FINAL REPORT

LAX Air Quality and Source Apportionment Study

Volume 1. Executive Summary

Prepared and Submitted to:

Los Angeles World Airports

Los Angeles World Airports
Environmental Services Division

by:

Tetra Tech, Inc.

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FOREWORD

The Los Angeles International Airport (LAX) Air Quality and Source Apportionment Study (AQSAS) was conducted to measure pollutant concentrations in the vicinity of LAX and to assess the potential impacts of airport-related emissions on ambient air quality of communities adjacent to the airport. The LAX AQSAS consisted of three phases. Phase I (preparation) and Phase II (Demonstration Project) were conducted between 2008 and 2011 by Jacobs Consultancy (later LeighFisher, Inc.) and included evaluations of available measurement techniques. In July 2011, the Los Angeles World Airports (LAWA) contracted with Tetra Tech, Inc. (Tetra Tech) to conduct the main field measurement program for Phase III and accompanying data analysis and modeling. The study was directed by the Environmental Services Division (ESD) of LAWA. CDM Smith (Anthony Skidmore, John Pehrson, and Dr. Richard Countess) served in a scientific advisory role and reviewed project reports on behalf of LAWA. An external Technical Working Group (TWG), serving in an advisory role for this Study, was comprised of representatives from the United States Environmental Protection Agency (U.S. EPA), California Air Resources Board (CARB), South Coast Air Quality Management District (SCAQMD), Federal Aviation Administration (FAA), California Office of Environmental Health Hazard Assessment (OEHHA), and community organizations. Volume 1 of the LAX AQSAS final report is an executive summary of the study objectives, technical approach and key findings and conclusions of the study. Volume 2 is the main technical report for Phase III, and Volume 3 reports the findings of Phase I and Phase II. The final report will be accessible to the public at the LAWA project web site (http://www.lawa.org/airqualitystudy/).

Tetra Tech, the prime consultant for the performance of Phase III, directed the project and coordinated the study team. Tetra Tech's Technical Project Manager was Dr. Charng-Ching Lin, assisted by Erica Alvarado, both working under the direction of Dr. Salar Niku, Program Manager. The study team of sub-consultants included: 1) Desert Research Institute (DRI) (Dr. Eric Fujita, David Campbell, and Dr. Xiaoliang Wang), responsible for air monitoring (including ultrafine particle (UFP) number concentration and size distribution, source profile sampling, chemical analyses (DRI's Organic Analytical Laboratory directed by Dr. Barbara Zielinska and Environmental Analysis Facility directed by Dr. Judith Chow), and chemical mass balance (CMB) receptor modeling; 2) SCS Tracer Environmental (Paul Schafer), responsible for site preparation, ambient air monitoring, field sampling, and field management; 3) T&B Systems, Inc. (Robert Baxter), responsible for independent quality assurance; 4) K&B Environmental Sciences, Inc. (Michael Kenny and Michael Ratte), responsible for emissions inventory; 5) Dr. Ronald Henry, Professor at the University of Southern California (USC), responsible for Nonparametric Trajectory Analysis; 6) Dr. Sarav Arunachalam, Research Professor at the University of North Carolina at Chapel Hill, responsible for dispersion and regional air quality modeling, and 7) Drs. Ivar Tombach, Charles Blanchard, and Eddy Huang as technical advisors.

LAWA and the study team wishes to acknowledge and thank the following community volunteers and agencies for providing access to sampling locations: Pastor Lawrence Becker and Fran Sanders of the Trinity Lutheran Church School in Hawthorne, Alex Gonzales of LaFeria Restaurant in Lennox, El Segundo Unified School District, South Coast Air Quality Management District, Crislyn McKerron in Hawthorne, F. Michael Lewis in El Segundo and Sally Lokey in Westchester. We also gratefully acknowledge the in-kind contribution of the Bay Area Air Quality Management District for use of their instrumented mobile monitoring van.

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LAX AIR QUALITY AND SOURCE APPORTIONMENT STUDY

Volume 1 – Executive Summary

Volume 2 – Phase III Sections 1 through 10

Volume 3 – Phase I and Phase II Technology and Methodology Feasibility Demonstration Project

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LAX AIR QUALITY AND SOURCE APPORTIONMENT STUDY

Volume 1 – Executive Summary

FOREWORD

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OVERVIEW

The completion of the Los Angeles International Airport (LAX) Air Quality and Source Apportionment Study (AQSAS) fulfills Los Angeles World Airports' (LAWA's) commitment to conduct an air quality study to evaluate the contributions of airport-related emissions to off-airport pollutant concentrations. The AQSAS report is presented in three volumes. Volume 1 provides the Executive Summary. Volume 2 provides detailed information of the results, and documents the methods and procedures used by an internationally recognized team of independent experts for air quality monitoring, chemical speciation sampling, laboratory analysis, quality control, data quality assessments, and data analysis and modeling. Volume 3 summarizes, as background information, the findings of a demonstration project and preliminary air quality measurements that were the basis for the technical approach used for the main work effort presented in Volume 2. The overview discussion below briefly describes the study and summarizes the key findings and conclusions. The remaining sections of the Executive Summary that follow describe, in summary fashion, the results that support the findings and conclusions presented in the overview.

Ambient Air Quality and Source Characterization Measurements

The air quality monitoring during Phase III consisted of two six-week field measurement campaigns: "Winter Monitoring Season" from 1/31/12 to 3/13/12 and "Summer Monitoring Season" from 7/18/12 to 8/28/12. Three types of monitoring sites (four "core", four "satellite" and nine "gradient"), with different combinations of continuous monitors and time-integrated (24-hour and 7-day) samples, were used to determine how the ambient concentrations of various chemical species of interest varies by location, time of day, day of the week, and season.

- **Core** sites, where the most extensive air quality measurements were obtained, were located within the communities of Lennox, Westchester, El Segundo and Playa Del Rey. These core sites are identified in the Study as the "Community East (CE)" site, the "Community North (CN)" site, the "Community South (CS)" site, and the "Air Quality (AQ)" site.[1] The detailed chemical and continuous time-resolved data from core sites were used to apportion a wide variety of pollutants to emission sources using two different receptor modeling methods.

- **Satellite** sites, with a smaller subset of monitoring data, provided a second community monitoring site in both Westchester (CN2) and El Segundo (CS2) to examine intra-community variations in pollutant concentrations. A third community satellite site was located in Hawthorne (CE2) about two miles south of the core site in Lennox (one mile east of the LAX South Airfield). Both sites were east of the I-405 Freeway and differences between this pair of sites were used to examine the incremental contributions of airport operations. A fourth satellite site (UW) was an upwind "urban background" location between the coastline and the west end of LAX.

[1] The reason why the nomenclature for the core site in Playa Del Rey differs from those of the other sites is because the monitoring station used for the Playa del Rey site is an existing permanent air quality monitoring station used by the South Coast Air Quality Management District; hence, it is referred to as the "Air Quality (AQ)" site, which provided air quality data representative of the surrounding local community.

- **Gradient** sites utilized highly portable samplers to measure pollutant concentrations in varying proximity to airport operations (BN, BS, SRE, BSR, NR, BNR, CT) and major roadways (SRN, R405). These measurements were used to characterize near-source pollutant gradients (i.e., help understand how and where pollutants disperse, based on differences in pollutant concentrations measured near pollutant sources compared to concentrations of those same pollutants measured at more distant monitoring stations).

Prior to the Winter Monitoring Season, a mobile survey was conducted to characterize the spatial variations of pollutant concentrations within the communities and at the periphery of LAX, as well as near operations areas within the airport property (e.g., Central Terminal Area and airport runways and taxiways). These results were used to refine the air quality monitoring plan and guide the selection of appropriate monitoring locations.

Over 400 individual compounds and pollutants were measured including criteria pollutants, regulated pollutants, compounds that have been designated as toxic air contaminants by the California Air Resources Board (CARB) or hazardous air pollutants by the U.S. Environmental Protection Agency (EPA), and other chemical species that are useful for source characterization and apportionment.

- **Criteria pollutants** have health-based National Ambient Air Quality Standards (NAAQS) that are set by EPA and California Ambient Air Quality Standards set by CARB. These pollutants include: carbon monoxide (CO); nitrogen dioxide (NO_2); sulfur dioxide (SO_2); particulate matter with diameter less than 2.5 micrometers ($PM_{2.5}$); and lead (Pb). Although ozone is a criteria pollutant, it was not measured in this study because ozone is formed by a complex series of photochemical reactions that occur in the atmosphere involving oxides of nitrogen (NO_x), the sum of nitric oxide (NO) and NO_2, and volatile organic compounds (VOC). The highest levels of ozone are measured in downwind locations of the central and eastern South Coast Air Basin (SoCAB). Specific siting criteria and statistical averaging requirements over periods of up to three consecutive years do not allow direct comparisons of the LAX AQSAS data to levels of the air quality standards. Nevertheless, other studies have shown that averages of seasonal data collected during representative winter and summer weather conditions are good approximations of annual averages. Such approximation can be reasonably compared to the ambient air quality standards with the caveat regarding the method used in calculating the averages.

- **Regulated pollutants** have standards established by federal, state and local agencies for allowable emissions from mobile and major stationary sources, and various smaller, but more numerous sources, such as fuel service stations, and surface coating operations. These pollutants include: CO, NO_x, SO_2, volatile organic compounds (VOC), and $PM_{2.5}$. Areas in nonattainment of the ozone NAAQS, such as the SoCAB, are required to establish Photochemical Assessment Monitoring Stations (PAMS) to monitor and report the concentrations of ozone precursors, including 55 specific target VOC. In urban areas, these 55 VOCs typically comprise about 80 percent of the total VOC.

- **Air Toxics** are designated by CARB, California Office of Environmental Health Hazard Assessment (OEHHA) and EPA based upon studies of potential chronic or acute health effects. Although ambient air quality standards or emission standards do not exist for air

toxics, their emissions have been significantly reduced by implementation of emission controls of regulated pollutants from industrial facilities and increasingly stringent emission standards for cars and trucks that have also effectively reduced the emissions of air toxics associated with unburned fuel and products of incomplete fuel combustion. In lieu of a risk assessment study, which is beyond the scope of this study, the AQSAS measurements of various air toxics are compared to relevant data from the on-going air toxics monitoring program and results from the Multiple Air Toxics Evaluation Study (MATES) by the South Coast Air Quality Management District (SCAQMD).

- **Ultrafine particles (UFP)** are a subset of $PM_{2.5}$ with particle diameters typically less than 0.1 micrometers (100 nanometers – 1 nanometer equals one-billionth of a meter). Past studies have shown much higher UFP number concentrations in near-source microenvironments (e.g., roadside and near airport runways). There is currently no ambient air quality standard for UFP. UFP number concentrations and size distributions were measured at the core community monitoring sites. Additional UFP measurements were made following the Summer Monitoring Season (referred to as "Supplemental Monitoring") to further examine the chemical nature of UFP in jet exhaust and source contributions of UFP in communities east of LAX.

