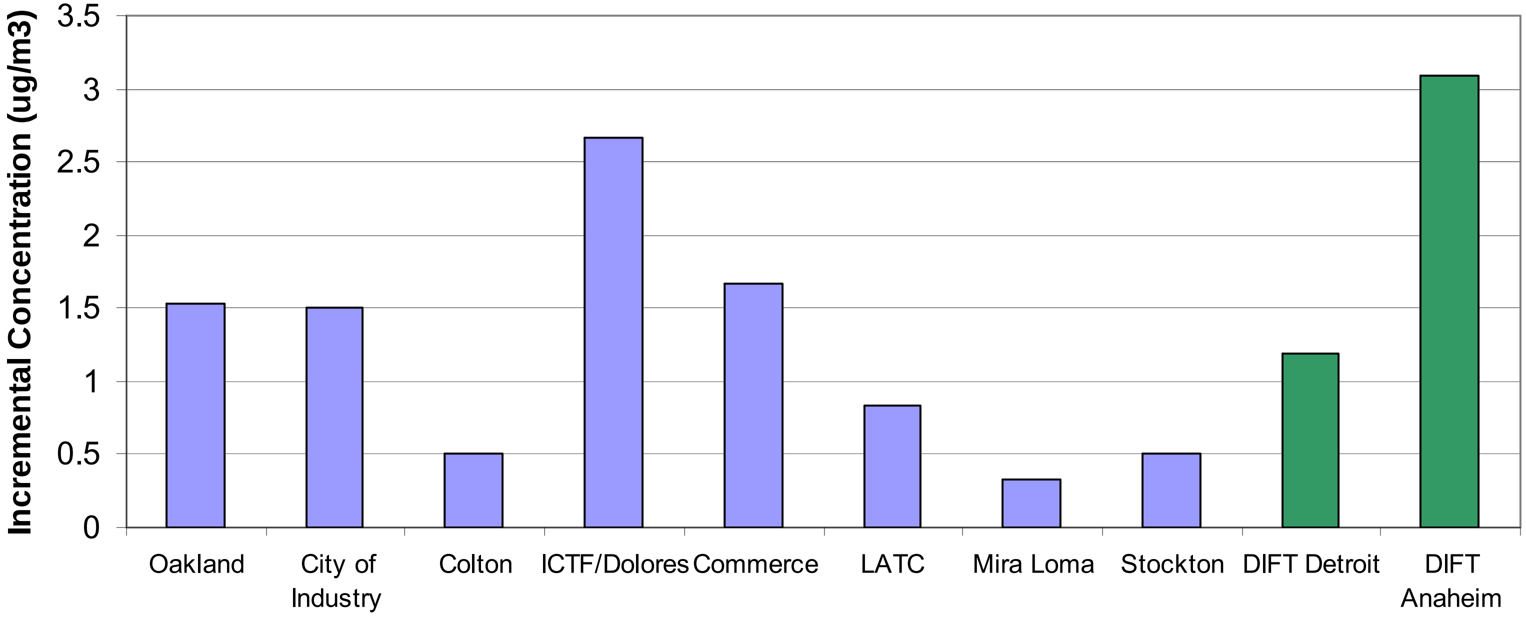
[13] Diesel particulate matter concentrations are estimated from the cancer risk estimates in the reports, a 70-year exposure period, and the California carcinogenic unit risk factor of 0.0003 $m^3/\mu g$.

Figure 5.32 Comparison of Maximum Predicted DPM Concentrations with Maximum Concentrations from Railyard Assessments Conducted in California



Source: Various reports downloaded from California Air Resources Board web site, http://www.arb.ca.gov/railyard/hra/hra.htm.

■ 5.4 Discussion

Within the IFT example, off-site road/traffic sources dominate intermodal project emissions and ambient air impacts for benzene and 1,3-butadiene, and also are important for other MSATs. The intermodal sources are of greatest importance to diesel particulate matter, but even this MSAT is influenced by traffic emissions. The importance of traffic-related emissions is enhanced by the proximity of these sources to receptor locations, compared to intermodal sources that generally have greater buffer distances. Assumptions used to spatially allocate emissions might be relevant in some cases. In this example, intermodal emissions are distributed uniformly over wide areas. If these emissions in fact are concentrated to smaller areas that are close to residential receptors, the relative importance of intermodal sources may be enhanced.

