FINAL REPORT

LAX Air Quality and Source Apportionment Study

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

Prepared and Submitted to:

Los Angeles World Airports

Los Angeles World Airports
Environmental Services Division

By Jacobs Consultancy, Inc. in April 2009

Subsequent Review of Data by Countess Environmental in May-June 2011

June 18, 2013

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LAX AIR QUALITY AND SOURCE APPORTIONMENT STUDY

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Phase III of the LAX Air Quality and Source Apportionment Study

Volume 3

Phase I and Phase II Technology and Methodology Feasibility Demonstration Project Report

Completed by Jacobs Consultancy in April 2009

June 18, 2013

Los Angeles
World Airports

Los Angeles International Airport Air Quality and Source Apportionment Study

DRAFT REPORT
Demonstration Project Report

April 2009

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SECTION 1

INTRODUCTION

1.1 BACKGROUND

Los Angeles International Airport (the Airport or LAX) is located within the South Coast Air Basin (Basin). Air quality within the Basin is widely regarded as among the poorest in the nation, and fails to attain national and state standards for several "criteria" air pollutants including ozone (O_3), particulate matter with an aerodynamic diameter of 10 micrometers or less (PM_{10}) and particulate matter with an aerodynamic diameter of 2.5 micrometers or less ($PM_{2.5}$). The Airport is adjacent to residential neighborhoods to the north, south and east. Significant concern has been expressed among local residents that the Airport is contributing to unhealthy air quality within their neighborhoods.

Distinguishing any potential LAX-generated air quality impacts in the surrounding neighborhoods is confounded by the presence of other significant sources of emissions in the local region. These other sources include two major freeways, several heavily traveled major arterial routes, marine vessels, and numerous industrial facilities including the Chevron El Segundo refinery, Hyperion Wastewater Treatment Plant, DWP Scattergood Generating Station, and El Segundo Generating Station.

A number of regional air quality studies, such as the second Multiple Air Toxics Exposure Study (MATES III) conducted in 2004-2006 by the South Coast Air Quality Management District (SCAQMD), have examined air toxics in general but not LAX or other sources specifically. During the summer of 1999, the SCAQMD conducted a short-term air toxics monitoring program in the area around LAX. The results of that short-term study indicate that air toxics levels in the neighborhoods surrounding LAX were consistent with those found elsewhere in the Basin. However, the SCAQMD study was limited in extent and duration and did not provide data that could be used to determine either long-term impacts or LAX's contribution to toxic air pollutants.

The Airport's owner, Los Angeles World Airports (LAWA), intends to conduct an Air Quality and Source Apportionment Study (AQSAS or Study) to increase understanding of concentrations and sources of air toxics near LAX. The Study will be one of the most comprehensive air modeling and measurement analyses to be undertaken. After multiple planning and peer review cycles, the *Air Quality and Source Apportionment Study of the Area Surrounding Los Angeles International Airport Technical Workplan* (Technical Workplan) was prepared. This plan was revised in June 2008, and outlines the process for which the Study will be completed.

The Study involves the completion of a "Demonstration Project"—described in the following section—and a future Long Term Study that will include twelve months of data collection and will examine the key criteria pollutants and air toxics that are associated with the operation of LAX.

The primary objectives of the Study are to:

- Quantify ambient air concentrations of gases and particles and particle deposition in neighborhoods near LAX and determine how these vary in space and time;

- Determine significant sources of air pollutant emissions in the Study Area and characterize the emissions with respect to rate and chemical composition; and

- Determine the contribution of various Airport-related activities on selected air pollutant concentrations relative to the contribution from other, non-Airport sources in the surrounding area

Figure 1-1 depicts the Study Area. The Study Area extends from the Pacific Ocean on the west to Prairie Avenue on the east and from Rosecrans Avenue on the south to a northern border made up of Florence Avenue, Centinela Avenue, and the Rancho Sausal Redondo/Rancho Ballona Grant Boundary.

The Study will provide ambient air quality data in the vicinity of LAX and apply receptor and dispersion modeling techniques to determine source contributions to those concentrations. The ambient data collected may be used for future studies of community exposure and mitigation options. *However, this Study does not include any health effects or risk analyses, nor does it address the impacts of potential emission mitigation measures*. A community outreach and involvement program is being developed as part of the overall Study to engage local stakeholders in issues related to LAX's impacts on local air quality.

1.2 TECHNOLOGY AND METHODOLOGY FEASIBILITY DEMONSTRATION PROJECT

Due to the size and scope of the Study, and the lack of an established protocol for a project of this type, the Study is being conducted in two parts. The first part is a Technology and Methodology Feasibility Demonstration Project (Demonstration Project) that was conducted in 2008. The second part is the Long Term Study that will complete the source apportionment using the current "best practices," including the results of the Demonstration Project.

The primary objectives of the Demonstration Project were to:

- Assess the type of monitoring/sampling equipment to be used for the Long Term Study;

- Assess the proper siting locations for the monitoring/sampling equipment during the Long Term Study; and
- Assess the feasibility of completing accurate and comprehensive source apportionment.

Figure 1-1

STUDY AREA

LAX Air Quality Source Apportionment Study
Los Angeles International Airport

Source: Camp Dresser & McKee Inc., Technical Work Plan, 2007.

The main components of the Demonstration Project included: developing protocols for both monitoring/sampling and modeling, completing 42 days of monitoring/sampling, and the analysis of monitored data—including an analysis of the feasibility of using Receptor Modeling to conduct a comprehensive source apportionment. These components and the reports that describe the work and results are summarized in Table 1-1.

Table 1-1
DEMONSTRATION PROJECT TASK REPORTS
Los Angeles International Airport

Task	Report Name	Author	Location
6	Quality Assurance Program Plan	Weston Solutions, Inc. and ENSR | AECOM	Module A
8	Source Apportionment Protocol	Trinity Consultants and Ronald C. Henry PhD.	Module B
2	Literature Review	KB Environmental Services, Inc.	Module C
3	Off-Airport Inventory	Aspen Environmental Group	Module D
4	Fuel Analysis	Atmospheric Analysis and Consulting, Inc.	Module E
5	On-Airport Inventory	Jacobs Consultancy	Module F
6	Monitoring and Sampling Report	Weston Solutions, Inc., and ENSR | AECOM	Module G
4, 6, 7	Quality Assurance Audits	T & B Systems, Inc.	Module H
8	Analysis of Air Quality Emissions Data	Jacobs Consultancy	Module I
8	Source-Oriented Air Dispersion Modeling	Trinity Consultants	Module J
8	Receptor Modeling	Jacobs Consultancy and Ronald C. Henry Ph.D	Module K
6	Gas Chromatograph/Mass Spectrometer Analysis	Weston Solutions, Inc.	Module L

*Tasks 1 and 7 are associated with general project and data management, and have no specifically associated documentation.

The Demonstration Project was conducted between March 2008 and December 2008. Monitoring/sampling was completed between June and September of 2008. Other key project dates are identified in Figure 1-2.

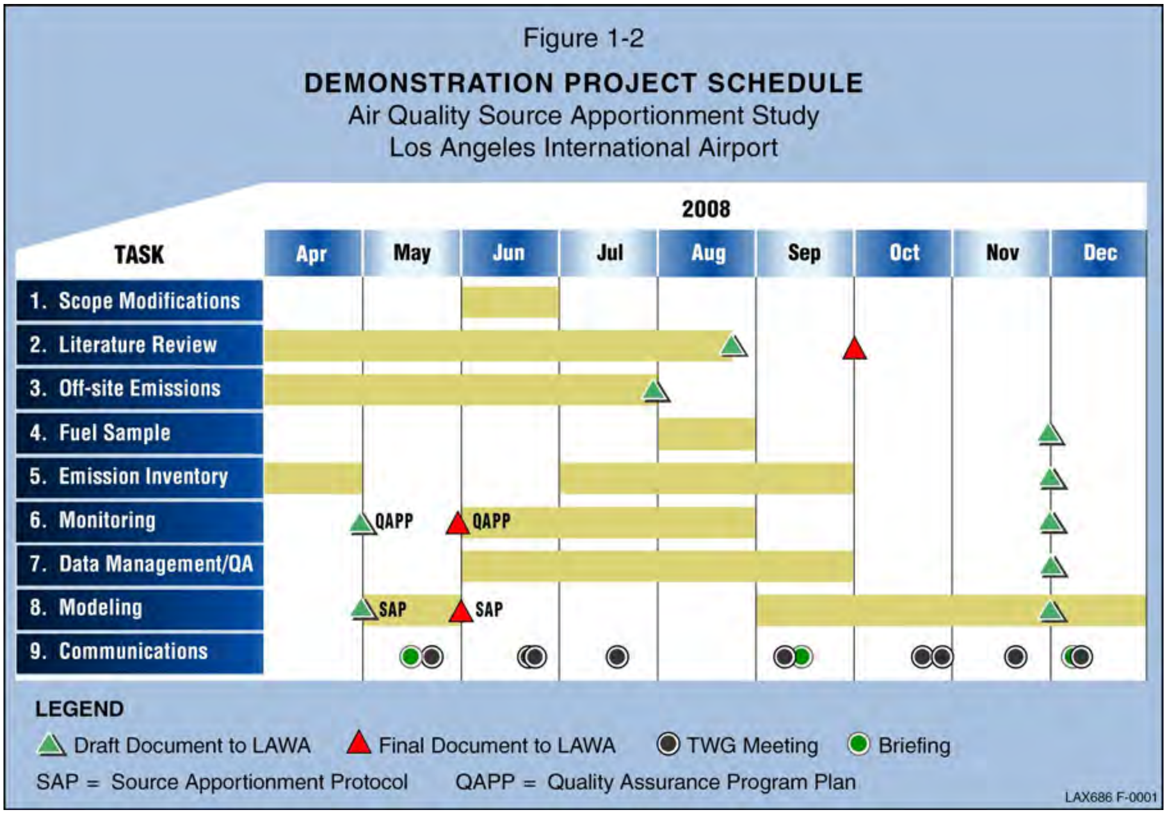


Figure 1-2
DEMONSTRATION PROJECT SCHEDULE
Air Quality Source Apportionment Study
Los Angeles International Airport

1.3 PROCESS

Although "monitoring" and "sampling" are often used interchangeably, they have two distinct meanings in the context of the Demonstration Project. Monitoring is the continuous collection of data, where short-term (e.g., one-second) measurements are made in place and averaged over longer time intervals (e.g., one minute, hourly). Sampling is the collection of a discrete sample (e.g., a filter) that is exposed to ambient air for a specific period of time (e.g., 12 hours), then analyzed in a laboratory.

- "Monitored" compounds include criteria pollutants. Criteria pollutants are substances with California or National Ambient Air Quality Standards (AAQS), and include ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), particulate matter less than 10 microns aerodynamic diameter (PM_{10}), particulate matter less than 2.5 microns aerodynamic diameter ($PM_{2.5}$), and carbon monoxide (CO).

"Sampled" compounds are compounds collected for discrete time periods and include diesel exhaust; polycyclic aromatic hydrocarbons (PAHs) such as benzo(a)pyrene and other semi-volatile organic compounds (SVOCs); volatile organic compounds (VOCs) such as benzene; and trace metals such as cadmium.

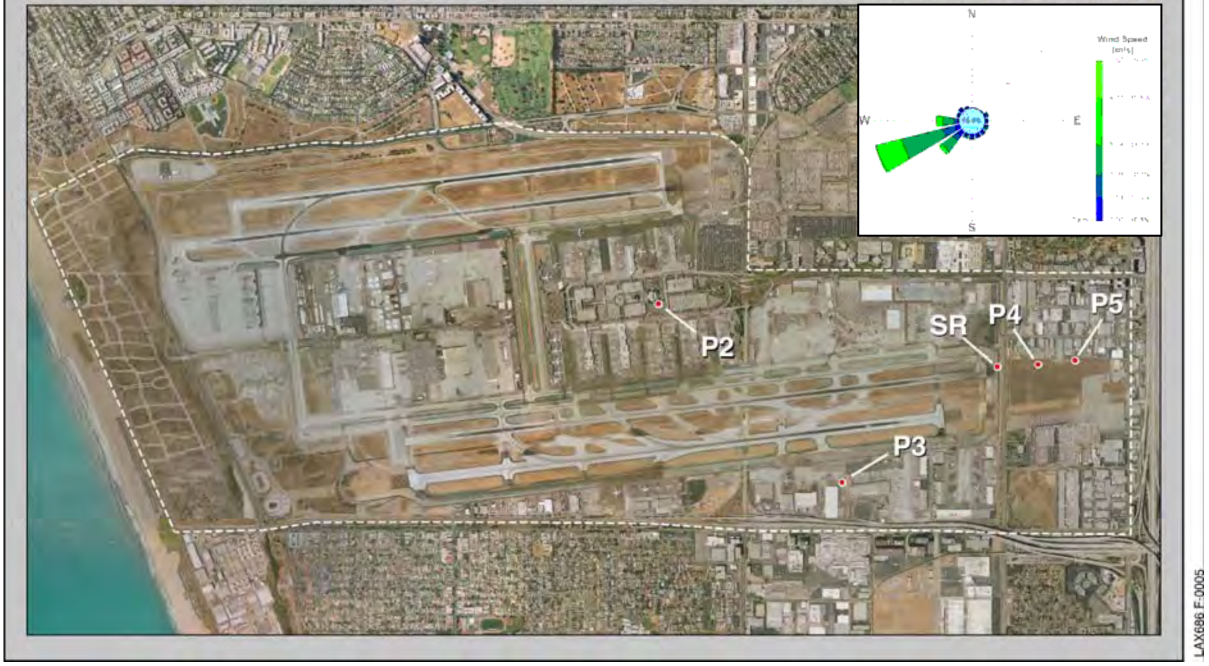
The basic strategy of the monitoring/sampling portion of the Demonstration Project was to first collect data at a location adjacent to the Runway 25R blast fence, in order to obtain information on aircraft-related emissions. Runway 25R is one of the two "South Runways" at LAX and is used primarily by departing aircraft. After data were collected at the South Runway site, select instrumentation was moved sequentially to four other locations on the Airport to gather information on additional sources. Collection occurred over a 7-day period at each of the four locations. The full range of monitoring and sampling approaches was deployed during the South Runway segment of the collection process. Only subsets of those approaches were carried out at the subsequent sites.

The names of the five collection sites are: South Runway (SR), Portable Site 2 (PS2), Portable Site 3 (PS3), Portable Site 4 (PS4), and Portable Site 5 (PS5). The locations of these sites and a wind rose depicting the predominant summer wind direction are shown in Figure 1-3; images of the actual monitoring sites are presented in Figure 1-4.

Figure 1-3

MONITORING LOCATIONS

Los Angeles International Airport



As identified earlier, a project of this size and scope has never been attempted at an airport. The purpose of the Demonstration Project was to identify the "best practices" to be used in completing the Long Term Study. In doing so, improvements were identified that would enhance the Demonstration Project results and additions to the original scope were incorporated. These additional efforts included: SO_2 and ultrafine particles (UFP) measurements at four portable sites, VOC analysis at the LAX fuel farm, VOC analysis from Sepulveda Tunnel, installation of a downwind meteorological station, Gas Chromatography/Mass Spectrometry (GC/MS) analysis in conjunction with SCAQMD, and analysis comparing pollutant data with aircraft operations.

Figure 1-4

MONITORING SITES

AQSAS—Demonstration Project
Los Angeles International Airport

Assessing the feasibility of completing an accurate and comprehensive source apportionment involved two types of air quality modeling: dispersion modeling and receptor modeling. Dispersion modeling requires the input of emissions data for sources of air pollution and the release characteristics of those emissions. Also required is the meteorology data and pollutant transport information to estimate downwind pollutant impacts.

Receptor modeling techniques utilize measured concentration data at specific locations (i.e., receptors), along with measured meteorological data (including back-trajectories of wind) and emission source characteristics to estimate the contribution of individual sources to measured pollutant concentrations. The following receptor models were considered for use in the Study: Chemical Mass Balance (CMB), Spatial Gradient Analysis, and Time Series Analysis.

Both Spatial Gradient Analysis and Time Series Analysis require simultaneous measurement of pollutants at multiple locations, which was not a component of the Demonstration Project. As a result, only the feasibility of using CMB to apportion the emissions in the Study Area was analyzed in the Demonstration Project.

Note that despite advancements in meteorology, atmospheric science and chemistry, monitoring techniques, and the aforementioned analysis methods, it is very difficult to fully characterize the impact of LAX sources on the ambient air. The meteorology, terrain, and emission sources in the Basin create a complex environs. There is no guarantee that the results will isolate Airport sources from other local, regional, and international sources in the Basin. Nonetheless, a well-conducted study can advance the understanding of the airshed and estimate possible impacts of LAX air emissions on the surrounding communities.

1.4 OUTREACH PROGRAM

In order to build a partnership between the project sponsor (LAWA) and interested community members, and to best communicate the progress and results of the Study, a community outreach and involvement program was developed. The outreach program consists of three levels: (1) the Technical Working Group (TWG), (2) the Briefing Group, and (3) public/community outreach.

The TWG includes experts in air quality and aviation from all levels of government, the community, academia, and LAWA. One of the primary responsibilities of the TWG is to reach consensus decisions on how to proceed with the study and to review and provide expert advice and opinions on subsequent monitoring and modeling protocols developed for the Study. The TWG also reviews and comments on all reports and deliverables developed for the Study. Information pertaining to TWG composition can be found in Table 1-2.

To ensure full disclosure to the community on a continuing basis, LAWA has developed a Briefing Group comprised of elected officials, regulatory agency representatives, LAWA staff, and others. The Briefing Group has met quarterly and is intended to help elected officials, agencies and other key stakeholders understand the scientific objectives and approaches being used in the Study as well as report on the status and key findings of the AQSAS as the Study progresses.

Table 1-2
TECHNICAL WORKING GROUP COMPOSITION

United States Environmental Protection Agency
Federal Aviation Administration
California Air Resources Board
South Coast Air Quality Management District
Office of Environmental Health Hazard Assessment
(California Environmental Protection Agency)
University of Southern California
Desert Research Institute
Scientific experts representing community organizations

LAWA appreciates the interest and support for this study that it has received from members of the public living and/or working in the community surrounding LAX. Therefore LAWA makes every effort to engage the community and inform them of all pivotal steps in the AQSAS. There will be public meetings at key milestones throughout the study. In order to encourage a dialogue with the community, LAWA has developed a project website that provides key project information including: a project description, fact sheets, meeting presentations, graphics, and schedule. The website can be accessed at: http://www.lawa.org/welcome_LAX.aspx?id=1060.

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SECTION 2

DEMONSTRATION PROJECT TASK REPORTS

2.1 QUALITY ASSURANCE PROGRAM PLAN AND SOURCE APPORTIONMENT PROTOCOL

The Technical Workplan provides guidance related to the development of protocols for the monitoring and modeling portions of the Demonstration Project. These methods are further refined and described in the Ambient Air Monitoring and Quality Assurance Program Plan (QAPP) and Source Apportionment Protocol (SAP) reports.

The QAPP covers the ambient air data collection activities conducted during the Demonstration Project. The QAPP is based principally on the information contained in Sections 4.6 and 4.7 of the Technical Workplan, regarding the Demonstration Project data collection & management.

The SAP describes the technical approaches used in the modeling portion of the Demonstration Project. The SAP is based principally on the information contained in Task 8 of the Technical Workplan.

Complete documentation of the QAPP is located in Module A.

Complete documentation of the SAP is located in Module B.

2.2 LITERATURE SURVEY

The Technical Workplan contains a "Bibliography of Prior Studies" which provides a comprehensive listing of reports on the topics of air quality monitoring and meteorology; aircraft and other Airport emissions sources; as well as facility operations and planning documents as they pertain to aviation, in general, and LAX, in particular.

Similar compilations on these technical subject matters have also been published by the U.S. EPA, the FAA, CARB and an assortment of other investigators—both public and private. There are also a brand new series of publications prepared by foreign, federal and state agencies, academic institutions, and other researchers specifically pertaining to aircraft engine emissions and air monitoring data at several large, medium and small airports.

The purpose of the Literature Review is to identify all of those publications that have the greatest potential for addressing the issues, information gaps and challenges of this Study and adding clarity to the expected outcomes. The results of the Literature Review were condensed into clear and comprehensible formats for ease of understanding by the Study Team, LAWA staff and the TWG. Additionally, significant information and data gaps relevant to this Study were characterized.

Information and data pertaining to the measurement and assessment of air quality around airports (including LAX) is somewhat voluminous and mostly technically oriented. Therefore, among the primary aims of this task was to consolidate and configure the findings of this Task into products and formats that are informative to the end-users.

Complete documentation of the Literature Review is located in Module C.

2.3 OFF-AIRPORT INVENTORY

This effort included an inventory of off-Airport onshore emission sources within the study area, and major offshore emission sources located west of the study area. Additionally, on-Airport third party (tenant) emissions were inventoried as part of this effort. The general types of emission sources identified and inventoried include: stationary sources, on-road traffic, off-road equipment, area sources, and marine vessels.

Though there are a number of potentially significant emission sources that need to be considered in the study area, some emission sources are critical for certain pollutants. For example, marine emissions are critical for SO_x emissions impact determination, but would be significantly less critical for CO emissions impacts.

The downwind concentrations from each source are also a function of their location and emission dispersion characteristics, so the emissions inventory alone cannot determine the potential contribution to ambient air quality impacts for each of the emission source types. This initial emissions inventory evaluation has determined that all of the emission sources described above will be modeled to determine if their impacts may be significant within any part of the study area.

The emissions data, representing the emissions provided for modeling, are summarized in Table 2-1.

The emissions in Table 2-1 do not include marine emissions outside of the Channel Islands or north of the extended Los Angeles County border or south of Point Vicente, or any harborcraft marine emissions.

Complete documentation of the Off-Airport Inventory is located in Module D.

Table 2-1

OFF-AIRPORT INVENTORY OF EMISSIONS (Average Tons/Day)

Los Angeles International Airport

Emissions Sources	NOx	CO	VOC	SOx	PM_{10}	$PM_{2.5}$
Major Point Source *(a)*	3	4	2	1	1	1
On-Road Traffic (*b*)						
Non Freeway Traffic Subset	3	29	3	0.1	0.3	0.2
I405/I105 Freeway Traffic Subset	3	9	1	0.01	2	0.2
Off-Road	4	10	1	0.1	0.2	0.2
Area Source	0.3	1	2	--	0.2	0.04
Aggregated Point Source	0.5	0.4	1	0.01	0.03	0.02
Marine Emissions *(c) (d)*	1	0.04	0.02	2	0.1	0.1
Totals	14	54	10	3	3	1

(a) Comprises the off-Airport and on-Airport tenant emissions that were modeled separately.
(*b*) Comprises airport-related off-airport traffic and non-airport-related traffic.
(c) Comprises only the emissions from the specific marine traffic links and El Segundo Marine Terminal buoys.
(d) Marine source emissions over 3200 sq. km. compared to 94 sq. km. for land based sources.

2.4 FUEL ANALYSIS

Fuel combustion in mobile sources represents the single most significant source of emissions in the Study Area. Therefore, definitive characterization of the fuels used in and around the Airport (i.e., for aircraft, construction, ground support equipment) is necessary to better understand the emissions produced during the combustion process.

The sampled fuels include, jet fuel (or Jet-A), diesel fuel (for construction), diesel fuel (for ground service equipment), and gasoline (used by Airport vehicles). Each of these samples was analyzed for speciated sulfur compounds, VOCs, halogenated hydrocarbons, polychlorinated biphenyls, detailed hydrocarbon speciation (composition/breakdown, markers/additives), and headspace analysis for VOCs and hydrocarbons.

For the purposes of the Demonstration Project the results of the fuel analysis was used in the search for a distinct chemical indicator of specific sources. Thus, the analysis of the fuel composition data reported as a result of this task can be found in the Receptor Modeling Report.

Complete documentation of the Fuel Analysis is located in Module E.

2.5 ON-AIRPORT EMISSIONS

The primary purpose of this task was to develop an inventory of on-Airport emissions, that when combined with the data and information gathered in the off-Airport Inventory (See Section 2.2), will provide a tabulation of emission sources that may materially affect the monitoring results. The information was prepared in a manner that is consistent with input parameters for dispersion modeling. Key aspects of this task included:

- Developing an inventory of emissions sources within the Airport boundary
- Developing an inventory of criteria pollutants emitted by sources on Airport property
- Spatially locating each of the emission sources on Airport property
- Temporally allocating criteria pollutant emissions from sources on Airport property
- Providing an inventory of spatially and temporally allocated emissions for use in the dispersion modeling analysis being performed for the Demonstration Project

The emission sources inventoried include aircraft, Auxiliary Power Units (APUs), Ground Service Equipment (GSE), Airport-related roadways, Airport-related parking facilities, and stationary sources. The pollutants inventoried include U.S. EPA criteria pollutants and ozone precursors, including: VOC, NO_x, CO, SO_x, Non-Methane Hydrocarbons (NMHC), total Hydrocarbons (THC), PM_{10}, and $PM_{2.5}$. The FAA's EDMS, Version 5.0.2, [FAA, 2007] and its internal databases were used to estimate the level of these pollutants. Emission sources are depicted in Figure 2-1.

Emissions for the three-month period June through August, 2008 were estimated from all sources of air pollutants at the Airport. This three-month period was chosen to coincide with the schedule of the emissions Monitoring and Sampling task of the Demonstration Project.

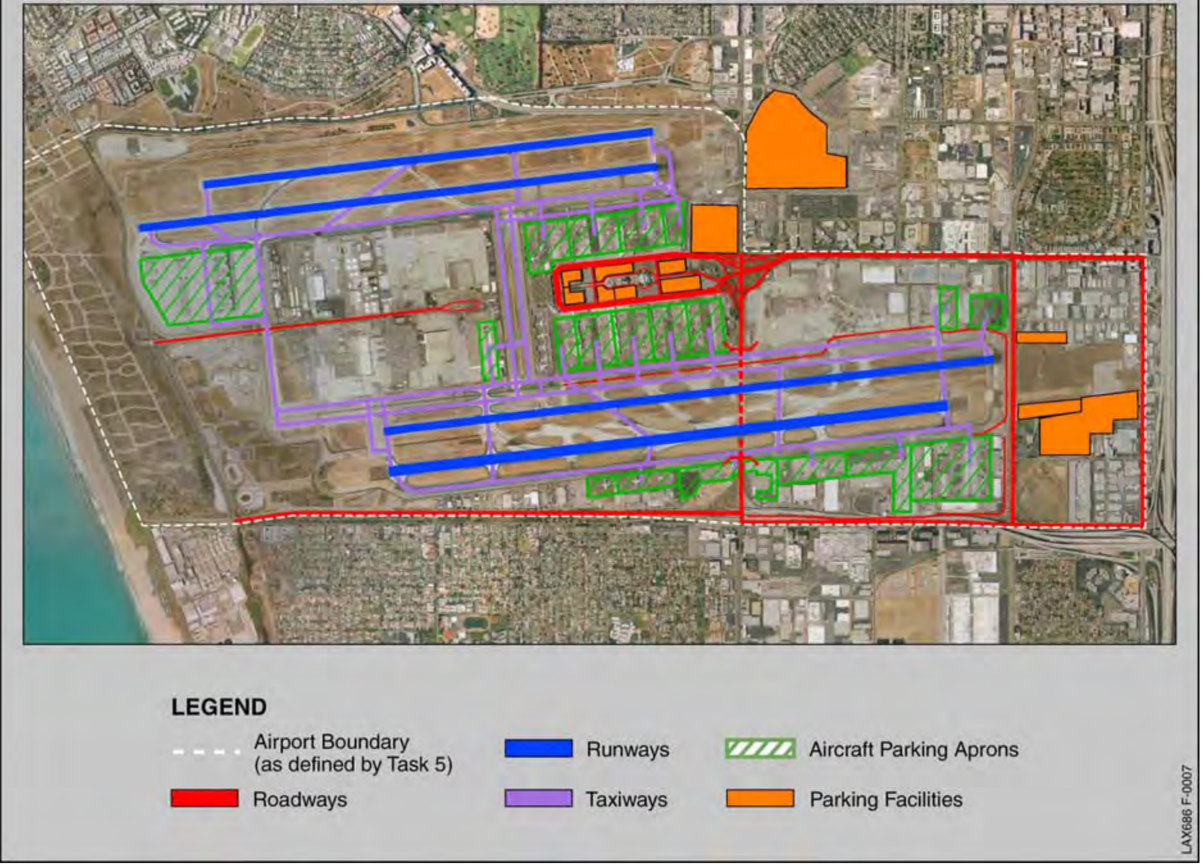
Aircraft emissions represent the largest portion of emissions from any one source group of on-Airport sources for all pollutants except carbon monoxide (CO). For six of the eight pollutants that are estimated by EDMS, aircraft emissions contribute more than 50% of the total emissions from on-Airport sources. Therefore, a reliable assessment of the emissions from aircraft operations is essential for this analysis to meet the needs and objectives of the Demonstration Project.

EDMS portrays aircraft operations in six modes of operation; taxi-out, takeoff, climb-out, approach, landing roll, and taxi-in. The modes "taxi-out" and "taxi-in" have identical emission factors, and any time spent idling is calculated using these same emission factors. These three modes combined are often referred to as the "taxi/idle" mode. EDMS distributes aircraft emissions along runways, taxiways, gates, and the flight tracks that aircraft follow into and out of the airspace around the airport.

Figure 2-1

SPATIAL ALLOCATION OF AIRPORT SOURCES

AQSAS—Demonstration Project
Los Angeles International Airport



In general, aircraft account for 38% of the CO emissions, 79% of the VOC emissions, 68% of the NOx emissions, 83% of the SOx emissions, 53% of the PM_{10} emissions and 55% of the $PM_{2.5}$ emissions. Totals for each emissions source are provided in Table 2-2.

In addition to providing the emissions inventory, this task identified recommendations for the on-Airport emissions inventory to be completed as part of the Long Term study.

Complete documentation of the On-Airport Inventory is located in Module F.

Table 2-2

ON-AIRPORT INVENTORY OF EMISSIONS (Tons/Study Period)

JUNE - AUGUST, 2008

Los Angeles International Airport

	CO	THC	NMHC	VOC	NOx	SOx	PM_{10}	$PM_{2.5}$
Aircraft	436	199	199	188	737	66	15	15
GSE	501	31	29	31	222	9	8	8
APU	38	3	3	3	30	4	--	--
Parking Facilities	28	5	4	4	6	0.02	0.09	0.07
Roadways (on-Airport)	139	11	9	11	59	0.30	4	3
Stationary Sources (on-Airport, LAX owned)	9	--	--	0.27	31	0.32	1	1
Total	1,151	249	245	238	1,086	80	28	27

Source: Jacobs Consultancy, August 2008.

2.6 MONITORING AND SAMPLING

The objective of the monitoring program was to collect meteorological and ambient air quality data over a two-month period. This data will subsequently be used (1) to evaluate whether there are unique compounds that can be used to distinguish any potential LAX-generated air quality impacts in the surrounding neighborhoods, (2) in the modeling efforts of the Demonstration Project, and (3) to evaluate ambient air data collection methods, collect source emissions inventory data, and perform preliminary data analysis and modeling. The siting considerations associated with meeting the project monitoring objectives included:

- Appropriately locating the ambient air quality monitors to detect Airport operations including takeoff and landings and other significant near-field sources of emissions.
- Selecting air quality monitoring sites that are located reasonably near existing electrical and telephone utility lines (where possible), and will be accessible by technical staff.
- Selecting sites to collect data representative of Airport and community air quality conditions.
- Selecting locations for the meteorological monitoring station that are also appropriate for monitoring dispersion meteorology such that the instrumentation is well exposed to prevailing winds and representative of dispersion conditions in the LAX area while still satisfying siting logistics (e.g., instrument exposure, access, utilities, etc.).

A broad target set of pollutants was chosen for the Demonstration Project, aimed towards the goal of identifying a subset of the target pollutants as "marker" compounds that were used to attempt to trace the Airport's impacts into the adjacent neighborhoods. Simultaneous collection of meteorological data is essential to understanding the sources and transport of the pollutants being measured. The actual monitoring data collections times for pollutants analyzed by receptor modeling are presented in Figure 2-2.

Samples were collected over three different time periods: 12-hour, daily (24-hour), and weekly. The 12-hour periods were used to assess variability in air quality during the on-shore and off-shore portions of the day (land/sea breezes). The daily and weekly samples were used to characterize long-term air quality.

In addition to conventional time-integrated sampling, the Demonstration Project tested the use of a snapshot portable GC/MS system to quantify VOCs in the immediate vicinity of sources at the South Runway and one portable location.

The quality of data collected during the Demonstration Project was managed by a systematic approach, involving multiple levels of project personnel, including technicians on-site collecting data and operating equipment, scientists in remote offices reviewing the data, and auditors responsible for independently verifying appropriate collection of the data.

Any procedures, changes in instrumentation, or adjustments that occurred during the Demonstration Project which were not originally stated in the QAPP were recorded. These deviations included: collection of additional samples, necessary equipment adjustments, additional monitoring, and changes in equipment location.

Finally, significant events were recorded. Significant events include events in which instruments may have been offline during moves, significant maintenance or repairs, and runway closures.

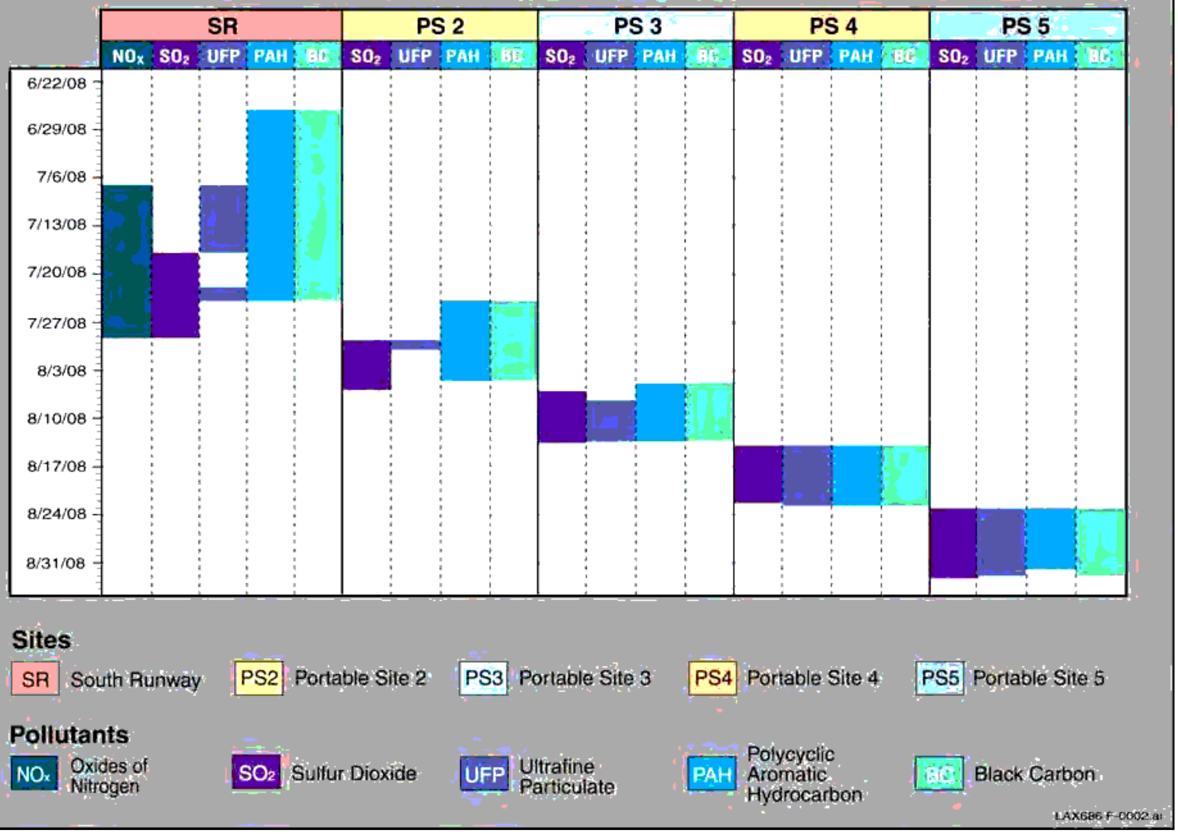
For more information on Monitoring and Sampling see Section 3.

Complete documentation of Monitoring and Sampling is located in Module G.

Figure 2-2

DATA COLLECTION SCHEDULES FOR CONTINUOUS NO_X, SO_2, UFP, PAH, AND BC MEASUREMENTS

AQSAS—Demonstration Project
Los Angeles International Airport



2.7 QUALITY ASSURANCE EDITS

As part of the monitoring effort, a number of external audits were conducted by T&B Systems, Inc. The audits consisted of a performance evaluation to review the measurements made and an assessment of the accuracy of the data collected. A system audit was also performed to assess the consistency of measurements with the applicable Standard Operating Procedures (SOPs) and program Data Quality Objectives (DQOs). From a systems aspect, recommendations were made during the audit process to improve the on-site documentation as well as the record-keeping as it related to the time synchronization of the data logging clocks.

Operationally, with the exception of the radar wind profiler reported winds, the accuracy of all instrumentation audited met the program objectives. The overall audit results showed that with few exceptions, the operations and procedures followed were appropriate to collect the desired data.

Complete documentation of the Quality Assurance Audits is located in Module H.

2.8 ANALYSIS OF AIR QUALITY DATA

The purpose of this preliminary data analysis was to provide an initial qualitative assessment of the monitoring results by:

- Examining the monitoring data for indications that it tracked with or “signaled” aviation activity that occurred over the same period
- Identifying which monitored pollutants clearly tracked with aviation activity and which did not
- Identifying data gaps or other data issues that could affect signal-tracking fidelity or quality
- Identifying preliminary observations relevant to the future AQSAS Long Term Study

Wind effects and data gaps were identified as two factors that generate misleading or erroneous charting results. Therefore a methodology was developed so that these complicating factors did not effect the analysis.

The following data issues were identified during this analysis: unidentified gaps in the LAX Noise Monitoring System (NMS) data, miscoded NMS data, time stamps, and intersection departures. These issues mostly pertain to NMS data used to develop the aircraft activity time series which were key in assessing signal quality and fidelity. These issues are not serious enough to invalidate the analysis results; however addressing them will improve accuracy for the Long Term Study. Additionally, it may be beneficial to augment the NMS data with other data on flight activity such as Performance Data Analysis and Reporting System (PDARS) and Aviation System Performance Metrics (ASPM).

For more information and results of tracking analysis see Section 4.

Complete documentation of the Data Analysis is located in Module I.

2.9 DISPERSION ANALYSIS

Dispersion Modeling was conducted to characterize the air quality impacts of the on-Airport and off-Airport emissions to support the siting of monitors for the Long Term Study. Source-oriented air dispersion modeling requires the input of emissions data for sources of air pollution, spatial allocation of those sources, and the release characteristics of emissions. Also required is the meteorology data and pollutant transport information to estimate downwind pollutant impacts. The dispersion model uses these data to determine the direction and distribution of the pollutants at defined time intervals.

As the study area is relatively small (approximately 8.5 by 8.5 km), a dispersion model suitable for near-field impacts is preferred. In addition, as this study sought to attribute impacts to individual sources, a source-oriented model that could model individual sources is preferred. The EPA-approved **A**merican Meteorological Society/**E**nvironmental Protection Agency **R**egulatory **M**odel (AERMOD) was selected* based on these criteria and the need for a robust model that can handle large number of sources and hourly data. However, further understanding of the land/sea interface is necessary before a model can be chosen for use in the Long Term Study.

AERMOD is a refined, steady-state, multiple-source, Gaussian dispersion model and was promulgated in December 2005 as the preferred near-field regulatory model [40 CFR 51, 2005]. Following procedures outlined in the Guideline on Air Quality Models, [40 CFR 51, 2005] AERMOD modeling was performed using the regulatory default option for most model options. The latest AERMOD version (07026) was utilized in these analyses. The AERMOD model calculates impacts at discrete locations defined by the user. In this analysis, receptors were evenly spaced 200 meters apart throughout the study domain.

Results were developed on an hourly basis to determine the worst-case short-term impact and on a period (three-month) basis to assess the long-term patterns. In addition, comparison evaluation was also conducted for potential ambient air impacts for other seasons (i.e., winter, spring, and fall of 2007) and summer time of additional years (i.e., 2003 through 2006).

The dispersion model was run for the meteorological period of June 2007 through August 2007 to coincide with the summer conditions of the measurement study period (i.e., June through August, 2008). Selected scenarios were also run for June - August of 2003 through 2006 and for spring, autumn, and winter 2007.

A summary of emissions from each source type is provided in Table 2-4.

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*40 CFR Part 51, Appendix W, Guideline on Air Quality Models.

Table 2-3
ON AND OFF AIRPORT INVENTORY OF EMISSIONS
(Tons in 3-Month Period)

Los Angeles International Airport

Source Group	CO	VOC	NO_x	SO_x	PM_{10}	$PM_{2.5}$
Aircraft	436	188	737	66	15	15
GSE	501	31	222	9	9	8
APU	38	3	30	4	*(g)*	*(g)*
Parking Facilities	28	4	6	0.02	0.1	0.1
Roadways *(a)*	139	11	59	0.3	4	3
Roadways *(b)*	3,510	353	582	7	169	32
Stationary Sources *(c)*	9	0.3	31	0.3	1	1
Stationary Sources *(d)*	14	4	7	0.2	4	3
Stationary Sources *(e)*	240	157	68	5	21	20
Chevron	225	159	254	100	71	71
Marine Sources *(f) (h)*	140	70	1,739	1,180	156	152
Off-Road Sources	928	112	333	5	19	17
Area Sources	47	186	26	0.4	15	4
Total	6,254	1,280	4,095	1,378	484	326

(a) On-Airport roadways
(b) Off-Airport roadways (including Airport-related off-Airport traffic)
(c) Stationary sources (on-Airport, LAX owned)
(d) Stationary sources (on-Airport, non-LAX owned)
(e) Stationary sources (off-Airport, not including Chevron)
(f) Sulfur emissions from marine sources reflect the high sulfur content of bunker fuels used by ships
(g) Outside the capabilities of EDMS Version 5.0.2
(h) Marine source emissions over 3200 sq. km. compared to 94 sq. km. for land based sources.

An inventory of sources was developed in the off- and on-Airport Inventory tasks (see Sections 2.2 and 2.4, respectively) for use in the dispersion modeling analyses. When combined these inventories provided nearly 11,000 individual sources for use in dispersion modeling from the following source categories:

- Aircraft and related emission sources
- LAWA-owned on-Airport stationary sources
- Individual stationary sources (on and off-Airport), including two power plants and the Chevron El Segundo refinery

- Marine sources
- Aggregated sources
- Individual on-road segments

Pollutants modeled included CO, NO_x, $PM_{2.5}$, PM_{10}, SO_2, and VOC.

For more information on Dispersion Modeling see Section 5.

Complete documentation of the Dispersion Analysis is located in Module J.

2.10 RECEPTOR MODELING

Receptor Modeling involves all monitoring and sampling data, the fuel analysis, and the portable GS/MS analysis, and holds the key to compiling a comprehensive source apportionment of the study area. However, for purposes of the Demonstration Project any receptor modeling performed was only to show the feasibility of using those receptor modeling techniques to attain the study objectives. Furthermore, a significant goal of the Demonstration Project's Rector Modeling task was to investigate the existence of a distinct set of pollutant identifiers for pollutant sources such as aircraft, diesel fuel, marine vessels, and the Chevron El Segundo Refinery.

The overall goal of the Demonstration Project's Receptor Modeling task was to assess the feasibility of completing comprehensive source apportionment using a combination of time-tested source apportionment techniques in conjunction with recently developed tools that make use of extremely detailed air quality data.

Air quality receptor models are mathematical models that estimate air quality based on measured concentrations from a monitoring station (or "site"). The Technical Work Plan recommended the use of one traditional receptor model, Chemical Mass Balance (CMB); and two data analysis methods, Spatial Gradient Analysis, and Time Series Analysis. In addition, during the Receptor Modeling work of the Demonstration Project, both Nonparametric Trajectory Analysis (NTA) and Multivariate Receptor Modeling are discussed and/or analyzed.

All analyses were performed using data from the Demonstration Project that was available as of November 9, 2008.

For more information on Receptor Modeling see Section 5.

Complete documentation of the Receptor Modeling Analysis is located in Module K.

2.11 CATEGORIZATION OF TASKS

Although all of the tasks described in Section 2 play important individual roles in the success of the AQSAS and each of the tasks have vital components that cross over into other tasks, there are clear lines that can be drawn that allow all tasks to be condensed into one of three main categories:

- Monitoring
- Data Analysis
- Modeling

All tasks involving monitoring, including the monitoring task, the fuel analysis, and the data management will be referred to as “monitoring” for the purposes of this report. All tasks involving modeling, including off-Airport Inventory, on-Airport Inventory, Dispersion Modeling, and Receptor Modeling will be referred to as “modeling” for the purposes of this report.

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SECTION 3

MONITORING AND SAMPLING

Preparation for monitoring and sampling began with the submission of the Quality Assurance Project Plan (QAPP). This detailed plan document outlined the intended implementation of the monitoring and sampling task including schedule, methodology, equipment, procedures, parameters, analytes, intervals, data collection, data management, quality assurance, and meteorology.

Meteorological data, ambient air monitoring data, and air quality samples were collected for 42 days during July and August of 2008 in order to evaluate data collection methods and equipment. Continuous monitors were deployed to measure minute-by-minute concentrations of NO, NO_2, NOx, O_3, CO, CO_2, SO_2, SOx, NMHC, PAH, PM_{10}, $PM2_{.5}$, UFP, Black Carbon, and Light Scattering. Also, numerous sampling methods were used including Aerosol Speciation Sampler, Carbonyl Sorbent Tubes, Summa Canisters, Heavy Hydrocarbon Sorbent Tubes, MiniVols, Deposition Plates, and Passive Samplers (images of some of this equipment can be seen in Figure 3-1). These sampling methods were utilized in order to analyze for numerous species including O_3, NO_x, NO, NO_2, SO_2, elemental carbon, cations (K, Na), anions (NO_3, SO_4), ammonia (gas + particle), nitrate (gas + particle), sulfate (particle), PAH, Hopanes, Steranes, carbonyl compounds (e.g. formaldehyde, acetaldehyde, methyl ethyl ketone) (i.e. EPA Method TO-11), EPA PAMS protocol compounds (i.e. EPA methods TO-15 and TO-12), chemical elements (e.g., Fe, Cl, Si), and C_{10} – C_{20} hydrocarbons (i.e. EPA Method 8015).

The data collection frequencies of all pollutants that were measured as part of the Demonstration Project are summarized in Table 3-1. The data capture rate (i.e. number of observations recovered as compared to the number of observations planned) for all continuous monitoring equipment used in this study is shown in Table 3-2. The number, type, and location of all samples can be found in Table 3-3. Any changes that were made during field deployment that were not originally stated in the QAPP can be found in Module G.

3.1 SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

Continuous monitoring data was also collected from the South Coast Air Quality Management District (SCAQMD), as described in the TWP. SCAQMD operates an air quality monitoring station within the study area but off Airport property (See Figure 3-2). This site provided valuable monitoring data including NO_x and SO_2 measurements, in one-minute increments, for the months of June and July, 2008. The site is located northwest of LAX and therefore provided the only data from a site that was not surrounded by Airport sources. This site was audited by the Study Team in much the same way sites operated by the Study Team were audited. Data from this site was used only in the assessment of Receptor Modeling techniques.

Figure 3-1

EXAMPLES OF SAMPLING EQUIPMENT

AQSAS—Demonstration Project
Los Angeles International Airport

Table 3-1

OVERVIEW OF PARAMETERS AND MEASUREMENT FREQUENCIES

Los Angeles International Airport

Observable	Sites	Duration	Frequency
Continuous for: $PM_{2.5}$ and PM_{10} mass Carbon Dioxide Carbon Monoxide Sulfur Dioxide	S. Runway and 4 Portable Platform Sites	27 days at S. Runway and 7 days at each of 4 Portable Sites, except for SO_2 which ran for 12 days at S. Runway and 7 days at each of 4 Portable Sites	PM mass – 1-Hr averages CO_2, CO and SO_2 – 1-Min averages
Continuous for: Nitrogen Oxides Ozone Non-methane Hydrocarbons	S. Runway	27 days at S. Runway	Continuous; 1-Min average
Continuous for: Light Scattering Black Carbon Ultrafine Particles Particulate PAH	S. Runway and 4 Portable Platform Sites	27 days at S. Runway and 7 days at each of 4 Portable Sites	Continuous; 1-Min average, Black Carbon 5-Min Average, Light Scattering 1-Hr Average
Diurnal Cycles for: Particulate Elements, Ions Carbon Speciation PAH Compounds, Hopanes, Steranes	S. Runway and 4 Portable Platform sites	7 days at S. Runway and 7 days at each of 4 Portable Sites	Consecutive 12-hr periods (on-shore/ off-shore flows)
Diurnal Cycles for: Aerosol Speciation Carbonyls Heavy hydrocarbons (C_{10} to C_{20})	S. Runway	7 days at S. Runway	Consecutive 12-hr periods (on-shore / off-shore flows)
Daily for: Light hydrocarbons (C_2 to C_{12})	S. Runway and 4 Portable Platform Sites	7 days at S. Runway and 7 days at each of 4 Portable Sites	Every day; 24-hr Sample
Daily for: Particulate Elements, Ions Carbon Speciation PAH Compounds, Hopanes, Steranes	S. Runway	16 days	Every 3rd day; 24-hr Sample
Particle deposition	S. Runway	1-week Episodic	Weekly for 2 weeks
Long-Term Exposure (Passive) for : Nitrogen Oxides Sulfur Dioxide, Ozone	S. Runway	1-week Episodic	Weekly for 2 weeks

Table 3-2
CONTINUOUS MONITORS DATA RECOVERY PERCENTAGE
Los Angeles International Airport

Continuous Monitoring Parameters	Analyzer	Percent Recoveries (%) of Hourly Data *(a)*
Polycyclic Aromatic Hydrocarbons (PAH)	EcoChem Analytics PAS 2000	99.1
Black Carbon (BC)	Magee Model AE-31 Aethalometer	98.5
PM_{10}	Met One BAM-1020 PM_{10} Monitor	76.8 *(b)*
$PM_{2.5}$	Met One BAM-1020 $PM_{2.5}$ Monitor	96.0
Carbon Dioxide (CO_2)	Thermo Electron Corporation Model 410i-D	88.6
Methane	Thermo Environmental Model 55C Methane, Non-Methane Hydrocarbon Analyzer	91.7
Non-Methane Hydrocarbons (NMHC)	Thermo Environmental Model 55C Methane, Non-Methane Hydrocarbon Analyzer	91.5
Carbon Monoxide (CO)	TEI Model 48 Analyzer	91.5
Sulfur Dioxide (SO_2)	Thermo Model 43C SO_2 Analyzer	90.2
Nitrogen Oxides (NO, NO_2, NO_x)	Thermo Electron Corporation Model 42C	91.7
Ozone (O_3)	Thermo Electron O_3 Model 49C	91.7
Light Scattering	Optec NGN-2 Nephelometer	89.6
Ultrafine Particles (UFP)	TSI Model 3091 Fast Mobility Particle Sizer	77.7 *(c)*

(a) Hourly Percent Recoveries are for the entire Demonstration Project.
(b) PM_{10} Monitor recovered 93.9% during SR, PS2 and PS3.
(c) UFP had 96% data recovery during the period August 7 – August 31.