- **Chemical composition profiles** are typically used to estimate emissions of specific compounds from aggregate VOC or PM emissions, which consist of many individual chemical species. The VOC and PM emissions from combustion sources have characteristic chemical profiles that are related to the type of combustible fuel or material (gasoline, diesel, jet, wood, meat), vehicle or appliance, and combustion conditions (temperature, pressure, air/fuel ratio). There are certain classes of organic compounds that can serve as tracers for different categories of emission sources, which have been used in receptor models for source apportionment. The source samples collected and analyzed at the end of the Winter Monitoring Season included jet fuel and representative selection of local gasoline and diesel fuels, jet exhaust from the end of the South Runway, and local soil samples. Chemical profiles that are available from past studies were used for other source categories.

Data Analysis and Modeling

The airport contributions to ambient air quality were estimated by the Chemical Mass Balance (CMB) and Nonparametric Trajectory Analysis (NTA) receptor models, and the American Meteorological Society/U.S. EPA Regulatory Model (AERMOD) Gaussian dispersion model, and the Community Multiscale Air Quality (CMAQ) grid-based air-quality simulation model. The receptor models use the measured pollutant concentrations to apportion the pollutants measured at a specific monitoring site to different source categories. The two source models use the emissions inventory estimates and the prevailing winds to estimate the downwind concentrations of the pollutants of interest. An emissions inventory was compiled for LAX and surrounding area to quantify airport-related and non-airport related emissions. Airport-related emissions included: aircraft operations, auxiliary power units (APU)/ground support equipment (GSE), stationary sources, and motor vehicles (both on and off-airport).

Analysis of the air quality data provided context and complemented the quantitative source apportionment results obtained by receptor and source modeling. Associations of spatial and

time variations in pollutant concentrations with emission source activity and pollutant transport patterns were examined in this study as indications of the impacts of airport-related emission sources on local air quality. Special emphasis was given to the temporal variations in size distributions of UFP concentrations and correlations to other pollutants by time of day, day of week, varying meteorological conditions, and emission source activity.

Key Findings

- The ambient concentrations of CO, NO_2, SO_2 and Pb within the communities adjacent to LAX were well below the threshold levels for exceedance of the national and state health-based ambient air quality standards during the study period. Highest pollutant concentrations were measured near emission sources (e.g., airport runways and major roadways). While high NO_x, SO_2 and black carbon (soot) levels were measured at the east end of the South Airfield, the concentrations dropped to approximately 10 percent of the peak values (i.e., near the surrounding urban background levels) within about 500 meters east of the runway.

- $PM_{2.5}$ levels were near the ambient air quality standard. Analysis of the chemical composition of the measured $PM_{2.5}$ concentrations show that about 50 to 75 percent of the ambient $PM_{2.5}$ mass was associated with ammonium nitrate, ammonium sulfate, and unapportioned organic matter (OM). The sum of sea salt aerosol, soil derived fugitive dust and wood smoke account for an additional 20 to 30 percent of $PM_{2.5}$ mass. Consequently, the incremental airport contributions (jet exhaust and airport-related vehicle traffic) to $PM_{2.5}$ levels are relatively small. The CMB estimates of source contributions to ambient $PM_{2.5}$ mass were 1 to 2 percent for jet exhaust and 8 to 17 percent for the sum of diesel plus gasoline vehicle exhaust. It is not possible for CMB to separately apportion airport- and non-airport-related vehicle emissions because there is no difference in chemical signature between the two groups of vehicles. However, adjusting the total vehicle source contribution from the CMB results by 2.3 (which is the ratio of non-airport to airport-related vehicle emissions from the Study Area emissions inventory), the airport-related vehicle exhaust contributions to ambient $PM_{2.5}$ is estimated to be 4 to 9 percent.

- Results of the CMAQ air quality modeling indicated that the nitrate and sulfate and most of the residual OM are formed outside of the Study Area and associated with the regional urban background. The incremental airport contributions (jet exhaust and airport-related vehicle traffic) to $PM_{2.5}$ levels were estimated to be comparatively small (5 to 20 percent) in reasonable agreement with the adjusted CMB receptor modeling results.

- The contribution of airport-related emissions can vary by hour of the day, day of the week, and by season. Factors such as airport activity levels, wind direction, wind speed, ambient temperature, and other meteorological parameters, affect the contribution of airport-related emissions to local ambient air quality. The NTA results show that the airport-related emissions contributions to the local ambient air quality were generally higher for a community station located directly east rather than north or south of the airport. During the winter, airport operations accounted for 15 to 22 percent for both CO and NO_x at all four core monitoring sites (CE, CN, CS and AQ). While contributions were about the same during summer and winter at CS and AQ, the airport contributions at

CE and CN were much higher during summer for CO (~40 to 50 percent) and NO_x (~50 to 75 percent). The airport contributions to black carbon show a similar seasonal pattern to CO and NO_x. Airport contributions to SO_2 were generally higher than for the other pollutants with less seasonal variation except at CS. The airport contributions to SO_2 during winter and summer were 40-80 percent at CE and CN and 10 to 50 percent at CS and AQ.

- The two-season average concentrations of key air toxics from the LAX AQSAS monitoring network are consistently lower than either the annual average concentrations for 2011 measured elsewhere in the basin or the average concentrations measured during the MATES-III study between 2004 and 2006.

- The ambient measurements showed that period average UFP number concentrations were about 3 to 5 times higher at the CE site than typical urban levels. Strong correlations of CO, NO, and BC with 30 to 160 nanometer (nm) UFP and distinct weekday versus weekend differences (i.e., lower on weekends compared to weekdays) in diurnal variations indicate these particles are most likely from vehicle exhaust-related emissions. In contrast, weak correlations of 7 to 30 nm UFP with CO, nitrogen oxide (NO), and BC, but strong correlation with SO_2 and NO_2, are indications of jet exhaust and potential secondary particles that are formed in atmosphere. Results of the Supplemental Study show that these particles are less than 30 nm in diameter and consist mostly of sulfuric acid aerosols. The spatial and temporal analyses as well as simultaneous sampling at the Trinity Lutheran Church School (TLCS) site, which was located 1.5 miles south of the CE site, indicated that the higher UFP number concentrations at the CE site were associated with jet exhaust from the South Airfield.

Overall Conclusions

In summary, the LAX AQSAS show that, with the exception of $PM_{2.5}$, the ambient concentrations of criteria pollutants within the communities adjacent to LAX were well below national and state health-based ambient air quality standards and ambient concentrations of air toxic contaminants were generally lower than measured elsewhere in the SoCAB. The generally lower pollutant concentrations in the LAX area can be attributed to its coastal location and the typical daytime sea breeze that helps to disperse local emissions. The concentrations of most measured pollutants were higher east of LAX compared to monitoring locations north or south of the airport.

Although $PM_{2.5}$ levels were near the standard, a substantial portion of the $PM_{2.5}$ mass is related to the regional urban background with airport-related emissions contributing a maximum of 5 to 20 percent. While UFP have negligible contributions to $PM_{2.5}$ mass, their number concentrations east of the LAX were higher than typical levels in the SoCAB. Supplemental Study measurements at the CE site and behind the South Airfield blast fence indicate that the very small UFP, which have disproportionately higher contributions to particle number concentrations, are largely sulfuric acid aerosol from jet exhaust. The larger UFP, which have disproportionately higher contributions to mass concentrations, appear to be related to on-road vehicle exhaust from local traffic.

To date, the evidence linking UFP number concentrations with adverse health effects has not been sufficiently definitive to support a separate health-based ambient air quality standard for UFP. The expectation for the effects of UFP is based upon their potential to carry toxic material deep into the lungs. In contrast to UFP in vehicle emissions that may be composed of adsorbed organic compounds, UFP associated with jet exhaust are dominated by sulfuric acid aerosol that is rapidly neutralized to relatively benign ammonium sulfate and increases in size due to absorption of water vapor. Future studies of the health impacts of airport emissions will need to consider these important chemical differences between UFP emissions from jet and vehicle exhaust.

INTRODUCTION

Los Angeles International Airport (LAX), the primary airport serving the Greater Los Angeles Area, is the sixth busiest airport in the world serving nearly 64 million passengers in 2012 and processing 1.9 million tons of air cargo valued at about $90 billion. To determine potential impacts of air emissions from LAX operations on air quality within the local neighborhoods, LAWA has conducted the LAX AQSAS. The primary objective of the LAX AQSAS was to assess the potential impacts of airport-related emissions on the local ambient air quality of communities adjacent to the airport. The Study was designed to answer the following questions.

- What are the concentrations of criteria and regulated pollutants, air toxic contaminants and ultrafine particle numbers and distributions in the communities adjacent to LAX and how do these measurements compare to applicable ambient air quality standards and comparable measurements elsewhere in the South Coast Air Basin (SoCAB)?

- How do the concentrations of various pollutants vary with time (seasonally, day-of-week, and diurnally) and proximity to emission sources? How are these variations related to temporal changes in meteorological conditions and emissions from airport operations versus non-airport emissions?

- Using multiple statistical and modeling methods, what are the relative contributions of airport-related emissions to the measured ambient pollutant concentrations?

The study is now complete and the study results are provided in this Executive Summary and the accompanying technical report volumes. The project report materials are accessible to the public at http://www.lawa.org/airqualitystudy, the project web site for the LAX AQSAS maintained by LAWA staff. This web site also includes information about the project, project materials, a public symposium, and an avenue to submit public comments.

SCOPE OF THE LAX AQSAS

Air quality monitoring for Phase III of the LAX AQSAS consisted of two six-week field measurement campaigns during winter and summer of 2012. These two sampling periods provided sufficient data to capture an accurate representation of the main wind patterns observed in study area. The 17 sites in the air monitoring network are listed in Table ES-1 and identified by location in Figure ES-1. The applicable sampling and laboratory analysis methods are documented in Section 3 of Volume 2. Over 400 individual compounds and pollutants were measured during Phase III, including criteria pollutants, regulated pollutants, compounds that have been designated as toxic air contaminants by the California Air Resources Board (CARB) or hazardous air pollutants by the U.S. Environmental Protection Agency (U.S. EPA), and other chemical species that are useful for source characterization and apportionment.

The following sets of measurements were made at core, satellite and gradient monitoring sites.

Core Sites (CE, CN, CS)

1. Continuous 1-minute average concentrations of nitric oxide (NO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and CO, 5-minute average ultrafine particle (UFP) number

concentrations and size distributions, 5-minute average light scattering, 1-minute average black carbon (BC), and 1-hour average fine particle ($PM_{2.5}$) mass concentrations.