Accordingly, we focused on identifying receptors where modeled concentrations were highest, and these, as expected, were closest to the source. We then assessed impacts using these receptors. It is true that the receptors that had the worst modeled concentration are not necessarily representative of receptors further from the road/source; however, to err on the side of being conservative (meaning representing worse environmental impacts), we selected the highest concentration sites for analysis.

Considerable variation in MSAT concentrations is predicted over the receptor network in the IFT example. For roadway project analysis, the literature, model simulations, and near-road measurement work all document that concentrations for the Maximally Exposed Individual (MEI) and exposures occur at the points closest to the road. Worst-case peak concentrations appropriate for assessing MEI exposure are significantly greater than general population exposures. The maximum predictions of MSAT concentrations are 12 to 17 times mean values, 17 to 43 times median values, and 4 to 7 times 95th percentile values. These factors indicate that the focus on MEI/worst-case exposure, though important for assessing a maximum exposure scenario, greatly overstates project impacts on a community-wide basis.

As in Case Study Number 1, overall meteorology makes a significant difference in the predicted concentrations. Use of the lower wind speed (Anaheim, CA) data set more than doubled concentration estimates based on the local Detroit meteorological data. Part of the difference may be attributable to anemometer sensitivity or data processing of very low wind speeds, as the Detroit data contained a much greater frequency of calm conditions (which are ignored by AERMOD). A lower wind speed component in the Detroit data (i.e., treating calms as low speed winds) or, conversely, treating low speed winds in the Anaheim data as calms, would serve to decrease the marginal difference between the predictions of the two meteorological data sets.

Decreases in emissions/concentrations in the IFT example from the 2004 Baseline to 2025 scenarios are larger than the differences between the 2025 No Action and Preferred Alternative scenarios. The Preferred Alternative does not increase local impacts at residential locations over the No Action scenario by large percentages when compared to background. For example, the maximum projected increase of 0.006 $\mu g/m^3$ for diesel particulate matter represents about 1 percent of the typical (current day) background level. Redistribution of emissions leads to a mix of very small increases and small decreases in concentration impacts at some receptors between the 2025 No Action and Preferred Alternative scenarios. The relatively larger (but still small) decreases result from the rerouting of some of the truck traffic to other gates. Upgrades in lower-emitting equipment also may in part offset a greater volume of activity due to consolidation.

Excepting diesel particulate matter and 1,3-butadiene for the low wind speed simulation, the maximum modeled increments of MSATs in the IFT example are generally smaller than the range of modeled background concentrations in the U.S. EPA's 2005 National Air Toxics Assessment. Total modeled concentrations (IFT increments plus background) are below non-cancer screening levels for all pollutants except acrolein. Additionally, for benzene, 1,3-butadiene, acetaldehyde, and formaldehyde, total MSAT concentrations are below the 10^{-4} screening level for incremental cancer risk, but above the 10^{-6} screening-level. Diesel particulate matter concentrations would exceed both the 10^{-6} and 10^{-4} cancer risk screening-levels if the controversial California unit risk factor is considered.

The IFT example demonstrates AERMOD to be a capable and versatile tool if ambient air impacts of MSAT emissions from transportation projects are to be estimated. AERMOD is especially well-suited to intermodal and other similar projects that are likely to emit pollutants over wide ranging areas, as opposed to the confined emissions from roadways. The area source algorithms of AERMOD can be applied to roadways as well, although AERMOD is not tailored to such applications as is the CAL3QHC/r model. Specifically, AERMOD does not contain queuing and similar algorithms to automatically distribute emissions temporally and spatially (although EPA's P.M. hotspot guidance for transportation conformity recommends against using CAL3QHCR's queuing algorithm, instead recommending the use of more up-to-date traffic analysis methods). AERMOD can consider detailed spatial patterns of emission sources to simulate complex geometries such as intersections, as well as assign hourly emission factors, but the onus is on the user to allocate and interface these factors within AERMOD's input framework. Although the dispersion algorithms within AERMOD may be superior, it is not clear that differences in predictions will be substantial at the near-source receptor locations characteristic of transportation projects. (EPA's P.M. hotspot guidance for transportation conformity recommends both AERMOD and CAL3QCHR for highway projects, and does not endorse one over the other.) A side-by-side comparison of AERMOD and CAL3QHC/r would be an interesting extension of this work.