Table 3-3

DEMONSTRATION PROJECT SAMPLE COUNT

Los Angeles International Airport

Number of Samples	SR	PS2	PS3	PS4	PS5	Total	QAPP	Difference
Aerosol Speciation Samples	72	42	42	42	42	240	224	+16 [a]
MiniVol Samples	18	--	--	--	--	18	18	0
Heavy Hydrocarbons - Charcoal	14	--	--	--	--	14	14	0
Carbonyl Tubes - DNPH	14	--	--	--	--	14	14	0
Dry Particle Deposition	2	--	--	--	--	2	2	0
Ogawa Passive Samples	2	--	--	--	--	2	2	0
SUMMA Canister	7	7	7	7	7	35	35	0

(a) During the South Runway monitoring period, the aerosol speciation samplers collected two extra days of samples. This was a result of condensation in the sample line affecting the quartz filters in Train 1 and Train 3 for the first two days of sampling. The moisture caused these filters to tear; therefore, two extra days of samples of Trains 1 through 4 were collected.

Figure 3-2

LOCATION OF SCAQMD AIR QUALITY SITE

AQSAS—Demonstration Project

Los Angeles International Airport

3.2 GAS CHROMATOGRAPH/MASS SPECTROMETRY (GC/MS)

A field-portable GC/MS, on loan from SCAQMD, was used to obtain ambient air VOC samples (30-second, manually collected samples) at all sites. At the SR site the GC/MS was used to sample ambient air proximate to aircraft while taking off and idling. The samples were analyzed with a generic VOC program on the GC/MS system while in the field. The analysis time ran approximately 30 minutes per sample.

Complete documentation of the GC/MS Report is located in Module L.

3.3 CONCLUSIONS ON MONITORING

As stated previously, an essential part of the Demonstration Project was to identify areas of major concern and to assess the technology used in the Demonstration Project in order to put together a most efficient plan for the Long Term Study. There were many lessons learned from the Demonstration Project including corrections or clarifications of previously-made assumptions, realization of unknown obstacles, and development of potential improvements.

One such important realization was at the SR site. The monitoring trailers were located directly behind the blast-fence designed to deflect the high speed air movement that occurs behind jets as they take-off (jet-blast). The SR site location was chosen to provide a site that was unquestionably dominated by aircraft. Once the monitoring program was underway it became obvious that both the jet-blast and the blast-fence have a considerable affect on near-field dispersion. As expected, data collected from the SR site was valuable in searching for pollutants that are present in aircraft exhaust; however, monitoring data from the SR site should not be used in modeling that includes regional wind data. It was also apparent that meteorological data taken at this site is not useful.

As stated in Section 1, in addition to the proposed strategy that was described in the TWP, the Study Team collected and analyzed event-specific samples using a portable GC/MS provided by SCAQMD. These GC/MS measurements provided valuable information showing that the aircraft exhaust during takeoff was different from exhaust during aircraft idle. Mostly notably, aircraft in takeoff mode did not yield hydrocarbon speciation. This realization may affect both the monitoring and the modeling tasks of the Long Term Study.

Also effecting monitoring and modeling is an appreciation for the very short time of events that are being captured. Events such as a single takeoff, taxiing aircraft traveling past a monitor, or the moment of idle between taxiing and taking off can be as short as 10 seconds. Given that the shortest monitoring interval was one minute, these 10-second events will affect modeling and therefore the monitoring protocols. Therefore it is recommended that all monitoring equipment collect data at the shortest possible intervals.

The Demonstration Project results have confirmed that meteorological data are a crucial part of performing a comprehensive source apportionment (discussed in detail in Section 4). Therefore, collection of meteorological data, more specifically wind speed and direction, will be a large part of monitoring during the Long Term Study. Simple meteorological stations can be used; and they do not have to be collocated with monitoring sites. Therefore implementation of a thorough meteorological data collection plan should be considered in the Long Term Study.

3.3.1 Monitoring Sites

During the Demonstration Project the location of sites were determined by the general placement cited in the TWP, coupled with logistical constraints such as access to electricity and requisite clearance from FAA navigational aids. In the Demonstration Project all sites were located on LAWA property. Even so, there were substantial difficulties in providing all the necessary attributes to monitoring sites, and therefore it is expected that providing these attributes for the Long Term Study sites that are not on LAWA property will be a great deal more difficult. Necessary attributes include meteorological adequacy (distance from nearby buildings), ambient air adequacy (distance from sources), electricity, a willing property owner, security, and the site will need to be accessible to the Study Team. Sufficient time in the schedule to pursue the appropriate locations for monitoring will be necessary.

Location of monitoring sites will be discussed in Section 6.

3.3.1 Assessment of Technology

A preliminary assessment of technology is part of the Demonstration Project. This assessment is not meant to be a comprehensive analysis of monitoring and sampling equipment, but instead a list of observations and lessons learned.

There are a number of data sets that were not used in the analysis of Demonstration Project monitoring data. These include (including reasons why data was not used):

- $PM_{2.5}$, PM_{10}, and Nephelometer or light scattering: the data were collected in one-hour increments, which is much longer than the modeling time increments for the receptor models being assessed.

- NMHC: this one-minute data was found to have intermittent, extremely high peaks that did not have a relationship to aircraft. Since further investigation is needed into the source of these peaks, no analysis of this data is provided at this time. Initial hypotheses for this phenomenon include individual GSE, aircraft, or diesel trucks with alarmingly high emissions levels traveled passed the monitor at the time of the peaks, and/or short-term (3 minutes or less) high pollutant level releases from community stationary sources.

- Portable GC/MS Analysis: this data set was used in searching for evidence of a set of indicators but it was found that not all peaks had been identified and therefore further investigation is necessary.

- Samples analyzed for PAMS, TO-11, and TO-15 compounds: these analyses were found to provide no new information about a potential set of aircraft indicators.

- PAH compounds, Hopanes, and Steranes: this data was not available before completion of the receptor modeling task.

Technology that was of particular value were the monitoring of criteria pollutants in one-minute increments at the SR site; CO_2 and SO_2 measurements at the four portable sites; PAH and black carbon measurements at all four portable sites; UFP size measurements/particle counts; the fuel analyses of diesel fuel and Jet-A; and $PM_{2.5}$ samples analyzed for elemental species, elemental carbon (soot), and organic carbon.

Technology that should be investigated in conjunction with the Long Term Study includes:

- All equipment that will provide measurements of pollutants and meteorological information, in one-minute increments or less. One-second data are preferred for SO_2, NO_x, CO_2, CO, and UFP

- Particulate elemental concentrations measured on a time scale of 30 minutes or less

- Potential use of an automated gas chromatograph that can speciate VOCs on a short term basis

SECTION 4

DATA ANALYSIS

An initial data analysis was performed in order to verify the quality of the data and to identify data gaps or other data issues that could affect fidelity or quality. The data analysis also identified which monitored pollutants clearly tracked with aviation activity and which did not. The approach used in this analysis was to examine the pollutant monitoring data for visual evidence of signal tracking using time-series charts.

Three important components to this analysis include, the continuous monitoring data for NO_x, NO_2, NO, CO, O_3, CO_2, CH_4, NMHC, SO_2, PAH, the ratio of nitrogen oxide to nitrogen dioxide (NO/NO_2), and carbon dioxide adjusted for a global constant (CO_2 adj); aircraft activity data collected from the Airport's radar-based Noise Monitoring System; and wind direction developed from one-minute data recorded at the Automated Surface Observing Systems (ASOS) weather station located on the Airport's south airfield.

Wind significantly affects how well a detection signal tracks with aviation activity. When the monitor is located down-wind from the source a stronger tracking signal should be evident. Conversely, when the monitor is up-wind the tracking signal should be weaker if not entirely absent. To capture wind effects that could influence a tracking signal's quality or strength, information on wind direction was incorporated into the qualitative analysis by plotting wind direction for each five-minute averaging interval as a colored background on the chart.

For purposes of this analysis, three wind direction categories were defined which were generally characterized as on-shore, off-shore, and neutral. Figure 4-1 is a diagram illustrating the compass sectors used to define these wind direction categories.

A summary of the tracking of each pollutant with respect to Airport operations is presented in Table 4-1. A series of charts presenting detection monitoring results for selected days at the SR site are provided below. In each chart, the monitoring results are compared to Runway 25R departures. Figures 4-2 through 4-13 present results for the various gas compounds that were monitored at the SR site. This series is based on data for Friday July 18, 2008.

Figure 4-1

COMPASS DIAGRAM FOR WIND DIRECTION CATEGORIES

AQSAS—Demonstration Project
Los Angeles International Airport

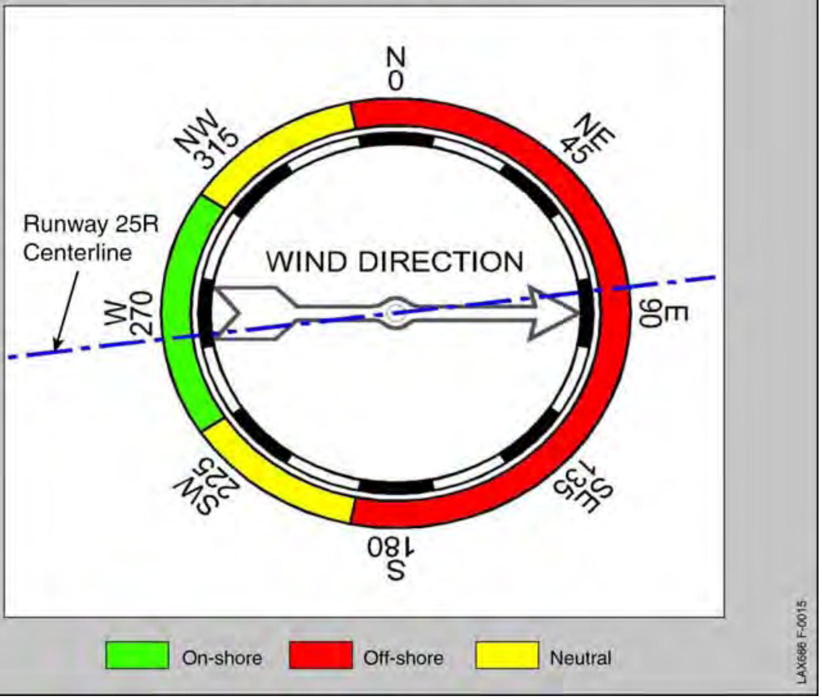


Table 4-1

TRACKING SUMMARY

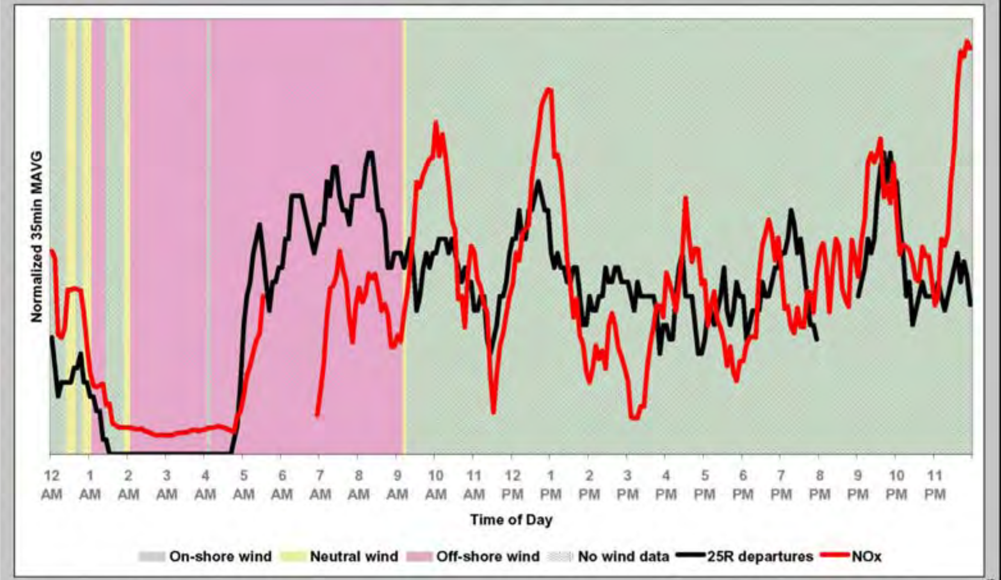
Los Angeles International Airport

Category	Symbol/Tag	Tracking
UFPs	Condensable Particulate Matter	Strong
	Carbonaceous Aircraft Particulate Matter	Strong
	Non-aircraft Particulate Matter	None
Gas compounds	NOx	Relatively strong
	NO_2	Relatively strong
	NO	Relatively strong
	NO/NO_2	Relatively strong
	Co	Relatively strong
	O3	None
	CO_2	None
	CO_2 adjusted	Relatively strong
	CH_4	None
	NMHC	None
	SO_2	Relatively strong
	PAH	Relatively strong

Figure 4-2

NOx COMPARED TO RUNWAY 25R DEPARTURES

AQSAS—Demonstration Project
Los Angeles International Airport



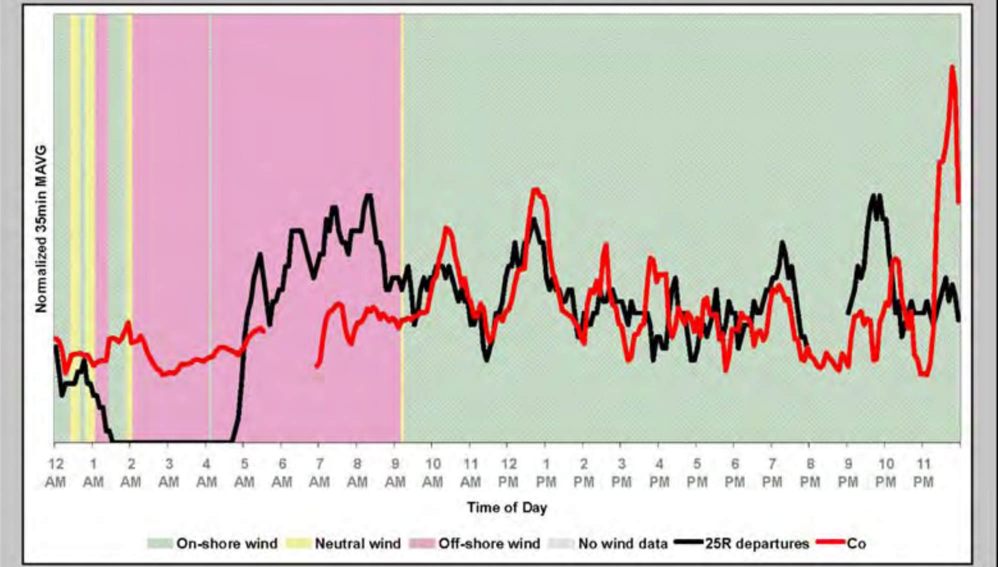
Note: SR, Friday July 18, 2008.
Daily peak value: 0.692 ppm

LAX686 F-0008

Figure 4-3

CO COMPARED TO RUNWAY 25R DEPARTURES

AQSAS—Demonstration Project
Los Angeles International Airport



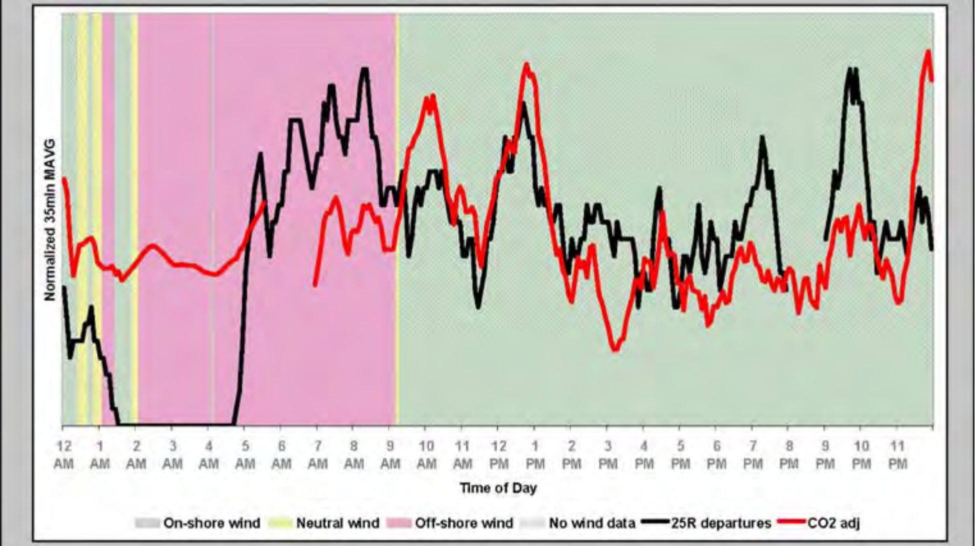
Note: SR, Friday July 18, 2008.
Daily peak value: 3.318 ppm

LAX686 F-0009

Figure 4-4

CO_2 (adj)* COMPARED TO RUNWAY 25R DEPARTURES

AQSAS—Demonstration Project
Los Angeles International Airport



* Detected concentration minus global average baselline of 360 ppm

Note: SR, Friday July 18, 2008.

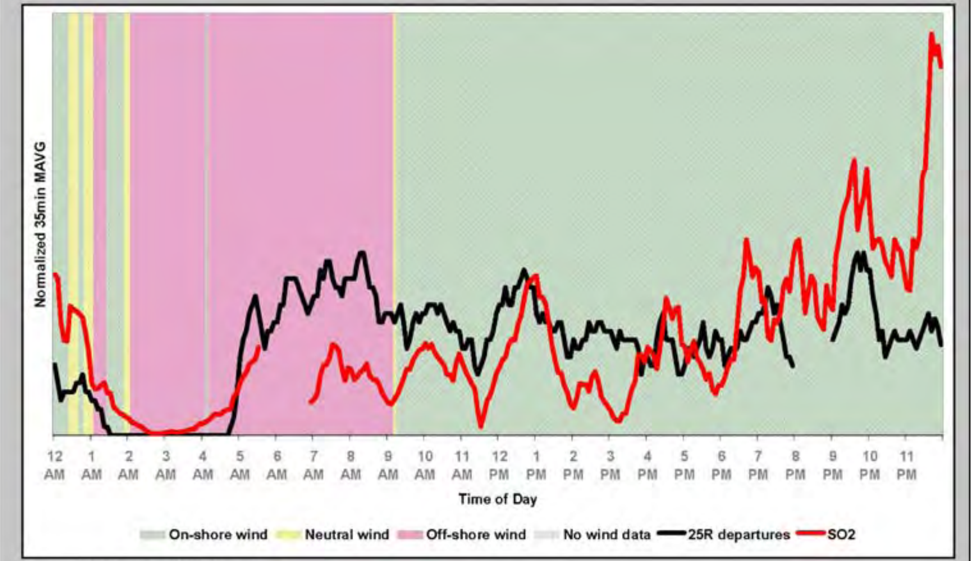
Daily peak value: 244.200 ppm

LAX686 F-0010

Figure 4-5

SO_2 COMPARED TO RUNWAY 25R DEPARTURES

AQSAS—Demonstration Project
Los Angeles International Airport



Note: SR, Friday July 18, 2008.

Daily peak value: 0.106 ppm

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Figure 4-6

PAH COMPARED TO RUNWAY 25R DEPARTURES

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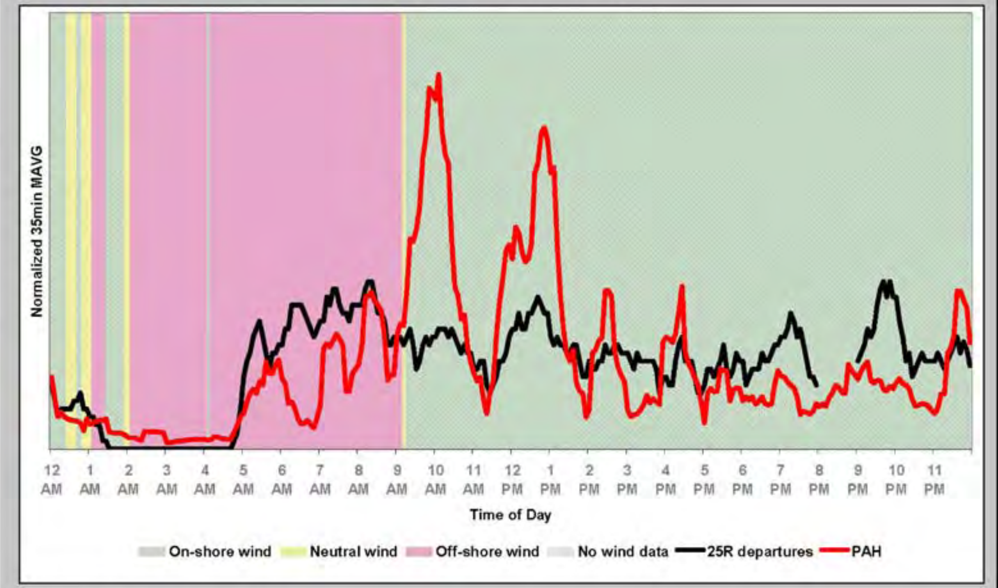

Note: SR, Friday July 18, 2008.
Daily peak value: 521.700 ppm

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4.1 SIGNAL LOSS BETWEEN SR AND P5 MONITORING SITES

The degree to which detected emissions diminish as the distance between source and monitor increases will be an important consideration in (1) setting the detection limits, and (2) locating monitoring sites for the Long Term Study. Data for the SR and PS5 sites were analyzed to provide a preliminary assessment of the amount of detection signal that was lost as emissions traveled the approximately 1,800 feet separating these locations.

Ideally an assessment of signal loss between two locations would analyze data covering the same time period. However, because each site was monitored in sequence there are no results for SR and PS5 that cover the same calendar dates. The following analysis is based on comparing data for two different days that were comparable in terms of aviation activity and wind conditions. For both days the data covers a four-hour period beginning at noon.

The results of the signal loss analysis are presented in Table 4-2. Averages for the detection signal at each site were approximated as the difference between maximum and minimum reported values, i.e., differences between peaks and troughs on a time-series chart covering a comparable four-hour period. With these signal estimates, an indication of the amount of signal loss between the two sites is given by the ratio of average PS5 signal to average SR signal.

Table 4-2
SR/P5 SIGNAL LOSS ANALYSIS

Detected values between 12:00 PM and 4:00 PM

	Monitored Emission					
	Ultra-fine particulates			Gas compounds		
Description	Condensable Particulate Matter (particles per cm3)	Carbonaceous Aircraft Particulate Matter (particles per cm3)	Non-aircraft Particulate Matter (particles per cm3)	CO2 adjusted (ppm) *(f)*	SO2 (ppm)	PAH (fA PAH PID Current Signal)
SR Site *(a)*						
Peaks (c)						
Maximum	23,906,869	559,044	2,621	279.2	0.090	457.6
Average of 5 highest peaks	19,863,325	466,868	2,118	219.4	0.075	383.2
Average of 10 highest peaks	17,970,725	425,732	1,723	199.4	0.067	323.1
Average of 15 highest peaks	16,854,055	387,696	1,551	189.2	0.063	269.7
Average of 20 highest peaks	15,711,285	362,680	1,438	181.6	0.060	237.3
Troughs (d)						
Minimum	28,754	8,310	246	27.9	-	1.5
Average of 5 lowest troughs	7,136,099	152,993	980	117.6	0.032	87.6
Average of 10 lowest troughs	7,443,867	158,874	989	119.7	0.032	90.9
Average of 15 lowest troughs	7,768,832	165,272	1,001	123.8	0.033	96.6
Average of 20 lowest troughs	8,120,102	176,537	1,013	127.6	0.035	100.6
Signal (e)						
Max - Min	23,878,115	550,734	2,375	251.3	0.090	456.1
5 Highest - 5 Lowest	12,727,226	313,876	1,138	101.8	0.043	295.6
10 Highest - 10 Lowest	10,526,858	266,858	733	79.8	0.035	232.2
15 Highest - 15 Lowest	9,085,222	222,424	550	65.4	0.029	173.1
20 Highest - 20 Lowest	7,591,183	186,142	425	53.9	0.025	136.7
P5 Site *(b)*						
Peaks (c)						
Maximum	1,472,187	56,477	1,805	47.4	0.004	42.9
Average of 5 highest peaks	1,221,043	53,403	1,775	43.5	0.003	34.3
Average of 10 highest peaks	1,112,552	47,410	1,740	41.0	0.003	29.2
Average of 15 highest peaks	1,005,518	44,090	1,650	39.2	0.002	26.4
Average of 20 highest peaks	927,809	41,739	1,589	37.8	0.002	24.7
Troughs (d)						
Minimum	22,460	5,192	506	4.3	--	2.2
Average of 5 lowest troughs	483,797	22,486	1,227	17.9	0.001	11.8
Average of 10 lowest troughs	500,760	22,854	1,234	18.3	0.001	12.5
Average of 15 lowest troughs	515,807	23,533	1,248	18.7	0.001	13.0
Average of 20 lowest troughs	531,916	24,518	1,270	19.3	0.001	13.5
Signal (e)						
Max - Min	1,449,727	51,285	1,299	43.1	0.004	40.7
5 Highest - 5 Lowest	737,246	30,917	548	25.6	0.002	22.5
10 Highest - 10 Lowest	611,792	24,556	506	22.7	0.002	16.7
15 Highest - 15 Lowest	489,712	20,557	402	20.5	0.001	13.4
20 Highest - 20 Lowest	395,892	17,221	319	18.5	0.001	11.2
P5 signal percent of SR signal						
Max - Min	6.1%	9.3%	54.7%	17.2%	4.4%	8.9%
5 Highest - 5 Lowest	5.8%	9.8%	48.2%	25.2%	5.6%	7.6%
10 Highest - 10 Lowest	5.8%	9.2%	69.0%	28.5%	5.2%	7.2%
15 Highest - 15 Lowest	5.4%	9.2%	73.2%	31.3%	5.0%	7.7%
20 Highest - 20 Lowest	5.2%	9.3%	75.1%	34.3%	4.4%	8.2%

(a) Data for SR site sampled on Thursday July 17.
(b) Data for P5 site sampled on Thursday August 28.
(c) Highest values detected in 48 5-minute averaging intervals from 12:00 PM to 4:00 PM.
(d) Lowest values detected in 48 5-minute averaging intervals from 12:00 PM to 4:00 PM.
(e) Average of peaks minus average of troughs.
(f) Detected CO2 concentration minus global average baseline concentration of 360 ppm.

SECTION 5

MODELING

Preparation for modeling tasks began with the development of the Source Apportionment Protocol (SAP) that was approved by the TWG. The final SAP is contained in Module B.

The goals of the modeling portion of the Demonstration Project are to:

- Determine significant sources of air pollution and their emissions
- Preliminarily estimate the contribution of LAX sources on air pollution levels
- Provide input to optimize monitor locations
- Identify the methods and measurements that will be most successful in determining LAX's air quality impact

For this project, two types of air pollutant modeling were performed to achieve the stated goals: source-oriented dispersion modeling and receptor modeling. Source-oriented air dispersion modeling requires the input of emissions data for sources of air pollution, the release characteristics of those emissions, and meteorology data and pollutant transport information to estimate downwind pollutant impacts. Receptor modeling techniques utilize measured concentration data at specific locations (i.e., receptors), along with measured meteorological data (including back-trajectories of wind) and emission source characteristics to estimate the contribution of individual sources to measured pollutant concentrations.

Note that despite advancements in meteorology, atmospheric science and chemistry, monitoring techniques, and the aforementioned analysis methods, it is very difficult to discreetly characterize the impact of LAX sources on the ambient air using dispersion modeling, receptor modeling, or both. The meteorology, terrain, and emission sources in the Basin create a complex atmosphere. There is no guarantee that the results will isolate Airport sources from other local, regional, and international sources in the Basin. Nonetheless, a well-conducted study can advance the understanding of the airshed and estimate possible impacts of LAX air emissions on the surrounding communities.

Since the inception of the AQSAS, the scientific approach has been to employ equipment and methods for comprehensive source apportionment that go beyond the established source apportionment tools currently used by the air quality community. The *Receptor Modeling Report* in Module K reviews the feasibility of completing comprehensive source apportionment using a combination of time tested source apportionment techniques in conjunction with recently developed tools that make use of extremely detailed air quality data. This report will show that traditional receptor modeling tools such as Chemical Mass Balance, as well as cutting-edge techniques such as Nonparametric Trajectory Analysis, play a critical role in the accurate apportionment of the Airport's contribution to air pollution in the communities surrounding LAX. This report seeks only to provide the reader with a sense that the AQSAS primary goal of source apportionment is feasible and attainable.

Comprehensive source apportionment will be a process that will involve methodologies that have been evaluated in the Demonstration Project (e.g. CMB and NTA), and methodologies that have not been evaluated in the Demonstration Project (e.g. Spatial Gradient Analysis and Multivariate Modeling). With the use of all models, tools, methods, and weather and pollutant data available it is apparent that source apportionment is feasible if an appropriate data collection program and analysis is implemented.

5.1 DISPERSION MODELING RESULTS

The modeling analyses are used to identify the potential impact patterns and characteristics due to emissions from both Airport-related and non-Airport related activities that may contribute to the air quality in the study area. Both a maximum one-hour concentration contour and a three-month average concentration contour are modeled for the pollutants CO, NO_x, PM_{10}, $PM_{2.5}$, SO_2, and VOC. Details of these modeling analyses are discussed in Module J.

The dispersion modeling results reveal several groups of sources including Chevron's El Segundo Refinery (Chevron), off-Airport Roadways, and Terminal Aircraft Parking Areas as the potential noticeable contributors to the air quality near LAX. Several on-Airport sources (e.g., runways, taxiways, and roadways) also contribute in narrow geographic areas inside or immediately adjacent to the Airport, with a much lower magnitude of impacts. Marine sources do not show significant impacts in the modeled domain.

While impact patterns due to Airport emissions are identifiable and distinctive for most analyzed cases, the high concentrations in the modeling domain can be dominated by contributions from off-Airport stationary sources (e.g., Chevron).

Additionally, the results of the Dispersion Model indicate patterns (i.e., locations and shape of concentration contours with respect to emission source locations) of long-term average (three-month) concentration distributions for the Airport sources are more distinctive than those for short-term (one-hour) averages. Impacts from Airport sources are more apparent in the concentration contour patterns of CO, NO_x, SO_2, and VOC than those of PM_{10} and $PM_{2.5}$. The impacts due to emissions of PM_{10} and $PM_{2.5}$ from off-Airport roads and large off-Airport point source (e.g., Chevron) mask and obscure the impacts due to the on-Airport sources.

Areas of elevated concentration and contour patterns resulting from Airport emissions (e.g., terminal aircraft parking areas, airport roadways, aircraft movements on taxiways and runways) are readily identifiable with little overlap from other source groups (e.g., Chevron or off-Airport roads). This finding is indicative that it will be possible to evaluate the apportionment of Airport sources in areas near the Airport.

Furthermore, the modeling results show the pollutant concentration and culpability at a given point for various contributing source groups could be orders of magnitude different. Thus the selection of monitoring equipment and related detection limits depends on the pollutants of interest (e.g., criteria pollutant vs. speciation of VOC and PM composition), location, and averaging periods (e.g., one-hour vs. three-month). For the six pollutants modeled in this demonstration study, concentrations of interest would be at least ten micrograms per cubic meter. These levels of concentrations should be considered when selecting equipment and detection limits.

This demonstration study provides a promising technical approach/tool for assessing the viability of Airport source apportionment. Recommended technical refinements that will assist future dispersion modeling efforts can be found in Module J. The Chevron emissions show dominant impacts for all modeled pollutants except VOC. The VOC emissions from the terminal gates source group contribute higher impact than the Chevron group. Furthermore, the off-Airport roadway source group shows noticeable impacts for all modeled pollutants along the highways near the Airport (e.g., I-405 and I-105).

The Airport source impacts are more apparently seen in the concentration contours of CO, NO_x, SO_2, and VOC than those of PM_{10} and $PM_{2.5}$. The impacts due to emissions of PM_{10} and $PM_{2.5}$ from off-Airport roads and large off-Airport point sources (e.g., Chevron) may mask or obscure the impacts due to the Airport sources.

Overall, while several off-Airport emission source groups (especially Chevron and off-Airport roadways source groups) are expected to create elevated concentration areas in the vicinity of their own locations, it seems the elevated concentration areas and contour patterns contributable to Airport emissions (e.g., terminal gates, on-Airport roadways, taxiways, and runways) are readily identifiable with little overlapping among the impact areas of interest contributed by other source groups (e.g., Chevron or off-Airport roads). This finding indicates encouraging possibility to evaluate the apportionment due to Airport sources in the nearby areas.

5.1.1 Developing a Robust Emission Inventory

The dispersion modeling is predicated on using publicly available information about off-Airport emission sources. Available information about emissions from Chevron's El Segundo Refinery is extremely limited and often contains only permitted emission rates (not actual emissions). The emissions are quantified, tracked, and reported to SCAQMD, but much of the data may be based on the use of emission factors and other calculations that include many potentially invalid assumptions. Given the importance of accurately establishing Chevron emissions, a likely method for garnering this information will be establishing monitoring sites upwind and downwind of Chevron and the Chevron marine terminal.

The dispersion modeling has only been completed for criteria pollutants because there is very little VOC speciation information for many off-Airport emission sources. Without a complete emission inventory of these emissions, the value of dispersion modeling of these pollutants is diminished. Given the likely futility of continuing to scour emission inventory reports, it may be more efficient to collect GC/MS grab samples at source-dominated locations throughout the study area. These samples would enhance the robustness of the emission inventory for speciated VOCs.

In addition to enhancing the robustness of the emission inventory for speciated VOCs, this approach may help identify indicator characteristics of the various source categories.

5.2 RECEPTOR MODELING RESULTS

5.2.1 Pollutant Species Interaction

5.2.1.1 Pollutant Characteristics

An initial step in determining the feasibility of using receptor modeling to apportion pollutants is to show that certain pollutants track well with aircraft activities and/or each other. Understanding the characteristics of all continuously monitored pollutants is an important step towards understanding the interactions among the pollutants. The following pollutant characteristic information precedes an investigation of pollutant correlations in order to better understand why there is a correlation when there is, and why there is no correlation when there is not.

These pollutant characteristics include:

- The generation of NO_x and NO is typically associated with any combustion source in the study area. For most combustion sources, the emission will be more than 90% NO, which oxidizes quite slowly to NO_2. NO_2, however, may have an atmospheric lifetime of only minutes: under strong sunlight it is rapidly converted back to NO. The chemical reactivity of NO_x makes it important, but usually of limited usefulness for receptor modeling.

- The State of California has implemented a law requiring all diesel fuel to be Ultra Low Sulfur. The only significant Airport-related emissions sources that emit SO_2 are aircraft. This potentially provides an excellent fingerprint of aircraft sources if there are no other major sources of SO_2 affecting the Study Area. However, both Chevron’s El Segundo Refinery and ships located offshore, and several less-significant stationary sources, have been shown to be sources of SO_2 that will complicate the use of SO_2 as an aircraft emissions fingerprint*.

- The production of CO and CO_2 are generally associated with any combustion source in the Study Area. CO_2 measurements in this Study were adjusted by subtracting 380 ppb, the global background CO_2 concentration, to increase emphasis on emissions in the vicinity of the monitors.
- There are no significant sources of ozone emissions in the Study Area. Ozone is generally formed by a photochemical reaction of precursor pollutants, PM, reactive organic gases, and NO_x.
- Diesel vehicles are likely the major source of BC and PAH emissions in the Study Area. The mass emissions of these pollutants from aircraft are likely substantially less than from diesel vehicles.
- Emissions of CH_4 and NMHC can be associated with any of the combustion sources in the Study Area.

Characteristics of UFP for the purposes of this study are much more complicated than the previously-mentioned pollutants. When UFP is characterized at the exhaust nozzle of typical commercial aircraft gas-turbine engines the UFP is found to be predominantly refractory, non-volatile and carbonaceous with diameters ranging from ~20 to 100nm. The particles are products of combustion in the gas-turbine engine and are found to have typical number concentrations on the order of 10^6 particles cm^{-3}. Non-aircraft UFP drawn into the engine with ambient air is also present at the exhaust nozzle. Its number concentrations are orders of magnitude lower than those of the carbonaceous UFP, typically $\leq 10^4$ cm^{-3}, with diameters that tend to cover a broad size range extending up to hundreds of nanometers, well beyond the size range of the engine-generated PM. The thermodynamic conditions at the exhaust nozzle preclude the formation of condensable PM at this location.

Downstream of the nozzle as the exhaust plume expands and mixes with the atmosphere, certain combustion-generated gases in the exhaust flow condense on some of the existing particles causing small shifts in their mean diameters, and undergo gas-to-particle conversion forming new particles. The new volatile UFP are much smaller in size with mean diameters on the order of 10nm. Typical number concentrations of these volatile UFP exceed those of the carbonaceous UFP by factors of 10 to 100. Therefore in the expanding exhaust plume both non-volatile and volatile engine-generated UFP are present. The fate of the volatile species is found to depend strongly on the ambient air meteorology whereas the size and mass of the carbonaceous UFP remain largely unchanged. (Whitefield, 2008)

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*See Task 3 Report, Identify Other Potentially Significant Emission Sources in the Study Area (Aspen, 2008).

Based on these general properties of aircraft UFP, it is reasonable for modeling purposes to examine the UFP measurements in three specific ranges:

- **Condensable particulate matter** (UFP1—the smallest size range)—UFP which includes particulates less than 29.4 nm in size
- **Carbonaceous aircraft particulate matter** (UFP2—the middle size range)—UFP which includes particles greater than 45.3 nm and less than 107.5 nm in size
- **Non-aircraft particulate matter** (UFP3—the largest size range)—UFP which includes particles greater than 191.1 nm and less than 523.3.0 nm in size

The specificity in these ranges is a function of the size categories measured by the monitoring equipment. These size categories output by the monitoring equipment are the nearest sizes corresponding to 30 nm, 50 nm, 100nm, 200nm, and 500 nm. It also is noted that Total UFP includes all sizes, not just these three ranges.

A paper published in 2002 (Yifang, 2002) shows that UFP size distribution near freeways in Los Angeles (i.e. diesel-related) has two peaks—one at about 12 nm and the other centered at about 30 nm, with most particles ranging from 20 to 40 nm. UFP from diesel vehicles are a potential interfering factor at community sites that are closer to major roadways than the Airport runways.

5.2.1.2 Correlation of Species Measurement

In the AQSAS's recent report on Analysis of Air Quality Emissions Data a comparison of pollutant measurements was made with aviation activity and demonstrated strong relationship between aircraft activity and pollutant measurements. It is also important to consider the relationship of multiple pollutants. This section looks at the relationship in the variation of four monitored pollutants. When evaluated at each of the monitoring locations, this reveals information about the nature of the pollutant sources. The following analysis is preliminary; a more complete analysis using advanced statistical methods such as Principal Component Analysis would be valuable.

Table 5-1 provides a summary of the statistical relationship of the UFP measurements with three monitored pollutants; NO, SO_2, and PAH. The values in the table reflect the minute-by-minute correlation of the data for each of the monitored pollutants with that of each category of UFP. A value of 1.00 indicates that the two pollutants vary uniformly, while a value of zero indicates there is no relationship in the variation of the two pollutants being considered. The values shown in the table represent all of the collected data and have not been corrected for wind direction or differing numbers of observations.

Table 5-1
CORRELATIONS OF UFP SIZE CATEGORIES

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Nitrous Oxide (NO)

	SR	PS4	PS5
UFP1	0.605		
UFP2	0.469		
UFP3	0.060		
UFP Total	0.611		

Sulfur Dioxide (SO_2)

	SR	PS4	PS5
UFP1	0.756	0.836	0.601
UFP2	0.535	0.670	0.666
UFP3	-0.045	0.028	0.220
UFP Total	0.761	0.846	0.629

Polycyclic Aromatic Hydrocarbons (PAH)

	SR	PS4	PS5
UFP1	0.345	0.465	0.435
UFP2	0.495	0.798	0.667
UFP3	0.011	-0.022	0.080
UFP Total	0.358	0.488	0.468

Note: SO_2 correlation at SR are based on approximately two days of data collection
NO and PAH correlations at SR are based on approximately 10 and 12 days of data collection, respectively.
PS4 correlations are based on approximately 10 days of data
PS5 are based on approximately eight days of data.

The pollutants were selected because they each can generally be associated with an emission source (i.e. supporting apportionment). The UFP is most likely to be generated by aircraft or diesel-powered vehicles. The NO is associated with fuel combustion near an emission source (further downwind it is converted to NO_2) and thus is most likely to be generated by aircraft or diesel-powered vehicles. The SO_2 is most likely generated by aircraft, but significant sources in the area include the

Chevron refinery and the Marine Terminal. Finally, the PAHs are most likely to be emitted by diesel-powered vehicles such as GSE and on-road trucks.

From Table 5-1 it is noticed that UFP1, UFP2, and UFP Total have much stronger correlation to the measured pollutants than UFP3. There are two conclusions from this observation:

1. UFP3 is comprised primarily of non-aircraft sources and should only show strong correlation when pollutant measurements are not dominated by aircraft—thus SO_2 measurements are likely aircraft-dominated
2. UFP measurements are of particle count and thus UFP Total is dominated by UFP1 and UFP2 (mass emissions of UFP Total may not show this trend).

UFP1, UFP2, and Total UFP are well correlated with both SO_2 and NO in all of the comparisons indicating that the main source of UFP1, UFP2, SO_2, and NO in these measurements is jet exhaust. The data also demonstrate that this correlation (indicative of aircraft exhaust) is seen at the most distant monitoring site, PS5. Thus, while the particle counts for UFP1 and UFP2 may be affected during the time taken to travel to PS5, it is clear that both the UFP and SO_2 measurements at these sites are dominated by aircraft exhaust.

UFP1 and Total UFP are not well correlated with PAH indicating that these pollutants are associated with different emission sources. Since the comparison with SO_2 and NO indicated that UFP has a strong association with aircraft exhaust, PAH in these measurements is likely associated with diesel vehicles and not aircraft. The diesel vehicles most likely emitting the PAH are either GSE or on-road trucks. This conclusion is corroborated by separate analysis of this data set that showed PAH and BC are very closely correlated at all sites.

UFP2 has a weaker statistical correlation with SO_2 than UFP1, although there still is a strong relationship. This is indicative of additional sources of UFP2 being part of the UFP2 measurements. It is also noted that UFP2 has a stronger correlation with PAH than SO_2 at PS4. Diesel equipment is thought to be the most likely source of UFP2 emissions that contain minimal SO_2 but substantial PAH. This indicates that some of the measured UFP2 could be generated from GSE at the SR site and from trucks traveling on Aviation Boulevard at the PS4 and PS5 sites. It is also noted that emissions from the diesel generators used at PS4 and PS5 could be affecting this correlation during periods with atypical wind patterns (i.e. nighttime winds from the east). Regardless, this correlation suggests further examination of whether diesel UFP emissions are a significant component of the measurements in the UFP2 size range

Figures 5-1 and 5-2 graphically represent a small fraction of the data that are summarized by Table 5-1. These figures demonstrate the rapid fluctuations in the data and the importance of one-minute data. It can also be surmised that the presence of a strong statistical correlation for the minute-by-minute time series of air quality data provides information about the pollutant sources. It is also clear UFP size data contains helpful information.

The data shown in Figures 5-1 and 5-2 was collected at the PS4 site on August 20 and 21, 2008. In both figures, the concentrations have been normalized by the average values, so 3 means three times the average.

Figure 5-1(a) is a plot of the SO_2 and UFP1 data for the middle of the day on August 21. Figure 5-1(b) is the time series of PAH and UFP2 for the same period. The figures show a remarkable minute-by-minute relationship between SO_2 and UFP1 and PAH and UFP2. As can be seen by comparing Figure 5-1(a) with Figure 5-1(b), there is much less relationship between the measurements contained on the two charts. At the time this data was collected, the wind was blowing directly from the south runways toward the PS4 site. The SO_2 can be assumed to be almost entirely from jet exhaust, and thus the UFP1 is also likely to be coming predominately from jet exhaust. This indicates that different emission sources contribute to the PAH and UFP2 measurements than contributed to the SO_2 and UFP1 measurements at PS4 during this period. The likely sources of PAH are diesel vehicles on nearby Aviation Boulevard and the Airport service road that runs parallel to it. The similar trends between PAH and UFP2 corroborates the conclusion that the PAH and UFP2 in this time series at this monitor are dominated by diesel exhaust. Further, it supports the observation on the correlations in Table 5-1 that UFP2 measurements may be influenced by diesel emissions.

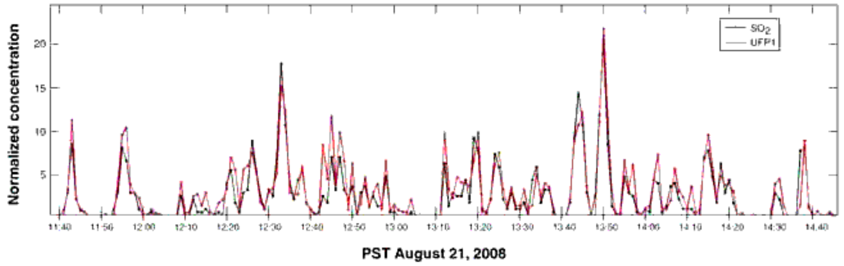
Different sources begin to impact the PS4 site when the wind direction changes. This is shown in Figure 5-2 which contains two plots similar to Figure 5-1, but for the time period 21:00 on August 20 to 12:00 on August 21. During this period, the winds veered from the typical daytime pattern of a westerly sea breeze to coming out of the north, east, and south. The winds finally return to a westerly flow at 10:00. Thus, during the period before 10:00 Airport emissions do not directly impact the monitoring site. This is indicated by the lack of similarity between SO_2 and UFP1 as seen in Figure 5-2(a) and by the lack of sharp peaks that characterize the discrete pollutant events resulting from aircraft takeoffs. Figure 5-2(b) also shows a breakdown of the similarity between UFP2 and PAH, indicating that the pollutant measurements are dominated by different emission sources than those depicted in Figure 5-1.

Figure 5-1

EXAMPLE OF POLLUTANT CORRELATION DURING DAYTIME PREVAILING WIND PATTERNS

AQSAS—Demonstration Project
Los Angeles International Airport

5-1 (a): SO_2 and UFP1 at PS4



5-1 (b): PAH and UFP2 at PS4

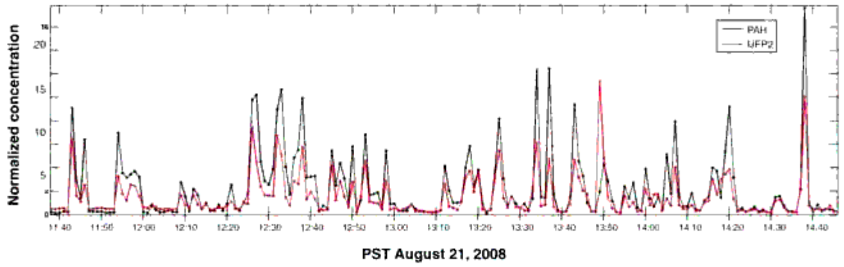


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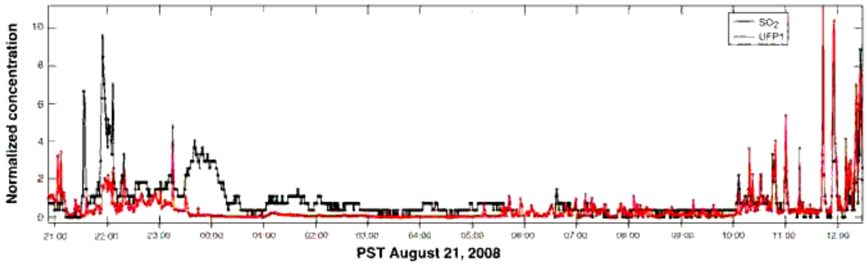
Figure 5-2

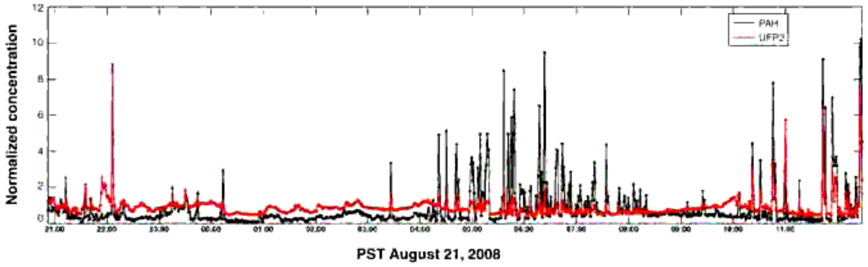
EXAMPLE OF POLLUTANT CORRELATION DURING NIGHTTIME PREVAILING WIND PATTERNS

AQSAS—Demonstration Project
Los Angeles International Airport

5-2 (a): SO_2 and UFP1 at PS4



5-2 (b): PAH and UFP2 at PS4



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5.2.2 Distinct Set of Indicators

Chemical Composition Receptor Models seek to quantitatively distinguish several emission sources based on a mass balance of several chemical components (i.e. particulate matter and volatile organic gases). Thus, these receptor models cannot distinguish a source of pollutants that is similar to another source of pollutants, or a source of a single measured pollutant (e.g. SO_2, or CO) since these have no markers to distinguish between the emissions from one source or another.