2. Continuous 1-minute measurements of wind speed and direction, temperature, and relative humidity.

3. Fourteen 24-hour (midnight to midnight) chemical speciation samples were collected during both monitoring seasons. The speciation data included canisters for 71 C_2-C_{11} hydrocarbons; Tenax cartridges for 66 C_7-C_{28} hydrocarbons; 2,4-Dinitrophenylhydrazine (DNPH) cartridges for 14 C_1-C_8 aldehydes and ketones; Teflon and quartz filters collected with medium-volume sequential filter samplers (SFS) for $PM_{2.5}$ mass, organic carbon (OC), elemental carbon (EC), elements Na to U, nitrate, sulfate, ammonium, sodium, chloride; and Teflon-impregnated glass fiber filters (TIGF) with backup XAD resin cartridges for separate analysis of particulate and semi-volatile phase alkanes, polycyclic aromatic hydrocarbons (PAH), hopanes and steranes, and polar organic compounds.

4. Seven-day integrated Teflon and quartz filters were collected with portable Airmetrics MiniVol samplers and analyzed for $PM_{2.5}$ mass, elements, and OC and EC.

5. Seven-day integrated passive samples for benzene, toluene, ethylbenzene, xylenes (BTEX), 1,3-butadiene, formaldehyde, acetaldehyde and acrolein using passive samplers.

Core/Satellite Site (AQ)

Measurements included Sets 1 (except particle size distributions), 2, 4 and 5.

Satellite Sites (CE2, CN2, CS2, UW)

Measurements included Sets 4, 5 and 6 (below).

6. Seven-day integrated passive samples for NO_2, oxides of nitrogen (NO_x), and SO_2 using passive samplers.

Gradient Sites (BN, BS, SRE, SRN, BSR, NR, BNR, CT and R405)

Measurements included Sets 5 and 6.

The main component of the monitoring program consisted of three community-scale monitoring sites: Community East (CE), Community North (CN) and Community South (CS). The CE core monitoring station was located in Lennox approximately one mile east of the South Airfield Runways and approximately one-third mile east of the I-405 Freeway. The CN core monitoring station was located in Westchester approximately one mile east of the North Airfield Runways. The CS core monitoring station was located at the former Imperial Avenue School in El Segundo, roughly 600 feet from the LAX southern boundary. The AQ monitoring station was the fourth core station and was located at the SCAQMD Hastings site situated northwest of the airport in Playa del Rey.

Table ES-1. List of Monitoring Sites for Phase III of the LAX AQSAS

Site Code	Site Type	Site Name	Address or Location
CE	Core	Community East (Lennox)	10903 S. Inglewood Ave, Inglewood, CA 90304
CS	Core	Community South (El Segundo)	559 E. Walnut Ave., El Segundo, CA
CN	Core	Community North (Westchester)	5843 W. 95th St, Los Angeles, CA 90045
AQ	Core/ Satellite	Upwind Northwest (AQMD Hastings Monitoring Station	9106 Hastings Avenue, Los Angeles, CA 90293
CE2	Satellite	Community East #2 (Hawthorne)	4151 W. 142nd St, Hawthorne, CA
CS2	Satellite	Community South #2 (El Segundo)	535 East Mariposa Ave, El Segundo, CA 90245
CN2	Satellite	Community North #2 (Westchester)	6460 West 81st St, Westchester, CA 90045
UW	Satellite	Upwind West (West of LAX)	Near east edge of Vista Del Mar Park
BN	Gradient	Buffer Zone North	Between Westchester Pkwy and Lincoln Blvd ~80m east of S. McConnell Ave.
BS	Gradient	Buffer Zone South	Cargo Terminal off Imperial Hwy ~ 300 m west of Sepulveda
SRE	Gradient	South Runway East	40m directly east of Runway 25R blast fence
SRN	Gradient	South Runway North	Intersection of Century Blvd and Aviation Blvd. - SW corner
BSR	Gradient	Buffer Zone South Runway	LAX Lot B ~ 600m east of Site SRE and 150m west of La Cienega Blvd.
NR	Gradient	North Runway	100m directly east of Runway 24L
BNR	Gradient	Buffer Zone North Runway	LAX Lot C ~ 600m east of Site NR
CT	Gradient	Central Terminal	Top level of parking structure P-3
R405	Gradient	Roadway I-405	East edge of I-405 at end of W. Spruce Ave.

The passive sampling at 17 sites (4 core, 4 satellite, and 9 gradient sites) comprised the saturation monitoring component of the monitoring program for Phase III of the LAX AQSAS. The gradient sampling sites were intended to characterize potentially higher concentrations that may exist within 100 meters of emission sources (e.g., near roadways and airport runways) and near edges of the airport by the adjacent communities. Measurements at these sites included only passive measurements (NO_2, NO_x, SO_2, BTEX, 1,3-butadiene, and carbonyl compounds) to allow maximum siting flexibility and the greatest number of sampling sites within the project constraints.

In addition to ambient chemical speciation measurements, local source samples were collected and analyzed for application in receptor modeling. These included the composition of local fuels (gasoline, diesel, and Jet-A) and jet exhaust during takeoffs. These source profiles and the chemical speciation data were used to estimate the source contributions to ambient VOC and $PM_{2.5}$ concentrations at 3 core sites using the chemical mass balance (CMB) receptor model.

Figure ES-1. Monitoring station locations for Phase III of the LAX AQSAS. Airport-related and other emissions were compiled for the LAX AQSAS within the boundary indicated by a black dotted line. The CN site was moved to the TLCS during the Supplemental Study of UFP.

Currently, the U.S. EPA and CARB have established health based ambient air quality standards for particulate matter in two size categories: those with aerodynamic diameters less than 10 micrometers (PM_{10}) and those with aerodynamic diameters less than 2.5 micrometers ($PM_{2.5}$). Chemical speciation showed that approximately 50 to 75 percent of the $PM_{2.5}$ mass is associated with secondary pollutants[2] such as ammonium sulfate, ammonium nitrate, and organic aerosols.[3] Ultrafine particles (UFP) are typically defined as having aerodynamic diameters of less than 0.1 micrometer (100 nanometers). Figure ES-2 provides a graphical comparison of the size differences. At this time no health-based standards have been developed for UFPs. However, UFP number concentrations and size distributions were monitored to establish the relative importance of airport operations on local UFP concentrations. In addition to UFP number concentration and particle size distribution (PSD) measurements at the CE, CN and CS core monitoring sites, a three-part supplemental monitoring study (Parts A, B, and C) was conducted

[2] Secondary components of $PM_{2.5}$ are formed by atmospheric reactions of directly emitted precursor gaseous pollutants, such as NO_x, SO_2, and VOC, that may be unrelated to airport operations. These secondary aerosols are part of the regional urban background resulting from chemical conversions that occurred over time periods that are much longer than would be required to transport pollutants across the Study Area.

[3] CMAQ (Community Multiscale Air Quality) modeling confirmed these findings, and indicated that these secondary components of $PM_{2.5}$ were transported to the sampling sites from regions outside the Study Area on several days during both seasons.

in September 2012, following the end of the Summer Monitoring Season, to examine the chemical nature and source contributions of UFPs in downwind areas.

- Supplemental Study A - Volatility Measurement. This experiment examined volatility of the UFPs by measuring PSD changes when heated to different temperatures to determine variations in chemical composition of UFP by size. Two particle sizing instruments were operated in parallel scanning the full size distributions, one with and one without a thermal denuder (TD), first at the CE site and then at the Trinity Lutheran Church/School (TLCS) located 1.5 miles directly south of the CE site and out of the LAX flight path. Previous studies indicate that sulfuric acid (H_2SO_4) and ammonium sulfate ($[NH_4]_2SO_4$) decompose and evaporate around 125 °C and 175 °C, respectively, along with some organics. After heating to 300 °C, only non-volatile materials are left. To infer particle chemical composition based on their volatility, measurements were taken with the TD heater temperature set at approximately 25°C (ambient), and then at 125°C, 175°C, and 300°C.

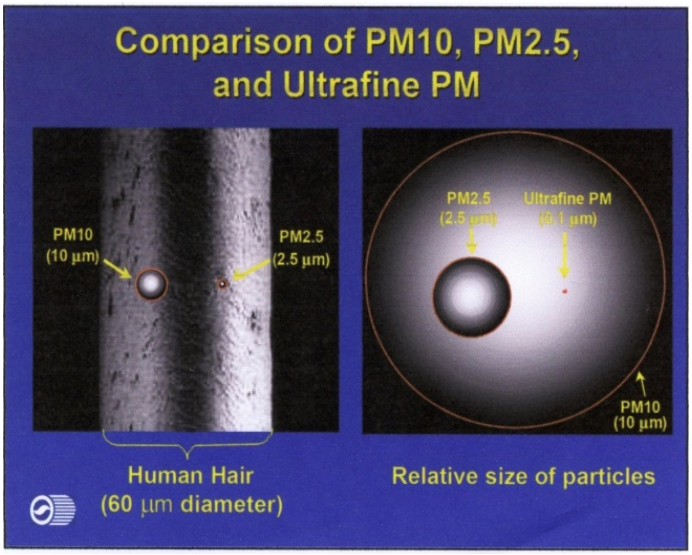

Figure ES-2. Particulate Matter Size Comparison

- Supplemental Study B - High Time Resolution PSD. Pairs of particle sizing instruments were operated at both CE and TLCS sites. One instrument measured 14.5 nm particle concentrations every second to capture brief increases that may be due to jet takeoffs. The second instrument measured PSD from 10 to 53 nm every 40 seconds to measure the relative concentrations of UFP that may be associated with jet exhaust and slightly larger particles that may be associated with on-road vehicle exhaust. Measurements were made continuously from Thursday to Monday in order to examine both diurnal and day-of-week variations. Comparisons of these measurements at CE to TLCS were used to estimate the incremental contributions of jet exhaust to UFP number concentrations at CE.

- Supplemental Study C – Jet Exhaust Characterization at Runway 25R Blast Fence. Four particle sizing instruments were installed behind the blast fence to measure varying size ranges of UFP using variable inlet temperatures to investigate the composition and size distribution of UFP in fresh jet exhaust. Additional measured parameters included continuous measurements of CO, NO_x, SO_2, and BC at the blast fence and CE site.

METEOROLOGICAL CONSIDERATIONS

In addition to the spatial and temporal patterns of pollutant emissions, changes in meteorological conditions cause variations in pollutant concentrations. During summer, the sea-land (onshore) breeze is strong during the day with a weak land-sea (offshore) breeze at night. Owing to the higher summer temperatures and extensive urbanization in the South Coast Air Basin (SoCAB),

the land surface temperature does not usually fall below the water temperature at night and nocturnal and morning winds are less vigorous than daytime winds. The land surface cools sufficiently to create surface inversions (i.e., a cooler, more dense, surface layer below warmer, less dense, air aloft that forms a "lid" and inhibits the upwards mixing of air pollutants) with depths as shallow as ~50 meters. Surface heating usually erodes the surface and marine layers within a few hours after sunrise each day resulting in lower pollutant concentrations during the day. During the Summer Season, the wind is predominantly from the west during the day and from the north to northwest at night. During the Winter Season, the wind is predominantly from the west to southwest during the day and from the northeast to southeast at night. Winds are typically light to calm overnight in both seasons. The rationale for the two sampling seasons was to capture an accurate representation of the main wind patterns observed in the SoCAB.