5.5 References

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U.S. EPA (2010). *Transportation Conformity Guidance for Quantitative Hot-spot Analyses in* $PM_{2.5}$ *and* PM_{10} *Nonattainment and Maintenance Areas.* U.S. Environmental Protection Agency, Office of Transportation and Air Quality, EPA-420-B-10-040.

6.0 Conclusions

The review of environmental documents and case studies conducted for this project were intended to provide information to help address the following key questions:

- Under what conditions might there be substantial differences in MSAT emissions among transportation project alternatives? Under what conditions might these result in significant differences in pollutant concentrations near the project?

- How might the MSAT effects of a project vary by type of project? How will this change over time as measures are phased in to reduce motor vehicle emissions?

- What are the key assumptions (emission rates, meteorological conditions, receptor locations, etc.) that affect changes in modeled pollutant concentrations in the vicinity of projects?

The following conclusions may be drawn considering the findings regarding MSAT emissions impacts in the environmental documents reviewed, along with the dispersion modeling and analysis of localized concentrations conducted for the two case studies.

1. *Under what conditions might there be substantial differences in MSAT emissions among transportation project alternatives? Under what conditions might these result in significant differences in pollutant concentrations near the project?*

   Whether the impacts of a project are "substantial" can be evaluated by comparing the change in concentrations between alternatives to benchmarks such as i) established risk thresholds for a pollutant; ii) the contribution of the transportation source under the no-project alternative; and/or iii) background concentrations. The following conclusions may be drawn from the case studies and review of environmental documents performed in this research:

   – Major transportation project improvements have generally been found to generate modest impacts on total MSAT emissions and local MSAT concentrations, compared to no-project alternatives and broad trends associated with changing fleet emissions over time. **Whether these impacts are positive or negative will depend upon the specific conditions of the project**. If the project increases traffic volume, higher emissions may result, holding other factors constant such as fleet mix and vehicle speed. However, in some situations these may be offset by improvements in traffic flow and speed that decrease emissions per vehicle. Projects also may redistribute the location of activity, increasing pollutant concentrations in some areas, and decreasing them in others.

   – **The impacts of transportation project alternatives on MSAT concentrations are generally fairly small relative to background levels of pollutants**. In the case studies, a change on the order of 5 to 15 percent (either positive or negative) relative to typical background conditions was generally observed at the maximum impacted receptor locations, for the project versus no-project alternative. Similarly, the environmental documents reviewed typically reported impacts of a few percent or less.

- While the impact of the project versus no-project alternative was small, **the contribution of the local transportation source (project or no-project alternative) was on the same order of magnitude as current background levels for most pollutants**.[14]
- Current background pollutant concentrations across the U.S. for the evaluated pollutants typically exceed one-in-a million 70-year cancer risk levels and the noncancer risk level for acrolein, but are lower than one hundred-in-a-million cancer risk levels and other noncancer chronic health risk levels of concern identified by EPA. **Adding the contribution from the local transportation source did not change whether any risk thresholds were exceeded in the case studies**. Therefore, adding the contribution of the project versus no-project alternative also did not change whether any risk thresholds were exceeded. Furthermore, the receptor placements in this study were conservative, i.e., the pollutant changes at the receptors of maximum impact (which are close to the roadway) are likely to be experienced by human populations only for short durations rather than over a long time period. An important caveat is that EPA does not define unit risk factors associated with diesel particulate matter.
- **The relative contribution of transportation sources (versus background) varies substantially by pollutant**. In the case studies, transportation sources created the lowest relative impacts for acetaldehyde and formaldehyde, and the highest relative impacts for diesel particulate matter and naphthalene. These impacts may vary seasonally depending upon differences in emission rates and background concentrations.

2. *How might the MSAT effects of a project vary by type of project?*

- The case studies focused on two types of projects that have previously been identified as leading to the most significant MSAT impacts of any transportation project: major highway expansions, and intermodal freight terminals. The case studies and limited review of environmental documentation found no reason to refute this, but also did not look at other types of projects. The findings presented here illustrate how MSAT impacts can vary with changes in volumes, fleet mix, and travel speed, with changing emission factors over time, with changing meteorological conditions, and with varying distances from the pollution source. These same principles apply to virtually all project types involving on- and off-road motor vehicle emissions.