Successful application of CMB requires that each of the sources have distinct chemical composition signatures or "set of indicators". To evaluate the applicability of CMB as an apportionment technique, this section examines the use of SO_2, UFP, PAH, BC, VOCs, PM composition, and the analysis of fuel samples to find indicators of sources.

It was found that the average concentrations for SO_2 and UFP at the PS4 and PS5 sites are about a fifth to a tenth of the concentrations at the SR site. As described in Section 4.2.1, these species correlate with aircraft and therefore this ratio of decreased concentration is indicative that a pollutant is associated with aircraft exhaust. Because of this, a species is considered to be dominated by aircraft emissions if the ratio of its mean at PS4 and PS5 to the SR mean is in the range of 5 to 10.

The average concentrations of PAH and BC decrease more slowly with distance, indicating a more complicated geometric configuration of emission sources relative to the monitoring locations. This could be indicative of sources of PAH and BC either upstream or downwind of the SR site. However, since the difference in values between PS4 and PS5 is nearly a doubling, this indicates a significant portion of the PAH and BC measured at PS4 and PS5 comes from a source downwind of the SR site. Indeed, there is significant diesel vehicle traffic on Aviation Boulevard, a north-south roadway between the SR site and the PS4 and PS5 sites. Thus Aviation Boulevard is downwind of the SR site but upwind of PS4 and PS5 sites during the prevailing daytime winds. This diesel vehicle traffic is the likely source of the additional PAH and BC at PS4 and PS5.

PAMS VOC concentrations were studied for all sites during the Demonstration Project. No two monitoring locations were collecting data at the same time, yet still no species are clearly 5 to 10 times higher at the SR site that could be the basis for a distinct aircraft signature. A possible exception is styrene (which could be related to aircraft exhaust) as it is the only species that is seen in all seven samples at the SR site but is not seen at the PS5 site and only reported once at the PS4 site. However, the levels of styrene measured at the SR site are in the range that is commonly observed in the Los Angeles area.

Similar to the PAMS compounds, the TO-15 and TO-11 compounds did not measure concentrations at the SR site that were substantially greater than measured at the other sites. The implication is that none of these compounds are dominated by aircraft emissions and thus cannot be a basis for a distinct signature for aircraft.

Samples of Jet-A, unleaded gasoline, and diesel fuel used by construction equipment, and diesel fuel used by GSE were subjected to several types of analyses in order to search for an indicator for exhaust from the chemical composition of the fuel (i.e. species that could comprise a distinct aircraft signature will have much higher concentrations in Jet-A fuel than diesel or unleaded gasoline).*

Analysis with the EPA Reference Method 8260 showed that concentrations of the trimethylbenzenes and xylenes are much higher in Jet-A than in diesel, and could be used to separate jet aircraft emissions from diesels. However, gasoline has very high concentrations of these species, thus using these as indicators may cause complications.

The fuel samples were also analyzed by GC/MS, maximizing the number of chemical species that can be uniquely identified and measured. The high carbon number species, dodecane and above (10 or more carbons) are seen to be very low in gasoline, but not in Jet-A or diesel fuel and can be used in receptor modeling of VOCs to separate gasoline from Jet-A and diesel fuel. Also, a number of species have much higher concentrations in Jet-A than diesel. Note that there are three dimethyl-2, 3-dihydro-1H-indenes that have concentrations of about 1 percent in Jet-A that are very low in diesel fuel. These explain most of the total indene concentration in Jet-A of about 3.1 percent. Total indenes in the diesel fuels are 0.7 and 1.5 percent. The two largest indene species in diesel are quite different from the Jet-A indene species; thus, the dimethyl-2, 3-dihydro-1H-indenes are potentially dominated by jet aircraft VOC emissions and could be a part of a set of indicators for jet aircraft.

$PM_{2.5}$ samples were analyzed for elemental species using the x-ray fluorescence (XRF) method. Nickel, chromium, and copper were found to be higher at the SR site than the other sites. However, examination of the data shows that the nickel and chromium have just one extremely high value at the SR site; if this one value is discounted, then nickel and chromium are not unusually high at this site. This leaves copper as the only species that is consistently and significantly higher at the SR site.

$PM_{2.5}$ samples were also analyzed for elemental carbon (soot) and organic carbon by a method used in the Interagency Monitoring of Protected Visual Environments (IMPROVE) network of air monitoring sites. The IMPROVE method measures the organic particulates in four ranges (O1 – O4) according to the temperature at which the particulate sublimates when it is heated. Three different ranges of elemental carbon (E1 – E3) are also quantified by the IMPROVE method. It is clear from the study data that there is an increased concentration of particulates at the SR site compared to the other sites, comprised of elevated levels of both organic and elemental carbon. This would suggest that organic and elemental carbon are both important components of jet exhaust and is consistent with the observations in the APEX series of experiments. Still unknown is if the ratios of the various ranges of organic carbon and elemental carbon in jet exhaust constitute a distinct set of indicators (compared to other sources). The presence of a set of indicators is

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*A complete list of analyses and results can be found in Module E.

possible, but more information is needed on the values of the organic and elemental carbon ranges for diesel, gasoline, and other sources in the Study Area.

In the Long Term Study, with data from many samples, an MVR receptor model may be able to discern a distinct set of indicators from these species for various sources, including jet exhaust. However, it is a concern that the organic/elemental carbon fingerprints for jet exhaust and diesel exhaust may not be unique.

Details of this investigation can be found in Module K.

5.2.3 Nonparametric Trajectory Analysis

Nonparametric Trajectory Analysis (NTA) allows for determining the location of nearby sources of specific pollutants in the area surrounding an air quality monitor based on one-minute observations of the pollutants and wind speed/direction. This method can be performed using data from one monitoring site and one meteorological site, but more robust information about local sources can be garnered with additional monitoring and meteorological sites.

NTA uses wind speed and direction to calculate the trajectories (or paths) from which monitored pollutants have come (these are referred to as "back-trajectories"). When wind passes over a pollutant source it carries the pollutants in the direction of the wind, creating a plume. Ultimately, the pollutants in a plume can be measured by air quality monitors. The NTA back-trajectories are used to determine the source of the pollutants that have been detected by monitors by tracing the path of the plume.

In the Demonstration Project, the NTA method was applied to the monitored data for SO_2, UFP, BC, and PAH from all sites that had data available except the SR site, and SO_2 and NO_x from the SCAQMD site. Since concentrations and meteorological conditions at the SR monitor are dominated by aircraft jet blast and the blast deflection fence, it is inappropriate to analyze the SR data using NTA.

If a unique set of indicators for aircraft exhaust cannot be identified, separating sources based on geographical location may be feasible using NTA.

DISCLAIMER

THE NTA RESULTS ARE DISCUSSED NEXT. BEFORE READING AHEAD THE READER IS STRONGLY ADVISED THAT THIS METHOD IS STILL UNDER DEVELOPMENT AND ITS APPLICATION HERE IS EXPERIMENTAL. THE READER IS ESPECIALLY CAUTIONED IN THIS CASE SINCE THE METHOD WAS ORIGINALLY DESIGNED TO WORK WITH THREE MONTHS OF ONE-MINUTE DATA FROM MONITORING STATIONS THAT ARE NOT WITHIN ONE KILOMETER OF MAJOR SOURCES. IN THIS DEMONSTRATION PROJECT, THERE ARE ONLY A FEW DAYS OF DATA AT EACH SITE AND THERE ARE SOURCES WITHIN HUNDREDS OF METERS OF THE MONITORS. THE RELATIVELY SMALL AMOUNT OF DATA MAKES IT IMPORTANT NOT TO INTERPRET EVERY HIGH POINT OR PEAK IN THE PLOTS. THESE COULD BE THE RESULT OF WORKING WITH TOO FEW DAYS OF DATA OR JUST THE EFFECT OF A FEW ERRANT DATA POINTS.

The NTA-derived contour maps are discussed in detail in Module K. For the purposes of this summary only SCAQMD results are highlighted.

Contour maps are superimposed on a base map of the area showing the coastline, the major freeways, the north and south runways, and the El Segundo Marine Terminal, and are centered on the location of the monitor. The areas without color were either not covered by the two-hour back trajectories calculated in this analysis, or the NTA value at that grid point was not significantly different from zero. These zero values in the NTA results at specific grid points are usually caused by too few data points where the detected air at the monitoring station had passed over the specific grid point (i.e. too few back-trajectories cross the specific grid point). The NTA results for each grid point are indicated by the colors in the figures.

The NTA values (i.e. color indicators in the figures) represent the average pollutant concentration measured at the monitor for air samples whose back-trajectory included that grid point. High values (shown in orange and red on the figures) are expected to be associated with pollutant sources, but the high values on the NTA map may extend past the source area itself if wind patterns consistently result in the same trajectory between the source and the monitor.

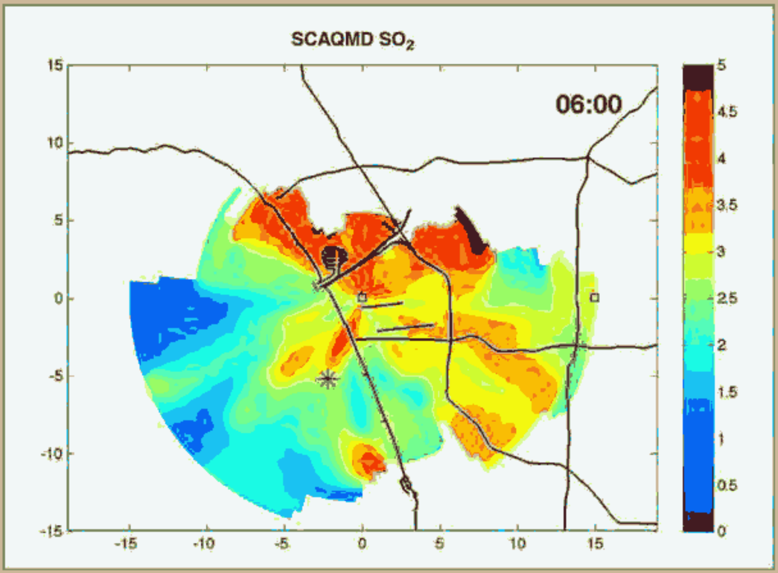
All relevant data from the SCAQMD site during the 61 days of the Demonstration Project for NO_X and SO_2 were analyzed using NTA. This generous amount of data made it possible to study diurnal patterns in the NTA. The diurnal differences at this location provide the ability to see individual emission sources since the site is very near the coastline and subject to sea breezes (primarily during the late morning and into the early evening, strong winds blow from the sea inland) and land breezes (late evening and early morning the winds reverse and flow more weakly from the land to the sea). This reversal of wind direction has a major influence on which emission sources impact the air quality measurements. During a sea breeze in the daytime hours the sources identified by NTA are offshore. Conversely, during a land breeze, typically at night, the sources discovered by NTA are inland, and were found to be east and north of the site.

These results are shown in Figures 5-3 through 5-6. Figure 5-3 shows that at 06:00 high concentrations of SO_2 are associated with air from all directions, including LAX, but primarily air coming from the north. Figure 5-4 shows that at 10:00 the sea breeze is becoming dominant (reflected in the lack of data from the east) and the possible influence of the El Segundo Marine Terminal can be seen to the southwest. Figure 5-5 shows that at 12:30 the sea breeze is fully established and what appears to be the influence of aircraft taking off from the north runways can be seen. Finally, Figure 5-6 shows that at 23:00 the shift to a land breeze from a sea breeze is seen, showing on and offshore sources.

Figure 5-3

NTA ANALYSIS OF SO_2 FOR SCAQMD SITE FOR ALL ONE-HOUR PERIODS IN JUNE AND JULY 2008 STARTING AT 6:00

AQSAS—Demonstration Project
Los Angeles International Airport



✳ Signifies the location of the El Segundo Terminal.

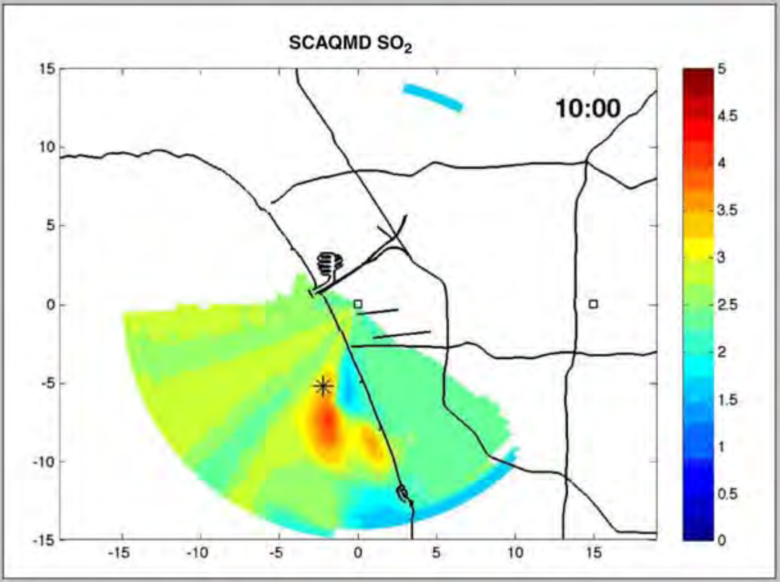
Note: Black lines are the coastline, major freeways, and the north and south runways.

LAX664 F-0015

Figure 5-4

NTA ANALYSIS OF SO2 FOR SCAQMD SITE FOR ALL ONE-HOUR PERIODS IN JUNE AND JULY 2008 STARTING AT 10:00

AQSAS—Demonstration Project
Los Angeles International Airport



✳ Signifies the location of the El Segundo Terminal.

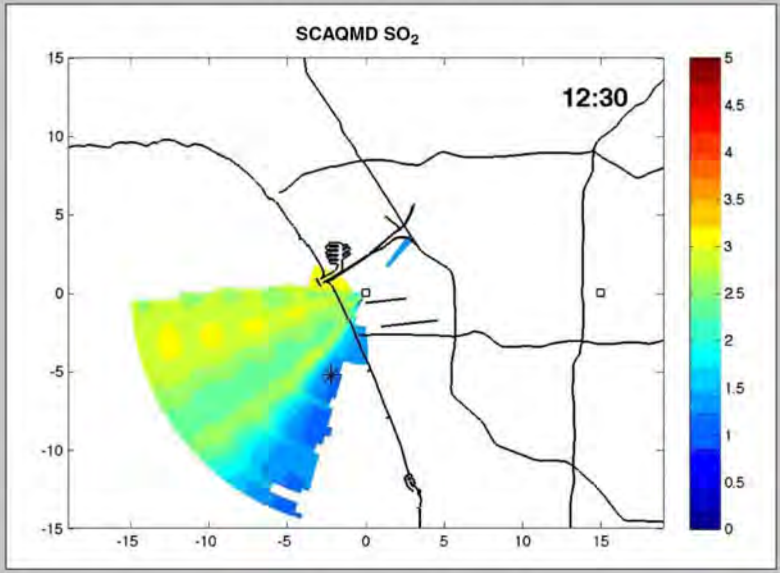
Note: Black lines are the coastline, major freeways, and the north and south runways.

LAX686 F-0016

Figure 5-5

NTA ANALYSIS OF SO2 FOR SCAQMD SITE FOR ALL ONE-HOUR PERIODS IN JUNE AND JULY 2008 STARTING AT 10:30

AQSAS—Demonstration Project
Los Angeles International Airport



✳ Signifies the location of the El Segundo Terminal.

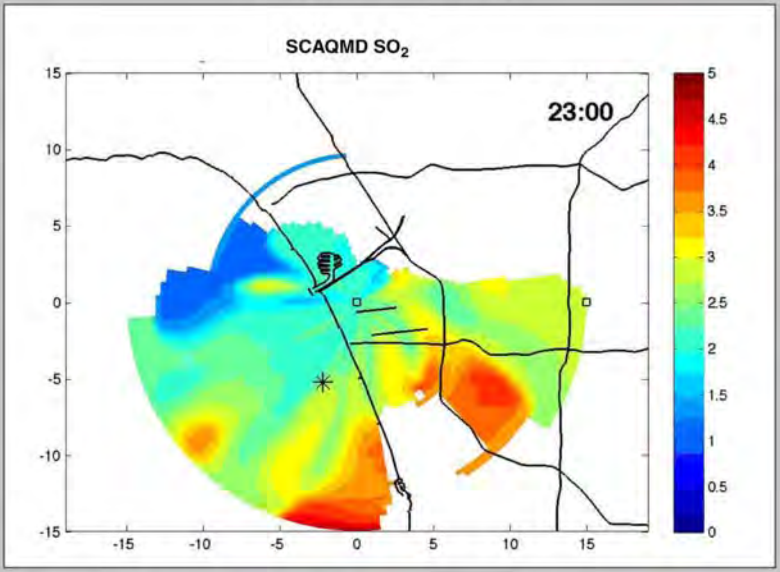
Note: Black lines are the coastline, major freeways, and the north and south runways.

LAX686 F-0017

Figure 5-6

NTA ANALYSIS OF SO2 FOR SCAQMD SITE FOR ALL ONE-HOUR PERIODS IN JUNE AND JULY 2008 STARTING AT 23:00

AQSAS—Demonstration Project
Los Angeles International Airport



✳ Signifies the location of the El Segundo Terminal.

Note: Black lines are the coastline, major freeways, and the north and south runways.

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SECTION 6

ROADMAP TO APPORTIONMENT (CURRENT STATUS)

It is important to understand that not all questions can be answered in the Demonstration Project. This report seeks only to provide the reader with a sense that the AQSAS primary goal of source apportionment is feasible and attainable. Comprehensive source apportionment will include use of all methods that have been discussed in this report (e.g., Dispersion Models and Receptor Models). With the use of all models, tools, methods, and weather and pollutant data available it is apparent that source apportionment is feasible if an appropriate data collection program is implemented.

It has been demonstrated that within close proximity to the Airport, SO_2, NO, and UFP1 are all very highly correlated with each other, and that the source of those pollutants is aircraft. It has also been determined that the source of BC and PAH is likely diesel-powered vehicles. Contradictory evidence has been found that the source of UFP2 within close proximity to the Airport may be dominated by aircraft and may be dominated by diesel vehicles. The dominant source of UFP2 and its utility in source apportionment will have to be investigated further. The overwhelming evidence is that UFP3 does not correspond to aircraft.

Results of the Demonstration Project have shown that collecting one-minute or shorter pollutant data wherever possible and reducing sample collection times to the shortest possible increments is imperative to the success of the Long Term Study. Also noteworthy will be an effort to gain greater understanding of the UFP size distribution for source categories. Analyzing the UFP2 data for inter-pollutant correlations (time series), NTA modeling, and CMB indicate that there may be more overlap in UFP size distribution of the aircraft and diesel sources than recognized in current literature. Resolving this understanding of UFP size categories will play an important role in source apportionment and therefore equipment that collects this data in one-minute increments or shorter should be used as extensively as possible in the Long Term Study. It was also found that one-minute meteorological data and a detailed video record of aircraft, GSE and airfield roadways will play key roles in the Long Term Study.

The analysis shown in this report has indicated that it is possible to identify pollutants from aircraft exhaust (during prevailing wind patterns) even as the monitoring stations get farther away from the source and these pollutants cross over a major source of diesel vehicles (e.g., GSE use and Aviation Boulevard). The analysis has also shown that it is also possible to discern aircraft pollutants from roadway pollutants. In addition to this time-series analysis, preliminary results of NTA have shown that the potential exists to separate SO_2 by source location. Together these results indicate that it is possible to evaluate the apportionment of aircraft sources near the Airport.

6.1 ROLE OF RECEPTOR MODELING

It is a requirement for both CMB and MVR that aircraft have a distinct set of pollutant indicators in order for either model to provide a quantitative apportionment of aircraft sources. This is because for CMB the indicators must be known, and for MVR if there is no distinct set of indicators aircraft will be combined with diesel sources in the apportionment.

Table 6-1 summarizes the results of the search for distinct indicators of Airport-related sources (e.g. aircraft, gasoline, and diesel). This investigation, fully described in Module K, has identified a number of pollutants that are potential indicators. These pollutants are in essence "rated" with green indicating strong applicability for the Long Term Study, yellow indicating further investigation needed but still good potential for use in the Long Term Study, and red indicating these potential indicators will not be key components used in the Long Term Study.

The use of NTA in the Demonstration Project was presented solely to demonstrate its capabilities and not to deduce any information about the location of sources in the communities surrounding LAX, nor to provide any source apportionment. NTA will be a valuable tool in source apportionment and in particular its capacity to geographically separate pollutants that are not unique to one source. NTA can also provide invaluable information on any unidentified sources in the Study Area. NTA captures the spatial complexity and temporal dynamics of sources better than other receptor models, but more work is needed to fully utilize the information in NTA when applied to sites on Airport property and monitoring locations proximate to a dominant source of emissions.

Table 6-1

POTENTIAL INDICATOR POLLUTANTS FOR APPORTIONMENT

AQSAS - Demonstration Project
Los Angeles International Airport

Potential Indicators	Characteristic Source	Applicability for Apportionment	
Black Carbon	Diesel	Direct relationship to diesel	Candidate for Apportionment
SO_2	Aircraft / Marine / Chevron	NTA can geographically separate these competing sources	
UFP3	Diesel	Direct relationship to diesel	
Dodecane and above (10 or more carbons)	Possibly Aircraft / Possibly Diesel	Useful in isolating gasoline	
PAMS plus high m.w. Carbons	Gasoline / Diesel	Delineate gasoline and diesel	
Nickel	Marine	Delineates PM from heavy fuel oil combustion from ships	
Chromium	Marine	Delineates PM from heavy fuel oil combustion from ships	
NO	Combustion	Only conservative near the source	Possible species for apportionment, but further study required
Total UFP	Diesel / Aircraft	Dominated by low mass, high count small UFP	
UFP1	Diesel / Aircraft	Not conservative over longer distance	
UFP2	Aircraft / Shoulder of diesel	Correlation to PAH indicated may not be unique to Aircraft	
Styrene	Possibly Aircraft	Styrene is the only PAMS species that is consistently detected at the SR site but not any other, therefore indicating that it is aircraft dominated	
Trimethylbenzenes	Possibly Aircraft / Possibly gasoline	Trimethylbenzenes were found to be higher in Jet-A than diesel fuel. However, gasoline has very high concentrations of these species and therefore these species are not likely to be unique to Jet-A	
Dimethyl- 2, 3-dihydro-1H-indenes	Possibly Aircraft	Further field measurements required	
Organics and Elemental carbon in particulates	Gasoline/ Diesel / Possibly Aircraft	Further field measurements required	
PAH (Continuous)	Diesel / Gasoline / (Aircraft small)	Not unique to any source	Not candidate for apportionment
NO_x	Combustion	Not unique to any source	
CO	Combustion	Not unique to any source	
CO_2	Combustion	Not unique to any source	
NMHC	Combustion	Not unique to any source	
Xylenes	Gasoline / Possibly Aircraft	Xylenes were found to be higher in Jet-A than diesel fuel. However, gasoline has very high concentrations of these species and therefore these species are not likely to be unique to Jet-A	
Copper		Not likely to produce a fingerprint	
PAH (Samples)	Diesel / Aircraft	No information available at time of report	No data available
Hopanes	Diesel	No information available at time of report	
Steranes	Diesel	No information available at time of report	

6.1.1 Apportionment of Aircraft (Jet-A)

Analyzing SO_2 data provides the best hope for separating aircraft engine impacts from heavy-duty diesel emissions, but only if NTA is used to separate out the impact of offshore sources and refineries. Based purely on the chemical makeup of SO_2, it is impossible to distinguish between multiple SO_2 sources. Thus NTA becomes an important tool in the ultimate goal of source apportionment. NTA has the ability to geographically locate the sources of SO_2 that are being detected at a monitor and therefore apportion SO_2 to more than one source. SO_2 can generally be treated as a conservative species over short time periods (about 1 hour). However, SO_2 can react rapidly in fog droplets with ozone and hydrogen peroxide. This will have to be taken into account in the Long Term Study. If NTA is to be used in this manner, background sites near the coast for the daytime data and inland for nighttime data are needed to help identify and eliminate the impact of refineries, off-shore sources, and regional emissions.

Aircraft are a dominant source of UFP at the monitoring sites in the Demonstration Project and their size distribution is different than UFP from diesel sources. Complete delineation between these sources is limited by overlap in the smallest particle sizes and the proximity of the peaks associated with the slightly larger particles. According to available literature, one of the peak particle sizes for diesel PM is about 30 nm, while a peak particle size for aircraft is about 70 nm. This proximity results in some overlap in the "tails" of each size distribution curve.

The size distribution curve for aircraft-generated UFP has a very narrow Gaussian distribution of particle size, potentially allowing for separation of aircraft emissions from diesel sources or ships. However, scientifically understanding the fate and transport of those particles is essential to using UFP measurements for apportionment, either qualitatively or quantitatively. UFP are inherently unstable in the atmosphere and are destroyed through interactions with surfaces. An understanding of the relative conservation of UFP compared to resident time in the atmosphere is essential if UFP are to be used for quantitative source apportionment.

The mass emission index of UFP contained in aircraft exhaust has been determined to be stable over distances of 1,000 meters during the APEX experiments (Whitefield, 2008). However particle counts were not stable in this period. Since UFP mass emissions are dominated by large particles (i.e., larger than from aircraft emissions), measurement of UFP mass emissions may not quantitatively apportion aircraft emissions.

Thus, for very short travel times UFP counts can likely be used for quantitative apportionment of jet aircraft. But since UFP counts are not conserved, they will only be useful as qualitative indicators of aircraft impact, and will not likely be the basis of a quantitative source apportionment.

6.1.2 Apportionment of Motor Vehicles (Diesel versus Gasoline)

Most of the PM_{10} and $PM_{2.5}$ from aircraft, gasoline vehicles, and diesel vehicles is organic. Source apportionment of organic aerosol was determined by Chow et al. (2007) to allow for separation of diesel and gasoline vehicle contributions using high molecular hydrocarbons such as coronene along with the usual suite of elemental analytes, sulfates, nitrates, and elemental and organic carbon. Fujita et al. (2007) found similar results for organic particulate from Southern California. Thus, given existing measurement and receptor modeling technology, organic material from diesel vehicles and gasoline vehicles is likely to be apportioned.

At present, this methodology has not contemplated separating organic particulate matter generated by aircraft from that generated by diesel equipment. As a result aircraft contributions are likely to be considered a part of the diesel contributions. This could change if aircraft particulate matter were found to be high in certain high molecular weight organics. Samples were taken for this analysis during the Demonstration Study but the results are not available at the writing of this report.

Thus, it is evident that through measurements of gaseous VOCs, separation of diesel and gasoline contributions by receptor modeling is possible. This requires the VOC measurements to extend beyond the standard PAMS list of VOCs to include higher molecular weight VOCs (e.g., up to C_{12}, C_{13}, or C_{14}). Collecting this robust sample allows gasoline vehicles to be identified by vehicle exhaust, gasoline vapor, and whole gasoline (Lewis et al., 1997). There is the possibility of separating aircraft VOCs from vehicle VOCs but further data is required to establish the existence of distinct profiles necessary for this delineation.

6.2 ROLE OF DISPERSION MODELING

It is important to mention that there are aspects of a comprehensive source apportionment that receptor modeling cannot address. There are many source categories that will be of interest in the AQSAS that will be indistinguishable using a chemical composition approach. For example, it is a goal of the AQSAS to be able to separate Airport-related vehicle traffic on roadways in the study area from vehicle traffic that is not Airport-related. Also, the separation of diesel GSE equipment from diesel vehicles in or around the Airport will likely be required.

These cases will be addressed using a comprehensive dispersion model. From a chemical composition standpoint these classes of sources cannot be separated from one another. A dispersion model can perform this apportionment by setting up a culpability analysis (i.e. separating these sources using the emissions inventory).

Dispersion modeling is also expected to provide some understanding of the geographic boundaries of pollutant impacts resulting from key sources. This will aid in monitor location selection and will provide understanding of plume dispersion.

Model runs will be conducted that incorporate not only indiscernible LAX sources, but the surrounding regional inventory. Results from this analysis will be used to assess the relative importance of LAX to the regional air pollutant concentrations. Impacts from LAX sources will be reviewed by source type, spatial, and temporal variability and will be compared to both the measured data and the receptor modeling. Dispersion and receptor modeling use disparate techniques and typically predict results over different temporal and spatial scales. Nonetheless, specific periods will be identified in the Long Term Study for comparison.

The model review and comparisons will provide insight to the influence of LAX on air quality in the surrounding area. In addition, the analyses will provide valuable information on improving future studies of both measurements and modeling.

6.3 ASSESSMENT OF LOCATION CRITERIA FOR THE LONG TERM STUDY

6.3.1 Pollutant Monitor Site Locations

Modeling results help to identify and evaluate the strategies for placement of the monitor network for the Long Term Study. Overall, the following aspects need to be considered in determining the placement of monitors:

- The monitors should be located near locations depicting pollutant concentration or specifically be located to inform modelers of "background" concentration levels. These locations can be based on the dispersion modeling analysis or on NTA results for different source group contributions.
- The distance to the monitors should consider the rate of concentration changes.
- The monitors should reflect seasonal variation of wind patterns (e.g., wind speed and direction).

The modeling task of the Demonstration Project has shown that pollutant concentrations decrease quickly as the pollutants disperse downwind. The pollutant concentrations can decrease by an order of magnitude between the elevated concentration areas inside the Airport (e.g., apron areas) and the Airport boundary at the east, southeast, and northeast sides. Within a distance of a few kilometers, the concentrations drop by several orders of magnitude from the peak concentrations. These findings conclude that the monitor placement should focus on the areas within a few kilometers from the east, southeast, and northeast boundary of the Airport.

This is also true of impacts from the refinery and I-405/I-105 emissions. Upwind and downwind sites will be necessary to capture their contribution to pollutants in the study area.

Based on the modeling results and the localized wind patterns, the monitors should be placed within a few kilometers from the east, southeast, and northeast boundary of any source of interest. The following strategy for monitor placement is recommended to best assess source apportionment in the Study Area:

- For NTA to be best utilized in the Long Term Study monitors should be located upwind and downwind of Airport sources to determine the differential pollutant contributions of LAX. These upwind sites should be placed near the coast and refinery for daytime background estimates, and inland for nighttime background estimates. These are needed to identify and measure the pollutant concentrations resulting from local sources.

- Locate monitor(s) in an area north and/or northeast of the refinery – these monitor(s) will help to capture the potential refinery downwind impacts toward the Airport. It is also desirable to have a site upwind of the refinery, but the site upwind of the Airport can potentially provide this information.

- Locate monitor(s) that are upwind and downwind of I-405 (e.g., northwest corner of I-405/I-105 intersection, southwest corner of I-405/Manchester intersection, and northwest corner of I405/El Segundo intersection) – these monitors will help discern whether the impacts from the off-Airport road emissions obscure Airport emissions.

- Locate monitor(s) in the vicinity of elevated concentration areas inside the Airport (e.g., cargo gate areas, east ends of runways) as well as downwind directions near those sources (e.g., PS4 and PS5 in the demonstration study) —these monitors will help to confirm the impacts from Airport source groups with potential significant impacts.

- Locate monitor(s) near the Airport (e.g., with a distance of a few kilometers) in the directions of east, southeast, and northeast of the Airport boundary— these monitor(s) will capture the identifiable impacts experienced by the surrounding communities.

- Place monitor(s) in downwind directions of prevailing low (e.g., 1-2 m/s) and intermediate (4-5 m/s) wind speeds that are have been identified by dispersion modeling as locations of elevated concentrations.

6.3.2 Meteorological Site Locations

The quantity and location of additional meteorological sites (specifically, wind speed and direction) are of the utmost importance to the quality of results that can be attained from NTA and all other receptor models. The Long Term Study should include meteorological stations geographically spread across the study area (approximately every 2 km is recommended). An offshore meteorological station would also be particularly useful, (e.g. the El Segundo Marine Terminal), and would help to understand the complex wind patterns associated with the land-sea interface.

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SECTION 7

RESOURCES

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Module A

Quality Assurance Program Plan

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ABBREVIATIONS

AAC	Atmospheric Analysis & Consulting, Inc.
AAQS	Ambient Air Quality Standards
CO	Carbon monoxide
CO_2	Carbon dioxide
EC	Elemental carbon
ENSR	ENSR Corporation
JC	Jacobs Consultancy
LAWA	Los Angeles World Airports
LAX	Los Angeles International Airport
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NO_3	Nitrate
NO_x	Oxides of nitrogen
O_3	Ozone
OC	Organic carbon
PAH	Polynuclear aromatic hydrocarbons
PM_1	Particulate matter with aerodynamic diameter less than 1 micron
$PM_{2.5}$	Particulate matter with aerodynamic diameter less than 2.5 microns
PM_{10}	Particulate matter with aerodynamic diameter less than 10 microns
SCAQMD	South Coast Air Quality Management District
SO_2	Sulfur dioxide
SO_4	Sulfate
T&B	T&B Systems
TWG	Technical Working Group
UFP	Ultrafine particles
WESTON	Weston Solutions, Inc.

1. INTRODUCTION

1.1 BACKGROUND

The Los Angeles International Airport (LAX) is a source of air pollutants situated between the Pacific Ocean on the west and residential areas on the remaining three sides. Due to the local prevailing wind patterns of alternating land and sea breezes, emissions from the airport are carried into the neighboring residential areas. The potential for health impacts from these emissions has been a local concern. However, distinguishing any potential LAX-generated air quality impacts in the surrounding neighborhoods is confounded by the presence of other significant sources of emissions in the local region. These other sources include three major freeways, several heavily traveled major arterial routes, and numerous industrial facilities including the Chevron El Segundo refinery, Hyperion Wastewater Treatment Plant, DWP Scattergood Generating Station, and El Segundo Generating Station.

The compounds emitted by LAX and other sources include criteria pollutants and other compounds referred to collectively as air toxics. Criteria pollutants are substances with California or National Ambient Air Quality Standards (AAQS), and include ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), particulate matter less than 10 microns aerodynamic diameter (PM_{10}), particulate matter less than 2.5 microns aerodynamic diameter ($PM_{2.5}$), and carbon monoxide (CO). Air toxics are a broad collection of other compounds which do not have AAQS, but have other health-related exposure guidelines. These include diesel exhaust, polynuclear aromatic hydrocarbons (PAHs) such as benzo(a)pyrene, volatile organic compounds (VOCs) such as benzene, and trace metals such as cadmium.

Due to the number of sources in the area surrounding LAX, with many emitting the same types of compounds, it is difficult to readily attribute the measured presence of any pollutant in nearby neighborhoods to a specific source. Other regional air quality studies, such as the second Multiple Air Toxics Exposure Study (MATES-II) conducted in 1998 by the South Coast Air Quality Management District (SCAQMD), have examined air toxics in general but not LAX or other sources specifically. During the summer of 1999, the SCAQMD conducted a short-term air toxics monitoring program in the area around LAX. The results of that short-term study indicate that air toxics levels in the neighborhoods surrounding LAX were consistent with those found elsewhere in the South Coast Air Basin. However, the SCAQMD study was limited in extent and duration and did not provide data that could be used to determine either long-term impacts or LAX's contribution to toxic air pollutants.

In order to begin to specifically address potential local impacts from LAX, Los Angeles World Airports (LAWA), the United States Environmental Protection Agency (USEPA), and a Technical Working Group (TWG) of aviation and air quality experts from government agencies, universities, and the private sector have been working since 1999 to plan and conduct a long-term local study specifically focused on LAX. The TWG members include experts from LAWA, USEPA, California Air Resources Board (CARB), SCAQMD, Federal Aviation Administration (FAA), Desert Research Institute, University of Southern California, and Camp Dresser & McKee, Inc. (CDM).

Multiple planning and peer review cycles culminated in May 2007, with the final *Air Quality and Source Apportionment Study of the Area Surrounding Los Angeles International Airport Technical Workplan* (Technical Workplan) prepared by CDM. This plan was revised in February 2008. The Technical Workplan outlines a multifaceted study that will be conducted in two phases. The first phase is a short-term Technology and Methodology Feasibility Demonstration Project ("Demonstration Project") that will be conducted during the summer of 2008 to evaluate ambient air data collection methods, collect source emissions inventory data, and perform preliminary data analysis and modeling. The second phase will be a year-long Long-Term Study slated to begin in 2009 that will include ambient air sample collection for specific compounds in neighborhoods surrounding the airport, based on results of the Demonstration Project.

In late 2007, LAWA chose to award the contract for conducting the study to a team led by Jacobs Consultancy, Inc. (JC). The overall project team includes consulting firms representing a variety of specializations including public outreach, ambient air monitoring and sampling, and air dispersion modeling. The overall project will be managed by JC. The emissions inventory portion of the program will also be headed up by JC. The ambient air data collection portion of the project will be led by Weston Solutions, Inc. (WESTON). The data analysis and modeling effort will be led by Trinity Consultants (TC).

This Ambient Air Monitoring and Quality Assurance Program Plan (Monitoring Plan) covers the ambient air data collection activities to be conducted during the Demonstration Project (Emissions inventory development and the modeling analysis are covered in separate plans). In order to complete the air data collection tasks, WESTON joins four additional data collection team members: T&B Systems (T&B), ENSR Corporation, ZM Associates, and Atmospheric Analysis and Consulting (AAC). The specific ambient air data collection team structure and project roles are detailed in Section 1.3.

This Monitoring Plan is based principally on the information contained in Sections 4.6 and 4.7 of the Technical Workplan, regarding the Demonstration Project data collection & management. The scope of work outlined in Section 4 of the Technical Workplan contained specific target pollutants, general groups of target pollutants, and general sampling and analysis methods. This Monitoring Plan provides the details of these general methods as they will be implemented for the Demonstration Project. Section 2 details the Methodology, including instrumentation descriptions, Data Quality Objectives, sampling locations, and the Schedule. Section 3 describes the Data Management strategy, including data access and reporting. Section 4 details Quality Management for the Demonstration Project, including Quality Control elements for field operations and the laboratories, and Quality Assurance auditing elements of the project.

1.2 STUDY OBJECTIVES

The primary technical objective of the overall study as stated in the Technical Workplan is "to assess the incremental impact of LAX operations on local air quality". Under that objective, the following three specific goals are given:

- Quantify ambient air concentrations of gases and particles and particle deposition in neighborhoods near LAX and determine how these vary in space and time.

- Determine significant sources of air pollutant emissions in the Study area and characterize the emissions with respect to rate and chemical composition.

- Determine the contribution of various airport-related activities on selected air pollutant concentrations relative to the contribution from other, non-airport sources in the surrounding area.

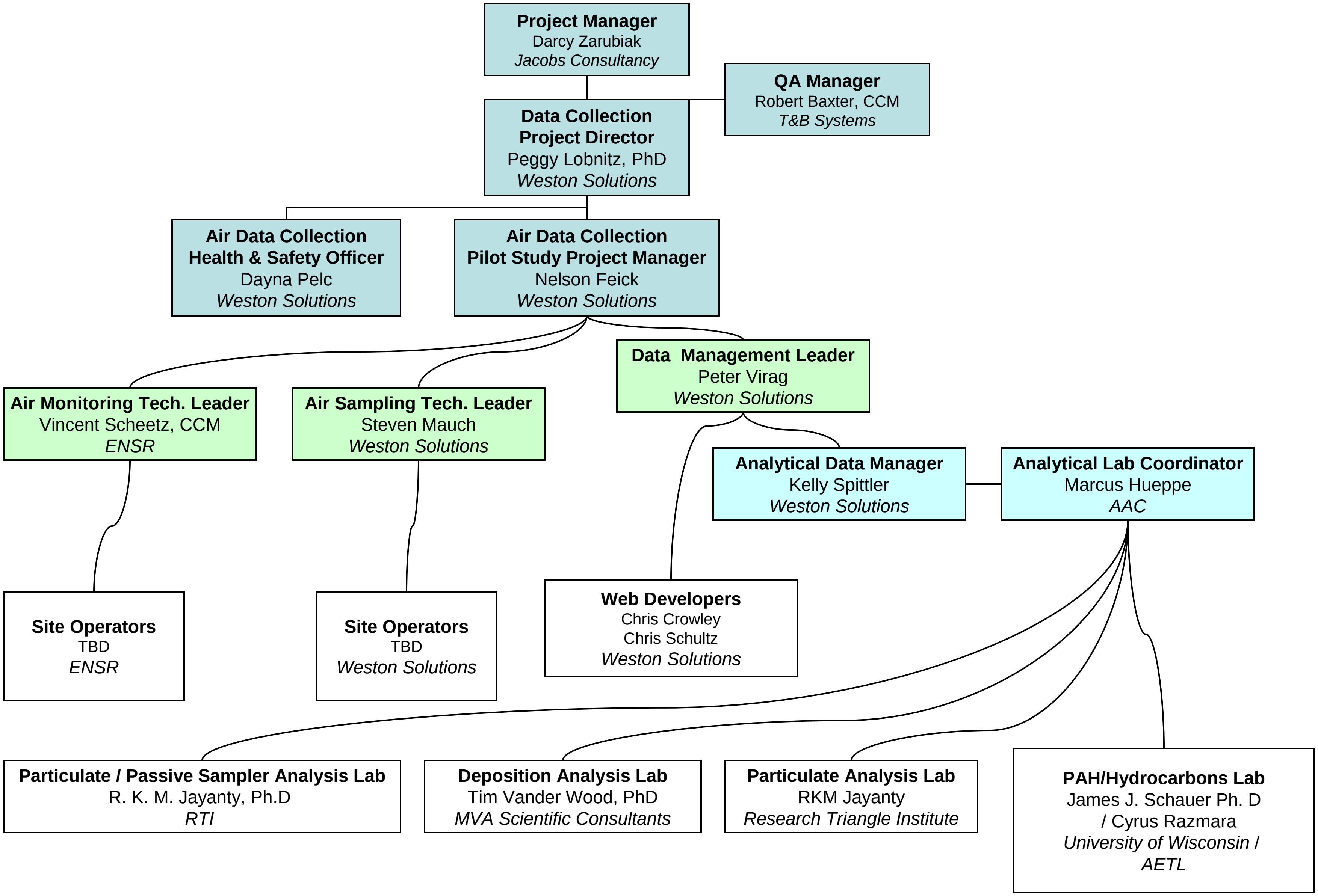
The secondary objective of the Long-Term study is to collect data that will be useful in defining existing baseline air quality, and in conducting future studies of human exposure and related issues. However, such analyses will not be conducted as part of this study.

1.3 TEAM ORGANIZATION

The Demonstration Project air data collection project structure is outlined in Figure 1-1. The figure is limited to the air data collection tasks that are the subject of this Monitoring Plan. There are other activities that will be conducted as part of the Demonstration Project. These are related to collecting emissions inventory related information and performing data analysis and air dispersion modeling. These inventory, analysis and modeling activities are not within the scope of this air Monitoring Plan. Contact information for the key personnel is included in Table 1-1.

The project management staff will provide personnel, budget, and quality management services for the Demonstration Project. The overall Project manager for JC will be Mr. Darcy Zarubiak. Mr. Zarubiak will act as the primary point of contact for the external stakeholders of the study, including LAWA, the TWG, and others. The overall Quality Assurance Manager for the project will be Mr. Robert Baxter, CCM, of T&B. Mr. Baxter will provide auditing services and quality assurance guidance for all aspects of the air data collection. Dr. Margaret (Peggy) Lobnitz of WESTON's Sherman Oaks, CA office will act as WESTON's local representative and overall Director of the Data Collection activities. The remainder of WESTON staff will support the project operating from the WESTON corporate headquarters in West Chester, PA. Mr. Nelson Feick will assist Dr. Lobnitz and act as Project Manager for Data Collection. Ms. Dayna Pelc will act as Health and Safety Officer (HSO) for the Air Data Collection portion of the Demonstration Project. The HSO will prepare a site-specific Health and Safety Plan (HASP), ensure that field team members are qualified to perform their tasks, and ensure that all team members are briefed on the HASP.

Figure 1-1
Pilot Air Quality Study Organization Chart



The technical leaders on the project will coordinate the air monitoring, air sampling, and data management activities for the Demonstration Project. Mr. Vincent Scheetz, CCM, will lead the ENSR air monitoring efforts, and will be assisted by ENSR field technical staff. Mr. Steven Mauch will lead WESTON's air sampling efforts, and will be assisted by Ms. Dayna Pelc, Ms. Stephanie Chesebro, and Mr. Tyson Belknap or other technical staff. Mr. Peter Virag of WESTON will lead the data management efforts. Ms. Kelly Spittler will assist Mr. Virag and will provide analytical database management for the EnviroData system. The laboratory analytical efforts will be led by Marcus Hueppe at AAC in Ventura, CA. AAC will perform several of the analytical procedures, and subcontract and manage cooperation among several other labs for specialized analyses. These labs are:

American Environmental Testing Laboratory (AETL)
2834 North Naomi Street
Burbank, CA 91504
Cyrus Razmara Ph.D., Laboratory Director
Tel: 818-845-8200
[cyrus@aetlab.com]

MVA Scientific Consultants (MVA)
3300 Breckinridge Blvd
Suite 400
Duluth, GA 30096
Tim Vander Wood, Ph.D., Executive Director
Tel: 770-662-8509
[tvanderwood@mvainc.com]

University of Wisconsin-Madison (UW-M)
Civil and Environmental Engineering Department
660 N. Park St.
Madison, WI 53706
Professor James J. Schauer, Ph.D., PE
Tel: 608-262-4495
Fax: 608-262-0454
[jjschauer@wisc.edu]

and

RTI International (RTI)
Research Triangle Park
NC 27709
R. K. M. Jayanty, Ph.D, Senior Fellow
Tel: 919-541-6483
[rkmj@rti.org]

AAC will perform the VOC, ammonia/nitrate aerosol speciation, and carbonyls analyses. AETL will perform the heavy hydrocarbons analyses. UW-M will provide analysis for PAHs, hopanes, and steranes. MVA will provide microscopy services for particle deposition samples. RTI will perform the particulate chemical speciation analyses (elements and ions excluding ammonia), including the IMPROVE carbon protocol. RTI is one of only a few commercial laboratories in the country that perform the IMPROVE carbon analysis. Details of sampling & analytical methods are provided in Section 2.

AAC will also act as the central laboratory for sample check-in and reporting. Samples will be delivered by a Field Technician to AAC's Ventura laboratory on a daily (weekdays) basis and shipped from there to the other laboratories as needed. All results reports from the other laboratories will be processed through AAC, who will assemble the deliverables packages (hard copy and electronic) and transmit them to the Data Management Team (Weston Solutions).

Table 1-1
Key Personnel Contact Information

Project Role	Name	Address	Phones	Electronic Mail
Project Manager	Darcy Zarubiak	Jacobs Consultancy 555 Airport Boulevard, Suite 300 Burlingame, California 94010	(214) 424-7597 [ofc] (214) 696-3499 [fax]	darcy.zarubiak@jacobs-consultancy.com
QA Manager	Robert Baxter, CCM	T&B Systems, Inc. 26074 Avenue Hall, Unit 9 Valencia, California 91355	(661) 294-1103 [ofc] (661) 294-0236 [fax]	bbaxter@tbsys.com
Data Collection Project Director	Peggy Lobnitz, PhD	Weston Solutions, Inc. Suite 1000 14724 Ventura Boulevard Sherman Oaks, Ca 91403-3501	(818) 464-7062 [ofc] (818) 905-5691 [fax]	Peggy.Lobnitz@westonsolutions.com
Demonstration Project Air Data Collection Project Manager	Nelson Feick	Weston Solutions, Inc. 1400 Weston Way West Chester, PA 19380	(610) 701-7305 [ofc] (610) 701-4530 [fax]	Nelson.Feick@westonsolutions.com
Air Monitoring Technical Leader	Vincent Scheetz, CCM	ENSR 1601 Prospect Parkway Fort Collins, CO 80525	(970) 493-8878 [ofc]	VScheetz@ensr.aecom.com
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Air Data Collection Data Management Leader	Peter Virag	Weston Solutions, Inc. 1400 Weston Way West Chester, PA 19380	(610) 701-7327 [ofc] (610) 701-7401 [fax]	Peter.Virag@westonsolutions.com
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2. METHODOLOGY

This section presents the methodology for the Demonstration Project. The basic strategy of the Demonstration Project is to collect data first at a location proximate to the South Runway blast fence, in order to obtain information on aircraft-related emissions. After data are collected at the South Runway, select instrumentation will be moved to four other locations on the airport to gather information on additional sources. The equipment to be used at the other four locations will be housed on the Portable Platform, which will consist of a combination of a monitoring trailer (Portable Platform Trailer) and adjacent scaffold-mounted sampling equipment. The Portable Platform will spend 7 days at each of the four locations. The full range of monitoring and sampling approaches will be deployed during the South Runway segment of the study. Only a subset of those approaches will be carried out at the Portable Platform sites.

Although “monitoring” and “sampling” are often used interchangeably, they have two distinct meanings in the context of the Demonstration Project. Monitoring is the continuous collection of data, where short-term (e.g., 1-second) measurements are made in situ and averaged over longer time intervals (e.g., one minute, hourly). Sampling is the collection of a discrete sample (e.g., a filter) that is exposed to ambient air for a specific period of time (e.g., 12 hours), then analyzed in a laboratory.

The following subsections detail all of the methods that will be used at the South Runway and/or the Portable Platform. Section 2.1 defines the parameters that will be collected, along with the Data Quality Objectives. Section 2.2 provides summary descriptions of the monitoring and sampling equipment for the Demonstration Project. Section 2.3 discusses the logistics and process for selecting the South Runway and four (4) Portable Platform site locations. Section 2.4 presents the schedule.