STUDY RESULTS

The objectives of the LAX AQSAS were achieved through analysis of the spatial and temporal variations in the measured ambient air concentrations of gases and particulate matter and applications of four modeling approaches, including two receptor-based models (Chemical Mass Balance [CMB] and Nonparametric Trajectory Analysis [NTA]), and two dispersion models (American Meteorological Society/U.S. EPA Regulatory Model [AERMOD] and the Community Multiscale Air Quality [CMAQ] model). This section recaps and integrates the significant results that support the study conclusions.

Emission Inventory

An emissions inventory was compiled for LAX and surrounding area to quantify airport-related and non-airport related emissions. Airport-related emissions included: aircraft operations, auxiliary power units (APU)/ground support equipment (GSE), stationary sources, and motor vehicles (both on and off-airport). Non–airport related emissions included: off-airport motor vehicles, nearby major stationary sources (such as power plants, and Chevron El Segundo Refinery), marine vessels, aggregate stationary sources, and off-road equipment. Emission sources located outside the Study Area boundary indicated in Figure ES-1 were not included in the emissions inventory, except marine vessels in coastal waters to the west, the Scattergood Generating Station, the El Segundo Energy Center, and the Chevron El Segundo Refinery.

All airport-related emission sources accounted for approximately 36 percent of CO, 25 percent of VOC, 36 percent of NO_x, 26 percent of SO_x, and 24 percent of $PM_{2.5}$ of all emissions, including emissions from marine vessels, refinery and power plants in the Study Area (average of both Winter and Summer Seasons). While marine vessels, power plants, and Chevron El Segundo Refinery are large contributors to emissions, especially NO_x and SO_x, these sources may not be large contributors to ambient concentrations in the vicinity of the airport due to wind patterns and distances to the monitoring stations. With the exclusion of emissions from marine vessels, refinery and power plants, the airport-related emission sources account for approximately 39 percent of CO, 34 percent of VOC, 64 percent of NO_x, 86 percent of SO_x, and 45 percent of $PM_{2.5}$ of the emissions in the Study Area.

All motor vehicles (both airport and non-airport) within the Study Area accounted for 41 percent of CO, 20 percent of VOC, 13 percent of NO_x, 2 percent of SO_x and 14 percent of $PM_{2.5}$ of the total study area emissions. Ratios of the non-airport to airport-related traffic emissions are 2.3

for CO, 8.9 for VOC, 6.7 for NO_x, 7.7 for SO_x, and 2.3 for $PM_{2.5}$. As observed from the ratios, a majority of the motor vehicle emissions in the Study Area were not related to the airport.

The emissions inventory for the LAX AQSAS was developed primarily as input for dispersion and air quality simulation modeling and cannot be used alone to infer source contributions at the monitoring stations. The ambient pollutant concentrations at community monitoring sites reflect the combined influences of local emissions and contributions of emissions from outside the Study Area, including the regional and urban background pollutant concentrations. Contributions of local emissions depend on proximity to the measurement sites and meteorological conditions that affect transport and dispersion of emissions.

Ambient Air Quality in Communities Adjacent to LAX

The maximum pollutant concentrations of CO, NO_2, SO_2, and $PM_{2.5}$ measured at each of the four core monitoring stations for the Winter and Summer Seasons combined are shown in Figure ES-3. Note that the maximum CO, NO_2, and SO_2 measurements are for one-hour averaging periods (i.e., the maximum one-hour average concentration), while the maximum $PM_{2.5}$ concentrations are daily values (i.e., the maximum daily average concentration). These averaging periods correspond with the short-term averaging periods for the ambient air quality standards set by U.S. EPA and CARB for these pollutants. To provide some context for these values, Figure ES-4 compares these results with the most stringent ambient air quality standards (National or California), as well as to measurements from several monitoring stations in the western half of the SoCAB outside of the Study Area. Please note that the LAX AQSAS statistical results, which cover two measurement periods lasting 6 weeks each, are not directly comparable to the ambient air quality standards. Compliance with the standards is typically based on a full year of data and, in some cases, an average of three consecutive years.[4]

Toxic air contaminants are often grouped into the following categories based on their physical and chemical characteristics: volatile organic compounds, semi-volatile organic compounds, and metals or elements. Average concentrations of key contaminants in each of these categories measured at the LAX AQSAS stations over both sampling seasons are presented in Figures ES-5, ES-6, and ES-7, respectively. Also included in these figures are the average concentrations of each contaminant in the SoCAB measured at SCAQMD/CARB monitors during 2011 (latest data available) and measured for the MATES-III study conducted by SCAQMD. Note that Figure ES-7 includes elemental carbon measurements. Elemental carbon is often used as a surrogate for diesel particulate matter, a listed toxic air contaminant in California. Figure ES-8 shows the mean UFP number concentrations at the four core sites compared to typical levels that are measured on-road (OR), roadside (RS) and various ambient sampling locations – urban winter (Ur-W), urban summer (Ur-S), rural (Rur) and clean background (Bkg).

[4] For NO_2, compliance with the U.S. EPA one-hour standard is based the three-year average of the annual 98th percentile of the one-hour maximum daily concentrations. For SO_2, compliance with the U.S. EPA one-hour standard is based the three-year average of the annual 99th percentile of the one-hour maximum daily concentrations. For $PM_{2.5}$, compliance with the U.S. EPA 24-hour standard is based on the three-year average of the annual 98^{th} percentile of the maximum daily concentrations.

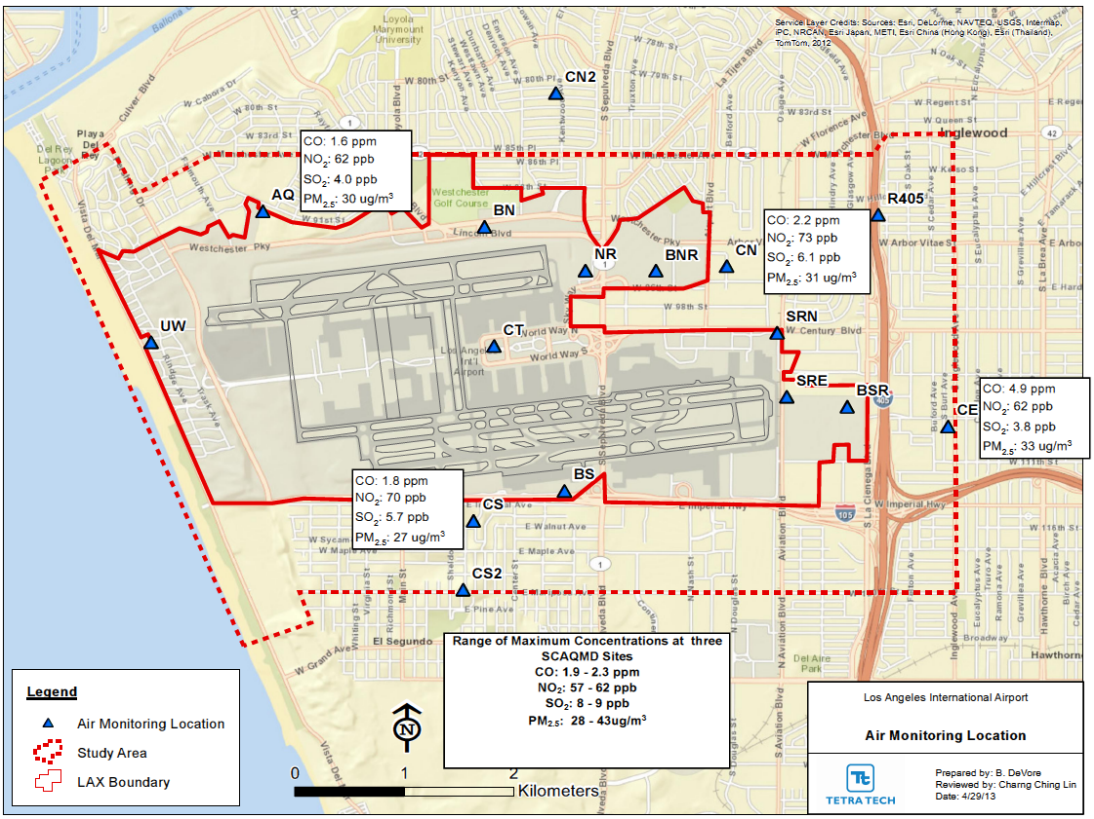

Figure ES-3. Maximum one-hour concentrations of CO, NO_2, and SO_2, and maximum daily $PM_{2.5}$ concentrations for the Winter and Summer Seasons combined at the four core stations (AQ, CE, CN, and CS) as compared to three SCAQMD stations (not shown on the figure).

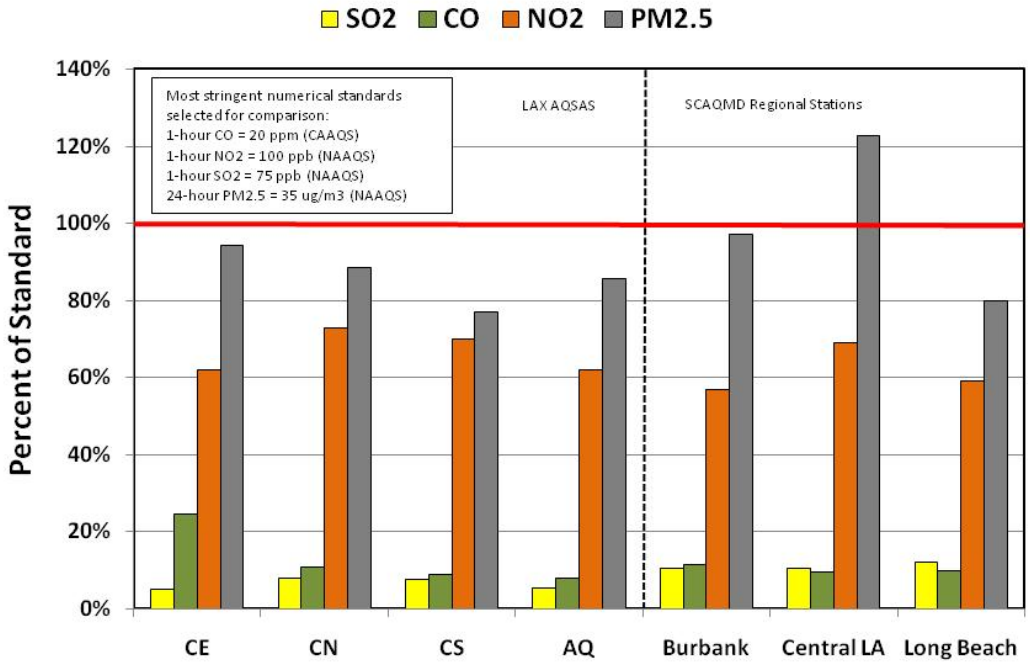

Figure ES-4. Comparison of CO, NO_2, SO_2, and $PM_{2.5}$ concentrations from the four Core Stations (AQ, CE, CN, CS) with the ambient air quality standards and with regional concentrations from several SCAQMD monitoring stations outside of the Study Area.