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[14] The study did not evaluate potential declines in background conditions in the future as total emissions from all sources decrease, which would make the future-year contribution of local transportation sources and project alternatives larger when expressed as a percent of background.

3. *How will impacts change over time as measures are phased in to reduce motor vehicle emissions?*

   - The relative impacts of project alternatives will remain consistent over time. However, **the absolute impacts (positive or negative) will become smaller as emission rates decrease**. Decreases in MSAT emission rates of 50 to 90 percent or more will be observed by 2035, comparing to 2005 emission rates, meaning that the impacts of project alternatives will decrease by this amount in absolute terms. These decreases are due to the continued introduction of cleaner vehicles and fuels in response to more stringent emission standards.
   - **The impacts of transportation projects on MSAT concentrations are generally small relative to changes in emissions levels over time** as cleaner vehicles and fuels are introduced into the fleet. In nearly all cases modeled (as well as reviewed in environmental documentation), decreases in emissions per vehicle more than outweigh any increases in traffic over time periods of 10 to 25 years.

4. *What are the key assumptions that affect changes in modeled pollutant concentrations in the vicinity of projects?*

   - In the highway project case study examined here, **intersections generated MSAT concentrations that were much higher than those modeled for highway mainlines** (considering receptor locations placed consistent with accepted modeling protocol). This was due primarily to closer proximity of receptors to vehicles at intersections (as small a distance as 3 feet from the traveled way, compared to 90 feet from the highway centerline), and secondarily to higher emission rates due to lower traffic speeds at intersections.
   - The intermodal freight terminal case study found the greatest pollutant concentrations to be directly adjacent to major roadways in the study area. **The physical (site) design of the project, and in particular the location of emissions sources relative to nearby populations, will affect its relative impacts**. Careful attention to the placement of receptors, and to assumptions about the spatial and temporal distribution of emissions from each source, is required to ensure that impacts on all affected populations will be accurately measured.
   - **Meteorological conditions make a difference**. In particular, an area that is characterized by generally light winds is estimated to have a traffic contribution to pollutant concentrations that is two to three times *higher* than an area where moderate to higher wind speeds are more prevalent.

Conclusions also can be drawn regarding the methods and procedures for modeling ambient concentrations of MSATs if such modeling is to be conducted:

- CAL3QHC/r may be more advantageous than AERMOD to apply for simple sources (such as a highway segment or intersection) commonly encountered in transportation analysis because it has the advantage of incorporating traffic queuing algorithms. However, AERMOD was necessary to model the intermodal facility (including multiple source types as well as roadways modeled as simple line sources) and provides substantial flexibility in how pollutant sources can be modeled.

- The use of an areawide grid of receptors, and production of visual outputs using this grid and reporting of average as well as maximum values, provided interesting and valuable insights that could not be gained simply from examining changes in maximum concentration levels.

There are numerous uncertainties inherent in any analysis of ambient pollutant concentrations, including assumptions about meteorological conditions, the spatial and temporal patterns of emissions, pollutant transport, secondary pollutant formation, averaging of daily conditions to represent annual exposure, the most appropriate location of receptors to represent human exposure, etc. Significant uncertainty also exists in relating pollutant concentrations to health risks. Modeling exercises such as presented in this research are intended to shed light on likely impacts but cannot fully overcome these uncertainties.

Appendix A

Emission Factors for Case Study Number 1

Table A.1 Emission Factors (g/mi)[1]