2.1 PARAMETERS

The parameters that are to be collected during the Demonstration Project include concentrations of ambient air pollutants as well as meteorological conditions related to the transport and dispersion of pollutants. A broad target set of pollutants was chosen for the Demonstration Project, aimed towards the goal of identifying a subset of the target pollutants as “marker” compounds that can be used to attempt to trace the airport’s impacts into the adjacent neighborhoods. Simultaneous collection of meteorological data is essential to understanding the sources and transport of the pollutants being measured.

The pollutants that will be measured as part of the Demonstration Project, their data collection frequencies and total number of samples (where applicable) are summarized in Table 2-1.

At the South Runway, monitors for criteria pollutants (PM_{10}, $PM_{2.5}$, CO, NO_2, SO_2, O_3), total non-methane hydrocarbons (NMHC), and CO_2 will be located in a stationary trailer (Main Trailer). The Portable Platform trailer will monitor for additional aerosol parameters of light scattering, black carbon, particle-bound PAHs, and ultrafine particles (UFP). The Portable Platform will be collocated with the Main Trailer at the South Runway for 14 days at the beginning of the study.

After the initial 14-day period, criteria pollutant monitoring will continue using the Main Trailer at the South Runway Site. Criteria pollutant monitoring will continue there for a minimum of 30 days, and may be optionally extended to the end of the Demonstration Project. The Portable Platform will then begin its 7-day rotations to the four other locations.

Sampling will be conducted both at the South Runway and at the four Portable Platform sites. The Portable Platform will be outfitted with samplers for aerosol speciation, carbonyls, light and heavy hydrocarbons, and PAHs. These samplers will be mounted on a scaffold platform erected immediately adjacent to the Portable Platform Trailer. Aerosol speciation sampling consists of using various filter packs to collect particle-phase ($PM_{2.5}$) metals, ammonia, nitrate, sulfate, and carbon. The speciation samplers also use annular denuders to collect vapor-phase nitrate and ammonia. At the South Runway, additional samplers will be deployed for a 2-week period to collect data on other organic compounds primarily of interest from aircraft exhaust.

Samples will be collected over three different time periods: 12 hours, daily (24-hour), and weekly. The 12-hour periods will be used to assess variability in air quality during the on-shore and off-shore portions of the day (land/sea breezes). The daily and weekly samples will be used to characterize long-term air quality. The different sampling periods will be applied to different sampling approaches, as outlined in Table 2-1.

In addition to conventional time-integrated sampling, the Demonstration Project will test the use of a snapshot portable gas chromatograph/mass spectrograph (GC/MS) system to quantify VOCs in the immediate vicinity of sources at the South Runway and at least one Portable Platform sampling location.

Table 2-1
Overview of Parameters and Measurement Frequencies

Observable	Sites	Duration	Frequency	Primary Samples	Field Blank Samples	Collocated Duplicate Samples	Total Samples
Continuous for: $PM_{2.5}$ and PM_{10} mass Carbon Dioxide Carbon Monoxide Nitrogen Oxides Ozone Sulfur Dioxide Non-methoane Hydrocarbons	S. Runway	30 Days (May extend to end of Demonstration Project)	Continuous; 1-Hr average	NA	NA	NA	NA
Continuous for: Light Scattering Black Carbon Ultrafine Particles Particulate PAH	S. Runway and 4 Portable Platform Sites	14 Days at S. Runway and 7 Days at each of 4 Portable Sites	Continuous; 1-Min average	NA	NA	NA	NA
Diurnal Cycles for: Particluate Elements, Ions Carbon Speciation PAH Compounds, Hopanes, Steranes	S. Runway and 4 Portable Platform sites	7 Days at S. Runway and 7 Days at each of 4 Portable Sites	Consecutive 12-hr periods (on-shore / off-shore flows)	70 (each)	5 (each)	2 (each)	77 (each)
Diurnal Cycles for: Aerosol Speciation Carbonyls Heavy hydrocarbons (C_{10} to C_{20})	S. Runway	7 Days at S. Runway	Consecutive 12-hr periods (on-shore / off-shore flows)	14 (each)	2 (each)	1 (each)	17 (each)

Table 2-1 (cont'd)

Overview of Parameters and Measurement Frequencies

Observable	Sites	Duration	Frequency	Primary Samples	Field Blank Samples	Collocated Duplicate Samples	Total Samples
Daily for: Light hydrocarbons (C_2 to C_{12})	S. Runway and 4 Portable Platform Sites	7 Days at S. Runway and 7 Days at each of 4 Portable Sites	Every Day; 24-hr Sample	35	2	2	39
Daily for: Light hydrocarbons (C_2 to C_{12})	Fuel Farm	3 Days	Every Day; 24-hr Sample; plus 1 Fuel tank headspace grab sample	3 + 1 grab	0	0	4
Daily for: Particulate Elements, Ions Carbon Speciation PAH Compounds, Hopanes, Steranes	S. Runway	16 Days	Every 3rd Day; 24-hr Sample	6 (each)	2 (each)	1 (each)	9 (each)
Particle deposition	S. Runway	One-week Episodic	Weekly for 2 Weeks	2	0	0	2
Long-Term Exposure (Passive) for : Nitrogen Oxides Sulfur Dioxide, Ozone	S. Runway	One-week Episodic	Weekly for 2 Weeks	2	1	1	4

General specifications of the various monitoring equipment and sampling methods are summarized in Table 2-2. The table details the types of analyzers/samplers to be used, the sensitivity of the analyzers and analytical methods, along with the data collection and reporting intervals. Table 2-2 also includes the Data Quality Objectives (DQO) for each approach. Detailed target compound lists including compound-specific detection limits are tabulated in Section 2.2.2 under the descriptions of the individual sampling approaches.

The operating ranges in Table 2-2 are the most sensitive (i.e., lowest) for each analyzer. Because the concentrations of the various pollutants that will be encountered are unknown, the lowest ranges will be used initially. During shakedown and the initial week of operational data collection, all analyzers will be monitored closely by the Site Operators for over-ranging. If actual ambient concentrations warrant, the analyzer ranges will be adjusted upward accordingly.

2.2 METHODS

The following subsections describe the equipment to be used in the air monitoring and sampling data collection during the Demonstration Project. Section 2.2.1 covers the monitoring equipment, and describes each instrument's basic operating principles, sensitivity, and the monitoring concentration ranges that will be employed. Section 2.2.2 presents summary descriptions of each of the sampling methods, including equipment descriptions, sampling media, and analytical methods. For each type of sampler, the target compounds are presented as well as their detection limits.

2.2.1 Air Monitoring

2.2.1.1 Carbon Dioxide

Using new optical filter technology, the Thermo Electron Corporation Model 410i-D is designed to monitor and report on carbon dioxide (CO_2) gas levels using optically fixed bandpass interference filters and quantum detection to analyze the gas stream. An expanded ambient temperature operating range provides excellent performance over a wide range of concentrations up to 10,000 ppm.

TABLE 2-2

LAX Pilot Study
Data Quality Objectives

MONITORING

Parameter	Instrument	Detection Level	Concentration Range	Precision	Accuracy	Averaging Time	Data Recovery
Carbon Dioxide	Thermo Model 410i-D	0.2 ppm[1]	0 - 10,000 ppm	±15%	±10%	1 min	80%
Carbon Monoxide	Thermo Model 48	0.1 ppm	0 - 50 ppm	±15%	±10%	1 min	80%
Nitrogen Oxides	Thermo Model 42C	0.001 ppm	0 - 0.500 ppm	±15%	±10%	1 min	80%
Non-Methane Hydrocarbons	Thermo Model 55C	0.05 ppm[2]	0 - 20 ppm	±15%	±10%	1 min	80%
Ozone	Thermo Model 49C	0.002 ppm	0 - 0.500 ppm	±15%	±5%	1 min	80%
Sulfur Dioxide	Thermo Model 43C	0.001 ppm	0 - 0.500 ppm	±15%	±10%	1 min	80%
Fine Particulates ($PM_{2.5}$, PM_{10})	MetOne BAM-1020 Beta Attenuation Monitor	1 μg/m^3	0 - 0.1 mg/m^3	±2 μg/m^3*	±8%*	1 hr	80%
Black Carbon	Magee AE-31 Aethalometer	<0.1 ug/m^3	0 - 1,000 ug/m^3	NA	5%*	5 min	80%
Particle PAH (Induced Charge)[3]	EcoChem PAS 2000	NA	0 - 100 pA	NA	NA	1 min	80%
Light Scattering	Radiance Research Model M903 with heater	<0.001 km^{-1}	0 - 10 Mm^{-1}	NA	NA	1 min	80%
Ultrafine Particles	TSI 3091 FMPS		32 log-spaced size ranges, counts over 4 orders of magnitude	NA	NA	1 min	80%

* - Manufacturers specifications. No precision or accuracy checks will be performed on these monitors.

[1] - For 5-minute averaging period

[2] - NMHC as propane

[3] - The PAS 2000 does not measure PAH concentration. Output is in terms of charge induced on PAH compounds by the excitation lamp, which is generally proportional to PAH concentration.

SAMPLING

Method	Compounds	Analytical Method	Sample Period	Sample Flow Rate[1]	Detection Limits	Data Recovery	Laboratory Precision[2]	Laboratory Accuracy[2]
Sequential Filter Sampler (ADS)	Ammonia (gas + particle), Sulfate (particle) , Nitrate (particle + gas)	IC and AA	12 hours	10.0 LPM (7.2 m^3 total)	0.070 ug/m^3	80%	15 - 25%	15 - 25%
	Potassium & Sodium (particles)	IC			0.070 ug/m^3			
	Elements	XRF			0.0028 - 0.28ug/m^3			
	Elements	ICP/MS			0.0028 - 0.28 ug/m^3			
	Carbon	IMPROVE			0.20 ug/m^3			
	Particle Mass	Gravimetric			1.04 ug/m^3			
	PAH, Hopanes, Steranes	GC/MS			0.00070 - 0.0028 ug/m^3			
MiniVol	Ammonia (particle), Sulfate (particle) , Nitrate (particle + gas)	IC and AA	24 hours	5 LPM (7.2 m^3 total)	0.069 ug/m^3	80%	15 - 25%	15 - 25%
	Potassium & Sodium (particles)	IC			0.0694 ug/m^3			
	Elements	XRF			0.0025 - 0.29 ug/m^3			
	Elements	ICP/MS			0.0025 - 0.29 ug/m3			
	Carbon	IMPROVE			0.19 ug/m^3			
	Particle Mass	Gravimetric			1.042 ug/m3			
	PAH, Hopanes, Steranes	GC/MS			0.00069 - 0.0028 ug/m^3			
DNPH Cartridge Sampler	Carbonyls	HPLC	12 hours	0.7 LPM (0.50 m^3 total)	0.74 ug/m^3	80%	15 - 25%	15 - 25%
Canister Sampler	PAMS Compounds (TO-12 & TO-15)	GC-FID/MS	12 hours	~6 cc/min (~4 L total)	1 - 5 ppbv	80%	10 - 30%	<25%
Tenax Cartridge Sampler	C_{10} - C_{20} Hydrocarbons	GC-FID	12 hours	0.5 LPM (0.36 m^3 total)	1 - 10 ppbv	80%	NA	NA
Deposition Plates	Particle Mass and Composition	CCSEM	7 days	NA	NA	100%	NA	NA
Passive Samplers	O_3, NO_X, NO, NO_2, SO_2	Colorimetry & Ion Chromotography	7 days	NA	0.3 - 0.6 ppb	100%	NA	NA

[1] - Sampling accuracy based only on the sampling apparatus is considered to be 10% based on the flow rate tolerance of particle size selective inlets being used on many of the samplers.

[2] - Based on % ranges of QA provided by AAC for CCV, LCS, MS/MSD and replicates.

Analysis Method Key

IC - EPA Method IO-4.2 (K and Na analyzed by RTI; all other by AAC)
AA - Ammonia, EPA Method IO-4.2 (analyzed by AAC)
XRF - X-Ray Fluorescence (analyzed by RTI)
ICP/MS - Inductively Coupled Plasma Spectroscopy / Mass Spectrography (analyzed by AAC)
IMPROVE - DRI Model 2001 Thermal/Optical Carbon Analysis (TOR/TOT) of Aerosol Filter Samples – Method IMPROVE_A (analyzed by RTI)
GC/MS - Gas Chromatography/Mass Spectroscopy (analyzed by UW-M)
HPLC -   High-performance liquid chromatography, EPA Method TO-11 (analyzed by AAC)
GC-FID/MS - Gas Chromatography w/ Flame Ionization Detector, EPA Method TO-12 (PAMS) and EPA Method TO-15 (GC/MS) (analyzed by AAC)
CCSEM - Compouter-controlled scanning electron microscopy prticle counts and composition (alayzed by MVA)
GC-FID - Gas Chromatography w/ Flame Ionization Detector, EPA Method 8015 (analyzed by AETL)

Analytical Laboratories Key

AAC - Atmospheric Analysis & Consulting
AETL - American Environmental Testing Laboratory
MVA - MVA Scientific Consultants
RTI - Research Triangle Institute
UV-M - University of Wisconsin Madison

The Model 410*i*-D operates on the principle that CO_2 absorbs infrared radiation at a wavelength of 4.26 microns. The sample is drawn into the Model 410*i*-D through the sample bulkhead. The sample flows through the optical bench. Radiation from an infrared source is chopped and then passed through a rotating optical wheel alternating between sample and reference filters. The radiation then enters the optical bench where absorption by the sample gas occurs. The infrared radiation then exits the optical bench and falls on an infrared detector. The chopped detector signal is modulated by the alternation between the filters with amplitude related to the concentration of CO_2 in the sample cell.

Because infrared absorption is a non-linear measurement, it is necessary to transform the basic analyzer signal into a linear output. The Model 410*i*-D uses an internally stored calibration curve to linearize the instrument output over any range up to a concentration of 10,000 ppm. For the Demonstration Project, the instrument will be operated on the full 0-10,000 ppm range. The CO_2 concentration outputs will be recorded at a minimum averaging time of one minute. The CO_2 analyzer detection limit is 0.2 ppm (300 second averaging time).

2.2.1.2 Non-Methane Hydrocarbons

The Thermo Environmental Model 55C Methane, Non-Methane hydrocarbon Analyzer will be used to provide a direct measurement of both methane and non-methane hydrocarbon (NMHCs). The Model 55C back-flushed gas chromatography system allows reliable measurements of NMHCs at sub-ppm concentrations, even in the presence of much higher concentrations of methane. In addition, the Model 55C's proprietary column design can achieve complete separation of methane from all C_2 compounds, is unaffected by the oxygen content of the sample, and provides complete recovery of low volatility compounds that other instruments may miss.

The analyzer cycles between measuring methane and NMHCs. At the start of an analysis cycle, a known volume of air is collected in the sample loop. The collected sample is then injected through a heated valve (150-200C) into a flowing stream of carrier gas. The sample is carried to the separation column located in a separate oven kept at 65C. As the sample is carried through the column, various hydrocarbons move at different velocities, based on their chemical and physical properties. Due to its low molecular weight and high volatility, methane is carried back to the detector oven and measured by the FID.

After the methane measurement portion of the cycle is complete, the valve system "backflushes" the non-methane hydrocarbons to the FID for measurement. While NMHCs are being measured, the next sample is simultaneously collected in the sample loop.

To start an analysis cycle, a known volume of air is collected in the sample loop. An eight port valve, which is located in a 150-200°C detector oven, is then rotated to inject the sample into a flowing stream of carrier gas. The sample is carried to the separation column located in a separate oven kept at 65°C. As the sample is carried through the column, various hydrocarbons move at different velocities, based on their chemical and physical properties. Due to its low molecular weight and high volatility, methane is carried back to the detector oven and measured by the FID.

The valve is then returned to the original position. This action reverses the direction of gas flow through the column, and “backflushes” the non-methane hydrocarbons to the FID for measurement. While NMHCs are being measured, the next sample is simultaneously collected in the sample loop. The complete cycle for both takes approximately 70 seconds.

The instrument will be operated on the 0-20 ppm range, and has detection levels of 0.05 ppm NMHC as propane, and 0.02 ppm methane. The NMHC and methane concentration outputs will be recorded at a minimum averaging time of one minute.

2.2.1.3 Carbon Monoxide

CO concentrations will be measured using a TEI Model 48 analyzer. The TEI 48 uses infrared detection and the gas filter correlation principle of operation for CO measurements. The basic components of the gas correlation system are: infrared source, chopper and rotating gas filter wheels, multiple optical pass sample cell, band pass filter, IR detector and electronic signal processor. Radiation from the infrared source is chopped and then passed through a gas filter that alternates between CO and N_2 due to rotation of the filter wheel. The radiation then passes through a narrow band pass filter and a multiple optical-pass sample cell and falls on a solid state

IR detector. The CO gas filter acts to produce a reference beam that cannot be further affected by CO in the sample chamber. The N_2 side of the filter wheel is transparent to IR radiation; therefore, it produces a measure beam that can be absorbed by CO. The chopped detector signal is modulated by the alteration between the two gas filters with amplitude proportional to the concentration of CO in the sample chamber. Other gases do not cause modulation of the detector signal since they absorb the reference and measure beams equally; therefore, the gas filter correlation system responds solely to CO.

The CO analyzer will be operated on the 0-50 ppm range with a minimum detection level of 0.1 ppm. Analyzer outputs will be averaged at a minimum interval of one minute.

2.2.1.4 Nitrogen Oxides

Ambient levels of NO_X will be monitored continuously using Thermo Electron Corporation (Thermo) Model 42C NO_X analyzer. This instrument has been selected for use in the proposed LAX study because it is sensitive, interference free, and provides long-term zero and span stability for continuous monitoring of NO, NO_2, and NO_X with a high degree of reliability.

The Thermo 42C detects NO in ambient air by reacting NO with O_3. The resulting chemiluminescent reaction is monitored through an optical filter by a photo-multiplier tube (PMT) which is located at the end of the reaction chamber. The optical filter limits the wavelength of light measured by the PMT, so that it corresponds to the wavelength of the chemiluminescent reaction between NO and O_3.

Total oxides of nitrogen will be measured by passing the sample gas through a catalytic converter which converts NO_2 quantitatively into NO which is subsequently measured by the detector. The microprocessor-controlled analyzer directs sample flow either through the catalytic converter (measuring NO_X) or by passing the sample directly into the detector (measuring NO). Signals from the PMT are conditioned and fed to the microprocessor where a sophisticated mathematical algorithm is utilized to calculate three independent outputs: NO, NO_2, and NO_X.

The NO_x analyzer will be operated on the 0-0.500 ppm range, with a minimum detection level of 0.001 ppm. Analyzer outputs will be averaged at a minimum interval of one minute.

2.2.1.5 Ozone

Ambient O_3 concentrations will be measured using a Thermo 49C O_3 analyzer. The Thermo 49C uses an ultraviolet (UV) photometric ozone analyzer design. It incorporates a unique two-sample absorption cell and detector design for increased sensitivity and accuracy.

In principle, the UV photometer determines ozone concentrations by measuring the attenuation of UV light due to ozone in the absorption cell. The concentration of ozone is directly related to the magnitude of the attenuation. In the Thermo 49C, an internally generated reference sample passes into the absorption cell to establish a "zero" light intensity reading. A solenoid valve then switches, and an ambient sample is taken, thereby establishing a "sample" light intensity reading. The ratio of these two readings is a measure of the light absorbed by ozone and is directly related to the concentration of ozone in the sample.

The Thermo 49C employs two photometers and uses two separate absorption cells and detector systems. These two detector systems operate simultaneously, alternating reference and ambient samples. When one detector is sampling ambient air, the other is sampling reference air. By integrating the signals and averaging each calculated chamber concentration, fluctuations in UV lamp intensity can be factored out. The microcomputer in the Thermo 49C calculates the O_3 concentrations directly for each cell and outputs the average concentration in both a front panel digital display and an analog output.

The O_3 analyzer will be operated on the 0-0.500 ppm range, with a minimum detection level of 0.002 ppm. Analyzer outputs will be averaged at a minimum interval of one minute.

2.2.1.6 Sulfur Dioxide

Ambient levels of SO_2 will be monitored continuously by using a Thermo Model 43C SO_2 analyzer. The Thermo 43C Pulsed Fluorescence SO_2 Analyzer provides unequaled ease of operations reliability, precision, and specificity. This analyzer does not use consumable gases or wet chemicals. The Thermo 43C operates on the principle of fluorescent radiation of SO_2 molecules. A reaction chamber is irradiated by UV light and the fluorescent radiation is detected by a sensitive PMT. Associated electronics amplify the output from the PMT. The output voltage is proportional to SO_2 concentrations.

The SO_2 analyzer will be operated on the 0-0.500 ppm range, with a minimum detection level of 0.001 ppm. Analyzer outputs will be averaged at a minimum interval of one minute.

2.2.1.7 Fine Particulates ($PM_{2.5}$, PM_{10})

Continuous monitoring of PM_{10} and $PM_{2.5}$ will be performed using beta-attenuation monitors manufactured by Met One Instruments, Inc. (Met One). Separate Met One BAM-1020 monitors will be used for continuous $PM_{2.5}$ and PM_{10} measurements. The instruments operate on the principle of beta attenuation.

The beta attenuation process uses a small source of beta particles (carbon-14, 60 microcuries) coupled to a sensitive detector that counts the emitted beta particles. The dust particles are collected on a glass fiber filter tape that is placed between the beta source and the detector. Dust on the filter will intercept some of the beta particles. The air stream is heated to reduce the relative humidity of the sample stream to below 60 percent in order to reduce positive artifact measurement due to condensation on the filter. The reduction of beta particles is proportional to the amount of dust on the filter, which allows the mass of dust to be determined from the beta particle counts. The dust mass is combined with the air volume collected during the filter exposure time to determine the PM concentration.

Both the BAM-1020 monitors will be equipped with particle size selective inlets. The design of the inlets is such that particles larger than the desired size range will be removed from the air flow, based on the air flow rate. Both units will be equipped with an inlet head to separate PM_{10}. The BAM-1020 measuring $PM_{2.5}$ will have an additional separator (sharp cut cyclone) downstream of the PM_{10} inlet to separate the $PM_{2.5}$ fraction. Sampling flow rate is critical to maintain the proper particle size cut points of the inlets. Flow rates are maintained at 16.7 liters per minute (LPM) in the BAM-1020 using an integral flow meter, pressure sensor, and ambient temperature sensor on board each monitor.

The data from the BAM-1020 units will be recorded by digital data loggers (described in Section 6.1), using the analog signal outputs of the monitors. The data from the BAM-1020 monitors will be recorded at a minimum averaging interval of 60 minutes, because the instrument is designed strictly to collect measurements over an hourly integration period to conform with its role as a USEPA Automated Equivalent Method for 24-hour PM_{10} measurements. The detection level of the BAM-1020 is 1 $\mu g/m^3$, and the instruments will be operated on the 0-0.1 mg/m^3 (0-100 $\mu g/m^3$) range.

2.2.1.8 Black Carbon

The Magee Model AE-31 Aethalometer (AE) uses a continuous filtration and optical measurement method to give a continuous readout of concentration of black carbon (BC). The AE-31 measures optical absorption over seven wavelengths: 370, 470, 520, 590, 660, 880 and 950 nm. The Aethalometer will be equipped with a BGI Model SCC 1.197 particle size-selective inlet port, and the Extended Range (ER) sampling head option. Air is sampled at a flow rate of 5 liters per minute, using an internal pump. The cut point of the inlet used for the Demonstration Project will be 1 micron (PM_1). The flow rate is monitored by an internal mass flow meter. The Aethalometer collects the sample on a quartz fiber filter tape, and performs a continuous optical analysis, while the sample is collecting. The roll of tape contains 1500 spots (on a 15 meter long roll) and the analysis gives a new reading every timebase period. The data is stored to media (diskette or memory card), transmitted via serial data port, and produced as an analog voltage.

The principle of the Aethalometer is to measure the attenuation of a beam of light transmitted through a filter, while the filter is continuously collecting an air sample. By using the appropriate value of the specific attenuation for that particular combination of filter and optical components, the BC content of the aerosol deposit at each measurement time can be determined. An increase in optical attenuation from one time period to the next is due to the increment of aerosol BC collected from the air during the period. This increment is divided by the volume of air sampled during that time and resulting in the calculation of the mean BC concentration during the period.

The AE-31 will be operated on the 0-1,000 $\mu g/m^3$ range, and has a sensitivity of $< 0.1\ \mu g/m^3$. Measurements for all seven wavelengths will be captured from the instrument's serial output port by a dedicated laptop computer.. Data for all seven wavelengths stored on disk by the system will also be archived. The AE-31 will initially be operated on the manufacturer-recommended 5 minute timebase. If operational experience indicates that BC levels are high enough that frequent filter tape increments cause significant data gaps, the timebase will be incrementally increased to 10 or 15 minutes to restore data continuity. In addition, the differing nature and intensity of BC sources at the various Portable Platform monitoring locations may necessitate use of different timebases at each site.

2.2.1.9 Light Scattering

The nephelometer (Radiance Research Model 903) measures light scattering in an airflow that passes through the scattering chamber of the instrument. The instrument reading is proportional to the light-scattering coefficient, which indicates the total amount of light scattered into all directions by the air sample in the scattering chamber.

The scattering volume is illuminated from the side by a diffuse light source. The photomultiplier detector views a dark trap through a conical scattering volume defined by a series of baffles with circular holes in them. The baffles prevent the photomultiplier from viewing any surface, other than the internal span calibration chopper, that is illuminated by the light source.

The geometry of the system is set so the light falling on the photomultiplier is very nearly proportional to the light-scattering coefficient of the air sample in the scattering chamber, which is a measure of the total amount of light scattered into all angles by the air sample. The nephelometer processes these data to subtract light scattering by air to obtain a measure of the scattering coefficient b_{sp}. The nephelometer is calibrated to read zero when filled with particle-free air, so the readings are proportional to light scattering by particles. A calibration span gas (Freon 134A SUVA), which has a larger scattering coefficient than air, is used to adjust the span of the nephelometer so the data are recorded directly in engineering units of m^{-1}.

2.2.1.10 Ultrafine Particles

The TSI Model 3091 Fast Mobility Particle Sizer (FMPS™) spectrometer measures particles in the range from 5.6 to 560 nm, with a total of 32 channels of resolution (16 channels per decade). The FMPS spectrometer uses multiple, low-noise electrometers for particle detection. This produces particle-size-distribution measurements with one-second resolution, providing the ability to visualize particle events and changes in particle size distribution in real time.

The FMPS spectrometer operates at a high flow rate (10 L/min) to minimize diffusion losses of ultrafine and nanoparticles. It operates at ambient pressure to prevent evaporation of volatile particles, and it requires no consumables.

Features of the FMPS include:

- Measures particles in the range from 5.6 to 560 nm
- Measures particle events and size distributions in real time
- Offers 32 channels of resolution
- Comprehensive software for data collection and analysis
- Single-box design for easy transport, set up, and operation

The FMPS will be operated to generate UFP distributions integrated over 60-second time intervals.

2.2.1.11 Particle PAH

The continuous PAH analyzer used will be the PAS 2000, manufactured by EcoChem Analytics. The PAS 2000 is an instrument used for real-time measurement of total particle-bound PAH concentrations in air. This instrument works on the principle of photoionization.

The Photoelectric Aerosol Sensor (PAS) draws in air at a controlled flow rate of 2 LPM using a built-in pump. The excimer lamp exposes aerosols in the air flow to a high intensity, narrow band source of ultraviolet (UV) radiation. The wavelength of the UV light is chosen such that only the PAH-coated aerosols are ionized, while gas molecules and non-carbon aerosols remain neutral. The ionized particles are collected on a filter inside an electrometer, where the charge is measured. The resulting electric current establishes a signal which is proportional to the concentration of total particle-bound PAH. The analyzer signal is thus correlated to total PAH adsorbed on carbon particles, but does not provide actual concentrations or speciation of specific PAH compounds.

According to the manufacturer, the PAS 2000 detection limit is approximately 3 nanograms per cubic meter. Because the nature of PAH aerosols varies depending on the source(s) of the emissions, and the analyzer response in turn depends on the PAH mixture’s relative responses to photoionization, the monitor must have site-specific calibration curves to convert the detector signals to concentrations for specific source applications. If no site-specific calibration is available, the amount of charge generated by the ionized particles can be recorded for screening and real-time trending applications. Since no specific calibration is available for this study, the analyzer readings in femtoamps (fA) will be recorded to obtain a measure of PAH that can be correlated with other measurements. A 1-minute averaging period will be used.

2.2.1.12 Gas Calibration System

The air quality monitoring station at LAX will be equipped with a Thermo Model 146C Multigas Calibration System. The TEI 146C is an air quality calibration system with mass flow controllers. The calibration system combines solenoid valves, power supplies, and other major components that have been used for air quality applications for several years with state-of-the-art control technology which will allow users to remotely conduct Level-1 precision checks and multi-point calibrations. The diluent air mass flow controller has a range of 10 standard liters per minute (SLPM) and the gas mass flow controller has a range of 100 cubic centimeters (cc)/minute. The mass flow controllers assure a precise mixing ratio for accurate and precise calibration gas generation using the electronic closed-loop control. The CPU calculates both the required gas and diluent air flow rate and controls the corresponding mass flow controllers accordingly. The TEI 146C will be used in conjunction with NIST traceable USEPA Protocol 2 bottled calibration gases to generate known gas concentrations to challenge analyzers for calibrations and zero/span checks.

In addition to its basic dilution function, the TEI 146C is equipped with an ozone generator. The O_3 generator is used to perform gas phase titration (GPT) for the NO_x analyzer. The principle of GPT relies on the rapid gas phase reaction between NO and O_3 which produces stoichiometric quantities of NO_2. Given that the NO concentration is known prior to this reaction, the resultant concentration of NO_2 can be determined. After the addition of O_3, the observed decrease in NO concentration on the NO channel is equivalent to the concentration of NO_2 produced. The Thermo 146C is designed to satisfy complete reaction (less than 1 percent residual O_3) based on USEPA guidelines for GPT. Ultraviolet (UV) photometer transfer standards for O_3 calibrations also will be employed.

2.2.2 Air Sample Collection & Analysis

The following subsections describe the various air sampling approaches to be used in the Demonstration Project. The sampling equipment and media are described, along with the laboratory analytical techniques. Specific lists of target compounds and detection limits are included for each type of sampler.

All active air samplers (i.e., samplers using pumps) will have pre- and post-sample flow rate checks performed and recorded on field data sheets. The flow checks will be performed with a BIOS Dry Cal piston flow meter, equivalent bubble flow meter and/or a NIST traceable Flow Calibration Orifice Device specific for each of the sampler types being used. If the Dry Cal does not respond properly due to pressure pulsation interference, then a bubble flow meter and/or a NIST traceable Flow Calibration Orifice Device will be used instead to ensure accurate flow measurements. The average pre- and post-sample flows will be averaged and used with the recorded sample elapsed time to calculate the air sample volume. The air sample volumes will be calculated in the field and conveyed to the laboratory with the chain of custody. The sample air concentrations will then be calculated by the laboratory and included as part of the analytical results reports.

2.2.2.1 Aerosol Speciation Sampler

Aerosol speciation samples will be collected using URG-2000-01K Dual Channel Sequential Fine Particle Sampler (DSFPS), developed by University Research Glassware (URG) in Chapel Hill, North Carolina. The DSFPS allows simultaneous collection of up to four pairs of sequential samples in parallel, using an annular denuder system (ADS) for sample collection.

The DSFPS is equipped with two inlets and manifolds. The two inlets are PM_{10} size selective inlets. At the head of each manifold, a cyclone cuts any remaining particles greater than 2.5 µm. The PM_{10} inlet is designed for an optimum 10 µm cutpoint at a 16.7 LPM flow rate, and the $PM_{2.5}$ cyclone is designed for a 2.5 µm cutpoint at a nominal flow rate of 10.0 LPM. The sampler will be operated at a 10.0 LPM flow rate. This will affect the exact large-particle cutpoint of the PM_{10} inlet, but this side effect is irrelevant because the $PM_{2.5}$ cut will still be correctly made by the cyclone. Each manifold has ports for four ADS trains. The ADS trains consist of annular denuders (if desired) to collect acidic and basic gases, followed by a multi-stage 47 mm diameter filter pack. The annular denuders have concentric etched-glass walls spaced 1 mm apart that are coated with specific chemicals to absorb the gaseous species of interest. The denuder tubes are designed to produce laminar flow through the channels, which allows the fine particles to pass through for collection on the filter pack. The first stage of the filter pack collects $PM_{2.5}$ for chemical analyses. The second stage of the filter pack is used with impregnated filters to capture gas-phase artifacts volatilized from the first-stage filter.

The broad range of aerosol analyses in the Technical Workplan require the use of four separate ADS trains to collect all required parameters. Since the URG-2000-01K can only collect two trains simultaneously, two units will be used. The fourth available port will be used to collect collocated duplicate trains for quality assurance. There will be four different ADS sampling train configurations used for aerosol speciation in the Demonstration Project:

Train 1 is focused on reactive gases, ammonia, and $PM_{2.5}$ mass & elemental composition. Its configuration will be as follows:

- Sodium carbonate (Na_2CO_3) coated denuder analyzed for HNO_3 by IC;
- Citric acid coated denuder analyzed for NH_4 by AA;

- Teflon 1st stage 47 mm filter analyzed for NH_4 by IC
- Citric acid impregnated 47 mm filter analyzed for volatilized NH_4 by AA.

The Train 1 configuration will only be run for 7 days at the South Runway. Because this train will occupy the 4th port normally available for duplicate samples, it will not be possible to collect a duplicate sample for this train.

Denuder and filter coatings, extraction, and analysis will be based on USEPA Method IO 4.2.

Train 2 is focused on $PM_{2.5}$ carbon and particulate cations/anions. Its configuration is:

- Quartz 1st-stage 47 mm filter analyzed for total elemental carbon (IMPROVE protocol), cations (K, Na by IC), and anions (NO_3, SO_4 by IC).
- Cellulose 2nd-stage 47 mm filter impregnated with sodium chloride analyzed for nitrate by IC

The full Train 2 configuration will only be run at the South Runway. At the Portable Platform Sites, the 2nd stage nitrate filter will be dropped, and Train 1 will consist solely of the quartz 47 mm filter.

Train 3 will collect a sample for PAH compounds (including hopanes and steranes) using a single-filter train with a

- 47 mm quartz filter

This filter will be solvent extracted and analyzed for PAHs, hopanes, and steranes by a method developed by the University of Wisconsin- Madison.

Train 4 is focused on $PM_{2.5}$ elemental composition. Its configuration will be a single

- Teflon 47 mm filter analyzed for elements by XRF

In addition, a subset of the Teflon filters (total of 10) will be analyzed for elements by ICP/MS following the XRF analysis.

The target compounds and detection limits for the aerosol speciation samplers are presented in Table 2-3.

All ADS trains will be prepared by AAC, and transported to the field disassembled and securely capped. In the field, the trains will be assembled, installed in the sampler, and leak checked

Table 2-3

Target Compounds and Detection Limits:
Aerosol Speciation Sampler

Analyte[a]	Detection Limit		
	Analytical (µg/sample)	Media	Air Concentration (µg/m^3)[b]
Train 1			
Particulate NH4	0.50	Teflon Filter (1st Stage)	0.069
Vapor NH$_3$	0.50	Citric Acid Denuder	0.000
Vapor NO$_3$	0.50	Sodium Carbonate Denuder	0.000
Volatilized NH$_4$	0.50	Citric Acid Filter (2nd Stage)	0.000
Train 2			
Particulate K, Na,SO4	0.50	Quartz Filter	0.069
E1 IMPROVE	1.1	Quartz Filter	0.15
E2 IMPROVE	0.7	Quartz Filter	0.097
E3 IMPROVE	0.2	Quartz Filter	0.028
EC IMPROVE TOR	1.6	Quartz Filter	0.22
EC IMPROVE TOT	1.2	Quartz Filter	0.17
O1 IMPROVE	3.8	Quartz Filter	0.53
O2 IMPROVE	3.5	Quartz Filter	0.49
O3 IMPROVE	6.0	Quartz Filter	0.83
O4 IMPROVE	3.2	Quartz Filter	0.44
OC IMPROVE TOR	11.1	Quartz Filter	1.54
OC IMPROVE TOT	11.6	Quartz Filter	1.61
OP IMPROVE TOR	0.2	Quartz Filter	0.028
OP IMPROVE TOT	0.8	Quartz Filter	0.11
Elemental carbon	2.4	Quartz Filter	0.33
Organic carbon	2.4	Quartz Filter	0.33
Pk1_OC	2.4	Quartz Filter	0.33
Pk2_OC	2.4	Quartz Filter	0.33
Pk3_OC	2.4	Quartz Filter	0.33
Pk4_OC	2.4	Quartz Filter	0.33
PyrolC	2.4	Quartz Filter	0.33
TC IMPROVE	1.4	Quartz Filter	0.19
Total carbon	2.4	Quartz Filter	0.33
Nitrate	0.25	Quartz Filter	0.035
Train 3			
PAH	0.005 - 0.020	Quartz Filter	0.00069 - 0.0028
Train 4			
Total PM2.5 Mass	7.50	Teflon Filter	1.042
Aluminum	0.03	Teflon Filter	0.004
Antimony	0.10	Teflon Filter	0.013
Arsenic	0.18	Teflon Filter	0.025
Barium	0.10	Teflon Filter	0.013
Bromine	0.31	Teflon Filter	0.043
Cadmium	0.05	Teflon Filter	0.007
Calcium	0.04	Teflon Filter	0.005
Cerium	0.12	Teflon Filter	0.017
Cesium	0.04	Teflon Filter	0.005
Chlorine	0.03	Teflon Filter	0.005
Chromium	0.05	Teflon Filter	0.006
Cobalt	0.21	Teflon Filter	0.029
Copper	0.08	Teflon Filter	0.010
Europium	0.03	Teflon Filter	0.004
Gallium	0.71	Teflon Filter	0.099
Gold	0.06	Teflon Filter	0.008
Hafnium	0.63	Teflon Filter	0.088
Indium	0.03	Teflon Filter	0.004
Iridium	0.09	Teflon Filter	0.013
Iron	0.09	Teflon Filter	0.012
Lanthanum	0.02	Teflon Filter	0.003
Lead	0.05	Teflon Filter	0.007
Magnesium	0.15	Teflon Filter	0.021
Manganese	0.11	Teflon Filter	0.015
Mercury	0.03	Teflon Filter	0.003
Molybdenum	0.10	Teflon Filter	0.013
Nickel	0.36	Teflon Filter	0.050
Niobium	0.03	Teflon Filter	0.003
Phosphorus	0.18	Teflon Filter	0.025
Potassium	0.14	Teflon Filter	0.019
Rubidium	2.10	Teflon Filter	0.292
Samarium	0.24	Teflon Filter	0.033
Scandium	0.40	Teflon Filter	0.056
Selenium	0.03	Teflon Filter	0.004
Silicon	0.57	Teflon Filter	0.079
Silver	0.02	Teflon Filter	0.003
Sodium	0.18	Teflon Filter	0.025
Strontium	0.07	Teflon Filter	0.010
Sulfur	0.97	Teflon Filter	0.135
Tantalum	0.44	Teflon Filter	0.061
Terbium	0.15	Teflon Filter	0.021
Tin	0.03	Teflon Filter	0.003
Titanium	0.02	Teflon Filter	0.003
Vanadium	0.02	Teflon Filter	0.003
Wolfram	0.11	Teflon Filter	0.015
Yttrium	0.05	Teflon Filter	0.007
Zinc	0.08	Teflon Filter	0.011
Zirconium	0.26	Teflon Filter	0.036

NOTES:

a - Based on target compound list supplied by RTI and AAC.

b - Based on target air sample volume of 7.20 m^3 (10.0 LPM for 12 hours).

immediately prior to sampling. The samples will be run for 12 hours. Upon completion of the sample, the ADS trains will be removed from the sampler. The individual train components (denuders, filter packs) will have pre-printed sample identification labels affixed, then the trains will be disassembled and the components securely capped. The ADS components will be stored on-site until transported to the laboratory. PAH filter samples will be stored and shipped chilled (4 C).

A single laboratory will perform all analyses for each ADS train. The trains will be delivered directly to AAC's Ventura lab and then shipped to the appropriate lab. Train 1 will be entirely analyzed by AAC. Trains 2 and 4 will be analyzed by RTI. Train 3 will be analyzed by UW-M.

2.2.2.2 Carbonyl Sorbent Tubes

The method used to collect samples for the analysis of carbonyl compounds, including formaldehyde, acetaldehyde, and methyl ethyl ketone (MEK) in the ambient air utilizes solid adsorbent media followed by extraction and analysis by High Performance Liquid Chromatography (HPLC). This method is based on the U.S. EPA Method TO-11.

Ambient air is drawn through chromatographic grade Sep-Pak silica cartridges with an ozone scrubber inline. The cartridges are coated with acidified 2,4-dinitrophenylhydrazine (DNPH). Air will be sampled using an AC-powered pump at a rate of 0.7L per minute for a 12-hour period. During sampling, formaldehyde, acetaldehyde, and methyl ethyl ketone react with the DNPH to form derivatives that are called hydrazones. The DNPH derivatives are eluted from the sampling cartridges using acetone-free acetonitrile (CAN) and are quantified using reverse-phase HPLC with ultraviolet absorption detection at 360 nm.

Sample hold time is 14 days. Laboratory analysis will be provided by AAC.

The target compounds and detection limits for the DNPH samplers are presented in Table 2-4.

Table 2-4

Target Compounds and Detection Limits
Carbonyls Sampler
U.S. EPA Method TO-11

Analyte[a]	Detection Limit	
	Analytical (µg/sample)	Air Concentration ($\mu g/m^3$)[b]
Formaldehyde	0.0375	0.0744
Acetaldehyde	0.0375	0.0744
Acrolein	0.0375	0.0744
Propionaldehyde	0.0375	0.0744
Crotonaldehyde	0.0375	0.0744
Methacrolein	0.0375	0.0744
Methyl Ethyl Ketone	0.0375	0.0744
Butyraldehyde	0.0375	0.0744
Benzaldehyde	0.0375	0.0744
Valeraldehyde	0.0375	0.0744
Tolualdehyde	0.0375	0.0744
Hexaldehyde	0.0375	0.0744

NOTES:

a - Based on target compound list supplied by the lab.

b - Based on target air sample volume of .504 m3 (0.7LPM for 12 hours).

Acetone will be reported from the TO-15 analysis

2.2.2.3 *Summa Canisters*

The laboratory will provide SUMMA canisters that were passivated using a special process involving electro-polishing and chemical deactivation of the internal surface of the vessel using a combination of exponential dilution, heat and high vacuum. The lab will certify that the canisters have been cleaned to the standards required for achieving the low sample detection limits. After cleaning, air from the canisters will be evacuated. The canisters will have a 6-liter capacity and an initial vacuum of approximately negative 30” Hg. A 7-micron pre-filter will be attached to the canister to minimize entry of particulates.

A vacuum gauge will be used to measure the initial and final vacuum of the canister, and to monitor the filling of the canister. The gauges will be used to provide a relative measure of change. Before sampling, the gauge will confirm the pressure reads between negative 29” and negative 30” Hg for each canister.

Fixed-rate flow controllers, along with micron particulate filter will be placed on the canister after measurement of initial canister pressure (normally measured between negative 29 and negative 30 “Hg using a pressure gauge). The flow-controllers will be pre-set to meter the flow of air into the canister at a relatively constant rate over the course of a 12 hour sampling period to fill approximately two thirds of the canister capacity (a 4 liter sample for a 6 liter canister). The flow controller and the filters will be cleaned and supplied by the laboratory, and will be dedicated for each sample. If necessary, in order to collect breathing zone (3 to 5 feet above ground or floor level) air samples, a metal cane may be attached to a sampling canister if needed. These metal canes should be used if the sampling canisters are placed on the ground. However, depending on the placement of the sampling canisters (on the sampling platform), the height adjustments may not be necessary. All air samples will be collected at a uniform height and will be positioned (if possible) to avoid direct sunlight during the sampling.

To begin sampling, the flow controller will be attached to the sampler. All connections between the canister and the flow controller must be tight enough so that the various pieces of equipment (flow controller, gauge, etc.) when assembled cannot be rotated by hand. Any leaks in these connections will be corrected prior to sampling or the canister will be replaced. After the canister has been placed at the sample location, the canister inlet valve will be opened.

At the end of the 24-hour sampling period, the final canister pressure will be measured using a vacuum gauge. The target final pressure is between negative 4" and negative 12"Hg (mercury).

The samples will be packaged and shipped to the laboratory for analysis. The final vacuum will be noted on the chain of custody. This documentation will allow the lab to compare the vacuum from sampling with the receipt vacuum. The sample integrity is ensured if the final field reading and the lab receipt reading are similar. The sample may have been compromised during shipment, if the readings significantly differ. Custody seals will also be affixed across box entry points to provide another method of discerning if the samples were tampered with during shipment to the laboratory.

SUMMA canisters and air analysis will be provided by AAC. Analysis will be conducted for a list of EPA PAMS protocol compounds, in accordance with EPA Methods TO-15 and TO-12. All of the samples will be analyzed for the VOCs listed in Table 2-5. Only a single analytical result will be reported for each compound. Where results are available for a compound from both methods, the results for Method TO-15 will be reported. Method TO-15 provides a more precise compound-specific measurement than the standard Method TO-12 protocol.

The target compounds and detection limits for the canister samplers are presented in Table 2-5.

2.2.2.4 Heavy Hydrocarbon Sorbent Tubes

The chosen method to perform the sampling of heavy hydrocarbons will be drawing air through charcoal tubes. The monitoring procedure involves pulling a volume of air through a sorbent packing to collect VOCs followed by desorption/extraction and analysis. The sampling apparatus will include an in-line particulate filter, a sampling tube, and a flow controller/pump combination. Samples will be collected over a 12 hour period at a flow rate of 0.5 lpm.

Table 2-5

Target Compounds and Detection Limits
Canister Sampler
U.S. EPA Method TO-12 / TO-15 [b]

Analyte[a] - TO-12	Detection Limit	Analyte[a] - TO-15	MDL	PQL
	Concentration ppbC		Concentration ppbV	
ethylene	1.00	chlorodifluoromethane	0.20	0.50
acetylene	1.00	dicldifmethanef-12	0.20	0.50
ethane	1.00	chloromethane	0.20	0.50
propylene	1.00	dicltetrafethanef114	0.20	0.50
propane	1.00	vinylchloride	0.20	0.50
isobutane	1.00	methanol	0.50	5.00
1-butene	1.00	1,3-butadiene	0.20	0.50
n-butane	1.00	bromomethane	0.20	0.50
trans-2-butene	1.00	chloroethane	0.20	0.50
cis-2-butene	1.00	dichlorofluoromethane	0.20	0.50
isopentane	1.00	ethanol	0.20	2.00
1-pentene	1.00	vinylbromide	0.20	0.50
n-pentane	1.00	acetone	0.20	2.00
isoprene	1.00	trichlorofluoromethane	0.20	0.50
trans-2-pentene	1.00	isopropanol	0.20	2.00
cis-2-pente	1.00	acrylonitrile	0.20	1.00
2,2-dimethylbutane	1.00	1,1-dichloroethylene	0.20	0.50
cyclopentane	1.00	methylenechloride	0.20	1.00
2,3-dmb	1.00	allylchloride(3-chloro...	0.20	0.50
2-methylpe	1.00	carbondisulfide	0.20	0.50
3-methylpentane	1.00	tricl-trifethanef-113	0.20	0.50
1-hexene	1.00	t-1,2-dichloroethylene	0.20	0.50
n-hexane	1.00	1,1-dichloroethane	0.20	0.50
mcpentane	1.00	mtbe	0.20	0.50
2,4-dmp	1.00	vinylacetate	0.50	1.00
benzene	1.00	mek	0.20	1.00
cyclohexane	1.00	c-1,2-dichloroethylene	0.20	0.50
2-methylhexane	1.00	hexane	0.20	0.50
2,3-dimethylpentane	1.00	chloroform	0.20	0.50
3-methylhexane	1.00	ethylacetate	0.20	0.50
2,2,4-trimethylpentane	1.00	tetrahydrofuran	0.20	0.50
n-heptane	1.00	1,2-dichloroethane	0.20	0.50
methylcyclohexane	1.00	1,1,1-trichloroethane	0.20	0.50
2,3,4-trimethylpentane	1.00	carbontetrachloride	0.20	0.50
toluene	1.00	1,2-dichloropropane	0.20	0.50
2-mhp	1.00	bromodichloromethane	0.20	0.50
3-mhp	1.00	1,4-dioxane	0.20	0.50
n-octane	1.00	trichloroethene	0.20	0.50
ethylbenzene	1.00	heptane	0.20	0.50
m/p-xylenes	2.00	cis-1,3-dichloropropen	0.20	0.50
styrene	1.00	mibk	0.20	0.50
o-xylene	1.00	trans-1,3-dichloropropene	0.20	0.50
nonane	1.00	1,1,2-trichloroethane	0.20	0.50
isopropylbenzene	1.00	2-hexanone	0.20	0.50
n-propylbenzene	1.00	dibromochloromethane	0.20	0.50
m-ethyltoluene	1.00	1,2-dibromoethane	0.20	0.50
p-ethyltoluene	1.00	tetrachloroethene	0.20	0.50
1,3,5-trimethylbenzene	1.00	chlorobenzene	0.20	0.50
o-ethyltoluene	1.00	bromoform	0.20	0.50
1,2,4-trimethylbenzene	1.00	1,1,2,2-tetrachloroethane	0.20	0.50
n-decane	1.00	benzylchloride(a-chlor...	0.20	0.50
1,2,3-trimethylbenzene	1.00	1,3-dichlorobenzene	0.20	0.50
m-diethylbenzene	1.00	1,4-dichlorobenzene	0.20	0.50
p-diethylbenzene	1.00	1,2-dichlorobenzene	0.20	0.50
n-undecan	1.00	1,2,4-trichlorobenzene	0.20	0.50
n-dodecan	1.00	hexachlorobutadiene	0.20	0.50

NOTES:

a - Based on target compound list supplied by AAC.

b - TO-12 will be reported in ppbC and TO-15 will be reported in ppbV. The identical compounds in both methods will be reported in the TO-15 limits.