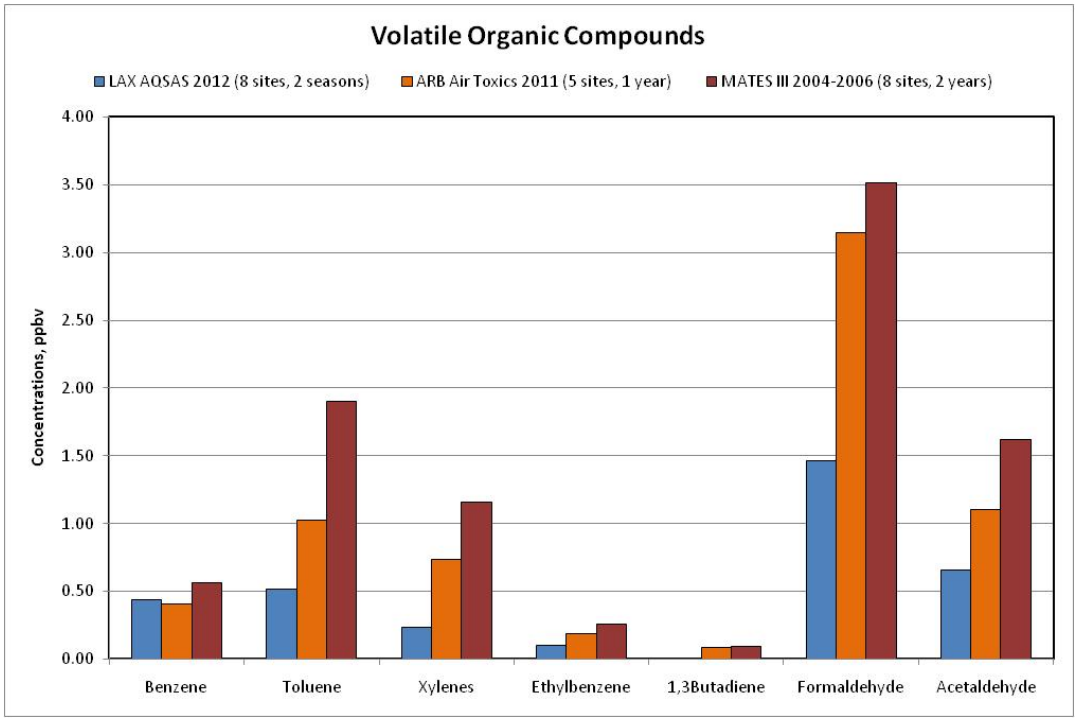

Figure ES-5. Period Average Concentrations of Key Volatile Organic Compounds.

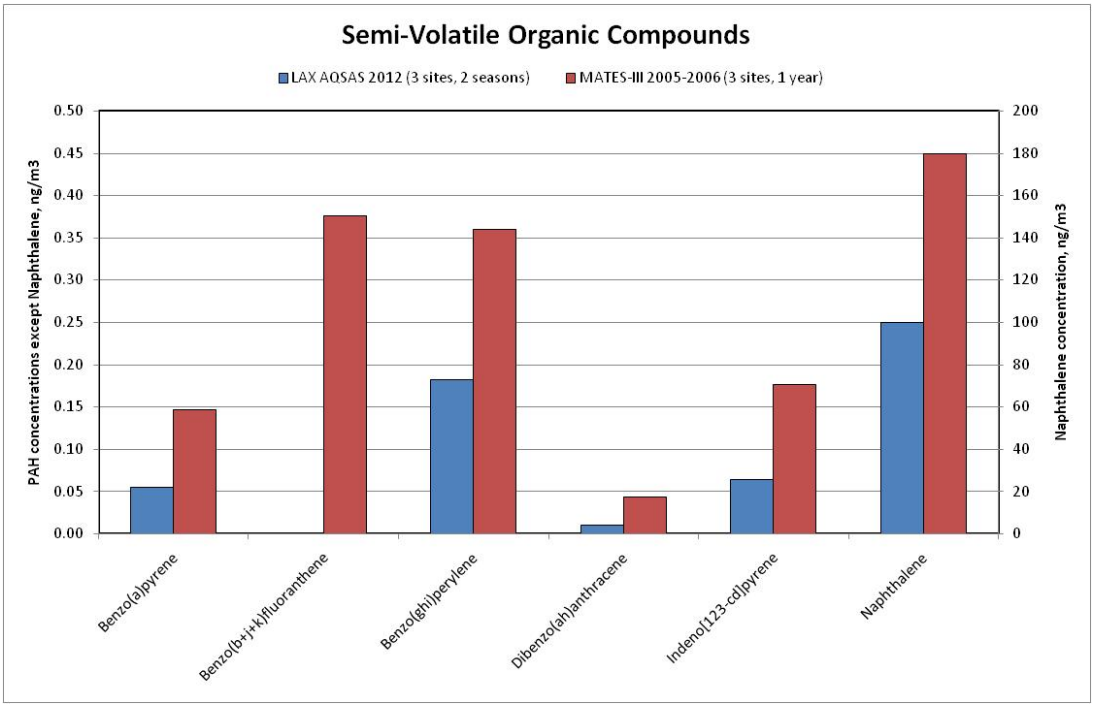

Figure ES-6. Period Average Concentrations of Key Semi-Volatile Organic Compounds (primarily polycyclic aromatic hydrocarbons – PAHs).

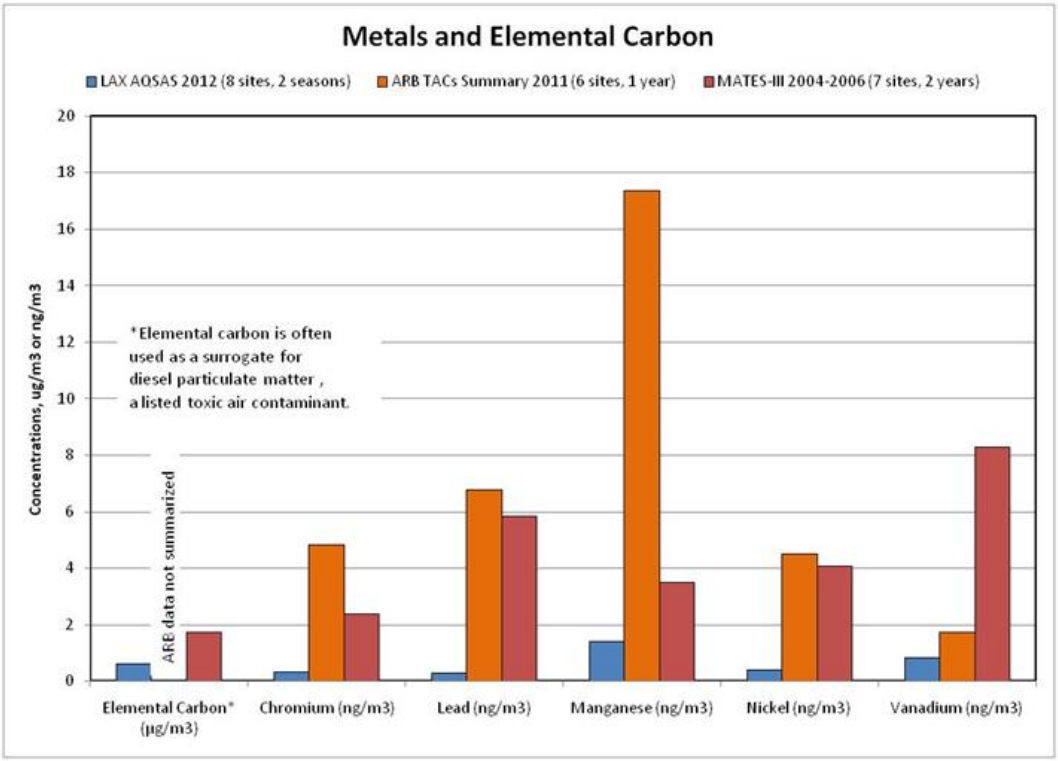

Figure ES-7. Period Average Concentrations of Elemental Carbon and Key Metals.

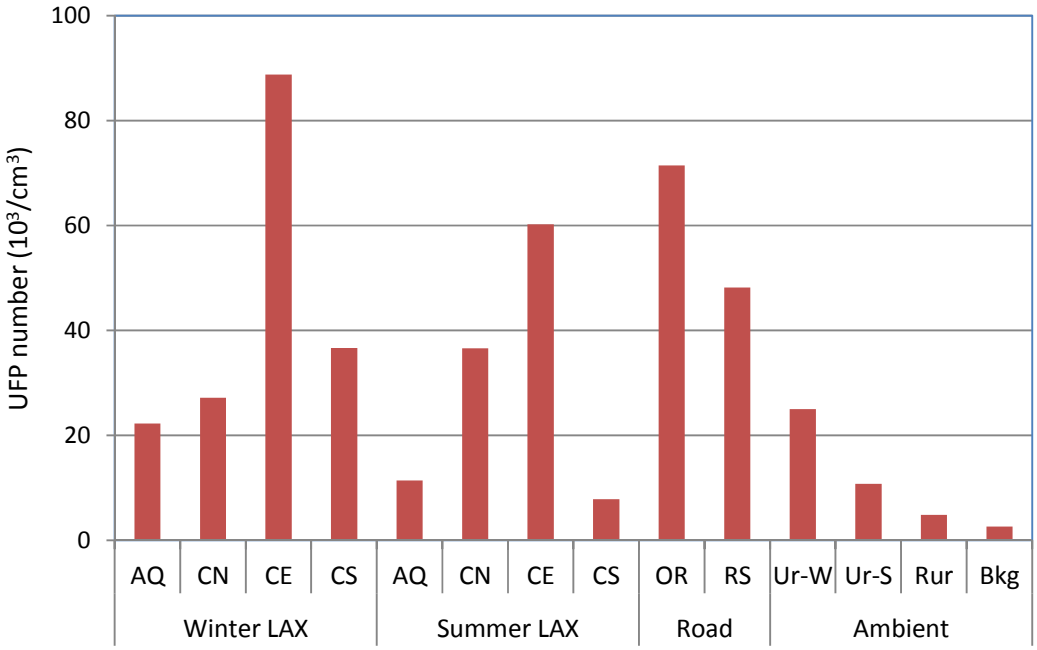

Figure ES-8. Mean UFP Number Concentrations at Core Sites Compared to Various Environments. Source: Morawska et al., 2008, *Atmos. Environ.* 42(35): 8113-8138; Hudda et al., 2010, *Atmos. Chem. Phys. Discuss.*, 10, 13902-13943.