Pollutant/Speed Bin (mph)	2005	2015	2035	Ratio, 2015/2005	Ratio, 2035/2005
Acetaldehyde					
<2.5	0.0286	0.0103	0.0028	0.36	0.10
2.5-7.5	0.0151	0.0055	0.0016	0.36	0.10
7.5-12.5	0.0085	0.0032	0.0010	0.37	0.12
12.5-17.5	0.0063	0.0024	0.0008	0.38	0.12
17.5-22.5	0.0052	0.0020	0.0007	0.38	0.13
22.5-27.5	0.0044	0.0017	0.0006	0.38	0.13
27.5-32.5	0.0039	0.0015	0.0005	0.38	0.13
32.5-37.5	0.0034	0.0013	0.0004	0.38	0.13
37.5-42.5	0.0031	0.0012	0.0004	0.38	0.12
42.5-47.5	0.0029	0.0011	0.0003	0.37	0.12
47.5-52.5	0.0027	0.0010	0.0003	0.37	0.12
52.5-57.5	0.0026	0.0010	0.0003	0.37	0.11
57.5-62.5	0.0025	0.0009	0.0003	0.37	0.12
62.5-67.5	0.0024	0.0009	0.0003	0.38	0.12
67.5-72.5	0.0024	0.0009	0.0003	0.40	0.14
>72.5	0.0025	0.0010	0.0004	0.41	0.17
Acrolein					
<2.5	0.00248	0.00101	0.00028	0.41	0.11
2.5-7.5	0.00129	0.00052	0.00015	0.40	0.12
7.5-12.5	0.00071	0.00029	0.00009	0.41	0.12
12.5-17.5	0.00053	0.00021	0.00007	0.41	0.13
17.5-22.5	0.00043	0.00017	0.00006	0.40	0.13
22.5-27.5	0.00036	0.00014	0.00005	0.40	0.13
27.5-32.5	0.00032	0.00013	0.00004	0.40	0.13
32.5-37.5	0.00028	0.00011	0.00003	0.40	0.12
37.5-42.5	0.00026	0.00010	0.00003	0.39	0.12
42.5-47.5	0.00024	0.00009	0.00003	0.39	0.11
47.5-52.5	0.00022	0.00009	0.00002	0.39	0.10
52.5-57.5	0.00021	0.00008	0.00002	0.38	0.10
57.5-62.5	0.00020	0.00008	0.00002	0.38	0.10
62.5-67.5	0.00019	0.00007	0.00002	0.38	0.10
67.5-72.5	0.00019	0.00008	0.00002	0.39	0.12
>72.5	0.00019	0.00008	0.00003	0.40	0.13

[1] Composite emission factors (all vehicle types from MOVES for July at 12 noon on an urban unrestricted access roadway. The full set of rates used as lookups for the CAL3QHCR runs also had four seasons, all 24 hours of the day, and an additional road type for urban restricted access.

Table A.1 Emission Factors (g/mi)[1] (continued)

Pollutant/Speed Bin (mph)	2005	2015	2035	Ratio, 2015/2005	Ratio, 2035/2005
Benzene					
<2.5	0.111	0.021	0.009	0.19	0.08
2.5-7.5	0.059	0.011	0.005	0.19	0.08
7.5-12.5	0.033	0.007	0.003	0.20	0.09
12.5-17.5	0.025	0.005	0.002	0.21	0.10
17.5-22.5	0.021	0.004	0.002	0.22	0.10
22.5-27.5	0.017	0.004	0.002	0.22	0.10
27.5-32.5	0.015	0.003	0.002	0.22	0.10
32.5-37.5	0.013	0.003	0.001	0.22	0.10
37.5-42.5	0.012	0.003	0.001	0.22	0.10
42.5-47.5	0.011	0.002	0.001	0.22	0.10
47.5-52.5	0.010	0.002	0.001	0.22	0.09
52.5-57.5	0.010	0.002	0.001	0.22	0.09
57.5-62.5	0.009	0.002	0.001	0.22	0.10
62.5-67.5	0.009	0.002	0.001	0.23	0.10
67.5-72.5	0.009	0.002	0.001	0.24	0.12
>72.5	0.010	0.003	0.001	0.26	0.13
1, 3-Butadiene					
<2.5	0.0127	0.0035	0.0012	0.27	0.09
2.5-7.5	0.0068	0.0019	0.0007	0.28	0.10
7.5-12.5	0.0039	0.0011	0.0004	0.29	0.11
12.5-17.5	0.0029	0.0009	0.0003	0.30	0.12
17.5-22.5	0.0024	0.0007	0.0003	0.30	0.12
22.5-27.5	0.0021	0.0006	0.0002	0.30	0.12
27.5-32.5	0.0018	0.0006	0.0002	0.30	0.12
32.5-37.5	0.0016	0.0005	0.0002	0.30	0.12
37.5-42.5	0.0014	0.0004	0.0002	0.30	0.12
42.5-47.5	0.0013	0.0004	0.0001	0.30	0.11
47.5-52.5	0.0012	0.0004	0.0001	0.30	0.11
52.5-57.5	0.0012	0.0004	0.0001	0.30	0.11
57.5-62.5	0.0011	0.0003	0.0001	0.30	0.11
62.5-67.5	0.0011	0.0003	0.0001	0.31	0.12
67.5-72.5	0.0011	0.0004	0.0002	0.32	0.14
>72.5	0.0012	0.0004	0.0002	0.34	0.16