AETL will analyze the sorbent tubes using EPA Method 8015.

The target compounds and detection limits for the charcoal samplers are presented in Table 2-6.

2.2.2.5 Minivol

Aerosol samples will also be collected using the MiniVol Portable air sampler manufactured by Airmetrics. The MiniVol is a compact portable, battery-operated sampler that is being evaluated in the Demonstration Project for use in the surrounding communities during the Long-Term Study. The MiniVols will collect $PM_{2.5}$ to be analyzed for elements, NH_3, Carbon (using the IMPROVE method), ions, volatile nitrate, and select organics (method TO-13A)

The Airmetrics MiniVol is equipped with an inlet impactor capable of separating particulate matter. The impactors to be used in the Demonstration Project will have a $PM_{2.5}$ cut point, and are designed to operate at a fixed flow rate of 5 LPM at actual conditions. The units are also equipped with a flow control device which will maintain a specified flow rate, and a flowmeter to measure the flow rate during the sampling period. An elapsed time meter and a programmable timer that starts and stops the sampler allow the sampler to run unattended. The exchangeable battery pack is capable of powering the pump and other electronics for a complete 24-hour sampling period.

The Minivol trains will be run using three configurations. MiniVol Train 1 will only use a single Teflon filter. Only elements by XRF and total particle mass will be analyzed from this filter. Minivol Train 2 will consist of only a quartz filter, to be analyzed for ions and carbon as for speciation sampler Train 2. MiniVol Train 3 will be identical to speciation samplers Train 3. Speciation sampler trains are described in Section 2.2.2.1.

All MiniVol filter packs will be prepared by AAC, and transported to the field securely capped. In the field, the trains will be installed in the sampler. The samples will be set to run for 24 hours. Upon completion of the sample, the filter packs will be removed from the sampler, securely capped, and have pre-printed sample identification labels affixed. The filter packs will be stored on-site until transported to the laboratory. The target compounds and detection limits for the MiniVol samplers are presented in Table 2-7.

Table 2-6

Target Compounds and Detection Limits
Charcoal Sampler

Analyte[a]	Detection Limit
	Ambient Concentration (ppbv)[b]
C_{10} Hydrocarbons	1 - 10
C_{12} Hydrocarbons	1 - 10
C_{14} Hydrocarbons	1 - 10
C_{16} Hydrocabrons	1 - 10
C_{18} Hydrocarbons	1 - 10
C_{20} Hydrocarbons	1 - 10

NOTES:

a - Based on target compound list supplied by AETL.

b - Based on target air sample volume of 0.36 m^3

Table 2-7

Target Compounds and Detection Limits: MiniVol Sampler

Analyte[a]	Detection Limit		
	Analytical (µg/sample)	Media	Air Concentration (µg/m^3)[b]
Train 1			
Particulate NH4	0.50	Teflon Filter	0.069
Train 2			
Particulate K, Na,SO4	0.50	Quartz Filter	0.069
E1 IMPROVE	1.1	Quartz Filter	0.15
E2 IMPROVE	0.7	Quartz Filter	0.097
E3 IMPROVE	0.2	Quartz Filter	0.028
EC IMPROVE TOR	1.6	Quartz Filter	0.22
EC IMPROVE TOT	1.2	Quartz Filter	0.17
O1 IMPROVE	3.8	Quartz Filter	0.53
O2 IMPROVE	3.5	Quartz Filter	0.49
O3 IMPROVE	6.0	Quartz Filter	0.83
O4 IMPROVE	3.2	Quartz Filter	0.44
OC IMPROVE TOR	11.1	Quartz Filter	1.54
OC IMPROVE TOT	11.6	Quartz Filter	1.61
OP IMPROVE TOR	0.2	Quartz Filter	0.028
OP IMPROVE TOT	0.8	Quartz Filter	0.11
Elemental carbon	2.4	Quartz Filter	0.33
Organic carbon	2.4	Quartz Filter	0.33
Pk1_OC	2.4	Quartz Filter	0.33
Pk2_OC	2.4	Quartz Filter	0.33
Pk3_OC	2.4	Quartz Filter	0.33
Pk4_OC	2.4	Quartz Filter	0.33
PyrolC	2.4	Quartz Filter	0.33
TC IMPROVE	1.4	Quartz Filter	0.19
Total carbon	2.4	Quartz Filter	0.33
Train 3			
PAH	0.005 - 0.020	Quartz Filter	0.00069 - 0.0028
Train 4			
Total PM2.5 Mass	7.50	Teflon Filter	1.042
Aluminum	0.03	Teflon Filter	0.004
Antimony	0.10	Teflon Filter	0.013
Arsenic	0.18	Teflon Filter	0.025
Barium	0.10	Teflon Filter	0.013
Bromine	0.31	Teflon Filter	0.043
Cadmium	0.05	Teflon Filter	0.007
Calcium	0.04	Teflon Filter	0.005
Cerium	0.12	Teflon Filter	0.017
Cesium	0.04	Teflon Filter	0.005
Chlorine	0.03	Teflon Filter	0.005
Chromium	0.05	Teflon Filter	0.006
Cobalt	0.21	Teflon Filter	0.029
Copper	0.08	Teflon Filter	0.010
Europium	0.03	Teflon Filter	0.004
Gallium	0.71	Teflon Filter	0.099
Gold	0.06	Teflon Filter	0.008
Hafnium	0.63	Teflon Filter	0.088
Indium	0.03	Teflon Filter	0.004
Iridium	0.09	Teflon Filter	0.013
Iron	0.09	Teflon Filter	0.012
Lanthanum	0.02	Teflon Filter	0.003
Lead	0.05	Teflon Filter	0.007
Magnesium	0.15	Teflon Filter	0.021
Manganese	0.11	Teflon Filter	0.015
Mercury	0.03	Teflon Filter	0.003
Molybdenum	0.10	Teflon Filter	0.013
Nickel	0.36	Teflon Filter	0.050
Niobium	0.03	Teflon Filter	0.003
Phosphorus	0.18	Teflon Filter	0.025
Potassium	0.14	Teflon Filter	0.019
Rubidium	2.10	Teflon Filter	0.292
Samarium	0.24	Teflon Filter	0.033
Scandium	0.40	Teflon Filter	0.056
Selenium	0.03	Teflon Filter	0.004
Silicon	0.57	Teflon Filter	0.079
Silver	0.02	Teflon Filter	0.003
Sodium	0.18	Teflon Filter	0.025
Strontium	0.07	Teflon Filter	0.010
Sulfur	0.97	Teflon Filter	0.135
Tantalum	0.44	Teflon Filter	0.061
Terbium	0.15	Teflon Filter	0.021
Tin	0.03	Teflon Filter	0.003
Titanium	0.02	Teflon Filter	0.003
Vanadium	0.02	Teflon Filter	0.003
Wolfram	0.11	Teflon Filter	0.015
Yttrium	0.05	Teflon Filter	0.007
Zinc	0.08	Teflon Filter	0.011
Zirconium	0.26	Teflon Filter	0.036

NOTES:

a - Based on target compound list supplied by laboratories.

b - Based on target air sample volume of 7.2 m3 (5LPM for 24 hours).

2.2.2.6 Deposition Plates

The method of collecting the deposition of dry particles or “fall out” particles analyzed for particle morphology & elemental composition (EDS) by computer controlled size elemental analysis (CCSEM) will be a 1 x 3 inch greased Mylar strip which has been previously mounted onto a clean PVC plate. The preweighed grease-coated Mylar strips are mounted onto the dry deposition plate (PVC plate) and will be kept in a Rubbermaid sample container during the sampling period. The PVC plate holds the strips horizontally so that dry deposition can collect on the strips' greased surfaces. The grease used (L-Apiezon) is non-volatile, so the difference between before and after sampling weights of the strips is measured for the amount of deposited material.

The plates will be exposed for periods of 7 days. If precipitation occurs during a sample exposure, the sample will be temporarily covered during wet periods, and the amount of time during the scheduled 7-day exposure the sample is covered will be noted. The sample will be covered, sealed, and shipped for analysis at the completion of the scheduled 7-day period.

The elemental analysis will be performed by MVA Scientific Consultants (MVA), located in Duluth, Georgia. The analysis technique by CCSEM will provide a particle size distribution as well as an elemental analysis of each particle. The elemental data is used to infer the type of particle (e.g. quartz, limestone, steel, soot, aluminum, etc.) Digital imaging under computer control with a scanning electron microscope makes the morphological and chemical analysis possible. MVA will utilize this computer control to obtain digital images that can be acquired into computer memory. The image can then be searched for particles based on computer programs that recognize image contrast. Size and shape calculations can then be made and recorded for each particle found, and the electron beam can be driven back to the particle for chemical analysis by energy dispersive x-ray spectrometry.

The analyses performed by MVA are primarily qualitative, and are not similar to routine analytical data. The MVA reports of the deposition plate results will be included in the Demonstration Project Data Report.

2.2.2.7 Passive Samplers

The Ogawa and Company of Pompano Beach, Florida (Ogawa) Model 3300 Passive Sampling Device (PSD) will be used to collect samples to be analyzed for O_3, NO_x, NO, NO_2, and SO_2. Passive samplers will be exposed for seven days each during the South Runway portion of the Demonstration Project for particulate deposition and diffusion collection of the organics. The PSDs rely on air diffusion without the need of a power source. The passive sampler uses acid-coated filter discs to trap samples across a known distance.

The PSD is composed of a plastic body with an air inlet on either side. This makes it possible to sample more than one gas simultaneously, since the two inlets are separated by the solid section of the body. The dual-sided body will be mounted on a clip that is installed in a protective outdoor shelter.

During the South Runway portion of the study period, one PSD will be set up to collect for 7 consecutive days. The PSD contains two gas collection pads in its dual inlet configuration. The pads are 14.5 mm in diameter, and are specially coated to react chemically with a selected gas or gases. Analysis of the collection pads takes place in a laboratory using routine analytical procedures to determine the average gas concentration level during pad exposure. The construction of the chamber in which the collection pad resides is carefully engineered to ensure representative sampling. Following the Ogawa-patented inlet (diffusion barrier), the collection pad is sandwiched between two stainless steel screens. Behind the screens, a ring and backing tab maintain the desired ventilation conditions.

RTI will perform the lab analysis on the filter pads from the PSD. The components in the Ogawa PSD will be prepared in the laboratory prior to exposure. Following exposure, the used sampler is placed into a labeled, brown airtight vial and shipped to the laboratory for analysis.

Exposed pads can be safely shipped in the PS-118 8 ml vial. These vials can be rinsed, dried, and reused many times.

The target compounds and detection limits for the Ogawa samplers are presented in Table 2-8.

2.2.2.8 Snapshot VOCs

In addition to the main sampling efforts in the Demonstration Project, an attempt will be made to use a field-portable GC/MS to obtain ambient air VOC "grab" samples during source-specific peak emission periods such as passenger jet takeoffs. The Inficon HAPSITE Smart Chemical Identification System is the field-portable GC/MS unit to be used, on loan from the local AQMD office. The unit will be used in the field to gather 30-second samples using the HAPSITE's built-in sampling system, and then analyze the sample with a generic VOC program on the GC/MS system. The analysis time runs approximately 30 minutes per sample. The samples will be collected by a Site Operator during time periods when peak source emissions are occurring, such as during a passenger jet takeoff at the South Runway.

Because of the complexities and limitations of portable GC/MS analysis in a field setting, it is uncertain whether the instrument will provide useful results. Therefore, it is planned to collect a maximum of 32 samples at the South Runway during the first 1 week of the Demonstration Project and for 2 additional days at the 1st Portable Platform site to evaluate the effectiveness of the HAPSITE for the application. In the event that a trial sample analysis captures recognizable VOC peaks, the results will be interpreted and examined.

Samples will be collected on the HAPSITE each day in the field. At then end of the day, the HAPSITE will be returned to the AQMD office for refurbishment and calibration of the instrument by AQMD personnel trained to operate and maintain the HAPSITE unit. Reduction of the GC/MS data will be performed by WESTON personnel experienced with GC/MS analyses.

Demonstration Project

Table 2-8

Target Compounds and Detection Limits
Passive Sampler

Analyte	Detection Limit
	Ambient Concentration (ppb)[a]
Nitrogen Dioxide (NO_2)	0.32
Nitrogen Oxides (NO_x)	0.32
Sulfur Dioxide (SO_2)	0.54
Ozone (O_3)	0.39

NOTES:

a - Based on 7-day exposure and lower detectable limits from RTI.

2.2.3 Meteorology

2.2.3.1 Runway

At the proposed LAX site, meteorological data will be collected from an instrumented tower. It is assumed that a location can be identified in or near the areas of interest for the Demonstration Project that will allow the wind instruments to be exposed at the standard reference height of 10 m above ground level.

The station will collect both routine meteorological parameters and additional parameters that are of use in characterizing turbulence conditions in the boundary layer. The specific instruments and equipment are described in more detail below.

Horizontal wind speed and direction

Horizontal wind speed and direction on the tower will be measured continuously at the proposed LAX site using RM Young Model 5305 wind systems. Wind speed will be measured using an anemometer where the principle of operation is based on a magnetically induced AC current that produces a frequency proportional to wind speed. The wind direction sensor will be a lightweight vane that senses position by a precision potentiometer. The wind sensors will be installed at 10 m (or the maximum feasible height given site restrictions). The standard deviation (sigma-theta) of the wind direction is computed by the data logger using the USEPA-preferred Yamartino method (USEPA 2000). Short-term sigma theta values (15 minutes or less) will be calculated using all scans in the interval. Hourly sigma-theta values will be calculated using the root mean square (RMS) average of 15-minute subintervals.

Temperature and temperature difference

Ambient air temperature at the proposed LAX site will be measured at two levels on the tower using a Climatronics Model 100093 temperature system. This motor aspirated system includes dual element thermistors mounted at 10 m (or maximum tower height) and 2 m above ground level. Delta-T is calculated by the datalogger based on the difference in temperatures measured by identical sensors at each of the levels, 10-2 m. The datalogger resolves the temperature difference to better than 0.1°C.

This sensor configuration is designed to provide complete signal wire compensation and to eliminate any measurement errors resulting from resistance of the signal cable. The motorized aspirator is mechanically ventilated with a fan to prevent conductive interference from precipitation and radiation from solar and terrestrial sources.

Solar radiation

At the proposed LAX site, incoming shortwave solar radiation measurements will be made using an Eppley Model 8-48 pyranometer located at about the 2 m level. The sensor is designed for measurement of global (sun and sky) radiation. The detector is a differential thermopile made of plated copper on constantan junctions. Hot-junction receivers are covered with a stable black coating, cold junction receivers are whitened with non-hygroscopic barium sulfate. The sensor is temperature compensated using thermistor circuitry to within 1.5 percent of the range of -20°C to +40°C. The sensor is sensitive to wavelengths of 0.285 to 2.800 µm.

Barometric pressure

Barometric pressure will be measured using a Climatronics Model 102663-G0-10 pressure sensor. The pressure sensor is a piezoresistive device. The sensor is ideally suited to applications requiring accurate measurement of pressure. The sensor provides a 0-1V DC signal over a 600 to 1,100 hectoPascals (hPa, also referred to as millibars or mb) range.

Surface Roughness

If a 10 m exposure can be obtained for the wind sensors, the meteorological datalogger will also be programmed to calculate an approximate surface roughness length (z_0). Surface roughness is an important factor in determining the turbulence profile of the boundary layer, which is used in newer air dispersion models to characterize dispersion. Section 6.6.2 of the “Meteorological Monitoring Guidance for Regulatory Modeling Applications” provides an equation (Equation 6.6.11) for estimating z_0 based on the mean and standard deviation of the horizontal wind speed. The guidance also states that these estimates should only be made for periods where the average wind speed is greater than 5 m/s (11.2 mph), and be stratified by wind direction sectors. The data logger will be programmed to output the mean scalar wind speed, mean scalar wind direction, standard deviation of wind speed, and estimated z_0 whenever the 5-minute mean wind speed exceeds 5 m/s.

2.2.3.2 SCAQMD Stations

There is an air quality monitoring station operated by SCAQMD, located to the north of Westchester Parkway roughly north of the west end of the North Runway. The address of the SCAQMD LAX monitoring station is 7201 W Westchester Parkway, Los Angeles CA 90045, and the ARB Number of the site is 70111. The station has a 10-meter meteorological station that monitors air temperature, wind direction, horizontal wind speed, barometric pressure, and solar radiation. The LAX station also monitors the criteria pollutants CO, SO_2, NO_2, and O_3. The data from this tower during the Demonstration Project will be will be used to supplement the data collected by the meteorological station to be operated by ENSR near the South Runway. Data from the station will be obtained from SCAQMD and provided as part of the final data report.

In addition to its LAX monitoring station, SCAQMD also operates two atmospheric remotes sensing units in the vicinity of LAX: a radar profiler and a sodar. The radar profiler measures wind speed and direction at multiple vertical levels, and is equipped with a Radio Acoustic Sounding System (RASS) to provide simultaneous profiles of air temperature at multiple levels. The sodar uses acoustic Doppler shifts to measure vertical profiles of wind speed, direction, and turbulence. The data from these units will also be obtained from SCAQMD to supplement the other surface-level meteorological data being collected in conjunction with the Demonstration Project.

The SCAQMD stations will be audited in conjunction with the Demonstration Project by T&B Systems. The audits of the upper air (sodar) and LAX monitoring station were completed on May 13, 2008. No significant issues were identified at either site. Auditing of the upper air profiler is planned for late May or June. Audit procedures are described in Section 4.2.

2.2.4 Data Acquisition & Telemetry

2.2.4.1 Data Loggers

The digital data loggers used will be CR-3000 or CR-1000 data loggers manufactured by Campbell Scientific, Inc. (CSI). The Campbell CR-series of data loggers are programmable, general-purpose data logging units that can accept a wide variety of sensors with analog outputs, and contain built-in algorithms for processing meteorological data.

The CR-3000 and CR-1000 both share a common programming language and communications interface, and differ primarily in the number of channels that can be measured. The CR-3000 logger can measure up to 28 single-ended (14 double-ended) analog channels, and up to 4 pulse counters. The CR-1000 logger can measure up to 16 single-ended analog channels, and up to 2 pulse counters. The analog measurements performed by the loggers have an accuracy of better than ± 0.1% of full scale voltage. Both loggers have programmable scanning rates that can scan a single channel as frequently as 64 times per second. The loggers can operate in outdoor environments, housed in weather-tight National Electrical Manufacturers Association (NEMA) standard enclosures for moisture protection, along with their power supplies and telemetry equipment.

The loggers are powered by small 12 VDC rechargeable batteries, or by typical 12 VDC deep cycle marine batteries. The batteries will be continuously trickle-charged with AC power chargers. When used with meteorological stations, the logger is also used to provide power for all of the meteorological sensors (excluding heaters & aspirators)

The loggers will be programmed at each site according to the instruments located at the site. Each logger will be programmed to scan its input channels once every second, and provide outputs (averages, maxima, minima, etc.) at the desired intervals.

The primary data collection interval for the Demonstration Project will be 1 minute, where allowable by individual instrument limitations. Because other longer time scales may also be of interest, the data loggers will also be programmed to calculate and directly output 5-minute, 15-minute, and 60-minute averages. Obtaining multiple averaging periods directly from the data logging systems avoids additional data post-processing efforts (and possible introduction of errors) that would otherwise be required to obtain longer averaging period from 1-minute data.

Data are stored on board the loggers in flash memory that is retained even if power is lost. The loggers also maintain their programming and internal clocks in the event of a power loss. No data will be collected if the battery becomes drained, but data collection will resume automatically when power is restored. The batteries at each station will be sufficient to power the loggers for several days if recharging power is lost. As an additional data integrity measure, each logger will be equipped with a memory card module, and all final storage data will also be written to the memory card. The memory cards will be replaced prior to becoming filled, and filled cards will be labeled and retained.

2.2.4.2 Data Telemetry & Review

The telemetry equipment for the study will be Redwing or Raven model CDMA Modems manufactured by AirLink Communications. Each cellular modem will have a separate telephone number. For data telemetry purposes, the Redwing or Raven cellular modem acts as a standard telephone modem, allowing direct connection to the data loggers for troubleshooting, programming, and data retrieval. The modems use 12 VDC power, which will be provided by a separate AC adapter.

The data from each station will be polled daily from WESTON's home office in West Chester, Pennsylvania. The retrieved data will be uploaded to a RespondFast^{SM} Real-Time Monitoring (RFRTM) database for review and processing. RFRTM is an Internet-based data telemetry and data management solution developed by WESTON. The data from the LAX monitoring systems will be reviewed on a daily basis during the work week by WESTON meteorologists who are experienced with continuous monitoring data.

ENSR will also poll its loggers to perform review of the monitors being operated by ENSR and the meteorological data. ENSR will provide to WESTON information regarding the reviewed data from its monitors, indicating periods of invalid data. WESTON will make the appropriate edits to the RFRTM databases to invalidate the data as noted by ENSR.

All data will be retrieved and reviewed daily during weekdays. Data will be marked in the RFRTM databases as raw until it is reviewed. Data will be reviewed by the next business day (or Monday for data collected Friday-Sunday).

2.2.5 Airport Data

Airport operations data for use in the Federal Aviation Administration (FAA) Emissions and Dispersion Modeling System (EDMS) will be collected from LAWA by JC. This data is not a part of the air monitoring and sampling program covered by this Monitoring Plan, but will be collected as part of the overall Demonstration Project.

2.3 LOCATIONS

Sampling and monitoring will be performed during the Demonstration Project at five (5) locations:

- South Runway (SR)
- Portable Platform Sites:
  - Site 2 (PS2) – Central Terminal
  - Site 3 (PS3) – Cargo Facilities
  - Site 4 (PS4) – Immediately East of Aviation Blvd
  - Site 5 (PS5) – East of SR

The general candidate areas for the specific sampling stations are shown on Figure 2-1.

None of the specific site locations are known at the writing of this Monitoring Plan. Specific locations will be determined by the Study Team in consultation with LAWA, based on the space and utility requirements presented in this section. All necessary security and aviation operational limitations will be observed in determining exact site locations. Geographic coordinates will be obtained for each final location selected, using a handheld Global Positioning System (GPS) receiver with Wide Area Augmentation System (WAAS) correction (approx. 5 m horizontal accuracy).

There will also be warehouse and office space designated for use by the Study Team outside of the secured perimeter of the airport, to be arranged by LAWA. This area will serve as staging area for equipment mobilization and demobilization, as well as sample storage and a base for routine daily operations during the Demonstration Project. These facilities will be north of the east end of the South Runway. The location of this area is also shown on Figure 2-1.

2.3.1 South Runway

The South Runway (SR) location will be positioned behind the blast fence on Runway 25R. Both the Main Trailer and the Portable Platform will be operated simultaneously at this location, prior to the beginning of the Portable Platform rotation to the other sites. The location will represent service dominated emissions from aircraft taxiing, takeoffs, and some roadway emissions.

2.3.2 Portable Platform

The following four areas will house only the Portable Platform for 7-day sampling periods. The Portable Platform will be relocated to each new position over a 2-3 day period. The exact siting location within each area (see Figure 2-1) will be selected based upon power availability, open space, and will avoid necessary traffic patterns.

The PS2 location will be positioned adjacent to the LAX Central Terminal Area. This location will represent landside and airside airport sources such as cargo, trucks, utility plant, PAX, and GSEs.

Site Locations:

SR - South Runway
PS1 - Fuel Farm
PS2 - Main Terminal
PS3 - South Air Cargo
PS4 - Near Plume (~200 m E of SR)
PS5 - Far Plume (~50 m E of SR)

Figure 2-1
Candidate Areas for
Placement of Portable Platform

Location PS3 will be positioned inside the area of the LAX cargo facilities. This site will represent airport sources from trucks and cargo GSEs.

Location PS4 will be positioned approximately 0.15 Km from the end of the South Runway and Site SR. This location will represent source dominated aircraft taxiing, takeoffs, and some roadway emissions. It may also be compared to the data from the SR site and PS5 site.

Location PS5 will be positioned approximately 0.75 Km from the end of the South Runway and Site SR. This location will represent source dominated aircraft taxiing, takeoffs, and some roadway emissions. It may also be compared to the data from the SR site and PS4 site.

2.3.2.1 Infrastructure Needs

The main infrastructure needs for the Demonstration Project are associated with the two trailers that will be used to house the monitoring instruments. The equipment for the Demonstration Project will be housed in two trailers, one stationary (Main Trailer) and one mobile (Portable Platform Trailer). In addition, there will be a scaffolding-mounted sampling platform that will be collocated with the mobile trailer. The Portable Platform Trailer together with its sampling platform will be referred to in this Monitoring Plan as the Portable Platform.

The Main Trailer to be located near the South Runway will be approximately 20 feet in length and 8 feet in height. This trailer will house and operate the following monitors:

- NOx
- O_3
- CO
- SO_2
- Continuous PM_{10}
- Continuous $PM_{2.5}$
- NMHC

Sampling inlets for all the monitors will be positioned on the roof of the trailer at a height of 1-2 feet above the roof level.

The Main Trailer will require electrical service to be provided by LAWA. The Main Trailer will need 220 V AC, 100 A service to the selected South Runway location. This connection will be needed for the duration of the Demonstration Project, including mobilization and demobilization (approximately 16 weeks). Wiring information will be provided to LAWA for the main trailer by ENSR.

The Portable Platform Trailer will be 26 feet long and 11 feet high. It will house the following monitors:

- Ultrafine particle number & size distribution
- Nephelometer
- Aethalometer
- CO_2 analyzer
- PAH analyzer

Sample inlets for these monitors will be positioned at 1-2 feet above the roof level.

The Portable Platform Trailer will require electrical service to be provided by LAWA at each of its locations (including the South Runway). The Portable Platform Trailer will need 220 V AC, 80 A service provided at each of the portable station sites and the selected South Runway location. The SR location power connection will be needed for the duration of the Demonstration Project. The connections at each of the other four Portable Platform Sites will be needed for approximately two weeks each location. See Figure 2-2 and Table 2-9 for project schedule dates. Wiring information will be provided to LAWA for the mobile trailer by WESTON.

A scaffolding-mounted sampling platform will be attached directly adjacent to the Portable Platform Trailer and will support the various sampling equipment for the Demonstration Project including the following samplers:

- Minivols (3)
- Sequential Samplers (2)
- Summa Canisters
  - Light hydrocarbons (TO12)
  - VOCs (TO15)
- Charcoal Sampler
  - Heavy hydrocarbons
- DNPH Sampler
  - Carbonyls
- Visible Particle Deposition Plates

The sampling platform will be constructed on scaffolding with access stairs and railings, in compliance with OSHA regulations. Power for the outdoor samplers will be obtained from the Portable Platform Trailer's electrical outlets.

2.3.2.2 Site Selection Process

All site preparation activities are the responsibility of LAX. These activities include gaining site access authorization, obtaining any necessary construction and special use permits, and arranging for utilities.

2.4 SCHEDULE

The general chronology of the Demonstration Project was described in the introduction to Section 2. The general duration of sampling events and the numbers of samples to be collected during the Demonstration Project were outlined in Table 2-1 (Section 2.1). This section provides further details on the entire Demonstration Project timeline, including preparation, mobilization, demobilization and reporting.

2.4.1 Project Timeline

Figure 2-2 presents the entire timeline for the Demonstration Project. The major milestone dates for monitoring & sampling are summarized in Table 2-9. The critical path items in the timeline are the items related to procurement of new equipment (Equipment Order and Equipment Delivery). Pending approval of this Monitoring Plan to finalize all equipment options, both WESTON and ENSR are prepared to order the new equipment needed to conduct the Demonstration Project. Manufacturer delivery times then require generally 8 weeks.

During the equipment delivery period, coordination will occur with LAX to define the specific locations of the South Runway trailer, Portable Platform sites, and meteorological monitoring tower. Once the locations are agreed upon, arrangements will be made to provide electrical power and any security access that will be required during the specific date ranges needed. In addition, clearance and badging of project personnel needing access to secured areas will be completed during this period.

Four weeks of off-site preparation are included in the schedule. This will allow WESTON and ENSR to completely assemble and bench test all of the new and existing systems in their respective local offices. This essential step will ensure that all components are present, calibrated, and in working order before the systems are shipped to LAX. Fully assembling and testing all components in a controlled setting ensures that all equipment is in proper working order before being shipped to the field, minimizing “surprises” during field deployment. Off-site preparation also includes setup of the data management systems, including the TeamLink^{SM} collaboration portal, the RespondFast^{SM} monitoring databases, and the EnviroData® sampling databases.

One week is then allotted for shipping and/or transporting the equipment to the staging area at LAX, and one week for on-site setup of the equipment. All systems will then be calibrated and shaken down for at least one week prior to actual data collection in order to allow all instrumentation to stabilize and allow fine-tuning of procedures for actual site conditions.

Once equipment shakedown is complete, full data collection will begin at the South Runway (SR) location. Monitoring and sampling will be conducted for 16 days at the SR site. After the

FIGURE 2-2

LAX Pilot Study Schedule & Time line

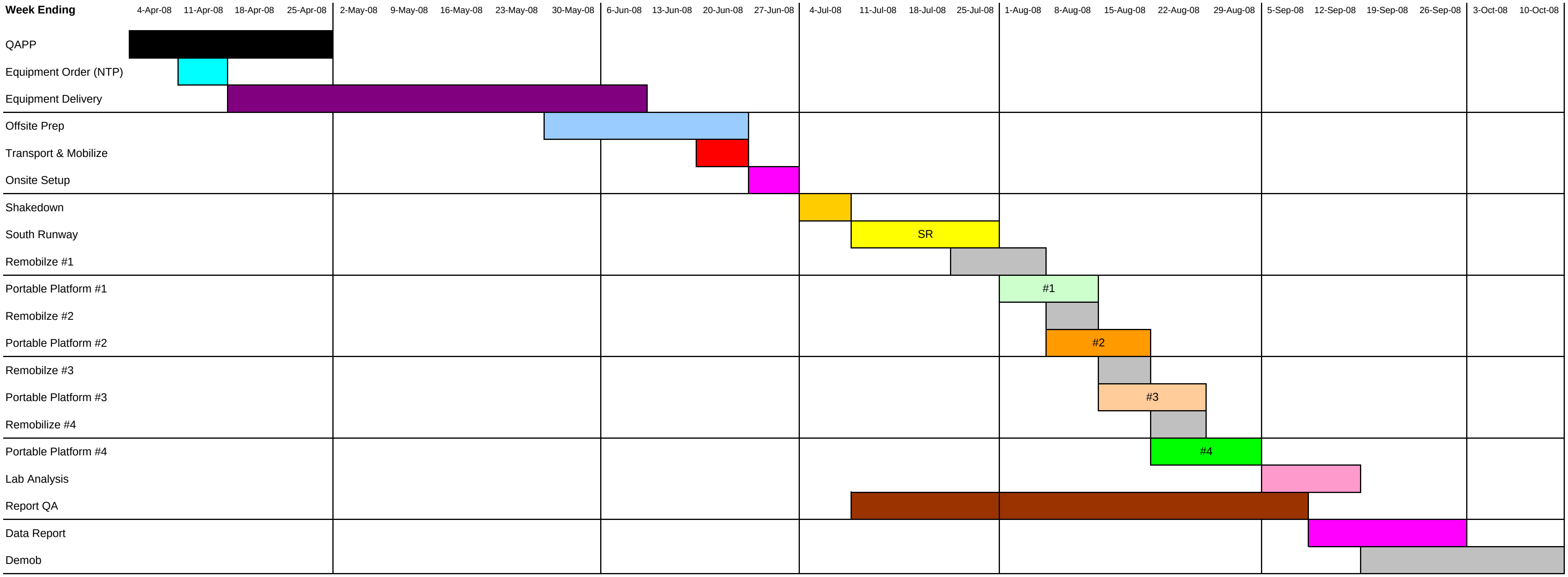

TABLE 2-9

KEY Monitoring Dates for the Pilot Study

Monitoring Schedule

Move Days	# of Days	Site	Start Day	Start Date	End Day	End Date
0	14	Equipt Prep	FRI	6-Jun	THU	19-Jun
0	5	Mobilize	FRI	20-Jun	TUE	24-Jun
0	7	Setup	WED	25-Jun	TUE	1-Jul
0	6	Shake Down	WED	2-Jul	MON	7-Jul
2	16	SR	THU	10-Jul	FRI	25-Jul
3	7	#1	TUE	29-Jul	MON	4-Aug
2	7	#2	THU	7-Aug	WED	13-Aug
2	7	#3	SAT	16-Aug	FRI	22-Aug
1	7	#4	SUN	24-Aug	SAT	30-Aug

16-day period is up, the Portable Platform will be moved to the first portable location and remain there for seven days. The program will then continue by moving the Portable Platform to the remaining three Portable Platform Site locations for seven days each. There will be an approximate transfer time of 1-3 days for each relocation (tear down the sampling platform, transport the trailer, re-establish the sampling platform).

After the end of data collection at the final Portable Platform location, roughly two weeks are allotted to receive the laboratory reports from that location. Concurrent with processing the final analytical data, Data Report preparation will begin. Since data management and review will be an ongoing task throughout the Demonstration Project, the overall Data Report will be able to be produced within two weeks.

All of the dates in Figure 2-2 are approximate, and may be affected by actual timing of the Notice to Proceed (NTP), decisions on monitoring locations, actual provision of utilities, etc. Assuming NTP during the Week of 11 April 2008, data collection at the SR location would begin approximately the Week of 11 July 2008. Data collection at the last Portable Platform site would then conclude the Week of 28 August 2008. The projected date for the Demonstration Project Data Report based on the assumed chronology in Figure 2-2 would be by the Week of 3 October 2008.

2.4.2 Portable Platform Schedules

Sampling frequency was listed in Table 2-1 for each sampling parameter. The intensive multi-pollutant sampling will take place at all five (5) sampling locations; SR, PS2, PS3, PS4, and PS5.

There are three sampling schedules assumed for the initial scope, for the three different types of sampling: intensive multi-pollutant sampling, Minivol sampling, and passive sampling. The planned schedule for the sample collection is presented in table form in Table 2-10.

Intensive multi-pollutant sampling will take place at five locations: the South Runaway, and Portable Platform locations PS2 through PS5. Each Portable Platform sampling period will last seven consecutive days, with two consecutive 12-hour samples collected each day (specific time periods will be fixed and based on the expected daily local land/sea breeze cycle). An initial estimate of this time period is 7:00 am to 7:00 pm. However, this Demonstration Project may later refine the

Table 2-10

Proposed Sampling Calendar

				ADS Samplers - Daytime				ADS Samplers - Nighttime				VOC		Carbonyls			Heavy HC			MiniVols			
Date	**Day**	**Site**	**Site Day**	**Port 1**	**Port 2**	**Port 3**	**Port 4**	**Port 1**	**Port 2**	**Port 3**	**Port 4**	**Can_Pri**	**Can_Dup**	**DNPH_AM**	**DNPH_PM**	**DNPH_Dup**	**Char_AM**	**Char_PM**	**Char_Dup**	**MV1**	**MV2**	**MV3**	**MV4**
10-Jul	Thu	SR	1																	MT1	MT2	MT3	
11-Jul	Fri	SR	2																				
12-Jul	Sat	SR	3																				
13-Jul	Sun	SR	4																	MT1	MT2	MT3	MT1
14-Jul	Mon	SR	5									(PS1)*											
15-Jul	Tue	SR	6									(PS1)*	(Fuel)*										
16-Jul	Wed	SR	7									(PS1)*								MT1	MT2	MT3	
17-Jul	Thu	SR	8																				
18-Jul	Fri	SR	9																				
19-Jul	Sat	SR	10	AT1	AT2	AT3	AT4	AT1	AT2	AT3	AT4	X		X	X		X	X		MT1	MT2	MT3	MT2
20-Jul	Sun	SR	11	AT1	AT2	AT3	AT4	AT1	AT2	AT3	AT4	X		X	X		X	X					
21-Jul	Mon	SR	12	AT1	AT2	AT3	AT4	AT1	AT2	AT3	AT4	X		X	X		X	X					
22-Jul	Tue	SR	13	AT1	AT2	AT3	AT4	AT1	AT2	AT3	AT4	X	X	X	X	X	X	X	X	MT1	MT2	MT3	
23-Jul	Wed	SR	14	AT1	AT2	AT3	AT4	AT1	AT2	AT3	AT4	X		X	X		X	X					
24-Jul	Thu	SR	15	AT1	AT2	AT3	AT4	AT1	AT2	AT3	AT4	X		X	X		X	X					
25-Jul	Fri	SR	16	AT1	AT2	AT3	AT4	AT1	AT2	AT3	AT4	X		X	X		X	X		MT1	MT2	MT3	MT3
26-Jul	Sat	MOVE	---																				
27-Jul	Sun	MOVE	---																				
28-Jul	Mon	MOVE	---																				
29-Jul	Tue	PS2	1		AT2	AT3	AT4		AT2	AT3	AT4	X											
30-Jul	Wed	PS2	2		AT2	AT3	AT4		AT2	AT3	AT4	X											
31-Jul	Thu	PS2	3		AT2	AT3	AT4		AT2	AT3	AT4	X											
1-Aug	Fri	PS2	4	AT2	AT2	AT3	AT4	AT2	AT2	AT3	AT4	X											
2-Aug	Sat	PS2	5		AT2	AT3	AT4		AT2	AT3	AT4	X											
3-Aug	Sun	PS2	6		AT2	AT3	AT4		AT2	AT3	AT4	X											
4-Aug	Mon	PS2	7		AT2	AT3	AT4		AT2	AT3	AT4	X											
5-Aug	Tue	MOVE	---																				
6-Aug	Wed	MOVE	---																				
7-Aug	Thu	PS3	1		AT2	AT3	AT4		AT2	AT3	AT4	X											
8-Aug	Fri	PS3	2		AT2	AT3	AT4		AT2	AT3	AT4	X											
9-Aug	Sat	PS3	3		AT2	AT3	AT4		AT2	AT3	AT4	X											
10-Aug	Sun	PS3	4	AT3	AT2	AT3	AT4	AT3	AT2	AT3	AT4	X											
11-Aug	Mon	PS3	5		AT2	AT3	AT4		AT2	AT3	AT4	X											
12-Aug	Tue	PS3	6		AT2	AT3	AT4		AT2	AT3	AT4	X											
13-Aug	Wed	PS3	7		AT2	AT3	AT4		AT2	AT3	AT4	X											
14-Aug	Thu	MOVE	---																				
15-Aug	Fri	MOVE	---																				
16-Aug	Sat	PS4	1		AT2	AT3	AT4		AT2	AT3	AT4	X											
17-Aug	Sun	PS4	2		AT2	AT3	AT4		AT2	AT3	AT4	X											
18-Aug	Mon	PS4	3		AT2	AT3	AT4		AT2	AT3	AT4	X											
19-Aug	Tue	PS4	4	AT4	AT2	AT3	AT4	AT4	AT2	AT3	AT4	X											
20-Aug	Wed	PS4	5		AT2	AT3	AT4		AT2	AT3	AT4	X											
21-Aug	Thu	PS4	6		AT2	AT3	AT4		AT2	AT3	AT4	X											
22-Aug	Fri	PS4	7		AT2	AT3	AT4		AT2	AT3	AT4	X											
23-Aug	Sat	MOVE	---																				
24-Aug	Sun	MOVE	---																				
25-Aug	Mon	PS5	1		AT2	AT3	AT4		AT2	AT3	AT4	X											
26-Aug	Tue	PS5	2		AT2	AT3	AT4		AT2	AT3	AT4	X											
27-Aug	Wed	PS5	3		AT2	AT3	AT4		AT2	AT3	AT4	X											
28-Aug	Thu	PS5	4		AT2	AT3	AT4		AT2	AT3	AT4	X	X										
29-Aug	Fri	PS5	5		AT2	AT3	AT4		AT2	AT3	AT4	X											
30-Aug	Sat	PS5	6		AT2	AT3	AT4		AT2	AT3	AT4	X											
31-Aug	Sun	PS5	7		AT2	AT3	AT4		AT2	AT3	AT4	X											

AT1 - Aerosol Speciation Sampler Train 1
AT2 - Aerosol Speciation Sampler Train 2
AT3 - Aerosol Speciation Sampler Train 3
AT4 - Aerosol Speciation Sampler Train 4

* - 24-hour samples at PS2 location
and fuel tank headspace grab

MT1 - MiniVol Sampler Train 1
MT2 - MiniVol Sampler Train 2
MT3 - MiniVol Sampler Train 3

time period based upon the actual meteorological data collected. This will produce 14 sample sets for each sampling train at each of the five sites (South Runway and four Portable Platform Sites), for a total of 70 samples for each analysis as outlined for the various trains. A QA sample rate of 10% was assumed, which adds 7 QA samples for each analysis. The QA samples will be divided among blanks (field and trip) and collocated duplicates (as shown in Table 2-1). The total number of samples per analysis is thus 77 for the entire intensive sampling portion of the Demonstration Project.

2.4.3 MiniVol & Passive Sampling

Minivol sampling will be conducted every third day for 16 days during the continuous pollutant monitoring segment of the study at the South Runway location. This will result in 6 primary sample sets being collected (a set consists of all three trains, as for the speciation samplers). Since less than 10 samples are being collected, a 10% QA sample rate would not result in sufficient samples. Therefore, three QA samples will be collected: one trip blank, one field blank, and one collocated duplicate. Single blanks for the Minivols should be sufficient, since the filter media being used for the Minivols are of the same types and will be prepared in the same fashion as the filters for the sequential samplers. Thus, the total number of samples per analysis for the Minivol sampling will be 9.

Passive samplers will be exposed for seven days each for particulate deposition and diffusion collection of organics, concurrent with the Minivol sampling. Two primary samples will be collected. For the diffusion collectors, two QA samples will be collected, one blank sample and one collocated duplicate. The deposition substrates are not planned to undergo any quantitative analysis methods, so no QA samples for those media will be collected in the Demonstration Project.

3. DATA MANAGEMENT

WESTON has developed an ensemble of systems for electronic data management of nearly all phases of environmental monitoring projects that will be used to manage the collection and reporting of data from this study:

- EnviroData® provides a standardized means for porting laboratory electronic data deliverables (EDDs) into Microsoft® Access© databases;
- RespondFast℠ Real-Time Monitoring provides a framework for automated data retrieval from monitoring stations to standardized SQL Server databases either periodically or in real-time; and
- TeamLink℠ provides a secure Web-based data access portal and project management tool.

The following subsections describe the specific data management approaches to be used in the Demonstration Project, using these data management tools.

3.1 AIR QUALITY DATA

Data management is the responsibility of all members of the project team. The project team is tasked to determine the work elements and protocols necessary to ensure that the data obtained are organized in a manner that can be readily retrieved and manipulated to meet LAWA's needs.

A team-oriented data approach and sound project/program planning documents alone cannot guarantee data management success, particularly where the data set is large or complex. The state-of-the-art computer-based systems identified herein comprise the third leg of the data management triangle. These systems are the tools by which the data management team (DMT) ensures that project/program DQOs are routinely achieved.

The DMT uses WESTON-developed technology in conjunction with the WESTON-customized industry-developed EnviroData® data management system. These tools are used to compile qualitative field monitoring data and standardized laboratory-provided electronic data deliverables (EDDs). This process facilitates the timely review of project data for completeness and accuracy.

These combined data will be broadcast to all members of the DMT via a secure, project-specific TeamLink^{SM} website. TeamLink^{SM} is WESTON's Web-based collaborative workspace that is accessible from any computer with Internet access via a Web browser. Data are secured by Secured Socket Layer (SSL) encryption technology and by individual user names and passwords. Multiple security levels allow control over which team, subgroup, or user can view which information on the site. TeamLink^{SM} will enable data interpretation and encourages an open dialog within the Project Team regarding relevant findings and project direction.

3.2 MONITORING

WESTON’s method of managing the data from the air monitoring systems will be via its RespondFast^{SM} Real-Time Monitoring system (RFRTM). The RFRTM system uses a SQL Server database to archive both raw and validated data from continuous instruments. The system is designed to automatically import polled data directly into the database, and provide a convenient standardized platform for accessing, editing and reporting of data. The system currently supports uploading of data from CSI dataloggers. Advanced instruments that produce multi-parameter data streams, such as the aethalometer and the ultrafine particle counter, will have customized uploading programs developed to port their outputs into RFRTM system. This will enable data from all monitoring instruments to be accessible through the same systems.

Data will be polled from all data loggers and self-recording instruments and uploaded daily, and the edited data will be updated as it is reviewed by ENSR and WESTON meteorologists. The RFRTM database will be exported to a Microsoft Access format database and placed on WESTON’s TeamLink^{SM} site for access by the project team on a daily (business day) basis.

Synchronized clock time reporting will be crucial for the monitoring portion of the Demonstration Project. All monitoring systems will have their clocks synchronized to NIST time servers automatically or set manually by on-site personnel. JC will ensure that time-based data to be obtained from LAWA (video, departures, etc.) have time stamps that are correctly synchronized.

All time synchronizations will be checked daily, and clocks will be adjusted if the unit's clock time differs from a reference time clock by more than 5 seconds. Digital clocks automatically synchronized by radio to the Naval Observatory Atomic Clock signal will be located in each monitoring trailer and in the on-site project office. All data times will be recorded in the project database as Pacific Standard Time, in military (24-hour) format. The time zone of all times included in project logs and notes will be indicated as either in Pacific Standard Time (PST) or Pacific Daylight Time (PDT).

3.3 SAMPLING

WESTON's data quality management (DQM) program is designed to provide LAWA with superior quality data. The WESTON DMT will manage the collection of analytical and related data using approved protocols and cutting edge data collection methods. Customized state-of-the-art and WESTON-developed computer software will be used.

3.3.1 Pre-Field Event Database Development

A project-specific database will be developed within EnviroData® into which all qualitative and quantitative field and laboratory information is archived for use and future retrieval upon demand.

The WESTON DMT will produce customized field form(s), a unique sample identification system, and preprinted sample labels, and Chain of Custody (CoC) forms. This effort greatly facilitates the field effort and virtually eliminates transcription errors between sample labels, the CoC forms, and laboratory sample log-in.

Each sample will be assigned a unique Sample ID that will be associated throughout the sample's "lifetime". The sample ID will appear on the sample itself when shipped to the laboratory, on the CoC, on the laboratory reports, and in the analytical database. This identification will be used in addition to any other media-related identification (e.g., filter numbers, canister serial numbers).

The sample IDs will encode the sample location, date, and analysis targets. The following system will be used:

ss-yymmdda-ppp-tt-qq, where

ss = Site (SR = South Runway, P2 = PS2, etc.)

yymmdd = Sample date (yy = Last 2 digits of year, mm = Month, dd = Day)

a = Sampling period (D = Daytime, N = Nighttime, F = Full day, W = Weekly)

ppp = Collection Media

SCD = Sodium carbonate denuder
CAD = Citric acid denuder
TF1 = Teflon filter, 1st stage
QF1 = Quartz filter, 1st stage
PAH = PAH filter
SF2 = Sodium chloride filter, 2nd stage
CF2 = Citric acid filter, 2nd stage
TNX = Tenax sorbent tube
DNP = DNPH sorbent tube
CAN = Summa canister
OG1 = Ogawa Sampler Setup #1 (O_3)
OG2 = Ogawa Sampler Setup #2 (NO_2, NO, NOx, SO_2)
MYL = Mylar plates

tt = Sampler type (An = Aerosol Speciation, Mn = Minivol, P1 = Others; n = Train 1 - 4

qq = Sample type (PR = Primary, DU = Duplicate, TB = Trip blank, FB = Field Blank)

As an example, the sample SR-080723A-TF1-A1-PR would be the primary Teflon filter sample from the Speciation sampler Train 1 collected during the 12-hour daytime period 7/23/08 at the South Runway.

3.3.2 Field Data Collection

All field-generated data will be recorded real-time to ensure accurate capture of information. Field team coordination of sample preparation and delivery to the receiving laboratory is crucial to maintaining sample integrity, as well as the validity and usability of chemical data test results. The field team leader is responsible for ensuring that samples are packed to prevent breakage, chilled to maintain a shipment temperature of 4 ($\pm$2) ^{o}C (if required) and proper preservation, and sample delivery coordinated with the laboratory at the end of each field day. Prompt sample delivery is a safeguard that ensures that the laboratory has ample time to log-in, prepare, and analyze the samples within applicable holding times.

3.3.3 Post-Field Data Management

At the end of each work day the field information is uploaded onto the TeamLink collaboration web site, pending subsequent review for accuracy and interpretation. The data are then thoroughly reviewed to confirm the following:

All required field data were collected.

1. Field data values were consistent with past sampling events.
2. Sample QA/QC samples (field duplicates, blanks) were collected at the appropriate frequency.
3. Data Administrator receipt of the following laboratory-provided information: sample log-in identification numbers, sample container integrity, and a sample preservation summary.
4. Consistency between sample log-in identification numbers and the CoC.

The speed offered by EnviroData® automation enables the field team to review all of these factors within minutes of data upload. Accelerated error recognition ensures that suspect information can be ground-truthed for accuracy or corrected in a timely manner not otherwise afforded using conventional data management practices.

The electronic data deliverables (EDDs) generated by the various project labs will be collected by AAC, and combined into a package ready for upload to EnviroData®. The laboratory EDDs will be posted to the TeamLink^{SM} site by AAC, and picked up from there by the Data Administrator for preliminary completeness review and verification that the electronic data meet contract requirements for data quality as specified in the QA/QC Plan, project-specific planning documents, and EnviroData® requirements for EDD submission. The unvalidated data are then uploaded into EnviroData® and a customized data mart is generated that enables review of the results against project-specific reporting requirements via TeamLink. Data is typically available to the project Team within 3 business days after WESTON receives the EDD from the laboratory.

3.4 METEOROLOGICAL DATA

Data from the ENSR-operated meteorological tower will be managed using the same RFRTM system being used for the air quality monitoring data. This will allow air quality data to be examined in parallel with the simultaneously collected on-site meteorological data.