Variations in Pollutant Concentrations by Location, Time of Day and Season

The diurnal and day-of-week variations in ambient pollutant concentrations and meteorological conditions were combined with the spatial and temporal patterns of pollutant emissions to examine potential impacts of local emission sources to pollutant concentrations at monitoring locations. During the Winter Season, morning winds from the northeast resulted in greater contributions from non-airport emissions at the CE and CN sites. The simultaneous peaks in CO, NO_x, and BC concentrations at these sites during the weekday (M-F) morning commute period and significantly lower concentrations during the same time period on Sundays indicate that these peak pollutant concentrations are mainly associated with off-airport vehicle emissions. In contrast, the SO_2 and UFP concentrations during this period were low at the CE, CN, and AQ sites, but substantially higher at the CS site. SO_2 and UFP concentrations gradually increased throughout the day at both the CE and CN sites when the winds were predominantly from the west, while concentrations were near background levels at the CS and AQ sites. These results, coupled with the minimal weekday dependences for both SO_2 and UFP, indicate airport emissions were the main source of SO_2 and UFP measured at the core monitoring sites during the Winter Monitoring Season.

Winds during the summer were more consistently from the west, and airport emissions were potentially transported to the CN and CE sites at all hours of the day and night. Pollutant concentrations were very low during the Summer Season throughout the day and night at both the CS and AQ sites due to the persistent west winds. Diurnal patterns for NO_x, CO, and BC concentrations were similar at the CE and CN sites during the Winter Season with morning peaks, very low midday levels due to greater vertical mixing and increasing concentrations during the evening starting at about sunset due to development of the stable nocturnal inversion layer. The substantially lower NO_x, CO, and BC levels at the CE and CN sites during the weekend mornings in both seasons are indications that on-road motor vehicles are likely the predominant source of these pollutants. Differences between the weekday and weekend were comparatively less for SO_2. UFP number concentrations showed no day-of-week dependence. This indicates these higher pollutant concentrations are associated primarily with jet exhaust.

The highest NO_x concentrations were measured near airport runways and roadways, but high SO_2 concentrations were only measured consistently near the airport runways. Although NO_x emission rates from jets are high they mix with emissions from other sources which have total area-wide emissions that substantially exceed the contributions of jet exhaust. While high NO_x, SO_2 and black carbon (soot) levels were measured at the east end of the South Airfield, the concentrations dropped to approximately 10 percent of the peak values (i.e., near the surrounding urban background levels) within about 500 meters east of the runway. The NO_x and SO_2 levels at the community core monitoring sites were both well below the national and state air quality standards and comparable to those measured at nearby SCAQMD monitoring stations outside the LAX AQSAS area.

BTEX levels in the Study Area were low relative to annual average concentrations measured elsewhere in the SoCAB in 2011 or the average concentrations measured during the MATES-III study between 2004 and 2006. BTEX emission rates from commercial jets were found to be relatively low and the spatial variations indicated that on-road gasoline-powered vehicles are likely the main source of BTEX.

The diurnal variations in UFP particle size distributions (PSD) provided useful insight regarding the relative importance of both freshly emitted and secondary particles. Strong correlations of CO, NO, and BC with 30 to 160 nanometer (nm) UFP and distinct weekday/ weekend diurnal patterns (i.e., lower on weekends compared to weekdays) indicate these larger sized particles are most likely from vehicle exhaust-related emissions. In contrast, strong correlations of the smaller sized 7 to 30 nm UFP with SO_2 and NO_2 coupled with weak correlations with CO, nitrogen oxide (NO), and BC are indications of jet exhaust and potential secondary particles. The Supplemental Study results showed that UFPs less than 30 nm in diameter near the runway consisted mostly of sulfuric acid aerosols. The average UFP number concentrations at the CE station, which is located approximately one mile east of the South Airfield runways, were approximately 3 to 5 times higher than typical urban levels. Simultaneous UFP measurements at a site 1.5 miles south of the CE station (located at the Trinity Lutheran Church parking lot) showed that the UFP number concentrations were much lower, indicating that the frequent spikes and higher UFP number concentrations observed at the CE station are associated with jet exhaust from the South Airfield.

Estimates of Airport-Related Emission Contributions to Ambient Pollutant Concentrations

The airport's contribution to the ambient air quality depends on the location where the pollutants are measured, the type of pollutants, and the hour of the day, day of the week, or time of the year. In this Study, the airport contributions to ambient air quality were estimated by the Chemical Mass Balance (CMB) and Nonparametric Trajectory Analysis (NTA) receptor models and by the American Meteorological Society/U.S. EPA Regulatory Model (AERMOD) Gaussian dispersion model, and the Community Multiscale Air Quality (CMAQ) grid-based air-quality simulation model. The receptor models use the measured pollutant concentrations to apportion the pollutants measured at a specific monitoring site to different sources. The CMB model infers contributions from different source types by statistically matching chemical composition of ambient samples to a linear sum of the products of source profile species and source contributions. NTA uses short time average concentrations and constructed local back-trajectories from similarly short time average wind speed and direction to locate and quantify contributions from local source regions. The two source models use the emissions inventory estimates and the wind data to estimate the downwind concentrations of the pollutants of interest.

CMB Source Apportionment Results

The CMB model results for $PM_{2.5}$ are summarized in Figure ES-9. Ammonium sulfate, ammonium nitrate, and residual organic matter (OM) not apportioned to combustion sources comprised approximately half to three-quarters of the $PM_{2.5}$ mass. The contributions of jet exhaust were consistently small accounting for 1 to 2 percent of $PM_{2.5}$ mass. These results appear to contradict the particle size distribution (PSD) measurements showing that jet exhaust was a significant contributor to number concentrations of UFP smaller than 30 nm. However, these very small particles contribute little to $PM_{2.5}$ mass. The estimated contributions of jet exhaust to sulfate in $PM_{2.5}$ are 2.0 percent at the CE site, 7.1 percent at the CN site, and 1.3 percent at the CS, assuming a conversion rate of SO_2 to sulfuric acid in jet exhaust of approximate one percent. This rate is consistent with the mass ratios of sulfate to the sum of SO_2 and sulfate (all background subtracted) from measurements behind the blast fence at the South Airfield Runway 25R. The average contributions to $PM_{2.5}$ mass of emissions from diesel vehicles accounted for 15 and 8 percent of the ambient $PM_{2.5}$ mass concentrations during the winter and

summer seasons, respectively. Emissions of gasoline vehicles accounted for 1.7 percent of the winter season and 0.3 percent of the summer season concentrations. While it is not possible for CMB to separately apportion airport- and non-airport-related vehicle emissions, the temporal and spatial analysis of ambient data suggests greater contributions from non-airport related traffic emissions. Adjusting the total vehicle source contribution from the CMB results by 2.3 (which is the ratio of non-airport to airport-related vehicle emissions from the Study Area emissions inventory), the airport-related contributions to ambient $PM_{2.5}$ is estimated to be 4 to 9 percent. Soil was generally a minor component (< 5 percent) of $PM_{2.5}$, except on windy days. Soil accounted for about 30 percent of $PM_{2.5}$ mass at the CS site during a strong wind event on March 7 and 8. The soil contributions were also higher at the CE and CN sites during these days.

The mean contributions of jet exhaust to the sum of 55 Photochemical Assessment Monitoring Station (PAMS) target hydrocarbons ranged from a few percent to as much as 20 percent. The PAMS target hydrocarbons include several toxic air contaminants. Jet exhaust accounted for 4 to 36 percent of the benzene levels, 1 to 5 percent of the toluene levels, and may contribute a significant fraction of the measured 1,3-butadiene, but with high uncertainty. On-road vehicles accounted for 25 to 40 percent of the total concentration of all 55 PAMS species and 50 to 75 percent of the measured benzene. CMB cannot distinguish between on- and off-airport vehicle emissions, so an unknown fraction of the on-road vehicle apportionment is associated with airport ground support vehicles and vehicle traffic to and from the airport. However, vehicles in closer proximity to the monitoring sites can be expected to have greater influence on the measured VOC levels.

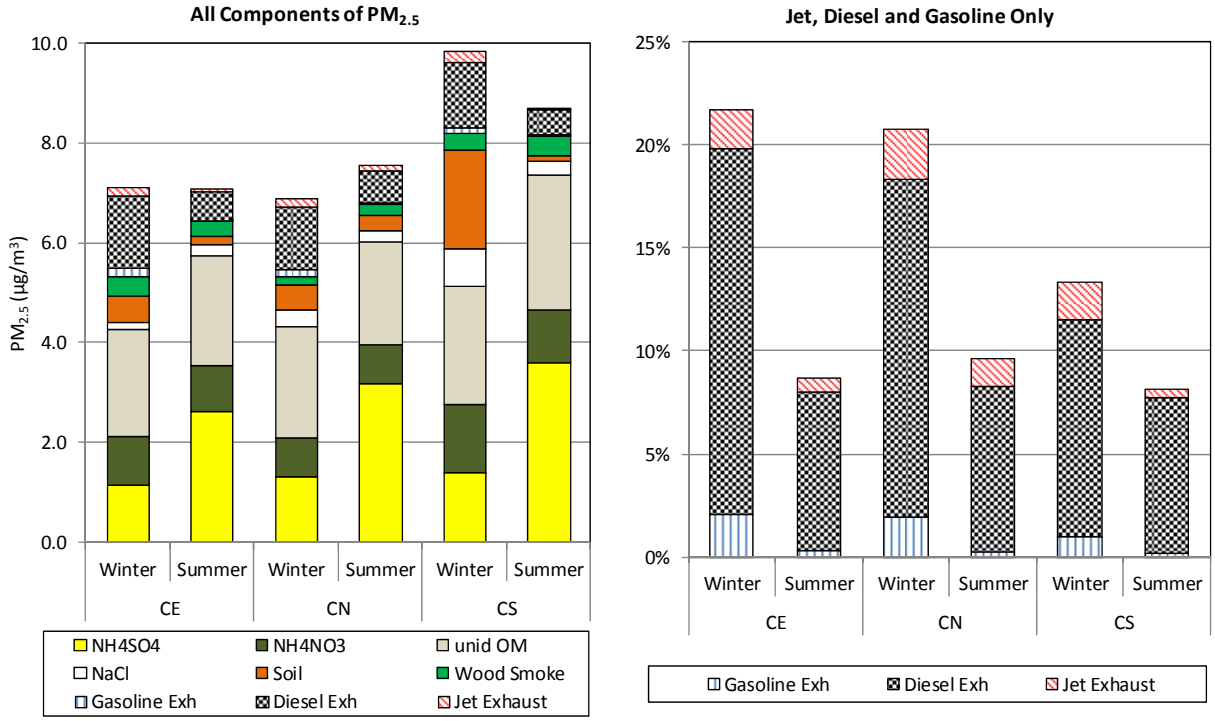

Figure ES-9. CMB source contribution estimates for all components of $PM_{2.5}$ in $\mu g/m^3$ in left figure and percent contributions to $PM_{2.5}$ for jet, diesel and gasoline exhaust in right figure.