Table A.1 Emission Factors (g/mi) (continued)

Pollutant/Speed Bin (mph)	2005	2015	2035	Ratio, 2015/2005	Ratio, 2035/2005
Formaldehyde					
<2.5	0.053	0.021	0.004	0.39	0.08
2.5-7.5	0.028	0.011	0.002	0.39	0.09
7.5-12.5	0.015	0.006	0.001	0.39	0.09
12.5-17.5	0.011	0.004	0.001	0.39	0.10
17.5-22.5	0.009	0.004	0.001	0.39	0.10
22.5-27.5	0.008	0.003	0.001	0.39	0.10
27.5-32.5	0.007	0.003	0.001	0.39	0.10
32.5-37.5	0.006	0.002	0.001	0.39	0.10
37.5-42.5	0.006	0.002	0.001	0.38	0.10
42.5-47.5	0.005	0.002	0.000	0.38	0.09
47.5-52.5	0.005	0.002	0.000	0.38	0.09
52.5-57.5	0.005	0.002	0.000	0.38	0.09
57.5-62.5	0.004	0.002	0.000	0.38	0.09
62.5-67.5	0.004	0.002	0.000	0.38	0.09
67.5-72.5	0.004	0.002	0.000	0.39	0.11
>72.5	0.004	0.002	0.001	0.40	0.12
Napthalene					
<2.5	0.0031	0.0018	0.0016	0.58	0.52
2.5-7.5	0.0020	0.0012	0.0010	0.59	0.50
7.5-12.5	0.0014	0.0008	0.0007	0.59	0.47
12.5-17.5	0.0012	0.0007	0.0006	0.60	0.45
17.5-22.5	0.0011	0.0007	0.0005	0.60	0.46
22.5-27.5	0.0009	0.0005	0.0004	0.61	0.49
27.5-32.5	0.0008	0.0005	0.0004	0.60	0.48
32.5-37.5	0.0008	0.0004	0.0004	0.58	0.47
37.5-42.5	0.0007	0.0004	0.0003	0.56	0.45
42.5-47.5	0.0007	0.0004	0.0003	0.55	0.44
47.5-52.5	0.0007	0.0004	0.0003	0.54	0.44
52.5-57.5	0.0008	0.0004	0.0003	0.54	0.44
57.5-62.5	0.0008	0.0004	0.0003	0.54	0.44
62.5-67.5	0.0008	0.0004	0.0003	0.54	0.43
67.5-72.5	0.0009	0.0005	0.0004	0.55	0.44
>72.5	0.0010	0.0005	0.0004	0.56	0.44

Table A.1 Emission Factors (g/mi) (continued)

Pollutant/Speed Bin (mph)	2005	2015	2035	Ratio, 2015/2005	Ratio, 2035/2005
Diesel PM					
<2.5	4.461	1.559	0.160	0.35	0.04
2.5-7.5	2.270	0.795	0.083	0.35	0.04
7.5-12.5	1.378	0.479	0.050	0.35	0.04
12.5-17.5	1.213	0.416	0.043	0.34	0.04
17.5-22.5	1.082	0.371	0.038	0.34	0.04
22.5-27.5	0.988	0.336	0.034	0.34	0.03
27.5-32.5	0.940	0.317	0.032	0.34	0.03
32.5-37.5	0.738	0.251	0.026	0.34	0.04
37.5-42.5	0.690	0.234	0.024	0.34	0.04
42.5-47.5	0.652	0.221	0.023	0.34	0.04
47.5-52.5	0.585	0.199	0.021	0.34	0.04
52.5-57.5	0.512	0.175	0.019	0.34	0.04
57.5-62.5	0.475	0.163	0.018	0.34	0.04
62.5-67.5	0.487	0.167	0.019	0.34	0.04
67.5-72.5	0.498	0.170	0.019	0.34	0.04
>72.5	0.486	0.167	0.019	0.34	0.04

Appendix B

Case Study Number 1 Synchro Output

Appendix C

Sample CAL3QHC/r Output for Case Study Number 1