3.5 DATA ACCESS

All project data will be accessed using WESTON's TeamLink^{SM} web-based collaborative workspace.

3.6 REPORTING

Because meteorological and some level of air quality monitoring will continue during the entire period of the Demonstration Project, project databases will be reviewed and updated on a daily basis (excluding weekends or holidays). As previously described, data updates will be distributed among the WESTON, ENSR, T&B, and AAC Team members via TeamLink^{SM}.

At the conclusion of the Demonstration Project, a Data Report will be generated. This report will consist of electronic databases of all monitoring and sampling data collected during the Demonstration Project, suitable for further analysis and processing by other Study Team members. The report will also include basic statistical summaries of the data, including information such as means, extremes, and detection frequencies. The extent to which the DQOs were met will also be assessed. Also, any unusual events will be described that may have occurred (e.g., fires, dust storms) during the Demonstration Project that were observed to affect results.

The analysis and interpretation of the Demonstration Project data, and making consequent recommendations for the Long-Term Study, is not part of this Monitoring Plan. A separate Interim Data Analysis Report will be prepared to address these issues, as described in the Technical Workplan.

4. QUALITY MANAGEMENT

The quality of data collected during the Demonstration Project will be managed by a systematic approach, involving multiple levels of project personnel, including technicians on-site collecting data and operating equipment, scientists in remote offices reviewing the data, and auditors responsible for independently verifying appropriate collection of the data.

Due to the need to achieve a high level of data recovery for such a short-term study, the relatively large number of monitors being operated, and the need to change diurnal cycle samples every 12 hours, at least one Site Technician will be on-site 24 hours a day, 7 days per week. Two 13-hour shifts will cover each day, with a 1-hour overlap between shifts. The Site Technician will be the front-line individual responsible for the quality of the data being collected.

The scientists and data managers in ENSR's and WESTON's main offices will support the Site Technicians and provide daily overall review of the monitoring data. They will also review laboratory analytical data to ensure that the information is in line with project objectives.

The following subsections describe quality management activities for the Demonstration Project. Section 4.1 discusses the quality control activities that will take place during routine operations and data review, which will be the responsibility of WESTON and ENSR managed personnel. Section 4.2 describes the quality assurance auditing activities that be conducted by T&B.

4.1 QUALITY CONTROL

4.1.1 Air Monitoring

4.1.1.1 Pre-Installation Testing

Considerable testing of the monitoring equipment will be conducted during the pre-operation phases of the program, both on- and off-site. Prior to systems integration and assembly, an operational check will be performed in the respective ENSR and WESTON laboratories on each individual instrument. Any instruments requiring repairs or maintenance will receive the necessary service before being sent to the field.

After all equipment has been checked and accepted, the monitoring systems will be assembled, integrated, and tested. The systems will be fully assembled, integrated, and labeled in exactly the same configuration as anticipated in the field. The systems will be activated for operational testing, including continuous analyzer calibration checks, meteorological system performance checks, and data collection system checks. The systems will also be allowed to run under ambient conditions for several days to check system stability and verify compliance with operational specifications.

4.1.1.2 Routine operations and maintenance

ENSR will operate the air quality and meteorological monitoring system according to USEPA PSD guidelines defined in 40 CFR 58 Appendix A, QA Requirements for SLAMS, SPM, and PSD Air Monitoring. ENSR supplements these guidelines with the Meteorological Monitoring Guidance for Regulatory Modeling Applications (USEPA 2000). ENSR will exercise good scientific judgment in operation of the network.

ENSR’s senior air quality technician will install and calibrate the air quality systems. The on-site technician will receive hands-on training at the site during and following installation, and will be given a site checklist to follow in the performance of duties. A list of Site technician duties is shown in Table 4-1.

Table 4-1
Field Operations Checklist for LAX Ambient Monitoring Network

Field Operations Activities	Checked
Upon arrival, note arrival time and date on the Station Log.	
Inspect the operational characteristics of each sensor/analyzer.	
Enter data in Site Checklist for each analyzer.	
Enter the applicable data on the Status/Data Assessment sheets.	
Record all pertinent observations and data in a narrative Station Log.	
Check the inside temperature of the trailer and record temperature extremes.	
Check condition of intake manifold filter cartridges. Change every 2 weeks.	
Inspect tower and check meteorological data sensor cables for wear.	
Check all equipment clocks versus reference clock. Adjust if more than 5 sec difference.	

The Campbell Scientific data logger gathers data from the station and met tower and will be equipped with a modem for access by ENSR and WESTON. This provides for daily station performance evaluation by ENSR/WESTON operations personnel responsible for the monitoring program. It provides valuable information on a near-real time basis on the condition of each monitoring system.

4.1.1.3 Calibrations

In order to ensure collection of high quality data, field calibration of monitoring instruments and recorders will be performed during the initial installation and at any time that certain criteria are met as listed below. These calibrations will be conducted by the trained Site Technicians. All calibration records will be examined by ENSR's project QA officer.

Instrument calibration checks will be required if any one of following criteria is met:

- At start-up;

- When any maintenance activity that may alter the response of any instrument is conducted;
- When the daily span of any of the continuous gas analyzers deviates by more than ±10 percent (5% for O_3) from the designated span value;
- When audit results of the continuous gas analyzers show that the difference between the audit standard and the instrument response exceeds ±10 percent (±5 percent for O_3);
- When audit results of meteorological instrumentation exceeds the audit acceptance criteria;
- When a continuous gas analyzer has been shut-off for more than 2 days; and
- Prior to removal of an instrument from a station if it is still operational.

Calibrations will be performed according to ENSR SOPs, which have been developed to meet the strict requirements of the USEPA regulatory guidelines for NIST traceability and documentation.

Documentation of all site visits will be provided through several forms. A station log will be maintained at the site detailing inspection, calibration, or repair activities. Records of measurements taken during calibrations will be recorded on forms designed specifically for the instrument under calibration.

Test equipment used for calibrations will be maintained and calibrated on a regular basis. Records that provide traceability to the NIST of all equipment used for adjusting monitoring systems are maintained by ENSR and WESTON. Calibration of the meteorological and data acquisition systems consists of pre- and post-maintenance dynamic calibrations in which the sensor (and/or system) is subjected to known conditions.

In order to ensure collection of high quality data, field calibration of monitoring instruments and recorders will be performed. These calibrations will be conducted by the trained Site Operators.

- Multi-point calibrations and spans will be performed using standards documented traceable to NIST.

- Calibrations, zero checks, span checks, and precision checks will be done through the normal sampling trains (i.e., those scrubbers and filters normally employed during sampling.
- Automatic zero/span checks will be performed daily under datalogger control. No automatic adjustment will occur, but the information will be used to detect sudden malfunctions or changes in calibration that may warrant unscheduled maintenance visits. The span check concentration will be at 70 to 90 percent of instrument full-scale response.
- Level-I span, zero and precision checks will be performed automatically every week. Multi-point calibrations will be performed whenever the daily span exceeds 15 percent (7 percent for O_3) of expected.

Multi-point calibrations of the continuous gas analyzers consist of challenging each instrument with known concentrations at approximately 20, 40, and 90 percent of full scale. In addition to these points, a zero check will be performed on each analyzer. Gas phase titration (GPT) with ozone will be performed to assess NO_2-to-NO converter efficiency in the NO_x analyzer. Linearity over the range of each analyzer will be checked and adjustments made, as appropriate, to bring the analyzer response within the control limits.

The control limits for multi-point calibrations for the SO_2, NO_x, CO, NMHC, and CO_2 analyzers is ± 15 percent for upscale concentrations, and ± 0.015 ppm for zero checks (± 1.5 ppm for CO, NMHC, and CO_2). The control limits for multi-point calibrations for the O_3 analyzer is ± 7 percent for upscale concentrations and ± 0.007 ppm for zero.

For gas analyzers undergoing daily automated calibration cycles, the instruments will not be able to collect ambient air data during approximate 15-minute windows of time. In order to minimize potential impacts on project objectives, the calibration windows will be timed to occur bracketing the top of the hour (e.g., from 10 minutes before the hour to 10 minutes past the hour), and during low-activity times of the day at the location being monitored. Dividing the calibration window on the hour allows complete (at least 45 valid minutes) hourly averages to be constructed. However, loss of a few short-period averages due to calibrations will occur due to calibrations.

Calibration checks of the AE-31 aethalometer will be performed when the instrument is initially deployed at the SR site, and then each time the Portable Platform is relocated. The AE-31's optical calibration is performed using an optical test strip to verify the performance of the photodetectors. The test strip is provided by the manufacturer, and is matched to the individual instrument. The strip provides a known response that is compared to the internal reference values stored in the instrument. The test is conducted manually, by initiating the Optical Test Procedure on the AE-31 interface, which guides the Technician through the necessary actions with prompts on the display screen. The procedure records data to the storage media, which will then be retrieved and reviewed by the Technician. If the instrument reports problems, corrective maintenance will be performed before the AE-31 is placed on-line at the new location.

The M903 nephelometer will be calibrated prior to the start of on-site data collection, then once per week during routine operations using SUVA (Freon) calibration gas. Following California Regional Particulate Air Quality Study (CRPAQS) guidance, adjustments will only be made to the calibration of the nephelometer if either the zero drift is more than 10 Mm^{-1} in two independent calibrations, or span differs from the expected value by more than 20% in two independent calibrations when the ambient temperature is less than 30°C (86°F).

The BAM-1020 particulate monitors will have vacuum and flow rate checks after each move from the South Runway to the Portable Sites. TSI Model 3091 ultrafine particle analyzer does not have any specific calibration routines that are required.

4.1.1.4 Preventive Maintenance

The preventive maintenance tasks and schedules recommended by the manufacturers of the continuous meteorological sensors will be followed. In conjunction with the preventive maintenance schedule, a spare parts inventory has been developed for the gas analyzers. These parts will be available for immediate installation. When any one of the critical spare parts is used a replacement part will be ordered immediately or the failed component will be repaired or replaced to maintain the inventory count.

4.1.2 Air Sampling

Many of the samplers to be used in the Demonstration Project have particle size-selective inlets. These inlets are designed to maintain certain particle size cut points based on very specific flow rates. All samplers with particle-sizing inlets will be checked for proper flow rate before sampling commences at any location (i.e., when a sampler is initially deployed or relocated) or when any maintenance is performed on the instrument. A primary flow standard, such as a BIOS DryCal piston flow meter, will be used with suitable inlet adapters to directly measure specific sampler flow rates. In order to avoid the DryCal's known flow pulsation sensitivity, any DryCal used in the Demonstration Project will be tested with all sampling equipment versus a Gilibrator or equivalent bubble flow meter prior to use. Flow rates will be maintained within the inlet manufacturer's specifications to maintain the desired size cut points.

For the aerosol speciation samplers, dry gas meters (DGMs) will be used to record actual volumes of air sampled. The DGMs will be calibrated versus a calibrated, NIST-traceable wet test meter at the beginning and end of the Demonstration Project.

In addition to flow checks of the various samplers, inspections of all the size selective inlets will be performed weekly by the Site Operators. The inlets will be inspected for insects, webs, or debris that may be blocking the inlets. Water collection traps will be emptied as needed. Any impaction surfaces will be inspected, cleaned, and recoated with manufacturer-specified greases as needed to maintain efficient removal of large particles.

All calibration, inspection, and cleaning activities will be documented in site log books and on checklists, including date and time of all activities.

4.1.3 Meteorology

Meteorological data collected from the ENSR-operated meteorological station will be compared daily to the data reported through the National Weather Service (NWS) from the station located on LAX. The comparison will be qualitative, and ensure that temperatures and winds are consistent and representative of actual conditions. Recorded conditions will also be compared to LAX climatological averages and record extremes to identify suspect data.

4.1.4 Laboratory

All of the project laboratories conduct quality control activities in conformance with the various analytical methods listed in Section 2. All of theses methods have been included for reference in Appendix A.

Standard laboratory reporting packages will be provided by the laboratories, which will include EDDs for uploading the analytical results to the project databases. Standard quality control results such as replicates and method blanks will be included as part of these routine laboratory data reports. The lab reports will be reviewed by WESTON's Data Manager and by WESTON's air quality scientists

In order to simplify reporting and reduce data manipulation, air sample volumes will be provided to the laboratories on the CoC. The laboratories will use these volumes to report results as ambient air concentrations in micrograms per cubic meter ($\mu g/m^3$), in addition to standard units of mass per sample. This will eliminate the need to perform post-analysis calculations of concentrations by combining separate concentration and analytical data sources.

4.2 QUALITY ASSURANCE

Key elements of a quality assurance plan (QA) for air quality monitoring are identified in USEPA (1999) and include the following:

- Project Management, including the roles and responsibilities of the participants.
- Data Generation and Acquisition, maintenance, data handling and sample custody, calibrations and quality control activities and the overall data quality objectives.
- Assessment and Oversight, including the activities for assessing the effectiveness of the implementation of the project and associated QA and QC activities. This includes the assessment and response actions and reports to management.
- Data Validation and Usability, including the activities that occur after the data collection or generation phase of the project is completed and includes the steps to validate the collected data and assess the usability for the intended purpose.

Each of these primary topics has been addressed in prior sections of this plan with the exception of the assessment and oversight. This is the focus of the QA program described below. As part of the program, system and performance audits will be conducted that will use an independent entity, instrumentation and personnel to verify the site operations and data accuracy. These audits will be conducted at the outset of the Demonstration Project of both the air quality and meteorological measurements and will review the data collection efforts to assess the compliance with the stated project Data Quality Objectives in section 2.2. The review and assessment will then continue through the data processing and validation stage to provide the independent assessment of the overall data produced by the monitoring program. Comments and recommendations resulting from the audits will be discussed immediately with measurement personnel at the time of the audit, with a formal audit report to project management within 30 days of the audit.

The following sections present the overall QA program procedures for the LAX Monitoring Demonstration Project and provide details on how audits will be conducted and how the results will be integrated into the overall monitoring program. For the Demonstration Project, audits will be conducted at both the South Runway and at one location of the Portable Site. All study-specific audits will be conducted within two weeks of the commencement of operations. The audit of sampling equipment will be scheduled to coincide with one of the 2-3 day relocation time windows for the Portable Platform. Audits of the monitors will be scheduled so as to provide minimal interference with primary data collection. Audits of SCAQMD monitoring efforts will be performed by T&B Systems. Audits of the LAX monitoring site and the sodar were completed on May 13 2008. Remaining audits of the radar profiler and RASS are anticipated in late-May or June.

4.2.1 System Audit Procedures

The purpose of the system audit is to assess consistency of measurements with the applicable Standard Operating Procedures (SOPs) and program Data Quality Objectives (DQOs). A system audit form/checklist is used to ensure that the pertinent items of the audit are covered and to report the audit findings. The audit procedures employed are consistent with *Meteorological Monitoring Guidance for Regulatory Modeling Applications* (EPA, 2000), and the EPA *Quality Assurance Handbook for Air Pollution Measurement Systems, Volumes I, II and IV* (EPA, 1994, 1997, 1998, 2008). Both Volume II (EPA, 2008 draft) and Volume IV (EPA 2008) of the EPA QA Handbook have been recently revised, and we will follow to the extent possible the revised guidelines.

The subjects that are addressed by the system audits include:

- Network design and siting
    - network size and design
    - sensor exposure
    - review of station

- Resources and facilities
    - instruments and methods
    - staff and facilities
    - standards and traceability

- Quality assurance and quality control
    - status of quality assurance program
    - audit participation
    - precision and accuracy checks

Additionally, once the system audits of all sites in a network are complete, the auditor checks for possible differences in operation among the various sites. This will be important, as data collected by the LAWA project contractors will be under different guidelines and objectives than data collected by the SCAQMD and others.

4.2.1.1 Gaseous Air Quality and Particulate Measurements

The system audit of air quality monitoring systems consist of an inspection to determine if the sampling and DAS equipment are operational, sample lines are clean and secure, and a review of the station check logs and onsite forms to determine if the documentation conforms to the specifications of the plan. The system audit of particulate samplers consist of an inspection to determine if the samplers are operational and clean, the spatial distribution of the samplers at each site conforms to the siting criteria and flow records and QC checks appear reasonable.

Specifically designed system audit forms are used to document the system audit results and are included in the final audit report.

An evaluation of the quality assurance/quality control plan procedures including preventive maintenance is performed. Reviews of calibration records and maintenance logs are checked for consistency, frequency and accuracy. Equipment settings including flow rates and zero/span settings are evaluated to determine if ranges are acceptable. Additionally, once the system audits of all sites in a network are complete, the auditor checks for possible differences in operation among the various sites.

4.2.1.2 Surface Meteorological Measurements

The system audit of the surface meteorological sensing systems consist of an inspection of the site to assess proper siting of the instrument sensors, a review of the station check logs and other site documentation, as well as an interview with the site operator concerning his or her knowledge of the QAPP and applicable SOP sections. Sensor siting criteria for meteorological sensors are specified in the EPA *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV* (EPA, 1995) and *Meteorological Monitoring Guidance for Regulatory Modeling Applications* (EPA, 2000). On-site forms and site logs are reviewed to check that the documentation conforms to the specifications of the plan.

4.2.1.3 Upper-Air Measurements

For the Demonstration Project there are no upper-air measurements to be made by the project team. However, SCAQMD operates an upper air station as part of their monitoring network on the airport property. The monitoring station is located at the west end of the airport, beyond the end of World Way and across Trask Avenue. This station consists of a miniSODAR, radar wind profiler and a Radio Acoustic Sounding System (RASS).

The sodar, radar wind profiler and RASS system audit is divided into several tasks. A description of each task is provided below:

The antenna and controller interface cables are inspected for proper connections. Antennas and enclosures or clutter fences are inspected for structural integrity. The orientations of the antennas are checked using either the solar siting or GPS “walk-off” methods. Both of these methods are described in detail in Baxter (2001). The levels of the antennas are measured using a Pro SMARTLEVEL. Measurements are made in at least two directions on the bottom of the antenna array’s support structure. For the multiple antenna systems the inclination angle is also measured and compared to the software setting. The results of the measurements are compared to the audit criteria of ±2° for orientation and ±0.5° for level.

A vista table is prepared that documents the surroundings of the site. The table identifies potential reflective sources for the radar or sodar signal, as well as potential active sources that could generate interference. The table also provides a description of the view in 30-degree increments around the antenna, including the elevation angle and estimated distance to potential sources. Pictures are taken in 45° increments looking from the antenna to further document the vista.

An evaluation of the site characteristics is performed. Passive and active noise sources are identified and noted to evaluate their impact on the sodar's or radar's ability to separate the return pulses from the background noise. Passive sources are objects that may reflect the pulse and contaminate the return spectra with what appears to be near-zero wind speeds. These sources include buildings, trees, nearby towers, road traffic, birds, etc. Active sources generate their own noise such as air conditioners, fans and industrial complexes for sodars and radio transmitters for radars. Low-level active white noise sources are not generally a problem except to reduce the maximum altitude. Active noise sources in the frequency spectrum of the sodar or radar operations may affect the operations. For the sodar, general sound levels are measured using an integrating sound level meter to measure levels, in at least the four cardinal directions. A spectral analysis of the background noise is also performed to determine if there are significant sources within the operating range of the sodar.

In addition to the evaluation of the noise spectrum above, a system check is performed with the system "listening only," i.e., without transmitting a pulse. The results of this check should produce no measured winds, or winds with very low reliability. If winds are reported at any level, then there is probably an active noise source in the area that is generating frequencies in the operational region of the sodar or radar.

Finally, the system computers are checked for the proper calendar and clock timing and the ability of the software to appropriately handle the current date and time formats. The network consistency of time zones is included in this check. All clocks are checked and compared to the PAMS specified ±2 minute criteria for the upper air monitoring site.

4.2.1.4 Laboratory

An audit of the AAC laboratory will be conducted through an on-site visit and review of the operations. This will include observing the sample preparation and handling procedures, QC checks, analysis procedures, and data integrity through the process of receiving the samples to the analysis and reporting of the final results. This includes a review of the sample media preparation and cleaning process for the media that are transported to the field for collection of ambient samples.

Included in the system audit will be a review of procedures followed by AAC in the use of additional laboratories for those analyses that are not performed by AAC. This will include a review of the sample custody, handling and individual laboratory procedures used as well as a review of other audits performed on the laboratories.

4.2.1.5 Data Management

The system audit of the data management will have several integral parts. Data will be collected, processed and validated by the groups responsible for their respective monitoring roles with the validated data transferred to Weston for integration into the project database. The audit will be conducted in an electronic form by obtaining the raw initial data, in the format originally collected, and validating it against the final generated database. This start to finish approach will also apply to other data providers, such as the data received from the SCAQMD and other participants. This system audit will be conducted prior to the final release of the database for analysis. No travel to the individual data providers is anticipated for this audit.

Each of the system audits conducted will have specific system audit forms that will be filled out over the course of the audit. These forms will become part of the final audit documentation.

4.2.2 Performance Audit Procedures

Performance audits will be conducted on all applicable measurement equipment. Table 4-2 provides a summary of performance audit procedures and criteria. Details on the performance audit procedures for each audit are provided below.

Table 4-2
Summary of Independent Audit Criteria and Procedures

Measurement Variable	Audit Criteria	Procedure Reference	General Procedure
Time	±5 seconds	Audit clock synchronized to either WWV or to the satellite GPS network	Comparison check to the data logging clocks.
Horizontal Wind Speed	Accuracy ±(0.2 m/s + 5% of observed) Equivalent wind speed starting torque to meet the wind speed starting thresholds for the respective sensors.	EPA-454/R-99-005 EPA-454/B-08-002	Three wind speeds within the expected range of operation. If any points are outside of criteria then corrective action is necessary.
Horizontal Wind Direction	Accuracy ±3 degrees for linearity, ±2 degrees for alignment to known direction. Equivalent wind speed starting torque to meet the wind speed starting thresholds for the respective sensors.	EPA-454/R-99-005 EPA-454/B-08-002	Depending on the mechanical sensor type from 4 to 36 points equally spaced around the compass are compared. If any points are outside of criteria then corrective action is necessary. Torque measurements are made to determine the mechanical sensor starting threshold. Sensor alignment is verified using solar or GPS methods.
Temperature	±0.5°C (monitoring criteria)	EPA-454/R-99-005 EPA-454/B-08-002	Three temperatures within the expected range of temperatures (0 to 40°C). If any points are outside of criteria then corrective action is necessary.
Temperature Difference (T)	±0.1°C	EPA-454/R-99-005 EPA-454/B-08-002	Three temperatures within the expected range of temperatures (0 to 40°C). If any points are outside of criteria then corrective action is necessary. The criteria refers to the tracking of the two sensors over the range of audit temperatures.
Solar Radiation	± 5% of observed + 10 w/m^2	EPA-454/R-99-005 EPA-454/B-08-002	Five measurements within the range of operations on a given audit day are made. If any points are outside of criteria then corrective action is necessary.
Relative Humidity	±1.5°C equivalent dew point	EPA-454/R-99-005 EPA-454/B-08-002	Three comparisons are made of the station sensor to an aspirated psychrometer. If any points are outside of criteria then corrective action is necessary. The preferred method uses a self-contained RH/Temperature data logging system, which is collocated with a site sensor, recording data over the audit period. These data are compared to several observed station readings. If any points are outside of criteria then corrective

Measurement Variable	Audit Criteria	Procedure Reference	General Procedure
			action is necessary.
Remote Sensing Horizontal Wind Speed and Direction (sodar and radar wind profiler)	Antenna alignment to true -- ±2° Antenna level and/or zenith -- ±0.5° Sodar transponder response -- ±0.2 m/s for component Comparison systematic difference – Beam component, ±1.0 m/s Comparison RMS difference – Beam component, ±2.0 m/s	EPA-454/R-99-005 EPA-454/B-08-002	Anticipated comparison instruments to be used include a rawinsonde. Three to four soundings will be conducted. For sodars that are amenable to a transponder audit that may be used in place of the comparison.
RASS Virtual Temperature	RASS element level -- ±1° Comparison systematic difference – ±1.0°C Comparison RMS difference – ±1.5°C	EPA-454/R-99-005 EPA-454/B-08-002	Anticipated comparison instruments to be used include a rawinsonde. Three to four soundings will be conducted.

Table 4-2 (continued)

Measurement Variable	Audit Criteria	Procedure Reference	General Procedure
Gaseous Air Quality Response	±15% of reading NO_2 GPT Efficiency -- ≥96%	EPA-600/R-94-038b EPA Draft (2008)	Dilution of known traceable concentrations of gas. Zero air to be provided by CO_2 free air for the CO_2 analyzer and by a zero air system for the remaining pollutants.
Particulate Matter Minivol	PM_{10} Filter -- ±10% (5 lpm)	EPA-600/R-94-038b and experience. No audit criteria exists specifically for the minivol. Methods also developed during the 2000 CRPAQS program.	Measurement of inlet flow using a certified Gilibrator flow device
Particulate Matter BAM $PM_{2.5}$ and PM_{10}	±5% of 16.67 lpm		Measurement of the inlet flow using a certified flow device
Ultrafine particle number and sizer	TBD		Measurement of the inlet flow using a certified flow device
Light Scattering (Nephelometer)	±10% response to SUVA ±1°C temperature ±5% RH ±3 mb pressure	CRPAQS Audit Methods	HEPA filter to zero the instrument and SUVA for the span check. Audit by comparison of the internal pressure, temperature and relative humidity sensors.
Black Carbon (Aethalometer)	±5% of audit flow ±5% flow difference from design flow		Measurement of the inlet flow using a certified Gilibrator flow device. Check of zero using a HEPA filter
PM2.5 mass and speciation	±4% of audit flow ±5% flow difference from design flow ±2°C temperature ±10mm Hg pressure	EPA Vol II, Part II, 2.12 (1998b)	Measurement of the inlet flow using a certified dry test meter. Comparison of the available temperature sensors to the audit standard. Comparison of the internal pressure measurement to the audit standard.
Carbonyls	±5% of audit flow		Measurement of the inlet flow using a certified Gilibrator flow device

TBD – To Be Determined

4.2.2.1 Gaseous Air Quality Measurements

NO/NO_x/NO_2, SO_2, CO, CO_2, THC

The entire sample train of the analyzer is connected to a certified Environics Series 100 dilution system output port via a glass manifold. Care is taken to introduce the audit span gas through as much of the normal sampling train (i.e., filters, and scrubbers) as possible. The analyzers are challenged with specific concentrations of span gas as follows. These ranges may vary depending on the final selected operational range.

Audit Points	Concentration Range (ppm)
	O_3, NO/NO_x/NO_2, SO_2
1	0.0
2	.03 to .08
3	.15 to .20
4	.35 to .45
	CO
1	0.0
2	3 to 8
3	15 to 20
4	35 to 45
	CO_2
1	0.0
2	325 to 375
3	1500 to 2000
4	3500 to 4750
	THC
1	0.0
2	1.2 to 3.2
3	6.0 to 8.0
4	14.0 to 18.0

Nitric oxide (NO), sulfur dioxide (SO_2), carbon monoxide (CO) and carbon dioxide (CO_2) concentrations are generated using National Institute of Standards and Testing (NIST) traceable EPA Protocol No. 2 cylinders and gas dilution. Zero air is used to dilute the concentrations of cylinder gas. The zero air is provided by Scott Marrin Inc., Riverside, California, or by a zero air generator. Zero air for the CO_2 dilution is provided by a cylinder of CO_2 free air or by using a soda lime scrubber in conjunction with the zero air generator.

Nitrogen dioxide concentrations are introduced into a $NO/NO_2/NO_x$ analyzer by gas-phase titration (GPT) of NO with O_3. Nitric oxide reacts completely with ozone to produce nitrogen dioxide and oxygen.

The NO_2 input concentration is determined by:

$$[NO_2 \text{ input}] = \frac{[NO \text{ initial}] - [NO \text{ final}]}{NO \text{ slope}}$$

[NO initial] = analyzer's NO channel response to the NO span prior to the addition of O_3

[NO final] = analyzer's NO response after the addition of O_3

NO slope = slope of the curve generated by linear regression of the NO concentrations versus the analyzer's response during the audit of the NO channel, where the NO input is the abscissa and the response is the ordinate

The final stage of the $NO/NO_2/NO_x$ analyzer audit is to determine the converter efficiency from the following relationships:

$$[NO_2 \text{ converted}] = [NO_2 \text{ input}] - \frac{[NO_x \text{ initial}] - [NO_x \text{ final}]}{NO_x \text{ slope}}$$

$[NO_x$ initial$]$ = analyzer's NO_x channel response before the addition of O_3

$[NO_x$ final$]$ = analyzer's NO_x response after the input sample of NO is titrated with O_3

NO_x slope = slope obtained from the audit of the NO_x channel

The converter efficiency for each audit point is:

$$\frac{[NO_2 \text{ converted}]}{[NO_2 \text{ input}]} \text{ x } 100$$

The analyzer converter efficiency is defined as the slope of the linear regression using the NO_2 source versus the NO_2 converted x 100. The converter efficiency must be greater than or equal to 96 percent to pass the audit.

Canister sampling

The canister sampling will be audited by measuring the flow rate with a certified flow device (e.g., calibrated rotameter, mass flow meter) that will not contaminate the critical orifice on the sampler inlet and verifying the rate is appropriate to fill the canister in a linear manner over the 12-hour sample period.

Carbonyls

The Carbonyl samplers will be audited by measuring the flow rate with the audit Gilibrator in the sampler inlet and comparing it to the sampler set point. As the key component is the total flow through the sampling media, the audit will just compare the sampler set point flow to the measured audit flow.

Light Scattering (Nephelometer)

The nephelometer zero is audited using particle free air generated by scrubbing the inlet with a HEPA filter. The response of the instrument is then verified by flooding the chamber with Freon 134a gas, also known as SUVA. The upscale response is then compared to the calculated response for the gas at the station altitude. The instrument relative humidity, pressure and temperature sensors are then compared to the audit standards.

4.2.2.2 Particulate Matter Air Quality Measurements

Minivols

Minivol samplers are turned on and allowed to warm up and the flow to stabilize with the sample filter in place. The rain cap is removed and an adapter used to connect the audit Gilibrator to the sample inlet. The readings from the Gilibrator are used as-is because the flow is provided at actual conditions. The measured audit flow rate is compared to the operator provided sampler flow rate as well as the manufacturer specified 5 lpm flow rate.

Beta Attenuation Monitors (BAMs)

PM_{10} and $PM_{2.5}$ BAM sampler flow rates are audited at the sample inlet by removing the sample head and using and adaptor to the audit Gilibrator at the sampler cyclone. Readings obtained from the Gilibrator are used as-is because the flow is provided at actual conditions. The measured audit flow rate is compared to the operator provided sampler flow rate as well as the manufacturer specified 16.67 lpm flow rate.

PM Speciation Samplers

PM Speciation samplers are audited by first performing a leak check in accordance with the manufacturer’s procedures. An audit filter cassette is then loaded into the sampler with the calibration/leak check adapter placed on the sampler inlet. The audit dry test meter is then connected to the sample inlet, via an adapter, and the sampler started and allowed to stabilize. Timing of the sampler total flow is then initiated and the audit flow rate is calculated from the audit dry test meter registered total flow and elapsed time. The measured audit flow is compared to the operator provided sampler flow as well as the manufacturer specified 16.67 lpm flow rate. The ambient temperature probe is audited by comparison of a collocated NIST-traceable digital thermometer. The audit probe is placed within the ambient temperature radiation shield. When both the audit and sampler temperature probe readings are stabilized, a one-point comparison is made. A one-point comparison of the sampler barometric sensor is conducted by comparing average audit standard and sampler readings based on three separate readings performed at 10-minute intervals.

Ultrafine Particles

Audit method in development but will likely only look at the sampler flow rate.

Aethalometer

As there are no practical field methods to audit the precision or accuracy of the aethalometer measurements, the only audit that will be performed is of the flow rate. This flow rate will be specific to the cut point of the sample inlet. The flow rate will be audited using the Gilibrator and the measured flow compared to both the sampler set point and specified flow to achieve the proper sampler cut point.

4.2.2.3 Surface Meteorological Measurements

Wind Speed

The wind speed audit begins with the inspection of the wind speed cups or propeller(s) to ensure that they are intact. The cups are then removed to produce a zero point. Next, the R.M. Young selectable speed anemometer drive is connected to the sensor shaft to simulate wind speeds of approximately 5, 15 and 35 m/s. Actual values depend on the sensor model and are determined by multiplying the motor speed by a cup or propeller transfer coefficient supplied by the manufacturer. The data logger responses are compared to the calculated actual values and the differences compared to the audit criteria.

The sensor bearings are then checked for excessive wear by manually turning the sensor shaft to determine whether there is any bearing drag. Next, the sensor is removed from the crossarm and the R.M. Young torque disk mounted on the sensor shaft. The starting torque is determined using the manufacturer-recommended procedures.

Wind Direction

The wind sensor crossarm alignment relative to true north is checked using a GPS unit or a tripod mounted Brunton surveyor compass. The angle of declination is taken into account when performing this check. This angle is verified using a solar siting. The wind direction vane is then pointed toward at least the four cardinal directions and the responses of the data logger and chart recorder are noted and differences calculated. The difference calculated for each input wind direction is compared with the criteria.

The sensor bearings are then checked for excessive wear, first by manually turning the sensor shaft to determine whether bearing drag is present and then by using an R.M. Young vane bearing torque gauge according to the manufacturer-recommended procedures.

Ambient Temperature

The temperature-sensing system is audited by immersing the system sensor and a calibrated precision digital thermometer, which is certified against a NIST-traceable mercury-in-glass thermometer in the same water bath. The thermometer readings are compared with the data logger and chart recorder outputs at approximately zero, 20° and 40° C. The difference calculated for each point is compared with the audit criteria.

Temperature Difference (ΔT)

The temperature difference-sensing system is audited by immersing the two system probes in the same water bath and comparing the readings of the probes at each of the audit temperatures. The difference in readings between the probes is calculated for each point and is compared with the audit criteria. This audit is performed in conjunction with the ambient temperature audit described above.

Relative Humidity and Dew-point Temperature

A self contained mobile data logger is collocated with the station sensor and records data for the duration of the audit. The data are downloaded and time averaged to match the interval reported by the station sensor. If readings do not agree, a psychrometer is used for backup verification. The muslin wick of the wet bulb thermometer of the motorized psychrometer is wetted with distilled water. The motorized psychrometer is then placed in close proximity to the relative humidity or dew point sensor and allowed to run for at least 5 minutes or until the thermometer readings stabilize. Once the readings stabilize, the audit psychrometer wet and dry bulb temperatures, the audit barometric pressure and the station relative humidity and ambient temperature or dew-point temperature are read simultaneously. These readings are used, along with a measure of pressure, to calculate the audit relative humidity and dew-point temperature. If the station reports relative humidity, it is converted to an equivalent dew-point temperature for comparison with the calculated audit dew-point temperature. If dew-point temperature is measured directly, the station value is directly compared with the calculated audit value. The difference between the station equivalent or measured dew-point temperature and the calculated audit dew-point temperature is compared with the audit criteria.

Solar Radiation

A certified LiCor pyranometer is collocated with the station solar radiation sensor and at least five simultaneous readings over the course of the audit are collected and the differences compared with the audit criteria. Similarly, the audit pyranometer may be hooked up to an audit data logger, and the audit readings can be averaged into periods comparable to those collected by the station.

4.2.2.4 Upper Air Meteorological Measurements

Sodar

The performance audit of the sodar may consist of two elements. The first is comparison with simulated winds from an Acoustic Pulse Transponder (APT), and second, by comparison to independent wind measurements. The latter comparison to the independent wind measurements is needed if the sodars are of the phased array variety. This comparison verifies the beam steering is appropriate by assessing the reasonableness of the data.

Unlike conventional sensors where known wind speeds and directions can be input directly to the sensor through various rotational methods, the acoustic system relies on the measurement of time and frequency shift of the backscattered acoustic pulse. The only means of truly providing a known input is through the introduction of fixed audio frequencies at known times. The frequency shift will correspond to a Doppler shift introduced by winds to or from an antenna. The timing of the simulated return will represent a known altitude based on the speed of sound. These simulations of the Doppler shifted signal are performed using the APT.

A comparison of the sodar response will also be made against independently measured winds. For this monitoring effort, a rawinsonde system will be used with several releases over the course of the day. This system will also audit the station radar wind profiler and RASS, and those data used to establish the confidence in the radar measurements.

All wind speed data are evaluated based on components along the sodar antenna axes. Where multiple comparisons are made, the systematic and RMS differences are calculated and compared to criteria of ±1 m/s and 2 m/s, respectively. In addition, comparisons are made to the sodar resultant vector values, but only for qualitative evaluation purposes. This is consistent with the newest EPA guidance and will help identify component related problems that may be missed by looking at the resultant data alone.

As a final check of the sodar data, data collected during several days prior to the audit are reviewed to establish the internal consistency of the values. As this is a qualitative check, there are no fixed evaluation criteria. The goal is to evaluate the following:

- Data reliability or quality codes for consistency
- Measured vertical intensity values for detection of potential fixed echoes
- Vertical profile of the individual wind components for detection of potential fixed echoes and consistency
- Vertical profile of the calculated vector winds for internal consistency
- Methods used to create hourly values from subhourly intervals

Radar Wind Profiler

There are two general sets of performance audit procedures that are specific to the site configuration. If the site is equipped with a collocated sodar with an appropriate altitude range, the profiling system can be audited by first establishing the on-site sodar as an audit device and then using the sodar data collected to audit the radar profiler data. Sites with a radar profiler only, or sodars that do not have an adequate overlap of range gates, are audited using another form of measurement, such as a rawinsonde. For the LAX audit, the radar profiler will be audited using the second method with multiple rawinsonde launches.

The EPA guidance for QA on radar profilers defines a series of system checks inherent to the profiler electronics. Unlike the sodar where instrumentation exists for simulation of winds by introduction of “Doppler shifted frequencies”, no such instrumentation exists for the profiler or RASS systems. Thus, to audit the data gathered by profilers, the data are compared to measurements from multiple rawinsonde balloon launches or other upper air data sources. At least three launches are performed over the course of a day to collect data under a variety of meteorological conditions. The collected meteorological data are then reduced into components along the radar wind profiler axes and the speeds compared with the radar data using the same systematic and RMS difference criteria as the sodar. This method is consistent with the newest EPA guidance. T&B Systems uses a suite of software programs that create compatible data files from the audit system and radar wind profiler, and perform statistical analysis of systematic differences and operational comparability between the systems.

As a final part of the audit, data from several days prior to the audit are reviewed for internal consistency. This type of review will check indicated flags for data reliability or quality codes for consistency, individual component intensity values to identify potential reflections, and the vertical profiles of the components and resultant values for internal consistency both in space and time.

Radio Acoustic Sounding System (RASS)

Audits of the RASS measurements are performed using at least three temperature and humidity soundings from the rawinsonde system over the course of the day. Sonde measurements are used to calculate the virtual temperature profiles (Tv) for comparison to the RASS-derived Tv values. The data collected from each launch is volume averaged to match the averaging intervals of the RASS. The results of the audit comparisons is evaluated against the criteria of ±1.0°C and 1.5°C for systematic and RMS differences, respectively.

As in the wind profiles, data from several days prior to the audit is reviewed. The review focuses on the internal consistency of the data in both space and time and look for the reasonableness of the Tv profiles.

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Module B

Source Apportionment Protocol

Source Apportionment Protocol for the Los Angeles World Airports (LAWA) Study

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1. INTRODUCTION

This protocol is provided to describe the technical approaches that will be used in the modeling portion (i.e., Task 8 in the Technical Workplan dated May 10, 2007) of the air quality and source apportionment study at the Los Angeles International Airport (LAX) administered by the Los Angeles World Airports (LAWA). The goal of the modeling portion of the pilot study is to:

> Determine significant sources of air pollution and their emissions;
> Estimate the contribution of LAX sources on air pollution levels;
> Provide input to optimize monitor locations; and
> Identify the methods and measurements that will be most successful in determining LAX's air quality impact.

For this project, two types of dispersion modeling will be performed to achieve the stated goals: source-oriented modeling and receptor modeling. Source-oriented air dispersion modeling requires the input of emissions data for sources of air pollution and the release characteristics of those emissions. Also required is the meteorology data and pollutant transport information to estimate downwind pollutant impacts. The U.S. EPA recommends several models for source-oriented dispersion modeling. Of which, AERMOD is recommended for near-field (<50 km) applications.[1] For the first phase of this project, the AERMOD model will be used. The techniques to be used for source-oriented modeling are discussed in Section 2 of this protocol.

Receptor modeling techniques utilize measured concentration data at specific locations (i.e., receptors), along with measured meteorological data (including back-trajectories of wind) and emission source characteristics to estimate the contribution of individual sources to measured pollutant concentrations. Technically, receptor models that use meteorological data are known as hybrid receptor models. This pedantic distinction is not followed here – hybrid models are simply grouped with receptor models. Details on receptor modeling are provided in Section 3 of this protocol.

Note that despite advancements in meteorology, atmospheric science and chemistry, monitoring techniques, and the aforementioned analysis methods, it is very difficult to discreetly characterize the impact of LAX sources on the ambient air. The meteorology, terrain, and emission sources in the Basin create a complex atmosphere. There is no guarantee that the results will isolate airport sources from other local, regional, and international sources in the Basin. Nonetheless, a well-conducted study can advance the understanding of the airshed and estimate possible impacts of LAX air emissions on the surrounding communities.

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[1] 40 CFR Part 51, Appendix W, *Guideline on Air Quality Models*

2. SOURCE-ORIENTED MODELING

MODEL SELECTION AND METHODOLOGY

SELECTION OF MODEL

The latest version (07026) of the AERMOD model will be used to estimate maximum ground-level concentrations. AERMOD is a refined, steady-state, multiple source, Gaussian dispersion model and was promulgated in December 2005 as the preferred model to use for industrial sources for near-field (< 50 km distant) analyses.[2] Although the analysis is not for regulatory purposes, most regulatory default model options will be used and will follow procedures outlined in the *Guideline on Air Quality Models*. Furthermore, even though the AERMOD model has the Plume Rise Modeling Enhancements (PRIME) incorporated in the regulatory version to assess the effects of buildings on air pollutant dispersion, the analyses for this study will not incorporate building downwash. Most of the airport sources will be represented as area or volume sources which are not impacted by downwash. In addition, the impacts will be predicted off-site from the airport, at a distance far enough that the impacts of turbulent wakes would be minimal.

As steady-state dispersion model, AERMOD is scientifically capable of predicting impacts at locations close to the emission sources (i.e., the near-field concept). For example, AERMOD can even predict impacts at locations within area emission sources. Considering the relatively short distances between the emission sources of interest (including both airport and regional sources) and the receptors (e.g., monitoring sites), it would be critical to represent the emission sources properly (e.g., type of emission sources and source characteristics) in the model as well as obtain representative meteorological and source data with sufficient temporal and spatial resolution. These considerations are discussed in more details in the following sections of this document.

TREATMENT OF TERRAIN

Complex terrain is defined as any terrain elevation exceeding stacktop height. Complex terrain is further sub-categorized into intermediate terrain (terrain elevation less than final plume rise height) and true complex terrain (terrain elevation greater than final plume rise height). The AERMOD model simplifies the treatment of terrain, as it does not have different algorithms for varying source-receptor elevation relationships described above. Through the use of the AERMOD terrain preprocessor (AERMAP), AERMOD incorporates not only the receptor heights, but also an effective height (hill height scale) that represents the significant terrain features surrounding a given receptor that could lead to plume recirculation and other terrain interaction.[3]

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[2] *Ibid.*

[3] US EPA, *Users Guide for the AERMOD Terrain Preprocessor (AERMAP)*, EPA-454/B-03-003, Research Triangle Park, NC

Receptor terrain elevations input to the model will be those interpolated from Digital Elevation Model (DEM) data obtained from the U.S. Geological Survey (USGS). DEM data consist of arrays of regularly spaced elevations and correspond to the 1:24,000 scale topographic quadrangle map series. The array elevations are at 30-meter intervals and will be interpolated using Trinity's *BREEZE*®*-AIR* software to determine elevations at the defined receptor intervals. All data obtained from the DEM files will be checked for completeness and spot-checked for accuracy against elevations on corresponding USGS 1:24,000 scale topographical quadrangle maps. Missing or erroneous data from the DEM files will be replaced by direct interpolation from the DEM data.

METEOROLOGICAL DATA

AERMET is the meteorological pre-processor associated with AERMOD. AERMET uses hourly observed surface and upper air meteorological data along with land use characteristics to determine the meteorological inputs (e.g., wind speed, direction, mixing heights, and turbulence) that drive the dispersion model. For example, the mechanical and convective mixing heights are calculated in AERMET for each hour based on the hourly surface and upper air input values (i.e., observed data). Tables 1 through 3 list the variables required as input data to AERMET. Tables 4 and 5 list the variables as output from AERMET and input to AERMOD. Note that the meteorological input data required by AERMET are based on single-station hourly observations. Furthermore, the LAX Airport is located in an urban area whose night-time heat island effect may significantly affect the atmospheric turbulence and thus the dispersion of urban source emissions. According to the U.S. EPA AERMOD implementation guide, in order to avoid double counting the effects of the urban heat island, on-site measured turbulence data should not be used when applying AERMOD's urban option. Therefore, on-site measure turbulence measurement is not necessary for AERMOD modeling. From the perspective of the meteorological data requirements, 3-dimensional wind data is not mandatory. Choosing the option between 3-D sonic and 2-D mechanical anemometers would depend on the quality and accuracy of the required data that can be obtained by each option.

TABLE 1. SURFACE OBSERVATIONAL DATA REQUIREMENT FOR AERMET

Variable	Unit	Mandatory/Optional	Note
Ceiling Height	Hundreds of Feet	Mandatory	
Wind Direction	Tens of Degrees	Mandatory	
Wind Speed	Knots	Mandatory	
Dry Bulb Temperature	Degrees Fahrenheit	Mandatory	
Total Cloud Cover	Tens of Percent	Mandatory	
Precipitation Amount	Millimeter	Optional	Used for wet deposition
Opaque Cloud Cover	Tens of Percent	Optional	Used when Total Cloud Cover not available
Relative Humidity	Tens of Percent	Optional	
Station Pressure	Inch Hg	Optional	Used only to calculate dry air density; default value of 1013.25 mb
Wet Bulb Temperature	Degrees Fahrenheit	Optional	
Dew-Point Temperature	Degrees Fahrenheit	Optional	
Present Weather	No Dimension	Optional	
Horizontal Visibility	Kilometers	Optional	

TABLE 2. UPPER AIR OBSERVATIONAL DATA REQUIREMENT FOR AERMET

Variable	Unit	Mandatory/Optional
Atmospheric Pressure	Millibars	Mandatory
Height Above Ground Level	Meters	Mandatory
Dry Bulb Temperature	Degrees Celsius	Mandatory
Dew-Point Temperature	Degrees Celsius	Mandatory
Wind Direction	Degrees from North	Mandatory
Wind Speed	Meters per Second	Mandatory

TABLE 3. SURFACE CHARACTERISTIC PARAMETERS FOR AERMET

Parameter Name	Unit	Mandatory/Optional
Bowen Ratio	No Dimension	Mandatory
Albedo	No Dimension	Mandatory
Surface Roughness Length	Meters	Mandatory

TABLE 4. AERMET SURFACE OUTPUT DATA

Parameter Name	Unit
Sensible Heat Flux	Watt per Square Meter
Surface Friction Velocity	Meters per Second
Convective Velocity Scale	Meters per Second
Vertical Potential Temperature Gradient Above PBL	Meters
Height of Convectively-generated Boundary Layer	Meters
Height of Mechanically-generated Boundary Layer	Meters
Monin-Obukhov Length	Meters
Surface Roughness Length	Meters
Bowen Ratio	No Dimension
Albedo	No Dimension
Wind Speed	Meters per Second
Wind Direction	Degrees
Reference Height for Wind Speed and Wind Direction	Meters
Temperature	Kelvin Degrees
Reference Height for Temperature	Meters
Precipitation Code	No Dimension
Precipitation Rate	Millimeter per Hour
Relative Humidity	Percent
Station Pressure	Millibar
Cloud Cover	Tens of Percent

TABLE 5. AERMET PROFILE OUTPUT DATA

Parameter Name	Unit
Height Above Ground Level	Meters
Temperature	Degrees Celsius
Wind Direction	Degrees from North
Wind Speed	Meters per Second

The measurement portion of this study will be collecting on-site meteorological data at two locations at LAX. These data will contain all of the necessary parameters (i.e., wind speed, direction, temperature, cloud cover) to represent surface meteorological stations for use in AERMET. Measured data will be quality assured and may be filled, as appropriate.

Trinity will utilize nearby upper air locations to obtain the upper air parameters necessary for processing of AERMOD. Based on a preliminary review of data quality, availability, and representativeness, it is proposed that the San Diego airport upper air station will be used for upper air data. Trinity will contact SCAQMD to determine if the profiler data from LAX would provide appropriate data that could be used instead. The land use parameters used in AERMET will be developed in accordance with U.S. EPA's recent guidance on the use of AERSURFACE.[4]

Model runs will be conducted using both sets of collected meteorological data for the study period (June – August 2008). The initial modeling for monitor review will utilize National Weather Service LAX data for June – August 2007.

RECEPTOR GRIDS

Ground-level concentrations will be calculated within receptors located within the 70 km^2 study area. Receptors will be evenly spaced at 200 m within three km of LAX and 1,000 m beyond three km. In addition, receptors will be located at the ambient monitor locations and possibly at sensitive receptors, such as schools, hospitals, or child-care facilities.

FORMATION OF SECONDARY AIR POLLUTANTS

As an objective for the long-term study, consideration of secondary air pollutants formation (e.g., secondary $PM_{2.5}$, sulfate, and nitrate) is important for understanding the impacts of these pollutants. However, from a technical perspective, secondary air pollutants are typically formed as a regional scaled rather than a short-distance local scaled phenomenon. Considering that the receptors of interest (e.g., nearby community) are located just outside the LAX Airport boundary, within such a short-distance, the formation of secondary air pollutants due to the airport emissions is expected to be limited. Moreover, it is believed that a regional model (e.g., CMAQ) designed to simulate regional and long-range transport air quality phenomena would not provide the resolution to resolve the local-scaled (e.g., hundreds of meters) dispersion and chemical transformation.