NTA Source Apportionment Results

In analyzing the data in Phase III, the source apportionment by NTA focused on criteria pollutants (CO, NO_x, and SO_2) and a non-criteria pollutant (BC) for two main reasons. First, the NTA method requires measurements with an averaging time of 1 to 5 minutes. CO, NO_x, SO_2, and BC were the only measurements taken during the Study with such short time averages. Other pollutants of concern, such as $PM_{2.5}$, benzene and other organic gases, can only be measured with longer averaging times, making it impossible to apply NTA to determine the airport contributions to these pollutants. Second, over the last several years the U.S. EPA has been reviewing and, in some cases, dramatically tightening the National Ambient Air Quality Standards for criteria pollutants. Thus, the emphasis of the NTA source apportionment on criteria pollutants is prudent given this increased regulatory activity.

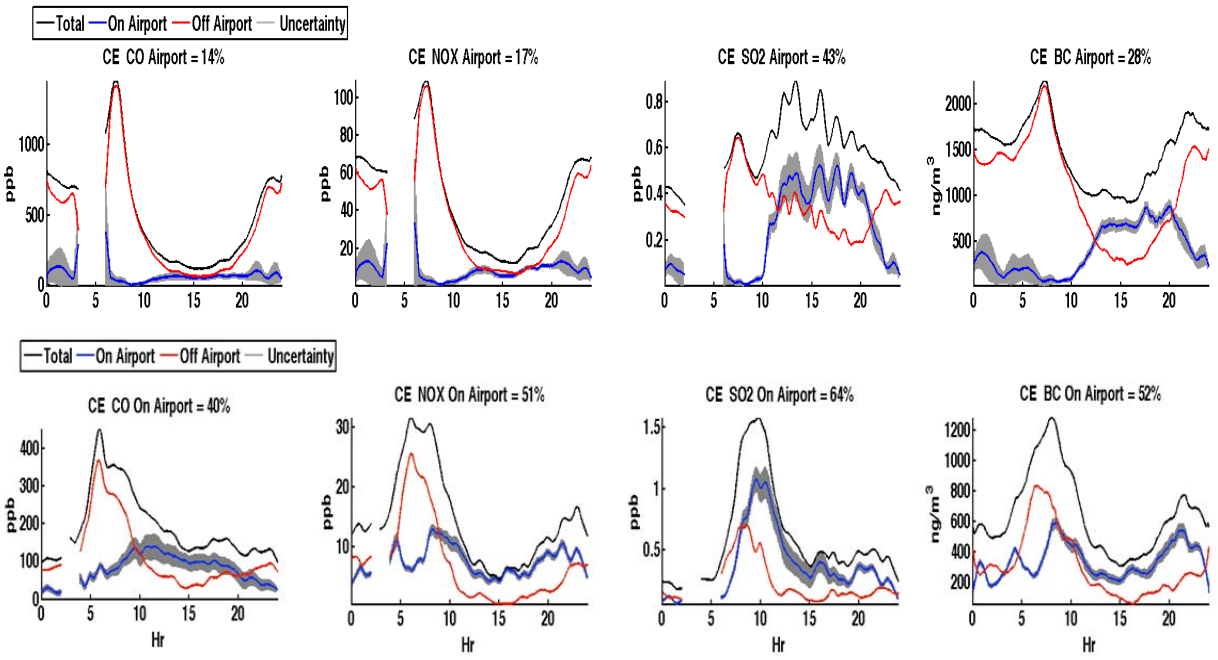

Figure ES-10. Hourly trajectory-based NTA source apportionment for the Winter (top) and Summer (bottom) Seasons at the CE station show high variability of concentrations by hour of the day and by season. The black line is the total contribution, the red line is the off-airport contribution, and the blue line is the on-airport contribution. The on-airport contribution line contains the upper and lower limits (gray shaded), which include the estimated effects of random error and assumptions made in the computations. Breaks in the lines occur in the early morning hours when automatic calibration of the gas monitors occurs.

Contribution of airport-related emissions can vary by hour of the day, day of the week, and by season. Figure ES-10 shows an example of the high variability in concentrations observed at the CE station for four air pollutants (CO, NO_x, SO_2, and BC) by hour of the day and by season. Therefore, the contribution of airport-related emissions is different for each community, depending on its geographical location (i.e., downwind or upwind from the airport) and relative distance from the airport.

Results from the NTA analysis show that the main sources of high concentrations of NO_x, CO, and BC were local traffic in the region of the I-105 and I-405 freeways. The region southeast of LAX was associated with elevated concentrations of all the pollutants measured. Since no obvious large sources are located within the proximity of this region, the NTA results indicated a flow of the abovementioned pollutants into the Study Area from sources located southeast of the airport. The possibility exists that some of the pollutants contained in the southeastern flow are re-circulated airport emissions from early morning winds from the north and northeast. Figures ES-11 and ES-12 provide summary graphics of the NTA source contributions of airport-related emissions to the CO, NO_x, SO_2, black carbon and UFP concentrations measured at the four core sites.

The contribution of airport-related emissions can vary by hour of the day, day of the week, and by season. Factors such as airport activity levels, wind direction, wind speed, ambient temperature, and other meteorological parameters, affect the contribution of airport-related emissions to local ambient air quality. The NTA results show that the airport-related emissions contributions to the local ambient air quality were generally higher for a community station located directly east rather than north or south of the airport. During the winter, airport operations accounted for 15 to 22 percent for both CO and NO_x at all four core monitoring sites (CE, CN, CS and AQ). While contributions were about the same during summer and winter at CS and AQ, the airport contributions at CE and CN were much higher during summer for CO (~40-50%) and NO_x (~50 to 75%). The airport contributions to black carbon show a similar seasonal pattern to CO and NO_x. Airport contributions to SO_2 were generally higher than for the other pollutants with less seasonal variation except at CS. The airport contributions to SO_2 during winter and summer were 40 to 80 percent at CE and CN and 10 to 50 percent at CS and AQ.

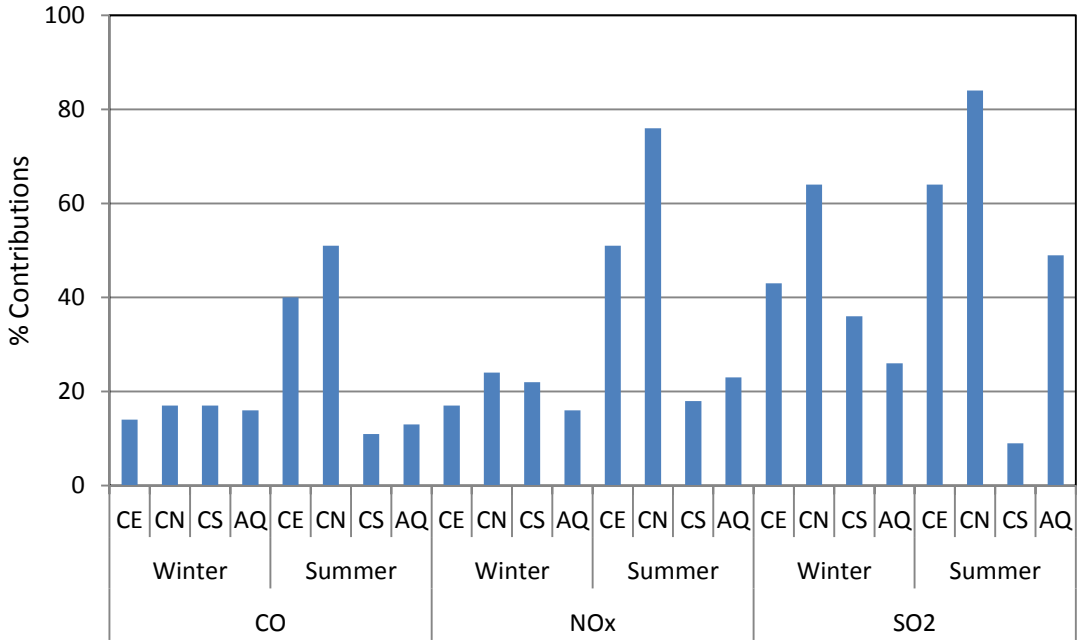

Figure ES-11. NTA Airport-Related Source Contribution Estimates for CO, NO_2 and SO_2.

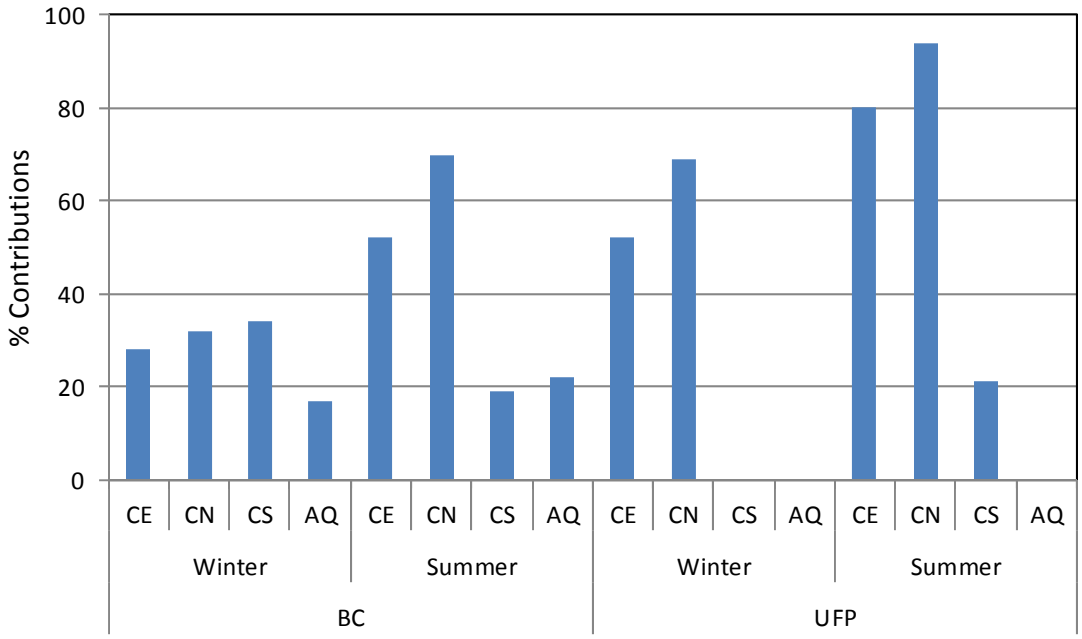

Figure ES-12. NTA Airport-Related Source Contribution Estimates for BC and UFP.

AERMOD Dispersion Modeling

The AERMOD dispersion model predicts the concentration impacts of different emission sources within the Study Area and permits comparison of the relative contributions from the modeled sources. The AERMOD model outputs of maximum 1-hour and maximum season averages at the four core sites were used for estimating airport contributions to the local ambient air quality. Results from the AERMOD prediction for the Winter Season indicated that more than 50 percent of the total modeled impact from sources within the Study Area on concentrations of CO, NO_x, $PM_{2.5}$ and SO_2 at the CS and CE sites, were contributed by non-airport related sources located off-airport such as off-airport roadway traffic not associated with the airport and local stationary sources. For the AQ and CN sites, more than 50 percent of $PM_{2.5}$ and SO_2 from sources in the study domain were contributed by on-airport sources. Results from the AERMOD prediction for the Summer Season indicated that more than 50 percent of CO, NO_x, $PM_{2.5}$, and SO_2 at the CE and AQ sites from Study Area emission sources were contributed by non-airport related sources. On-airport sources were the dominant contributors at the CS and CN sites, and comprised more than 75 percent for all pollutants from study domain sources impacting the CN site. Dominant airport-related sources were major roadway sources at the CS site and aircraft takeoff at the CE site.

AERMOD provides predictions of the airport contributions as a fraction of the total contributions from sources within the study domain, but not the fractions of the totals occurring downwind (since these totals also include contributions from sources outside the study domain). Additionally, it does not address chemical reactions that account for the formation of secondary pollutant along the transport trajectory, and also does not account for the regional or urban background contributions to the ambient pollutant concentrations at the receptor site.

CMAQ Simulation Modeling

The Community Multiscale Air Quality (CMAQ) model was used to estimate incremental (above regional background) concentrations contributed by airport-related sources to the total ambient concentrations. Unlike AERMOD, CMAQ also has the ability to estimate secondary aerosols that are formed inside as well as outside the Study Area including sulfate, nitrate, and organic aerosols. Inputs to the CMAQ model were from the 2008 application files, such as emission rates, and meteorological files, provided by SCAQMD. The base case ($AQMD_{zero}$) was run with all airport-related emissions removed, which provided the background concentration. Three additional emissions scenarios were modeled using CMAQ to estimate the incremental contributions of:

1) Jet exhaust, APU, and GSE minus $AQMD_{zero}$ (Sens1),

2) All airport-related sources minus $AQMD_{zero}$ (Sens2), and

3) All airport-related sources and non-airport related sources (i.e., local background sources) within the Study Area minus $AQMD_{zero}$ (Sens3).

CMAQ was run with a grid resolution of 4 kilometers by 4 kilometers (i.e., an area of 16 km^2), while the Study Area for Phase III is approximately 35 km^2 (8.5 km by 4.2 km). As a result, the entire Study Area lies within two grid cells with one cell containing the AQ and CS sites and the adjacent cell to the east, containing the CN and CE sites. The model predictions of the average air pollutant concentrations for only two grid cells do not capture the fine scale of spatial variability that may be observed in and around the airport. For example, ambient air quality measurements at the AQ site were generally low and near background levels, but the CMAQ-predicted concentrations at AQ site are the same as at the center of the airport.

The CMAQ outputs were analyzed for an array of nine grid cells that included the two cells centered on the airport. Airport contributions to ambient air quality based on CMAQ predictions were estimated using the adjacent cells. This is a technique that is used often in CMAQ model evaluation, where an array of grid cells around a given monitoring location are reviewed to see if the model predicts reasonably well when a point measurements is compared with an array of grid cells. The estimated percent contributions to above-background modeled ambient concentrations in the two grid cells containing the airport and the four core sites are listed in Table ES-2

Reconciliation of Source Attribution Results

Spatial and temporal analysis provided valuable information on qualitative assessment of airport contributions to ambient air quality by examining diurnal patterns, spatial distributions, and weekday-weekend differences to identify potential contributions from airport and non-airport emission sources. The quantitative assessment of airport contributions was accomplished by the modeling portion of the LAX AQSAS, which included both receptor and source-based models. It should be noted that each model has its own limitations and unique features, such as modeling domain and required inputs; therefore, it is misleading to directly compare results from various models. The following are examples of potential causes that contribute to differences in source contribution estimates observed by the various modeling approaches:

Table ES-2. Average airport-related source apportionment for the Winter and Summer Season expressed as a percentage (%) above background concentrations predicted by CMAQ modeling.

Percent (%) airport-related incremental contributions to CMAQ modeled ambient concentrations								
Sites	CO		NO_x		SO_2		$PM_{2.5}$	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
CE and CN	5	10	16	27	14	16	5	11
CS and AQ	16	26	35	49	31	30	15	20

CMB and NTA use data collected at the core monitoring sites located in the communities that were representative of middle-scale (100 meters to 0.5 km) to neighborhood-scale (0.5 km to 4 km). AERMOD receptors had a resolution of 0.5 km, which is comparable to the middle to neighborhood scales used by CMB and NTA. However, CMAQ has a grid resolution of 4 km by 4 km (or 16 km^2). The Study Area for Phase III is approximately 35 km^2 (8.5 km by 4.2 km). The coarse resolution of the grid cells used in CMAQ was unable to capture the spatial variability occurring on a finer scale that may be observed in and around the airport. Nevertheless, the issue with CMAQ grid-resolution was addressed by expanding the analysis from two to nine grid cells centered on the airport to better capture the impacts of airport sources in the corresponding grid cells, as described above.

Although aircraft emissions can be one of the largest emission sources at any airport, ambient concentrations observed at a specific receptor location tend to depend on distance from the sources. For example, the CN site is located directly downwind of the North Airfield runways for certain time periods and, therefore, is heavily influenced by airport operations during those periods. The CE site is located downwind of both the airport and the I-405 freeway and was influenced by airport operations, the freeway, and local traffic.

Different groupings of emission sources in the "on-airport" or "airport-related" and "off-airport" or "non-airport-related" categories used by various models may cause discrepancies in the modeling results. For example, airport-related source categories used in AERMOD and CMAQ included vehicle traffic emissions that occurred outside of the airport property but were related to airport operations. However, the NTA analysis used strictly an on-airport versus off-airport comparison. Therefore, it is important to keep this in mind when comparing various modeling results.

One of the important considerations when using dispersion modeling is to accurately estimate background concentrations when they are equal to or greater than the modeled concentrations. One of the main objectives of CMAQ is to provide regional background concentrations to allow for a proper estimate of incremental airport concentrations, which may not be accounted for in AERMOD, and to account for pollutants where atmospheric formation is important. CMAQ provided assessments of the incremental contribution of airport emission sources to the background concentrations in 4 by 4 km grid cells surrounding the airport. These predictions for nine grid cells indicated airport-related incremental increases of about 2 to 25 percent for CO,

about 1 to 30 percent for SO_2, about 2 to 50 percent for NO_x, and about 1 to 20 percent for $PM_{2.5}$, depending on location and season.

The CMB model estimates the impacts of various emission source categories at specific receptor sites relative to the total air pollution concentrations occurring at those sites. This capability is due to the fact that CMB is tied directly to the ambient measurements made at the receptor sites and apportions those totals among each of the source types. However, CMB apportions source categories and cannot distinguish locations of the emission sources that have the same chemical composition profile. For example, CMB is unable to separately apportion on-airport and off-airport related vehicle emissions. The CMB analysis indicated that airport jet exhaust was responsible for 2 percent of the average fine particle mass concentrations and 3 to 8 percent of the average fine particle BC (soot) concentrations measured in surrounding communities. The sum of jet, diesel, and gasoline engine exhaust accounted for 8 to 22 percent of $PM_{2.5}$ mass, approximately all the fine particle BC concentrations, and 13 to 44 percent of the fine particle OC concentrations (i.e., the diesel and gasoline engine exhaust is emitted by local traffic, freeway traffic, and on-airport sources combined).

NTA quantifies the directional impacts of emissions to the measured ambient pollutant concentrations at a receptor site. The NTA analysis of wind directions and monitoring data indicated that, depending on location and time of year, emissions from on-airport operations were responsible for 11 to 51 percent of the average measured CO concentrations, 16 to 76 percent of the average NO_x concentrations, 9 to 84 percent of the average SO_2 concentrations, and 17 to 70 percent of the average fine particle BC (soot) concentrations.

CONCLUSIONS

In summary, the LAX AQSAS shows that, with the exception of $PM_{2.5}$, the ambient concentrations of criteria pollutants within the communities adjacent to LAX were well below national and state health-based ambient air quality standards and ambient concentrations of air toxic contaminants were generally lower than measured elsewhere in the SoCAB. The generally lower pollutant concentrations in the LAX area can be attributed to its coastal location in the South Coast Air Basin and the typical daytime sea breeze that helps to disperse and transport local emissions inland toward the east. Consequently, the concentrations of most measured pollutants were higher east of LAX compared to monitoring locations north or south of the airport.

Although $PM_{2.5}$ levels were near the standard, a substantial portion of the $PM_{2.5}$ mass is related to the regional urban background with airport-related emissions contributing up to 5 to 20 percent. While UFP have negligible contributions to $PM_{2.5}$ mass, their number concentrations east of the LAX were higher than typical levels in the SoCAB. Supplemental Study measurements at the CE site and behind the South Airfield blast fence indicate that the very small UFP, which have disproportionately higher contributions to particle number concentrations, are largely sulfuric acid aerosol from jet exhaust. The larger UFP, which have disproportionately higher contributions to mass concentrations, appear to be related to on-road vehicle exhaust from local traffic.

The health effects of UFP are largely unknown. A recent review of 300 studies of the health effects of ambient UFP funded by the Health Effects Institute (HEI Perspective 3, January 2013)

concluded that experimental and epidemiologic studies provide suggestive, but no consistent evidence of adverse effects of short-term exposure to ambient UFP. At present, a separate health based NAAQS for UFP does not exist. The expectation for effects of UFP is based on their potential to carry toxic material deep into the lungs. In contrast to UFP in vehicle emissions that may be composed of adsorbed organic compounds, UFP associated with jet exhaust are dominated by sulfuric acid aerosol that is rapidly neutralized to relatively benign ammonium sulfate and increases in size due to absorption of water vapor. Future studies of the health impacts of airport emissions will need to consider these important chemical differences between UFP emissions from jet and vehicle exhaust