In this pilot study, the impacts of the LAX airport emissions will be assessed based on the primary emissions of criteria pollutants. It is believed that this approach would be sufficient to characterize the potential impacts and hot spots due to the airport emissions. The selected dispersion model (i.e., AERMOD) for this pilot study is capable of modeling dispersion of the primary emissions with the consideration of effects due to various atmospheric boundary layer phenomena including complex terrain, building downwash, plume rise. In addition, deposition can also be modeled with AERMOD if required.

REPRESENTATION OF EMISSION SOURCES

LAX EMISSION SOURCES

An emissions inventory will be developed for airport-related sources using the Federal Aviation Administration's (FAA) Emissions and Dispersion Modeling System (EDMS). EDMS is the

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[4] AERSURFACE User's Guide, U.S. EPA, EPA-454/B-08-001, January 16, 2008.

required air pollution model for FAA applications.[5] EDMS develops time- and location-varying emissions from aircraft, ground support equipment, mobile sources related to airport activity and other airport related emissions sources. EDMS incorporates specific details on types of airplanes and typical aircraft schedules for taxi and take-off to develop robust temporal and spatial representation of airport emissions. Although the EDMS can incorporate the emissions data to run AERMOD directly, Trinity will take the emissions data and set up additional details in the AERMOD runs. Trinity will evaluate the emission data for opportunities to simplify the data (to improve model run time), while maintaining the fidelity of the model results. For example, Trinity will evaluate the conversion of area sources to volume sources.

In addition to the emissions developed by the EDMS, emissions from the support combustion equipment will be developed. These emission units consist of boilers used to provide comfort heating and cooling and generators for emergency purposes. Emissions from these units will be based on LAX emissions inventories which incorporate actual fuel usage and U.S. EPA-developed emission factors.

REGIONAL EMISSIONS INVENTORY

In addition to the sources at the airport, a regional inventory of sources will be incorporated into the model. This will allow the model results to be compared directly against ambient measurements. The regional inventory will be based on data collected by the South Coast Air Quality Management District (SCAQMD). These emission sources may include the shipping and port emissions as well as emissions from nearby stationary sources (e.g., power plant and refinery).

COORDINATE SYSTEM

In all modeling analyses input and output files, the location of emission sources, structures, and receptors will be represented in the Universal Transverse Mercator (UTM) coordinate system. The UTM grid divides the world into coordinates that are measured in north meters (measured from the equator) and east meters (measured from the central meridian of a particular zone, which is set at 500 km). The LAX location is approximately 369,877 m East and 3756,673 m North in Zone 11S (NAD 83).

SOURCE TYPES

The AERMOD dispersion model allows for emissions units to be represented as point, area, or volume sources. For point sources with unobstructed vertical releases, it is appropriate to use actual stack parameters (i.e., height, diameter, exhaust gas temperature, and gas exit velocity) in the modeling analyses. Units such as the boilers and generators units will be modeled as point sources using actual stack parameters. Roadway sources and aircraft mobile sources (e.g., taxing, queuing, take-off, and landing) are represented in EDMS as area sources, although Trinity will look at converting these to volume sources. Gate activities will be represented as volume sources.

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[5] Federal Register, Volume 63, No. 70, April 13, 2998.

MODELED POLLUTANTS

In the initial modeling scenarios, the model runs will be performed for the following "criteria" pollutants: nitrogen dioxide (NO_2), carbon monoxide (CO), sulfur dioxide (SO_2), volatile organic compounds (VOC), and particulate matter (PM). Note that ozone is formed from a photochemical reaction between NO_X and VOC and requires the use of a photochemical model to appropriately estimate impacts. Therefore, ozone will not be addressed as part of this study. Additional pollutants of interest, such as individual organic compounds, will be modeled as VOC initially and may be identified during the study process. Dispersion modeling may also be conducted for these pollutants.

Predicted ambient air impacts will be predicted for the above pollutants at each receptor location over several averaging periods, ranging from 1-hour to annually. The impacts will be separated by LAX airplane and airport sources and the regional inventory sources.

3. RECEPTOR MODELING

METHODOLOGY

The receptor modeling methodology described below is considered to be the most likely receptor modeling approach to provide results that shed light on the study goal with the study constraints. The receptor modeling method to be applied to the Pilot Study data will be Nonparametric Trajectory Analysis (NTA). An overview of the proposed method is described below. Details from an example analysis are provided at the end of this section and additional information can be found in the peer-reviewed paper (Henry, 2007).[6]

NONPARAMETRIC TRAJECTORY ANALYSIS WITH MINUTE DATA [7]

The NTA receptor modeling method utilized in the pilot study uses back trajectories along with kernel smoothing methods to locate and quantify the sources of emissions on a local scale using short-term data. Wind speed and wind direction data from all the monitoring sites will be used to calculate back trajectories. The concentration of the pollutant at the time of arrival at the monitor is associated with the points along the corresponding trajectory. For a suitably spaced grid of points, the expected value of the concentration associated with trajectories passing near the grid points is calculated by a nonparametric regression analysis method or kernel smoothing. The kernel function is usually Gaussian and the smoothing results from a moving average using weights derived from the kernel. The result is a contour map with the average value of the concentration at the monitor given that the air passes over of near that part of the map. The only adjustable parameter in the analysis is the kernel smoothing parameter. If it is too small the results will be very lumpy and clearly under-smoothed, while if it is too large the result will be

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[6] Henry, R. C. 2007. Locating and Quantifying the Impact of Local Sources of Air Pollution. *Atmospheric Environment* 42, 358-363.

[7] Refers to data taken on a 1-5 minute frequency.

very broad regions with little variability and clearly over-smoothed. Generally, an appropriate smoothing parameter is chosen by trial and error, fortunately the results are not sensitive to small changes in the smoothing parameter.

NTA will be applied to minute data from each site for PM_{10}, $PM_{2.5}$, SO_2, NO, NO_2, NO_X, CO, and black carbon. The back trajectories will be calculated by inverse distance weighted averages of all available minute data. NTA will identify the regions associated with high concentrations of each species at the monitors. The average amount of selected pollutants coming from appropriate wind direction sectors will be calculated with uncertainties. The NTA results will be interpreted in terms of the impact of airport operations and other sources on each species. The location of the monitoring sites will also be evaluated in light of the NTA results.

REVIEW OF ADDITIONAL RECEPTOR MODELS WITH PARTICULATE COMPOSITION DATA

The possible use of other receptor models that use observations of particulate composition will be evaluated. These models will be restricted to EPA-approved versions of Chemical Mass Balance (CMB) and the multivariate model Unmix. The likelihood that the full study would produce data of sufficient quantity and quality for the application of these models will be addressed. Specifically, the existence of compositional “fingerprints” for sources of interest will be evaluated in light of available particulate composition data. Possible technical difficulties due to near multicollinearity of sources with similar composition will be considered. The possibility of using particulate lead as a tracer for aviation gasoline is an example of the possibilities that will be considered.

EXAMPLE OF NONPARAMETRIC TRAJECTORY ANALYSIS

The result of the method is a map of showing the average concentration of a pollutant at the monitor if the air has passed over a point on the map. The following example is for 1-minute concentrations of sulfur dioxide gas measured at the north Long Beach site by the South Coast Air Quality Management district (SCAQMD). The result in Figure 1 was obtained using only data from the north Long Beach site from the three-month period January, February, and March 2005. The monitor is located at (0, 0) on the map, which is superimposed on an aerial photo of the Los Angeles – Long Beach port area. The contour lines are sulfur dioxide concentrations in parts per billion. The highest contours are for 5.5 parts per billion of sulfur dioxide; these are shown in deep red. The area encompassed by the red contours is centered on the facilities of the Valero refinery, indicating that this is the source of much of the sulfur dioxide gas impacting the north Long Beach monitor. The area also includes parts of another refinery, Long Beach Generating Station, and part of the facilities of the Port of Los Angeles. These sources are also contributing to the burden of sulfur dioxide at the monitor. Applying the method to data from another nearby monitor would help to distinguish the contributions of these sources.

The method starts by calculating back-trajectories using the wind speed and direction data from one or more sites. Figure 2 is an example of three back trajectories calculated for the north Long Beach site. The trajectories trace the path of the air for the previous two hours. The red dots on the trajectories are placed at 30-minute intervals. Back trajectories are calculated covering the entire time period of interest. In the example in Figure 1, this is three winter months. Once the trajectories have be calculated, the concentration of the pollutant at the time of arrival at the monitor is associated with each point on the trajectory. For a suitably spaced grid of points, the expected value of the concentration associated with trajectories passing near the grid points is calculated by a method know as nonparametric regression or kernel smoothing. The result is a contour map as shown in Figure 1. The values of the contours give the average value of the concentration at the monitor given that the air passed over of near that part of the map. The areas associated with the highest values are the location of the major sources contributing to concentrations of the pollutant at the monitor. In this way the major sources of pollution are identified and the impact of them on the monitor quantified.

MATHEMATICAL DETAILS

Back Trajectory Calculation

If there is only one site with meteorological data, calculate the trajectories as follows from wind speed and azimuth data.

As shown in Figure 3, the wind azimuth is the direction the wind is coming *from* measured clockwise from north. To calculate the x (east-west) and y (north-south) coordinates of the direction the wind is coming from, the azimuth angle must be converted to the usual mathematical definition of angle, i.e., measured counterclockwise from the x-axis. If the azimuth angle is *Z*, and the mathematical angle is , then
= 90 – *Z* , for 0 *Z* 90, and
= 450 – *Z* , for Z otherwise,
As defined above, is between 0 and 360.

If the wind speed is *u*, the x and y coordinates of the wind velocity at time t_k are then

$$v_x(t_k) = u(t_k)\cos(\theta(t_k))$$

$$v_y(t_k) = u(t_k)\sin(\theta(t_k))$$

Then the x and y coordinates of the points on the back trajectory starting at time t_j are

$$x_k(t_j) = \sum_{i=0}^{k} v_x(t_{j-i})\Delta t$$

$$y_k(t_j) = \sum_{i=0}^{k} v_y(t_{j-i})\Delta t$$

$$k = 1, \cdots, N$$

where t is the time step, that is the time between measurements and *N* is how many steps backward in time are taken. More complex schemes to calculate back trajectories using wind and other meteorological data from additional can also be used. Each point on the trajectory is associated with c_j the concentration at time t_j when the air arrives at the receptor. Finally, all the points from the set of all the trajectories of interest starting at all possible times along with the associated concentrations are assembled in a set of ordered triples (x_i,y_i,c_i), where the index i ranges over all the points of all the trajectories.

Smoothing

Next, kernel smoothing is used to estimate the average concentration at the monitor if the air passes over a point on the map from the set of trajectory points and concentrations *(x_i,y_i,c_i)* as calculated above. Any type of smoothing may be used but to demonstrate the method, smoothing with the Epanechnikov kernel *K(x)* is chosen. By definition,

$$K(x) = 0.75(1 - x^2) \quad -1 \leq x \leq 1.$$

Define some equally-spaced set of *x* and *y* coordinates given by *(X_i,Y_j)*. Then the average concentration at the receptor of air that has passed over point *(X_i,Y_j)* is given by

$$\overline{C}(X_i,Y_j) = \frac{\sum_k K\left(\frac{(X_j - x_k)}{h}\right) K\left(\frac{(Y_j - y_k)}{h}\right) c_k}{\sum_k K\left(\frac{(X_j - x_k)}{h}\right) K\left(\frac{(Y_j - y_k)}{h}\right)}$$

where *h* is the smoothing parameter defined by

$$h = \frac{FWHM}{\sqrt{2}}$$

and *FWHM* is an adjustable parameter giving the full width at half maximum of the smoothing function. The variance of this estimate is given by

$$\mathrm{Var}(\overline{C}(X_i,Y_j)) = \|K\|^4 \frac{\sum_k K\left(\frac{(X_i - x_k)}{h}\right) K\left(\frac{(Y_j - y_k)}{h}\right) (c_k - \overline{C}(X_i,Y_j))^2}{\left[\sum_k K\left(\frac{(X_i - x_k)}{h}\right) K\left(\frac{(Y_j - y_k)}{h}\right)\right]^2}$$

where,

$$\|K\|^2 = \int_{-\infty}^{\infty} K^2(x)dx = 0.6, \text{ for the Epanechnikov kernel.}$$

EXTENSIONS OF THE METHOD

Forward Trajectories

The same methodology as outlined above can be applied to forward trajectories instead of back trajectories. An example is shown in Fig. 4. In this case the Long Beach 1-minute sulfur dioxide data from the summer months of 2005 (May, June, July) was used. The figure shows the average value of sulfur dioxide at the monitoring site for air that has passed over the monitoring site. Since the sources of sulfur dioxide are southwest of the monitoring site, the impact of sulfur dioxide at the site will be to the northwest. The forward trajectory method is valuable in defining a “region of influence” for a pollutant.

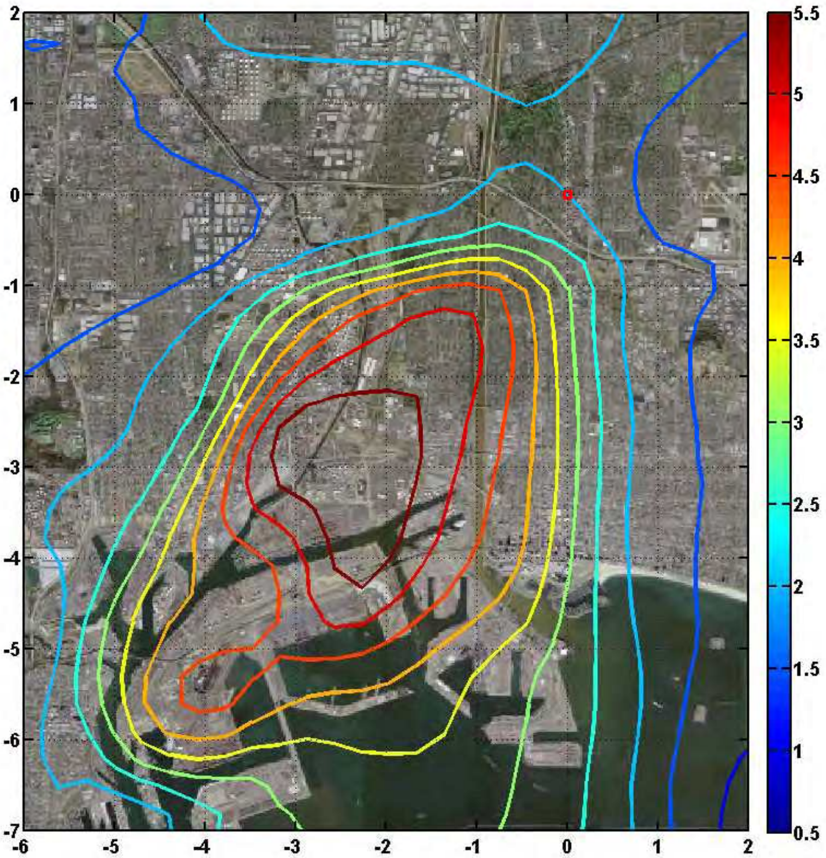

Figure 1. Average concentration of sulfur dioxide measured at the north Long Beach site if the air passes over a point on the map. The monitor is located at the red point at (0,0) on the grid; the units of the grid are miles.

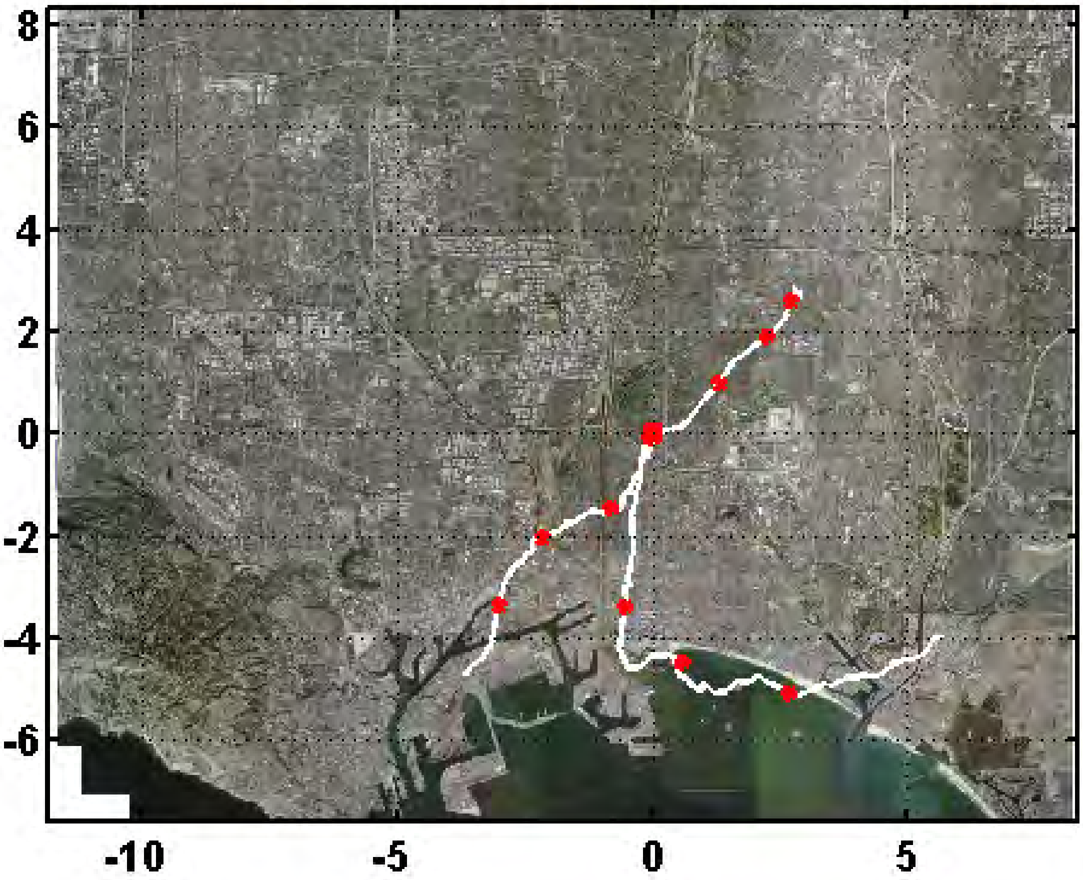

Figure 2. Three typical back trajectories calculated from 1-minute wind speed and direction observed at the SCAQMD north Long Beach monitoring site. The trajectories trace the path of the air back two hours. The red '+' marks are placed at 30 minute intervals.

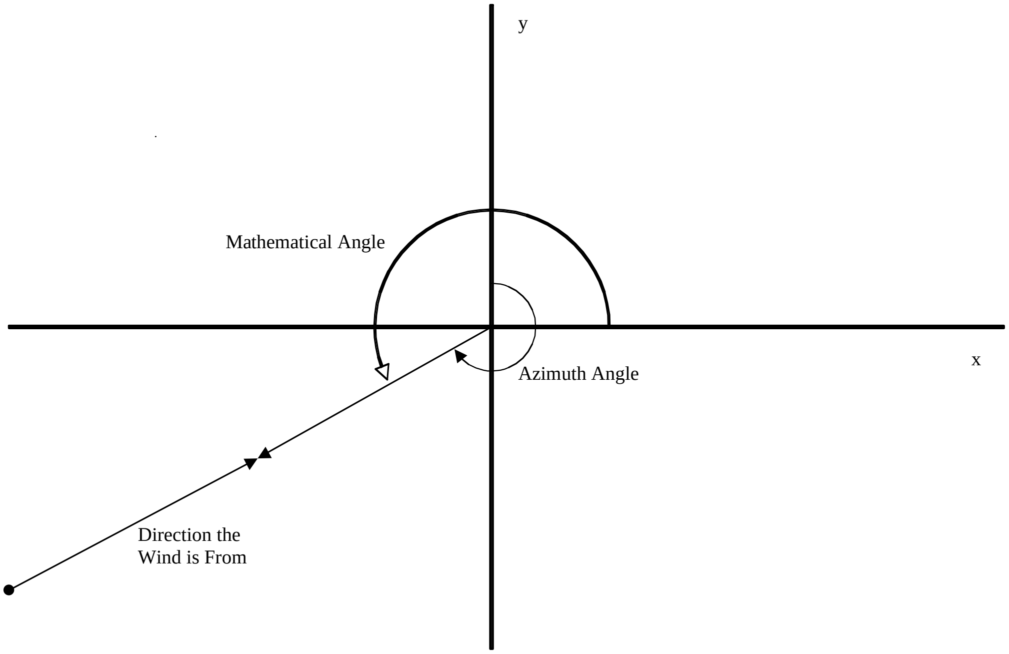

Figure 3. Definition of angles used for trajectory calculations.

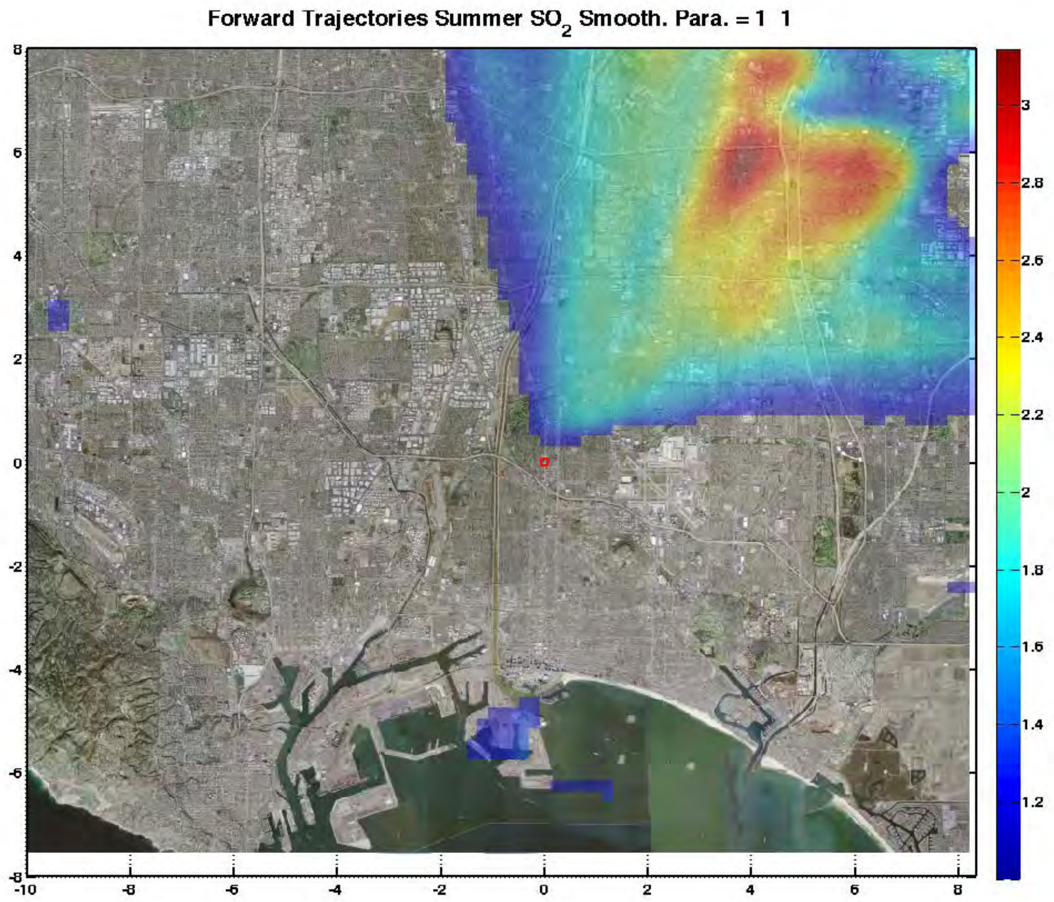

Figure 4. Forward trajectory analysis of sulfur dioxide for the summer months of 2005. The color scale is dimensionless, 1 represents the average value and 3 is 3 times the average value. Values below the mean are not shown.

4. STUDY IMPLICATIONS AND INTEGRATION

The source-oriented modeling will provide predicted impacts of air pollutant concentration at areas surrounding the airport. Preliminary model results using the methods described above will be developed using LAX emissions sources only to provide feedback on measurement station location. Additional model runs will be conducted that incorporate not only LAX sources, but the surrounding regional inventory. Results from the inventory analyses will be used to assess the relative importance of LAX to the regional air pollutant concentrations. Impacts from LAX sources will be reviewed by source type and compared to impacts from the regional inventory. The comparisons will review spatial and temporal variability and will be compared to both the measured data and the receptor modeling.

Using the methods detailed above, receptor modeling will be completed using selected pilot study data and aims to resolve source-specific details on LAX emissions sources and their air quality impact. The receptor modeling will also identify areas of improvement for future studies to better resolve the LAX source.

Source-oriented and receptor modeling use disparate techniques and typically predict results over different temporal and spatial scales. Nonetheless, specific periods will be identified for comparison. In this study, SO_2 and $PM_{2.5}$ results will be compared. SO_2 is chosen due to the expected signature of airplanes using higher sulfur fuel and $PM_{2.5}$ is of interest due to health risks. The team will evaluate substituting the $PM_{2.5}$ results with those of another species in the case it is determined that secondary compounds creating $PM_{2.5}$ are affecting the results.

The model review and comparisons will provide insight to the influence of LAX on air quality in the surrounding area. In addition, the analyses will provide valuable information on improving future studies of both measurements and modeling. All of the analyses and recommendations will be provided to LAWA in a final report.

Module C — Literature Review

Literature Search of Existing Information and Data
(Task 2)

EXECUTIVE SUMMARY

LAX is a source of air pollutants situated between the Pacific Ocean on the west and residential areas on the remaining three sides. Due to the local prevailing wind patterns of alternating land and sea breezes, emissions from the airport are carried into the neighboring residential areas. The potential for health impacts from these emissions has been a local concern. However, distinguishing any potential LAX-generated air quality impacts in the surrounding neighborhoods is confounded by the presence of other significant sources of emissions in the local region.

Due to the number of sources in the area surrounding LAX, with many emitting the same types of compounds, it is difficult to readily attribute the measured presence of any pollutant in nearby neighborhoods to a specific source. Other regional air quality studies, such as the second Multiple Air Toxics Exposure Study (MATES-II) conducted in 1998 by the South Coast Air Quality Management District (SCAQMD), have examined air toxics in general but not LAX or other sources specifically. During the summer of 1999, the SCAQMD conducted a short-term air toxics monitoring program in the area around LAX. The results of that short-term study indicate that air toxics levels in the neighborhoods surrounding LAX were consistent with those found elsewhere in the South Coast Air Basin. However, the SCAQMD study was limited in extent and duration and did not provide data that could be used to determine either long-term impacts or LAX's contribution to toxic air pollutants.

This Literature Survey is designed to identify, analyze and summarize existing information and data pertaining Ambient Air Monitoring, Emissions Source Characterization and Source Apportionment Techniques. The Principle Aim of preparing this information is as follows:

Principle Aim of the Literature Survey

Determine the feasibility of achieving the Study's Objectives following the air quality monitoring/sampling and source apportionment program.

In order to accomplish this task, a wide array of articles, reports and other documents were consulted. The most relevant and potentially useful of these were cataloged into a Bibliography Matrix, abridged in Annotated Summaries and are reported upon in this report. In all, approximately 75 individual citations are included and the essential findings from this body-of-work are as follows:

Ambient Air Monitoring – Information and data recently collected in the vicinities of LAX and other airports have enabled researchers to identify compounds that aid in assessing the potential effects of aircraft emissions. Principal among these are nitrogen dioxide (NO_2), black carbon, ultrafine particulate matter ($PM_{0.1}$) and formaldehyde; although other candidate compounds are similarly regarded.

Emissions Source Characterization - Emission factors presently exist for most airport-related sources and work is underway to improve and supplement these databases. The most significant of this research include recently completed and ongoing studies aimed at measuring emissions from aircraft engines. Early outcomes emerging from this work have contributed to important advancements in the characterizations of these emissions that occur in both the gaseous and particulate phases.

Source Apportionment Techniques - There is prior experience successfully using source apportionment techniques at airports in general, and at LAX and in the Los Angeles area in particular. Examples include non-parametric regression analyses that help to identify emission source contributions to air monitoring data; time series analyses that enable better correlations between air monitoring data and emission events; and the combined applications of emissions inventories, air dispersion modeling and other technical analyses to compute the types and amounts of emissions generated and their transport.

This information and data are considered "key" to achieving the Study's objectives, particularly in support of the efforts to quantify the impacts of LAX-related emissions in the adjoining neighborhoods, differentiate them from "background" levels and identify the effects of other non-airport sources. The results of this survey support the principle aim of the Study and demonstrate that the Study's objectives can be feasibly obtained using a combination of air quality monitoring, sampling, source apportionment and results analysis.

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SECTION I. Introduction & Background Information

A. Study Objectives and Components

This section provides a broad overview of the LAX Air Quality and Source Apportionment Study including the objectives, technical analyses and the supporting tasks.

1. Primary Objective of the Study

Los Angeles World Airports (LAWA) has initiated a study designed to evaluate air quality conditions in the vicinity of Los Angeles International Airport (LAX). Entitled the *Air Quality and Source Apportionment Study of the Area Surrounding Los Angeles International Airport* (the "*Study*"), this multi-faceted initiative involves air quality monitoring, preparation of an emissions inventory, air dispersion modeling and the characterization of emission sources located both on and off the airport property. As restated below in summary form, the Primary Objective of the Study is to develop detailed information on the potential impacts of LAX-related emissions on air quality in neighborhoods that surround the airport.

Primary Objective of the Study

Develop detailed information on the potential impacts of LAX-related emissions on air quality in neighborhoods that surround the airport.

LAX is among the top five airports in the world based upon passenger enplanements and serves as a principle gateway for both domestic and international air travel for Southern California and the Los Angeles area. Located in the South Coast Air Basin (the "Basin"), this area does not meet national and state air quality standards for several "criteria" air pollutants.[1] There are emerging concerns about hazardous air pollutants (HAPs) within this airshed as well.[2]

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[1] Criteria pollutants are those that have National or California Ambient Air Quality Standards (NAAQS/CAAQS). Presently, the area around LAX does not meet the NAAQS/CAAQS for carbon monoxide, ozone and particulate matter.

[2] Hazardous air pollutants (HAPs) are also known as "air toxics" and are pollutants for which there are no NAAQS/CAAQS (e.g., benzene, formaldehyde, diesel particulate matter, etc.).

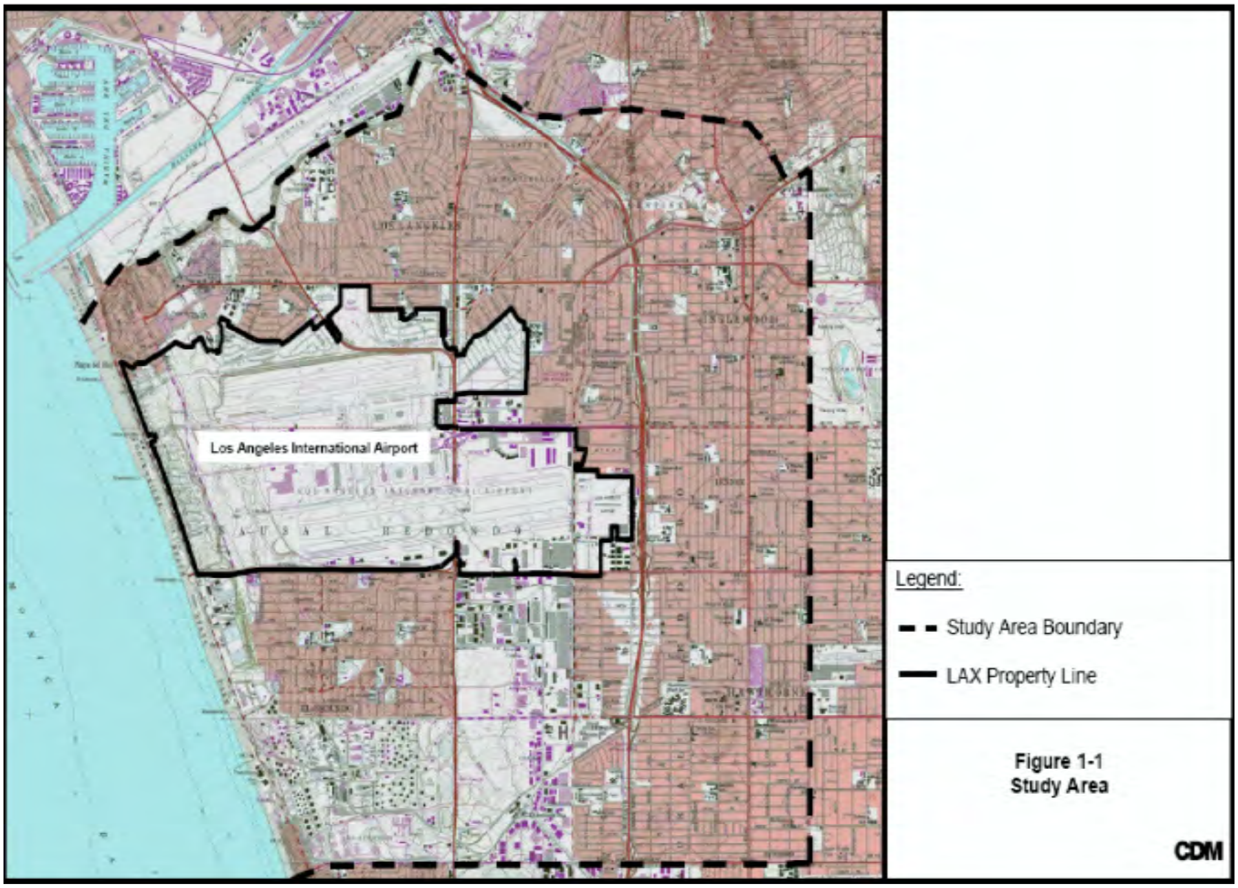

Figure 1 – Study Area

As shown in Figure 1 (*Study Area*), LAX is in an area that contains residential land uses located to the north, south and east of the airport. (The Pacific Ocean lies immediately to the west.) Other nearby land uses that generate air emissions include a vast network of surface transportation facilities (e.g., I-105/I-405, local arterials, frontage roads and surface streets); a wide assortment of commercial/light-industrial facilities; and large power generation and waste water treatment facilities. However, the potential effects on local air quality from the emissions associated with the airport remain a primary and growing concern among the neighboring residents.

As part of the ongoing Master Plan process for LAX, LAWA is involved in the preparation of Environmental Impact Statements/Reports (EIS/EIR) under federal and state guidelines to evaluate the potential impacts associated with planned future improvements to this airport (including those pertaining to air quality).[3] By comparison, this Study involves the assessment of air quality independently from these EIS/EIR analyses, but is far more comprehensive than any undertaken thus far at LAX or at any other airport nation- or world-wide.

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[3] See www.ourlax.org/publications.cfm for more information.

2. Technical and Non-Technical Objectives

The principle objectives, overall approach and technical elements of the *Study* have been coordinated with federal, state and regional agencies involved with aviation and air quality management in the Los Angeles area. In addition to LAWA, these agencies include the U.S. Environmental Protection Agency (EPA), Federal Aviation Administration (FAA), California Air Resources Board (CARB) and the South Coast Air Quality Management District (SCAQMD). The outcome of this coordination is codified in the *Technical Workplan* (the "Workplan") for the *Study* (LAWA, 2007). From the *Workplan*, the individual technical and non-technical objectives for the *Study* are summarized below (Table 1):

Table 1 - Technical and Non-Technical Elements of the Study

Assess the impact of LAX on local air quality by completing the following technical analyses:

- Quantify ambient (i.e., outdoor) concentrations of air pollutants in the neighborhoods surrounding LAX and determine how they vary spatially and temporally;
- Identify significant air emission sources in the airport area and characterize their emissions;
- Determine the relative significance of airport-related emission sources compared to non-airport sources; and
- Collect baseline data for future studies aimed at further assessing human exposures, pollutant transport/ transformation, and emission control strategies.

In addition, the Study objectives are also aimed at fostering and achieving the following non-technical elements:

3. Technical Analyses

In order to meet the objectives, the technical aspects of the *Study* are varied, relatively complex and many are considered to be "state-of-the-art" and "first-of-their-kinds". In all cases, they were specifically selected or developed for being the most appropriate for this unique and challenging application. Again, excerpted from the *Workplan* and listed in Table 2, these analyses comprise both emission source-oriented and receptor-oriented air quality monitoring and source apportionment methods.

Table 2 - Technical Analyses of the Study

- Ambient air monitoring;
- Emissions source characterization; and
- Source apportionment techniques, including
  - Receptor modeling,
  - Spatial gradient analysis,
  - Time series analysis,
  - Emissions inventory development, and
  - Air dispersion modeling.

Notably, to help ensure the Study Objectives are met and the Technical Analyses remain current, a Technical Working Group (TWG) and project Briefing Group (BG) comprised of agency representatives combined with technical experts in the fields of air monitoring, modeling and source apportionment as well as aviation and airport management will oversee the Study. Again, these agencies include LAWA, EPA, FAA, CARB, and SCAQMD. In addition, a *Community Outreach and Involvement Program* is also being developed separately by LAWA as part of this overall initiative.

A more complete explanation of the Study Objectives, the Technical Analyses as well as the roles of the TWG/BG is contained in the *Technical Workplan* for the *Study* (LAWA, 2007).

B. Purpose of the Literature Survey

This section provides information pertaining to the purpose, objectives and individual components of the *Literature Survey of Applicable Air Quality and Airport Studies*.

1. Task Objectives and Elements

The Literature Survey presented in this report is designed to identify, analyze and summarize existing information and data pertaining to air quality monitoring, emission source characterization and source apportionment techniques related to airports, in general, and LAX, in particular. It is intended that this body-of-work will help to further verify the feasibility of achieving the *Study's* overall Objectives, support the Technical Analyses and enable the subsequent study objectives to proceed expeditiously. In summary, the principle aims of this task are to accomplish the following (Table 3):

Table 3 - Literature Survey Overview

Principle Aim

Determine the feasibility of achieving the Study's objectives following the air quality monitoring/sampling and analysis program.

Supporting Objectives

- Identify existing information and data on the topics of:
    - Ambient air monitoring,
    - Emissions source characterization, and
    - Source apportionment techniques,

  as they pertain to airports in general with an emphasis on LAX.
- Collect, analyze and summarize these materials for use by the Study Team, LAWA staff, members of the TWG/BG, and other interested parties.
- Identify information and data gaps for consideration in the sampling and analysis tasks.
- Determine the feasibility of achieving the study's objectives following the air quality monitoring/sampling and analysis program.

The scope of the Literature Survey is divided into the three following sub-tasks:

Literature Search of Existing Information and Data - Under this subtask, relevant reports, articles and other publications with the greatest potential for addressing the issues, information gaps and challenges of the *Study* are identified. These select materials are reviewed with the principal aim of extracting that information and data that best support the stated objectives, technical analyses and tasks of the *Study*. The findings are then condensed into clear and comprehensible formats for ease of understanding by the Study Team, LAWA staff and the TWG/BG.

Identification and Assessment of Information and Data Gaps – Under this subtask potentially significant information and data gaps that are relevant to this *Study* are identified and characterized. From these findings, the potential impacts, limitations and uncertainties attributable to these information/data gaps are summarized and assessed. The extent to which these shortcomings may be quantified or compensated for are also evaluated and discussed.

Presentation of Findings and Recommendations – The information and data collected and developed to complete this Literature Survey, is somewhat voluminous, mostly technically oriented and presently scattered among a number of different collections and sources. What is presently known about the information and data gaps can be similarly characterized. Therefore, the primary aim of this subtask is to consolidate the findings into formats that are useful, informative and easy to access for the end-users.

2. Intended Audience

As briefly mentioned above, the Literature Survey is principally designed for the intended use by the Study Team, LAWA staff, members of the TWG, and other interested parties.

C. Sources of Information and Data

This section provides an explanation of the overall approach used and the individual steps taken to identify, select, obtain, review and summarize the materials included in Literature Survey. A summary discussion of the sources of information and data consulted is also provided.

1. Overall Approach

Among the challenges in the development of this Literature Survey are (a.) identifying and locating the sources of information and data, (b.) determining which of the materials are pertinent and helpful to the *Study*, and (c.) retrieving, reviewing and summarizing the resources that are selected for inclusion. As a means of accomplishing these tasks, a three-step process was developed and used, which is simply illustrated in Figure 2 and summarized as follows:

Step 1: Define the Subject Matter(s) of Primary Interest – In accordance with the Study's primary objectives and technical analyses described above, the following generally comprise the subject matter of primary interest:

- Ambient air monitoring;
- Emissions source characterization; and
- Source apportionment techniques, including:
  - Receptor modeling,
  - Spatial gradient analysis,
  - Time series analysis,
  - Emissions inventory development, and
  - Air dispersion modeling.

Because the application of these topics in this *Study* are aimed principally at addressing air quality conditions in the vicinity of LAX, the priority and emphasis is placed on information and data pertaining to LAX in particular, and airports in general.

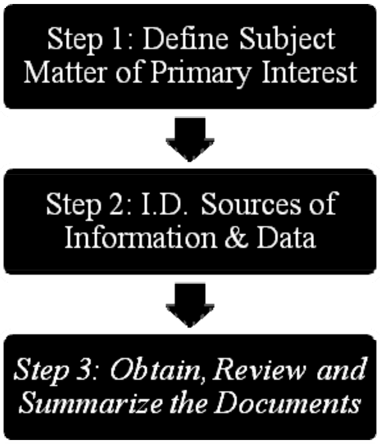


Figure 2 - Literature Survey Process

Step 2: Identify the Sources of Information and Data – There presently exist a wide collection of reports, articles and other documents or records pertaining to the combined topics of air quality and aviation. Several examples include publications by the U.S. EPA, the FAA, CARB and an assortment of other investigators – both public and private. Added to these are a growing body of new publications by foreign, federal and state agencies; academic institutions; and other researchers evaluating monitoring data at several large, medium and small airports. Therefore, in order to focus the search for existing information and data, the preference was for materials that met the following criteria:

- Relevancy to the Subject Matter (see Step 1);
- Publicly available (i.e., not proprietary);
- Available in Final form (i.e. not Draft); and
- Published after 1990.

The citations contained in the Technical Workplan *Bibliography of Prior Studies* were evaluated first, followed by searches of governmental agency, university and public library listings; appropriate professional, scientific and trade journals; "in-house" resources of select Study Team members; and the internet.

Step 3: Obtain, Review and Summarize the Documents – Based on the combined outcomes of Steps 1 and 2, the identified materials were obtained in electronic and/or hard copy formats. Upon receipt, each document was reviewed for its content and relevancy to the *Study*. Selected documents were logged into the Summary Matrix by subject matter, title, author(s), publication or source, date, etc. For ease in review and retrieval, key words were also recorded in the Summary Matrix, a synopsis of the material was prepared in the form of an Annotated Bibliography by qualified individuals. Each reviewed document was assigned a numerical ranking calculated by averaging the ranks of the following five categories (Table 4). An overall ranking of 5 represents the best score while 1 represents the worst:

Table 4 – Reference Ranking Summary

Category Definitions:	Numerical Ranking
1. Date of Publication -- weights study in terms of scientific and technological advancement of knowledge	1 = before 1970 ; 2 = 1970 to 1980 ; 3 = 1980 to 1990; 4 = 1990 to 1998 ; 5 = since 1998
2. Geographic Relevance -- weights study in terms of proximity to LAX	1 = not relevant/useful ; 2= marginally relevant/useful ; 3 = moderately relevant/useful ; 4 = very relevant/useful ; 5 = most relevant/useful
3. Source Relevance -- weights study based upon presence/absence of investigated sources at or around an airport	
4. Project Relevance -- weights study based on applicability to project goals	
5. Methodology -- weights study on merit of scientific methodology and quality/robustness of data	1 = unsound methodology ; 2 = sampling/instrumental error or study limitations impacting results ; 3= sampling/instrumental error or study limitations impacting results with possibility of correction ; 4 = sampling/instrumental error or study limitations with marginal impact on results ; 5 = sound methodology

2. Sources of Information and Data

Consistent with the principle objectives, subject matter and technical elements of this Literature Survey, the sources of information and data consulted in support of this task were also numerous and varied. Characteristically, these documents and materials are typically not confined within a centrally-located repository or amongst a small group of suppliers, sources or other collections. Rather, the vast majority are scattered across a wide array of sources and locations. Broadly speaking, these include scientific and trade journals in fields of air quality and aviation, respectively; airport-related publications and web sites, both domestic and international; and technical presentations at conferences and symposia in electronic or hard-copy formats.

As discussed above, Appendix B (*Bibliography of Prior Studies)* of the *Technical Workplan* for the *Study* (LAWA, 2007, presented as Appendix D of this document) contains a compendium of reports on the topics of air quality monitoring and meteorology, aircraft and other sources of airport emissions, as well as LAX-related planning and environmental documents. This bibliography served as the foundation and springboard from which this more expansive, comprehensive and updated Literature Search was undertaken. Arranged in alphabetical order, a partial listing of the sources of information and data consulted during the course of this initiative is provided below in Table 5:

Table 5 - Principal Sources of Information and Data Consulted

- Aerosol Science and Technology
- Atmospheric Environment
- Environmental Science and Technology
- Inhalation Science and Toxicology
- International Journal of Thermal Sciences
- Journal of the Air & Waste Management Association
- South Coast Air Quality Management District
- LAX Study Technical Workplan Appendix B (Bibliography of Prior
- Journal of Aerosol Science
- Journal of the Air Pollution Control Association
- Proceedings of the National Academy of Sciences
- California Air Resources Board
- Federal Register / EPA
- Journal of Engineering for Gas Turbines and Power
- Federal Aviation Administration
- Journal of Environmental Science and

3. Organization and Presentation of the Literature Survey

This report represents the first of three components of the *Literature Survey* of the *Air Quality and Source Apportionment Study of the Area Surrounding Los Angeles International Airport* (the *Study*). The contents of this report are arranged as follows:

> Section I, *Introduction and Background Information* provides a broad overview of the air quality and source apportionment study including the objectives, technical analyses and the supporting tasks.
>
> This section also provides information pertaining to the purpose, objectives and individual components of this task, which is comprised of three elements:
>
> - Literature Search of Existing Information and Data.
> - Identification and Assessment of Information and Data Gaps.
> - Presentation of Findings and Recommendations.
>
> Within Section I, the *Sources of Information and Data* section provides an explanation of the overall approach used and the individual steps taken to identify, select, obtain, review and summarize the materials included in the Literature Survey.

> Section II, *Presentation of Findings* contains an overview of the essential findings derived from this task with an emphasis on information that is most relevant to the subject matter and has the greatest potential for advancing the goals of the Study.
>
> Section III, *Summary of Findings and Their Application to the Study* contains concluding remarks about the information contained in the report along with recommendations for applying this information to the Study.

Appendix A of this document provides the Summary Matrix of the articles, reports and other documents collected and reviewed as part of this task as well as short summaries of these materials. The Annotated Bibliography (Appendix B) contains one page abridgements of each document. The individual documents can be provided separately and individually upon request. Appendices C and D of this document provide information taken from the *LAWA Technical Work Plan* (2007), outlining the summary of knowledge from that effort and its associated bibliography. Appendix E of this report delineates which materials reviewed in association with this task are new sources of information above and beyond those which have been included in the *LAWA Technical Work Plan* (as summarized in Appendices C and D of this document)

SECTION II - Presentation of Findings

This section contains a summary overview of the essential findings derived from the Literature Search.

A. Overall Approach

For ease of review and assimilation, the presentation of this summary information and data is organized around the central topics of interest associated with the Study (e.g., air monitoring, emissions source characterization, source apportionment techniques). The materials are also, by design, presented in simplified, straight-forward and streamlined formats. Further and more detailed information can be obtained from links to the cited references, the Annotated Bibliography and/or the original documents, if desired. This approach is necessary (but also considered to be the most effective), given the vast array of available subject matter materials and their technical complexities combined with the varying backgrounds of the reviewers.

In summary, the overall approach to presenting the information and data collected in support of the Literature Search is as follows (Table 6):

Table 6 - Approach to the Presentation of Information and Data

Principal Aim

Provide resources to help verify the feasibility of achieving the Study's objectives

Supporting Objectives

- Focus on existing and relevant information and data on the topics of:

B. Summary Overviews

As discussed previously in Section I.C. (*Technical Analyses*), the Work Plan identified three broad topics of primary interest in connection with this *Study*. They comprised: (1) ambient air monitoring; (2) emissions source characterization; (3) and source apportionment techniques, including receptor modeling, spatial gradient analysis, time series analysis, emissions inventory development, and air dispersion modeling. Consistent with these central subject matters, the following summary overviews are presented under the same categories and in the same order.

1. Ambient Air Monitoring

For the purposes of this overview, the information on this topic is further sub-divided into what is known from air quality monitoring in (a) the South Coast Air Basin area, (b) at LAX Airport, (c) other airports, (d) for surface roadway studies, and (e) for Marine emissions at the Port of Los Angeles.

a. Air Quality in the Study Area

Overview of Existing Conditions

Air quality monitoring data is collected throughout the South Coast Air Basin (SCAB) by the South Coast Air Quality Management District (SCAQMD) as part of its permanent, in-place network of over 30 air quality monitoring stations (Figure 3). The closest air

Figure 3 - SCAQMD Air Monitoring Stations

monitoring station to LAX is located immediately north of the airport on Westchester Parkway and collects data for carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), lead (Pb), particulate matter (PM_{10}) and volatile organic compounds (VOCs). Known as the "LAX-Hastings site", additional information on this station can be obtained at www.aqmd.gov/tao/AQ-Reports/AQMonitoringNetworkPlan/LAXHastings.

Based upon air monitoring data collected throughout the SCAB, the area surrounding LAX is currently designated as "non-attainment" of the National Ambient Air Quality Standards (NAAQS) for the "criteria" pollutants CO, O_3, and PM_{10}, and is designated as "maintenance/attainment" for NO_2. The area is also designated as being "non-attainment for O_3 and PM_{10} with respect to the California Ambient Air Quality Standards (CAAQS).

Climate and Meteorology

Topographic influences of nearby mountain ranges and the presence of a semi-permanent high pressure zone over the Pacific Ocean are the primary controls on the climate of the SCAB. Northward movement of the Pacific high in the summertime reduces precipitation although the generally maritime climate allows for rather high average relative humidity (Fanning et al., 2007). Conversely, in the wintertime the high pressure zone moves southward and allows storm tracks to enter the area, producing a moderate to heavy precipitation regime in the winter.

A temperature differential between the Californian land mass and the Pacific Ocean, due to oceanic upwelling along the Californian coast, increases the incidence of morning fog in the area. This differential heating also sets up a diurnal wind variation, with a westerly sea breeze dominating in the daytime and switching over to an easterly land breeze in the evening (Camp Dresser & McKee, Inc., LAX Master Plan EIS/EIR, Appendix G, 2001). This effect is demonstrated in the wind rose for the LAX area (Figure 4).

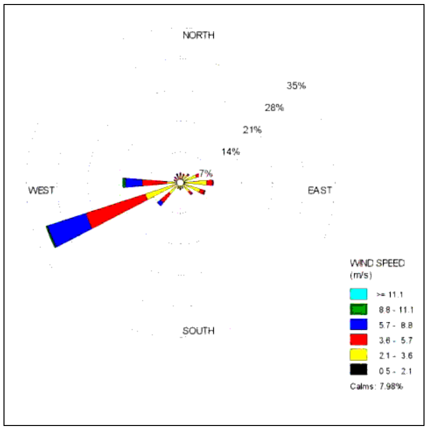


Figure 4 - LAX Wind Rose

Typical summertime diurnal temperature variations range from 57 to 76 °F, and in the winter the typical range is 47 to 60 °F (Fanning et al., 2007). Mountain influence on the maritime air promotes a temperature inversion that limits vertical mixing in the region, allowing for accumulation and persistence of urban pollution at ground level in the region (Camp Dresser & McKee, Inc., LAX Master Plan EIS/EIR, Appendix

G, 2001).

LAX Area Studies and MATES III

A great deal of information on "non-criteria" air pollutants is also available for the SCAB. For example, it is reported that vapor-phase polycyclic aromatic hydrocarbons (PAH), dominated by naphthalene, constitute more mass in the ambient air relative to particle-phase PAH, and are most concentrated around Los Angeles and diffuse with distance downwind (Fraser et al., 1998). Particle phase PAH such as benzo[ghi]perylene also show a similar trend of decreased concentration with increasing distance from urban Los Angeles. Particle-phase PAH concentrations similarly vary inversely with temperature (Eiguren-Fernandez et al., 2004), and hence tend to express concentration minima between the hours of 12 and 4 pm in most areas (Lu et al., 2005; Fraser et al., 1998), when radiative heating encourages both a greater air mixing depth at ground level and the preferential volatilization of the gas-phase species. Naphthalene concentrations reportedly show a seasonal pattern of variation, with winter concentrations exceeding summer concentrations (Lu et al., 2005).

MATES III (Multiple Air Toxics Exposure Study in the South Coast Air Basin III), conducted between 2005-2006 by the SCAQMD (2008), expands upon the Los Angeles area emissions trends discussed above; both to assess how levels of specific pollutants have changed since 1988-1989, when MATES II was conducted, as well as to incorporate regional and microscale modeling to inventory the geographically specific impacts on human health.

For example, 1,3-butadiene and benzene levels since MATES II have reportedly fallen drastically across the entire SCAB, resulting from the widespread adaptation of reformulated gasoline (RFG). Industrial solvent concentrations from processes including dry cleaning, such as perchloroethylene and methylene chloride, have also been greatly reduced since 1989. However, carbonyl compound concentrations (i.e. formaldehyde and acetaldehyde) are still considered high in many urban and suburban areas including central Los Angeles. Reportedly, PM metals have been widely reduced, with a few isolated exceptions.

The MATES III data also shows that the largest contributions to area-wide hazardous air pollutants (HAPs) are from acetaldehyde, acetone, formaldehyde, methyl ethyl ketone, and diesel particulate matter including elemental and organic carbon. When the data is weighted for toxicological risk factors, the compounds of greatest human detriment become 1,3-butadiene, benzene, perchloroethylene and diesel particulates. Although the data shows that on-road, point and area carcinogen emissions have decreased between 13 and 65 percent since 1989, on-road and off road mobile sources are still the largest contributors.

MATES III regional modeling results show that Los Angeles County is the most at-risk area of the SCAB, while the highest simulated risk neighborhoods include Wilmington, Los Angeles, Long Beach and Compton, of which South Central Los Angeles, and the Ports of Los Angeles and Long Beach have sustained the most risk between the years of MATES II and MATES III (1989 and 2005). Coinciding with these areas of most intense risk are "hot spot" areas of increased diesel particulate concentrations. Additionally, "hot spots" for formaldehyde accumulation overlap with areas of the highest ozone concentrations, signifying that formaldehyde is from secondary formaldehyde production formed from photochemical smog activity.

b. Airport Air Quality Studies

The following material summarizes air quality monitoring programs previously conducted or presently underway at airports (including LAX).

<u>LAX Studies</u>

A number of air quality monitoring studies have already been undertaken at LAX (Figure 5) by a variety of investigators in an attempt to characterize the potential effects of airport-related emissions on local conditions. These studies are summarized as follows.

Figure 5 - LAX

<u>CARB Study</u> – Commissioned by the California Air Resources Board (CARB), this study focused on "real time" monitoring of $PM_{0.1}$ and black carbon (BC) as a means of identifying reliable "markers" for aircraft exhaust, their emission characteristics and their spatial distribution both on and off the airport site (Figure 6) (Fanning et al., 2007).

The study was completed over two five- to eight-day periods in 2005/06 and involved continuous sampling of BC, $PM_{2.5}$, $PM_{0.1}$, CO_2 and time-integrated sampling of HAPs (e.g., VOCs, PAHs, and formaldehyde). Monitoring was undertaken very close to the source (i.e., aircraft engines) at a blast fence near the runway ends, at varying distances down-wind and at a "back-ground" site. The measurement methods included water-based Condensation Particle Counters

(CPC) for $PM_{0.1}$, Beta-attenuation monitors (BAMs) for $PM_{2.5}$, aethelometers for BC and EPA Reference Methods for VOCs, PAHs, etc. The air monitoring data was also correlated to simultaneous aircraft operations at the airport.

The summary findings report significantly higher levels of BC, $PM_{2.5}$, $PM_{0.1}$, CO, CO_2 and HAPs near the source when compared to background and more distant locations. Other potentially important findings revealed $PM_{0.1}$ levels to be size-dominant near the source, the $PM_{0.1}$ "spikes" correspond to aircraft activity levels at the airport, and these characteristics extend outwards to at least 300 meters away.

<u>SCAQMD Studies</u> – In 1998 and 1999, the South Coast Air Quality Management District conducted four short-term air quality monitoring studies at, or in the vicinity of, LAX. These studies were conducted in response to concerns of nearby residents to aircraft emissions and of airport workers to motor vehicle emissions.

<u>Airport Worker Study</u> – Conducted in 1998, this study involved sampling of CO using infrared (IR) spectrophotometry monitors, PM using BAMs and VOCs using summa canisters and gas chromatography (GC) along curbsides in the main terminal areas. The findings revealed that curbside levels of VOCs were elevated compared to background conditions and were indicative of automobile exhaust (South Coast Air Quality Management District, 1998).

<u>Airport Studies, Parts I and II</u> – Conducted in 1999, Part I involved sampling of PM_{10} using BAMs and VOCs using summa canisters and GC at seven sites near the airport over a three-day period (South Coast Air Quality Management District, 2000a). The findings were not able to differentiate airport-related VOC contributions from those associated with nearby roadways but concluded that particulate matter fallout may be influenced by airport activity. Part II was conducted during the busy Thanksgiving holiday travel period and included sampling of CO, VOCs and PM. The results reported higher than average levels for these pollutants when compared to other locations in the South Coast Air Basin (South Coast Air Quality Management District, 2000b).

Figure 6 -- CARB LAX Study Area

<u>Inglewood Fallout Study</u> – Conducted over two separate weeks in 2000, samples of atmospheric fallout mass and carbon were collected on fiber

filters and glass plates at 14 locations; most of them residences (South Coast Air Quality Management District, 2000c). The results did not detect any discernable pattern of either carbon mass (organic, elemental or total) or total fallout under the aircraft flight path to LAX.

<u>Other LAX Studies</u> – Three other air monitoring studies conducted at LAX involved the sampling of coastal sands, particulate matter from aircraft exhaust behind a blast fence and the behavior of aircraft plume characteristics.

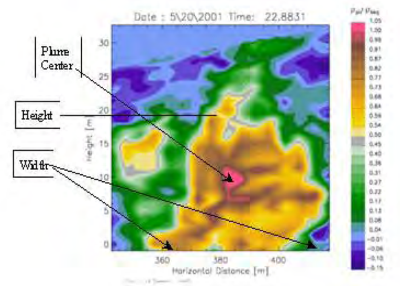


Figure 7 - Aircraft Engine Plume Study

<u>Coastal Fallout Study</u> – Conducted in 1996, this short-term study used settling plates placed around LAX and under the flight path to collect atmospheric fallout (Boyle, 1996). The results reported elevated levels of metals but offered little explanation as to their source.

<u>Particle Research Center Study</u> – Conducted by the Southern California Center for Particle Research, this study sought to characterize particles from aircraft exhaust in the "near field". PM, soot, NO_x and particle phase polycyclic aromatic hydrocarbon concentrations were measured around the immediate vicinity of LAX using condensation particle counters (CPC's), aethelometers and differential mobility analyzers. The most pertinent conclusion from this monitoring study was that ultrafine particulate matter ($PM_{0.1}$) was most concentrated in neighborhood areas adjacent and downwind of LAX (Westerdahl et al., 2008).

<u>Aircraft Engine Plume Rise Study</u> – Conducted by FAA, NOAA and others, this study utilized remote sensing techniques (e.g., infrared) to delineate the shape or height of aircraft engine exhaust plumes at the ends of the runways (Figure 7).

Figure 8 - Boston-Logan Aerial

c. Other Airport Studies

Air quality studies have also been conducted at a number of other airports in California, elsewhere in the U.S. and in foreign countries by both airport operators and regulatory agencies alike. Several of the most relevant of these studies are summarized as follows (listed by airport name and in alphabetical order).

Anchorage International Airport – Conducted by the Alaska Department of Environmental Protection in 2002, this six-month study monitored ambient levels of CO using IR (infrared) remote sensing and VOCs using GC at the airport, and compared the results to concurrent measurements taken elsewhere in the area (Alaska Department of Environmental Protection, 2003). Reportedly, toluene and CO were the only compounds detected above reporting limits, VOCs were generally lower at the airport compared to other sites, and no indicator differentiating diesel emissions from aircraft emissions could be determined.

Boston-Logan International Airport – Conducted by Massport, there are three separate air quality monitoring programs historically associated with this airport located in Massachusetts (Figure 8).

> Soot Study - The first "soot" deposition study using settling plates and Advanced Chemical Finger-Printing (ACFP) was conducted here in 1996 and, using "advanced chemical fingerprinting" combined with a source-apportionment study, concluded that airport-related emissions account for less than one percent of local atmospheric fallout – the vast majority being attributed to earthen crustal materials and sea salt (Hoffnagle et al., 1997; Ernst and Goldman, 1997).
>
> NO_2 Monitoring Program – Considered to be the longest-continuously running air monitoring program at any U.S. airport, this program monitors NO_2 levels both on the airport and in neighboring communities at over 25 locations. Collected using "passive" adsorption badges and reported as annual average values, the data reveals elevated NO_2 levels near areas of high motor vehicle traffic volumes located off site and near runway ends. Long-term trend lines reveal declining NO_2 levels at all the monitoring stations, no violations of the NAAQS and reasonably good agreement with data from active monitoring stations operated by the Massachusetts Department of Environmental Protection. The results are reported upon annually in the Environmental Data Report for Logan Airport (Massport, 2008).
>
> Air Quality Monitoring Study – This study began in 2007 and is subdivided into two one year programs: before and after the construction of the new Centerfield Taxiway (Massport, 2007). Continuous air sampling for $PM_{2.5}$ and BC is

Figure 9 - Chicago-O'Hare Aerial

conducted at three "primary" sites located at the end of an active runway, in an adjoining neighborhood and at a nearby DEP station. Sampling for VOCs, carbonyls and SVOCs is also conducted using EPA Federal Reference Methods (FRM). Sampling of PM_{10} using mini-vols and VOCs/SVOCs/carbonyls is also conducted with passive samplers and laboratory GC at 12 "satellite" sites in the nearby neighborhoods and on the airport. The results of the first "baseline" year of sampling will be available in 2009.

Charlotte/Douglas International Airport - A soot study using ACFP was also conducted at this airport in 1998 similar to the one conducted at Boston-Logan and with comparable results (KM Chng, 1998).

Chicago O'Hare International Airport - Two separate air monitoring programs designed to assess HAPs have been competed at this airport (Figure 9); one of the world's busiest.

City of Park Ridge Study – Commissioned by the neighboring community of Park Ridge in 1999, this study involved the measurements of particulate matter using BAMs and HAPs using summa canisters and laboratory GC adjacent to the airport (City of Park Ridge, 2000). Combined with a source-apportionment study and human health risk assessment, the outcome was published in a four-volume report. The findings concluded that airport-related emissions were crossing over into the adjoining neighborhoods, are measurably higher downwind when compared to upwind levels, and health risks (both cancer and non-cancer) are greater at the fence-line when compared to background conditions.

IEPA Study – Largely in response to the City of Park Ridge Study, the Illinois Environmental Protection Agency undertook this six-month study and measured HAPs using FRMs at two locations near the airport and, for comparative purposes, at two locations elsewhere in Chicago (Illinois Environmental Protection Agency, 2002). The findings revealed that HAPs downwind from O'Hare were generally higher when compared to up-wind levels, but the concentrations were not substantially different from values found elsewhere in the Chicago area.

A soot study using ACFP was also conducted at Chicago O'Hare in 1999 similar to the ones conducted at Charlotte and Boston-Logan and with comparable results (KM Chng, 1999).

Dustin (Florida) Airport – Commissioned by the City of Dustin (Florida), this study was conducted over a four-day period in 2007 at this medium-sized general aviation (GA) airport (City of Dustin, 2007).

Designed to identify "markers" of avgas emissions and evaluate if up- and down-wind samples differed, total suspended particulate matter (TSP) using hi-volume samplers, lead using laboratory mass spectrophotometry (MS) and various organic compounds using summa canisters and GC were collected at three sites adjacent to the airport and at two "background" sites. The results were correlated with wind direction and analyzed statistically.

The findings are somewhat inconclusive but appear to suggest that the selected parameters do not provide a strong or reliable link to GA airport activity; possibly because the levels are so low, are difficult to distinguish from background concentrations and/or are below the detection levels of the monitoring methods. A follow-up study is planned in early July 2008.

Hartsfield-Jackson Atlanta International Airport – The APEX1 (Airport Particle Emissions Experiment) campaign undertaken at this airport in September of 2004 utilized a wide array of instruments such as CPC (condensation particle counter, a device used to measure and count particulates in an exhaust plume), MS, non-dispersive infrared absorption (NDIR) instruments and differential mobility analyzers (DMOA), to monitor the concentrations of CO, NO, NO_2 and formaldehyde emitted from aircraft operating at take-off and idle modes. Sizes and concentrations of particulate matter, including BC using aethelometers, aerosol mass spectrometers and LIDAR (ultraviolet absorption instrument) were also recorded. Four aircraft (and paired engines) commonly in use at this airport, including Boeing 757 and 767 series, were measured at both typical LTO thrust intermediate settings (Lobo et al., 2008).

The results of the APEX1 studies report that measured CO emissions indices at idle power settings exceed the ICAO databank predicted values by as much as 50 percent, while measured NO_x emissions indices at idle and take-off settings are considerably lower than the ICAO predictions. By comparison, measurements of formaldehyde as well as PM particle number and diameters are in good agreement with previous measurements of emissions from comparable engine types (Herndon et al., 2008). Lobo et al. noted with regards to PM measurements that extensive secondary volatile aerosol formation occurred during plume advection, and the black carbon component strongly related to the type of engine tested (2008). Also, particle number-based emissions indices ranged from $3x10^{16}$ to $2x10^{17}$ particles per kg fuel, while particle mass based emissions indices spanned between 0.1 and 0.35 g/kg fuel (Lobo et al., 2008).

London-Heathrow International Airport – There are presently eight air monitoring stations located within one mile of this large commercial airport (Carslaw, et. al, 2006). Monitoring of NO_2 using continuous-running instrumentation has been the primary focus as violations of the government standards have occurred over the past few years. These data have caused future development plans for the airport to be more carefully scrutinized.

Minneapolis St. Paul International Airport - Conducted in the summer of 2005 by the Minnesota Pollution Control Agency (MPCA), a six-month air quality study was performed at this airport located in Minnesota (Minnesota Pollution Control Agency, 2006).

The program involved the collection and analysis of $PM_{2.5}$ and HAPs (e.g., VOCs, carbonyls and metals) using FRMs at two on- and two off-site locations; including a school. The findings indicated that formaldehyde was the only compound that occurred over health benchmarks, but these levels did not differ significantly from other locations in the Minneapolis/St. Paul area. The levels of $PM_{2.5}$ and the other VOCs were also comparable to conditions elsewhere and were well within federal and state guidelines.

Munich (Germany) International Airport – Air monitoring has been underway using continuous-running instrumentation at this airport since 1991 for CO, NO/NO_2, O_3, SO_2 VOCs and particulate matter. The reported levels are comparable to conditions found in small- to medium-sized cities and with the exception of O_3 are within regulatory criteria.

Oakland International Airport – In conjunction with the APEX2 (Airport Particle Emissions Experiment) series of studies, dedicated engine testing was performed on a Boeing 737 aircraft at a ground run-up enclosure at Oakland International Airport in 2005. These measurements were collected while simulating typical LTO thrust settings. Mobile laboratories stationed downwind of the plumes on the eastern runway were equipped with spectrometers to measure particulate matter size distributions and total concentrations as well as condensation particle counters to measure particle number concentrations. CO_2 readings were also taken in order to use as a standard by which to calculate emissions indices. The study concluded that number-based geometric mean diameters or particulate matter in the exhaust plumes were similar for all engines between taxi and take-off operational mode. Mass-based geometric mean particle diameters were found to vary directly with engine power setting, and were much higher for take-off plumes than taxi plumes. Mass based emissions indices were much higher for older technology (300 series Boeing jets) aircraft than their more modern counterparts (Whitefield et al., 2006).

Santa Monica and Van Nuys (California) Airports – Conducted by the staff of the SCAQMD, air monitoring was performed in the communities of these two GA airports between 2005 and 2007 (Fine, 2007). Measurements of particulate matter (e.g., PM_{10}, $PM_{2.5}$, $PM_{0.1}$) using BAMs, BC using aethelometers, lead and chromium using laboratory MS, VOCs and carbonyls using FRMs were completed.

The draft summary findings indicated that lead levels were elevated at runway ends, but below federal and state standards; BC levels were elevated slightly, but comparable to regional averages; $PM_{2.5}$ and benzene contributions from the airports were inconclusive; and $PM_{0.1}$ particles were measurable and may be influenced by airport activities. It is expected that the final report on these two monitoring programs will be published in 2008.

Seattle-Tacoma International Airport – Commissioned by the Port of Seattle and conducted in 1993, this study involved sampling of CO using IR and select VOCs using FRMs around Sea-Tac International Airport (Port of Seattle, 1995). Samples were collected both on and off the airport site and under differing airport operational and meteorological conditions. The CO levels were within air quality standards and the VOCs were within the ranges expected in urban areas.

Figure 10 - Teterboro Airport Aerial

Teterboro Airport – Located near Newark, N.J., an air quality study of this busy GA airport (Figure 10) was commissioned by the New Jersey Department of Environmental Protection (NJDEP). This multi-phased program first comprised a two-day screening study in 2001, followed by a source-apportionment study in 2003, and then an air monitoring/risk assessment study in 2007 (Environ, 2008).

Both gas- (i.e., VOCs, formaldehyde using FRMs) and particle-phase (i.e., $PM_{2.5}$ and BC using BAMs and aetholometers) were measured along with traffic volumes on nearby roadways. Remote sensing using open path differential optical absorption spectrophotomety (DOAS) was also used. Four of the essential findings revealed that (a) certain VOCs and $PM_{2.5}$ levels were elevated near the airport when compared to other locations in the state; (b) health risks are also higher, but comparable to other locations; (c) BC levels are influenced by local roadway traffic and airport operations; and (d) signals from the DOAS open path system can detect aircraft-related plumes.

The study conclusions also called for the continuation of the monitoring program with particular emphasis on the use of the DOAS to better ascertain the spatial characteristics of the aircraft plume.

T.F. Green Airport – Located in Warwick, R.I., air monitoring (Figure 11) has been underway in the vicinity of this airport since 2005 under three separate programs.

City of Warwick Study - Initially conducted by the Rhode Island Department of Environmental Management (RIDEM) at four locations (three in neighborhoods adjoining the airport and one "background" site), the 16-month program concluded the following:

Figure 11 - T.F. Green Airport Air Monitoring Station

- Levels of $PM_{2.5}$ from BAMs and HAPs using FRMs are within standards or short-term benchmarks.
- Levels of HAPs exceed long-term benchmarks but do not differ from other locations statewide.
- Slightly elevated BC using aethelometers and formaldehyde using FRMs levels occur downwind from airport (Rhode Island Department of Environmental Management, 2008).

RIDEM has received a grant to continue portions of this initial study but the elements of this follow-up work have not yet been defined.

Long-Term Study – Using the three RIDEM airport monitoring stations and mandated by state law to continue for 15 years, this program is now under the direction of Rhode Island Airport Corporation (RIAC) (Rhode Island Airport Corporation, 2007). Resumed in 2007, the program added a fourth airport site and also includes monitoring of $PM_{0.1}$ and particle-based PAHs. The data from the first 12-month period are expected to be available in mid-2008. (Notably, an "Interim" monitoring program was conducted to bridge the gap between the end of the RIAC study and the beginning of the RIDEM study, but the data is unremarkable.)

Soot Study – Conducted in 2006 in conjunction with an environmental assessment for the airport, this short-term study using ACFP concluded that the "chemical fingerprint" of the atmospheric deposition has little resemblance to airport sources (VHB/KM Chng, 2006).

Two other published studies from T.F. Green involved (1.) the sampling of soil near an end-of-runway blast fence using laboratory GC/MS concluded that contaminates were not above naturally-occurring levels and (2.) the sampling of air using personal exposure equipment along the main terminal arrival curbside roadway concluded that the levels of NO_2 and $PM_{2.5}$ were well within OSHA guidelines (Wallace, M.C., 2004).

Zurich (Switzerland) International Airport – Conducted over a 15-day period during the summer of 2004, this study was undertaken by the airport operator (e.g., Unique) and involved the measurements of NO, NO_2, CO, CO_2 and VOCs along the taxiway and apron areas at the main terminal (Schurmann, G,. et al., 2007). Samples were collected using continuous-running instruments (for NO_2) combined with open path spectrophotomety and canisters/GC (for VOCs). Several conclusions derived from this study include the following: CO levels are highest on the taxiway due to aircraft exhaust; NO levels are highest on the apron due to GSE emissions; NO_2 levels are dictated by "background" levels, including the airfield; and VOC emissions are characterized by short-chain alkenes. Comparisons to ICAO emission rates for some aircraft indicate that the measurements from this study are higher. (Notably, air monitoring for NO_2 has been underway at Zurich Airport for several years as part of a permanent installation using both continuously-operating equipment and open path technology.)

d. Surface Roadway Studies

Air quality monitoring near surface roadways has proved useful in the characterization of the potential effects motor vehicles have on local air quality conditions. A small sampling of these studies conducted in the Los Angeles area is summarized below.

Because airport-related emissions are so similar to emissions from roadway traffic, the proper assessment of motor vehicle emissions is considered to be one of the "key" elements of the Study.

In one case it was reported that the composition of highway vehicle traffic exhaust changed markedly between 1995 and 1996 with the advent and use of reformulated gasoline (RFG) in California. RFG is chemically modified to reduce ozone precursors such as VOC, NO_x and CO, accomplished mainly by replacing high-reactivity alkenes with methyl tert-butyl ether (MTBE). Alkenes in vehicle emissions, namely benzene and other aromatic hydrocarbons showed significant decreases with the incorporation of RFG, although this pollutant decrease is in part offset by an increase in oxygenated compounds ensuing from complete fuel combustion (Kirchstetter et al., 1999).

Particulate matter concentrations and the associated ratio of elemental to organic carbon in traffic emissions has also been shown to exhibit a weekly pattern, increasing from Monday to Friday and decreasing to a Sunday minimum over a given weekend. This pattern is attributed to the local patterns of mobile source activity, especially with regard to the reduced amount of diesel traffic over the weekends in the Los Angeles area. Associated with this pattern is the accumulation of volatile photochemical precursor compounds throughout the week due to heavy traffic, and the subsequent buildup and development of secondary photochemical pollutants on the weekends (Lough et al., 2006).

Similar diurnal patterns have been established for NO_x (mid-day) and PAH and elemental carbon (evening) emissions in the Los Angeles area (Watson et al., 2000). Highway $PM_{0.1}$, NO and elemental carbon concentrations can exceed those of residential areas by as much as twenty times (Westerdahl et al., 2005). CO and CO_2 concentrations in exhaust emissions are also shown to be traffic volume-dependent (Westerdahl et al., 2005; Zhu et al., 2002). Diesel exhaust contribution to PM ($PM_{2.5}$ and $PM_{0.1}$) is concentrated in urban areas in and around Los Angeles (Westerdahl et al., 2005; Schauer et al., 2002).

Naphthalene emissions are strongly influenced by local emissions sources and prevailing wind patterns, but show a strong trend of correspondence to areas with the highest amounts of vehicle emissions, like transportation corridors. Diesel fuel contributions to the naphthalene concentrations are as high as 9 percent in most model scenarios (Lu et al., 2005).

Reportedly, gasoline-based vehicle emissions exceed diesel vehicle emissions in areas of high traffic density, but diesel emissions are associated with higher levels of ultrafine particulate matter

Highway specific emissions trends are also well documented in the literature. I-710, open to all types of vehicle traffic, has much higher PM concentrations and elemental carbon levels relative to the diesel traffic-restricted I-110 and I-405 freeways (Westerdahl et al., 2005; Zhu et al., 2002). Moreover, Zhu et al., (2002) suggests that 60% of PM emissions (especially ultrafine $PM_{0.1}$) on the I-710 are attributable to diesel traffic, and that larger particle size diameters with increasing distance from the highway are associated with soot agglomeration.

In an effort to assess the gradients of pollutant transport from urban to rural areas, pairings of two sites were made around the SCAB: one from the original selection of sites (referenced above) and the other a 'microscale' site that was monitored by a moving platform. For example, San Bernardino greatly exceeded its companion fixed site, Fontana, in ambient air concentrations of the following compounds: acetaldehyde, benzene, formaldehyde, carbon tetrachloride, methyl ethyl ketone and others, the cause of which is considered to be differences in traffic volumes. This was the case for another set of vehicle related pollutants between the Santa Ana site and its fixed companion site, Anaheim. This approach allows for a “snapshot” effect of how vehicle-related and other ambient air pollutants relate between adjoining areas.

Diesel exhaust measured in the Los Angeles area contains many more three-ringed quinones than two-ringed quinone compounds, with elevated levels of 9,10-Anthraquinone reported in Riverside, Atascadero and San Dimas. However, Atascadero, which is upwind and 350 km northwest of Los Angeles, reports lower levels of other measured quinones relative to the other sites (Cho et al., 2004). San Dimas and Riverside, at varying distances downwind of Los Angeles portray similar ambient air quinone trends. This can be explained by secondary formation of quinones from photochemical activity during transport, after buildup of their precursor compounds closer to the urban center (Lu et al., 2005; Cho et al., 2004). Like quinones, nitrates and nitrated aromatics accumulate near inland areas and are prevalent at inland sites such as Azusa and Claremont, for similar reasons (Lough et al., 2006; Fraser et al., 1998). Sulfate concentrations are also highest at inland localities such as Azusa (Lough et al., 2006).

e. Port of Los Angeles Marine Emissions

In 2001 the Port of Los Angeles sponsored a baseline emissions inventory of the main marine and support sources characteristic of, and widely used in, port operations (Port of Los Angeles, 2006). For the purposes of this inventory, these sources were classified as ocean-going vessels such as carriers, container, cargo and cruise ships; harbor craft such as tugboats, towboats, ferries, commercial and recreational vessels; cargo handling equipment; railroad locomotives; and heavy-duty on-road and on-terminal vehicles.

Operational and activity data were compiled by direct observations, instrumental records, fuel usage data, personnel and operator interviews, and other existing inventories and studies. EPA and CARB sanctioned applications such as EMFAC and OFFROAD were populated with this compiled operational and activity data in order to calculate in-port emissions of pollutants including NO_x, CO, PM_{10}, $PM_{2.5}$, SO_x and TOG (defined as all gas-phase organic hydrocarbon compounds contained in exhaust or evaporative emissions).

Assessment of the total port-related emissions estimates by pollutant and source category from this study show that ocean going vessels are the most significant sources of PM_{10} (~52%), $PM_{2.5}$ (~48%) and SO_x (>90%). Heavy-duty vehicles reportedly contributed ~41% to the NO_x emissions and were the largest contributors to inventory levels of greenhouse gases, CO and hydrocarbons. Rail locomotives, cargo equipment and harbor craft all made minor contributions to the reported inventory totals.

2. Emissions Source Characterization

Under this topic, the subject matter is generally restricted to summary discussions of exhaust and evaporative emissions, but specific to the individual emissions source(s). Particular emphasis is placed on aircraft, ground support equipment (GSE), motor vehicles, and stationary sources that can be found both at airports, in general, as well as specifically at LAX. Available emissions data for these sources are discussed first, followed by descriptions of their emission characteristics. Where available, current and relevant emissions factors and indices are presented for each source discussed. These numbers should be construed to reflect the most exact and current values associated with the emissions sources.

Emissions Data

In 1984, aircraft emission testing was conducted on two turbofan engines (Spicer, 1984). These tests became the basis in which HAP speciation profiles were documented within the EPA SPECIATE database (and the similar CARB SPECIATE database). In the 1990s, the USAF conducted an extensive aircraft engine testing program which included several military-equivalent turbofan, turboshaft, and APUs (Gerstle, 1999) engines. The testing was performed to document emissions of, and to develop emission factors for, the EPA criteria air pollutants and HAPs from the combustion of JP-8 fuel. The Gerstle tests were performed using aircraft engine test cells.

More recently, the National Aeronautics and Space Administration (NASA), EPA, the Department of Defense (DoD), and FAA collaboratively sponsored three separate commercial aircraft engine exhaust measurement campaigns in 2004 and 2005, known as the Aircraft Particle Emission eXperiments (APEX1, APEX2, and APEX3). The three campaigns were designed to evaluate the effects of engine thrust and fuel type on the levels of particulate matter and gaseous emissions from commercial aircraft engines (sensu Lobo et al., 2008; Herndon et al., 2008). Separate analyses have also been conducted to develop an estimate of the trace elements with aircraft fuel (Shumway, 2000).

The FAA's Emissions & Dispersion Modeling System (EDMS) contains a database of aircraft engine-specific emission factors based on engine make, model and the four LTO operational modes (i.e., taxi/idle, takeoff, climb out, and approach). Emission indices and time- in-mode data for the aircraft were developed based on data from the International Civil Aviation Organization (ICAO) Engine Exhaust Emissions Data Bank.

The EPA MOBILE6.2 emissions model provides emission factors for the "criteria" pollutants and the six of the most common HAPs associated with motor vehicles. The HAPs component of the model computes these substances as both exhaust and evaporative emissions based on appropriate HAPs-to-TOG ratios coded into the model. The output is expressed in units of grams/vehicle-mile and can be segregated by vehicle type. MOBILE6.2 also allows the user to enter emission factors or HAPs-to-TOG ratios for other substances that are not among the six pollutants pre-coded into the model[4]. These ratios are expressed as fractions of VOC, TOG or PM for each HAP. The CARB EMFAC2007 provides similar information for California-based fleets for the criteria pollutants and the CARB SPECIATE database allows for the HAP speciation of motor vehicle emissions.

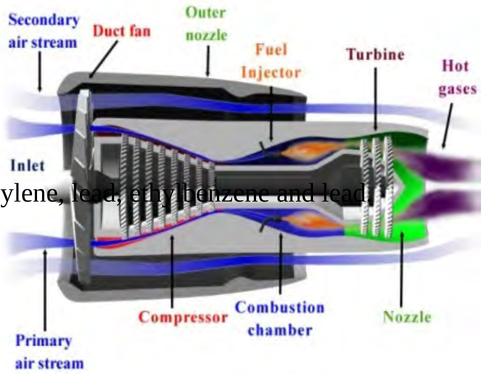
CARB's OFFROAD emissions model (along with EPA's NONROAD model) provides emissions characterization of non-road equipment such as construction equipment, ground support equipment, and other mobile industrial support vehicles. NONROAD provides criteria pollutant estimates while OFFROAD will provide both criteria and HAP estimates. Lastly, the USAF has produced guidance for mobile source emission inventories (O'Brien, 2002).

The EPA's "Compilation of Air Pollutant Emissions Factors" (also known as AP-42) provide emission factors (both criteria pollutants and HAPs) for a variety of stationary sources such as boilers, generators, engine testing, solvent degreasers, surface coating, fire training, and fuel storage. The USAF has also produced guidance for stationary source emission inventories (O'Brien, 1998).

Emission Source Characteristics

This section provides an overview of what is reported in this *Literature Survey* with regard to characteristics of airport-related emission sources. The information is presented by engine type.

Aircraft -Turbofan Engines



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[4] The additional HAPs include naphthalene, styrene, toluene, xylene, lead, ethylbenzene and lead.

Turbofan engine (Figure 12) particulate matter emissions are composed primarily of organic carbon compounds at engine idle (Agrawal, et al., 2008), although research also suggests that idle plumes contain significant amounts of elemental carbon and other inorganics (Herndon et al., 2005). As the engine power setting increases from idle, the amount of elemental carbon in the particulate matter emissions also increases (Agrawal et al., 2008; Petzold and Schroder, 1998). Particulate matter size distributions frequently display bimodality, with a larger particle size (approximately 80 to 90 nm) dominant at all power settings, and a smaller particle size mode (approximately 12 to 30 nm) most strongly expressed at idle power (Westerdahl et al., 2008; Herndon et al., 2005). The larger size is often attributed to soot particle formation, especially during take-off thrust (Petzold and Schroder, 1998). When measured close to the engine exit plane, mean particle sizes have been found to decrease with increasing engine power, while particle number-based emissions indices tend to increase with increasing power (Lobo et al., 2007).

Figure 12 - Turbofan Engine

Hydrocarbon emissions indices in idle exhaust plumes from turbofan engines approximate 3 g per kg fuel (Herndon et al., 2006). Hydrocarbon emissions vary as a function of engine power and are most typically concentrated at idle power settings (Lobo et al., 2007; Anderson et al., 2006; Herndon et al., 2006); although a hydrocarbon species' chemical size and structure largely dictate its presence and magnitude at a given setting. For example, hydrocarbons with lower molecular weights are more commonly emitted at low power settings while average hydrocarbon molecular weight increases with increasing engine power (Anderson et al., 2006).

Furthermore, alkenes and alkynes, defined as double-bonded and triple-bonded carbon compounds respectively, constitute approximately 70 percent of total hydrocarbon emissions at idle power, while at cruise settings aromatics, those compounds comprised of carbon ring structures, comprise approximately 50 percent of the total hydrocarbon emissions. Carbonyl compound (containing at least one carbon doubly bonded to an oxygen atom) emissions indices increase with increasing engine power.

The three most ubiquitous carbonyl compounds in turbofan engine exhaust are formaldehyde, acetaldehyde and acetone (Lobo et al., 2007). Polycyclic aromatic hydrocarbons emissions indices have been reported to both increase (Agrawal et al., 2008) and decrease (Rogers et al., 2005) with engine power, stressing the impact of engine type, fuel type and operational conditions with regard to pollutant emissions. Naphthalene concentrations are highest among polycyclic aromatic hydrocarbons found in aircraft emissions. (Agrawal et al., 2008).

Nitrated hydrocarbons are typically emitted at both high and low power settings, but are not typically present at medium thrust (Anderson et al., 2006).

Certain criteria pollutant emissions such as CO and NO_2 vary significantly by engine type, operational mode, age and condition, especially at idle power settings (Carslaw et al., 2008; Herndon et al., 2005; Heland and Schafer, 1998). Reportedly, ICAO engine databank estimations of CO and NO_x underestimate and overestimate actual measured emissions, respectively, when measured at idle power (Herndon et al., 2008; Schafer et al., 2003). Modeled CO emissions have been shown to vary inversely with Mach number and engine operational mode (Lee et al., 1996). Sulfurous compound reactions and emissions in the exhaust plume usually occur independently of engine power setting or operational configurations (Petzold and Schroder, 1998).

In contrast, emissions indices for all binary nitrogen species (NO_x) as well as NO vary directly with engine power setting (Wood et al., 2008). The greatest amount of nitrogen is typically emitted during takeoff (Westerdahl et al., 2008; Herndon et al., 2006). The NO_2 component of NO_x typically decreases with higher engine power as well as with increasing altitude—a 50 percent reduction of the NO_2 component is observed between 500 and 3000 feet (Wood et al., 2008). It should be noted that while NO_2 typically decreases with altitude, NO_x emissions tend to increase with altitude and power setting (Lee et al., 1996). Reactive nitrogen (NO_y) fuel-based emissions indices in the take-off operational mode approximate 15-23 g kg^{-1} of fuel burned (Herndon et al., 2006).

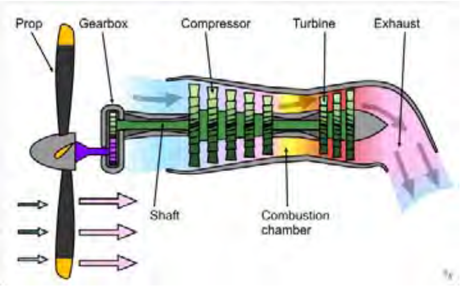

Figure 13 - Turboprop Engine

Aircraft - Turboprop Engines

As is the case with turbofan engines, turboprop engine (Figure 13) particulate matter particle size distributions are bimodal. The main mode ranges from 50 to 80 nm and varies directly with engine power setting both at the engine exhaust as well as at distance intervals downwind from the exit nozzle. A 20 nm particle mode is expressed in diluted plumes measured at distance downwind from the engine exit nozzle. As stated previously, the smaller particle size mode is a result of secondary particle nucleation and soot formation. (Cheng et al., 2008). However, at the engine exhaust, particle size distributions shift toward larger sizes with increasing thrust (Corporan et al., 2008).

Particle number counts typically range from 6.4 x 10^7 to 14.3 x 10^7 per cubic centimeter (Corporan et al., 2008). Number concentrations of particles also increase with increasing engine power, although a large amount of concentration variability exists in measurements taken at low-speed engine idle settings (Cheng et al., 2008). Mass concentrations typically range from 10 to 25 mg/m^3 between idle and maximum thrust, decrease significantly with plume age, and are lowest at idle settings (Corporan et al., 2008) due in part to semi-volatile organic pollutants being lost to gas-phase at low-speed idle settings (Cheng et al., 2008).

Criteria pollutant emissions can often vary based on operational configurations, aircraft-engine pairings, engine age and maintenance (Carslaw et al., 2008; Herndon et al., 2005; Heland and Schafer, 1998). CO_2, while more concentrated at higher engine power, decreases with increasing plume dilution (Cheng et al., 2008). Conversely, emissions indices for CO are highest under engine idle conditions (Corporan et al., 2008; Heland and Schafer, 1998). There exists more NO_x in a plume relative to CO_2 as engine power increases, resulting in NO_x and NO emissions indices that vary directly with engine power and exhibit co-variation with engine fuel to air ratios (Cheng et al., 2008, Corporan et al., 2008; Heland and Schafer, 1998).

Aircraft - Turbojet Engines/Gas Turbine Engines/Auxiliary Power Units

Particulate matter in the exhaust of gas turbine based engines tends to exhibit particle number concentrations on an order of magnitude less than those reported for other engine types (7.6 x 10^6 per cm^3), and with larger average particle sizes (110 nm). Mean particle size varies inversely with engine power, caused by a reduction in particle volume from increased engine pressure at high power settings. Particle number concentration is virtually invariate with changing operational setting. Particle size distributions become bimodal only with increased dilution ratios (modes of 170 and 40 nm). The size bimodality represents soot agglomeration in the exhaust plume. The particle size average is reduced by as much as half when influenced by high dilution ratios (Johnson et al., 2003).

While similar to gas turbine engines, auxiliary power units have characteristically different emissions profiles, owing to the fact that they operate at idle for extended periods of time and have three unique operational modes that are very different than those of the aircraft to which they are attached: no load, environmental control condition and engine start condition (ACRP sensu Webb et al., 2008).

Aircraft - Turboshaft Engines

Robust emissions data for turboshaft engines (Figure 14) are somewhat lacking. Rogers et al (2005) tested a

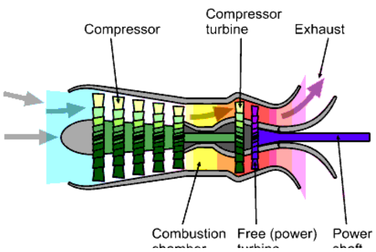

Figure 14 - Turboshaft Engine

T700 turboshaft engine and found that light absorbing particles (i.e. black/elemental carbon) comprised nearly 100 percent of the particle load. Particulate matter emissions, namely elemental carbon and polycyclic aromatic hydrocarbons, exhibited a direct proportional relationship to power setting. Of the polycyclic aromatic hydrocarbons, phenanthrene, fluoranthrene and pyrene were the present in the largest amounts. Total carbon emissions (elemental and organic) indices for the T700 engine are estimated to be 0.24 g per kg fuel.

Aircraft - Piston Engines

The majority of general aviation aircraft are powered with piston engines fueled with avgas. With the exception of lead, the composition of avgas is similar to motor vehicle gasoline. Because there currently are no test data for piston engines (civilian or military), emissions data from the CARB are used as surrogate data (with the addition of lead). The CARB data (Profile 413) are representative of composite non-catalyst, gasoline engines (CARB, 2004).

On-road Traffic - Gasoline, LPG and Diesel Powered Vehicles

Particulate matter number counts are shown to be up to 200 times higher in leaded gasoline exhaust relative to unleaded gasoline exhaust, with concentrations exceeding those of unleaded exhaust by one order of magnitude. Engine condition impacts unleaded gasoline particulate matter emissions significantly, and unleaded fueled vehicles tend to emit fewer particulates at higher traveling speeds. When compared to liquid petroleum gas (LPG), submicrometer particulate emissions were actually found to be lower in gasoline engine exhaust than in LPG engine exhaust (Ristovski et al., 1998).

Oxygenated polycyclic aromatic hydrocarbons are of particular detriment to human health and are formed readily via secondary photochemical reactions in the lower atmosphere during atmospheric transport. Diesel exhaust frequently contains such compounds, called quinones, and has been shown to emit high concentrations of naphthoquinones, phenanthraquinones and anthraquinones into the ambient air (Cho et al., 2004). Additionally, diesel exhaust contains elevated levels of NO and especially ultrafine particulate matter ($PM_{0.1}$), which have been found to be more detrimental to human health than any other particulate matter size fraction (Westerdahl et al., 2005).

Diesel exhaust is also characterized by high concentrations of black carbon relative to organic carbon, which can be expressed in day-of-week ambient air quality trends in high volume traffic areas (Lough et al., 2006; Westerdahl et al., 2005; Zhu et al., 2002; Dreher et al., 1998). Moreover, light absorption capabilities of black carbon can accentuate photolytic reactions in the lower atmosphere and enhance ozone production in photochemical smog (Dreher et al., 1998). Diesel engines tested while running on biodiesel blended fuels show reduction in CO, NO_x, total hydrocarbon and particulate matter emissions, owing to facilitation of complete combustion due to the higher oxygen content of the fuel (Wang et al., 2000).

Stationary Source - Natural Gas / Fuel Oil Fired Boilers

Figure 15 - Boilers at JFK

The EPA has established emissions factors for natural gas fired boilers (Figure 15) for criteria and hydrocarbon pollutants (AP-42, 1998). According to these factors, the most prevalent criteria pollutants emitted from all types of boilers are NO_x, CO and CO_2. Alkanes comprise the largest fraction of the total VOC emissions, followed by alkenes and aromatics, polycyclic aromatics and carbonyls. Of these categories, benzene, naphthalene and its derivatives, phenanthrene, anthracene and formaldehyde report the highest emissions factors. Metals emitted in the highest concentrations from natural gas combustion include zinc, molybdenum, nickel, lead, cadmium and chromium (U.S. EPA, AP-42, 1998).

Emissions factors for boilers burning fuel oil are influenced by the oil grade and sulfur content of the fuel oil. Formaldehyde, naphthalene and toluene are the most concentrated in terms of VOC emissions, however other polycyclic aromatic hydrocarbons and alkenes report significant emissions factors as well (U.S. EPA, AP-42, 1998).

Boilers burning No.2 distillate fuel oil were characterized by Rogge et al (1997), whereby total emissions were composed of 32 percent sulfur compounds, 29 percent elemental carbon, 6 percent ammonium and 6 percent organic matter. Of the organic matter fraction, only approximately 30 percent was able to be identified using gas chromatographic or mass spectrometric methods, and the compounds totaling the identifiable fraction included carboxylic acids, normal, oxygenated and chlorinated polycyclic aromatic hydrocarbons, alkanes, ketones and quinones.

Stationary Source - Emergency Generators and Construction Equipment

Emissions from emergency generators and heavy-duty construction equipment are characterized by the EPA as stationary internal combustion engines, and depend largely on the engine size and fuel type (U.S. EPA, AP-42, 1998).

With respect to large gas turbine engines, considerable differences in emissions factors can be observed based on fuel differences. SO_2 emissions factors are comparable between fuel types and are more largely governed by the sulfur content of the fuel. PM_{10} emissions factors for distillate fuel oil double those of natural gas, although the PM size fraction distribution is not significantly different between fuel types. (U.S. EPA, AP-42, 1998).

Criteria pollutant emissions factors for gasoline and diesel fueled industrial engines, commonly used to power construction equipment, show that diesel fuel emits larger quantities of NO_x, SO_x, PM_{10} and CO_2 when combusted, while gasoline fuel combustion emits more aldehydes and much more CO. Total organic compounds emissions factors are highly variable between fuel types for this type of engine and are highly differentiated between the exhaust, evaporative, crankcase and refueling exhaust emissions components. Speciated organic emissions factors are available for diesel fueled engines, and are dominated by formaldehyde, propylene and two-ringed polycyclic aromatic hydrocarbons (U.S. EPA, AP-42, 1998).

Figure 16 - Solvent Vapor Recovery

Stationary Source - Solvent Applications and Surface Coatings

Emissions from cold cleaner solvent degreasers (Figure 16) commonly occur through evaporative processes relating to waste, carryout, bathing, spraying and agitation. Open top vapor degreasing emissions occur mainly via diffusion and convection into the ambient air (U.S. EPA, AP-42, 1998).

Cold cleaning solvents emit trichloroethane, CFCs, ketones, alcohols, methylene chloride, petroleum distillates, terpenes, toluene, and xylenes. The most significant contributors among these compounds are the petroleum distillates. Solvents used in open vapor degreasing processes include trichloroethane, CFC's, perchloroethylene, trichloroethylene and perfluorocarbons. Trichloroethylene concentrations are significantly higher in vapor degreasing processes than in cold cleaning processes.

A wide range of surface coatings and solvents are used in the treatment of surfaces during application, dilution and coating removal. In order to estimate emissions from these sources, the VOC content of each component must be fully known and characterized; the weight percentage of each species comprising the VOC emissions as well as the density of the coating must be known. The EPA recommends calculation of emissions factors as a simple product of either the volatile weight percentage or volume percentage (including water in the case of water based paint) and the coating density (U.S. EPA, AP-42, 1998).

Stationary Source - Training Fires

Pollutant emissions from training fires (Figure 17) are calculated based on the quantity of fuel burned in the fire and the pollutant specific emissions index. EPA (AP-42, 1995) estimates these emissions indices, specific to JP-4, JP-8 and propane fuel types. A general trend is observed, where emissions indices for propane are the lowest of the three fuel types and emissions indices for JP-8 are the highest. Additionally, JP-4 emissions indices are generally comparable to JP-8 and greatly exceed those of propane. Qualitative analysis of these ranges shows that, regardless of fuel type, fire training emissions are dominated by CO, PM and VOC (U.S. EPA, AP-42, 1998).


Figure 17 - Live-Fire Training

Stationary Source - Fuel Storage

Typical types of fuel storage tanks (Figure 18) include fixed-roof, external floating roof and internal floating roof tanks. Emissions from fuel storage tanks are mainly evaporative and are caused either by standing storage (passive) or working (active) processes. Total hydrocarbon emissions are influenced by climate data and throughput, but are calculated as a product of roof type, activity and standing or working processes. Fixed roof fuel tanks experience breathing emissions during standing storage processes, occurring due to changes in temperature that cause a pressure differential between the inside and outside of the tank. Consequently, the differential must be relieved by opening breather valves on the tank.


Figure 18 - OSL Fuel Tanks

Working emissions with regard to fixed roof storage tanks occur either via displacement of tank gas by liquid, or saturation of air in the tank during filling that causes a vapor pressure differential. External floating roof standing storage emissions happen mainly as a consequence of escape of gas from the rim seal due to a vapor pressure differential between the inside and outside of the tank. This also occurs with internal floating roofs, although additional leaks often occur around the deck fitting and deck seam areas. However, emissions from external roof tanks tend to be higher due to increased wind exposure. Working emissions from floating roof tank occur due to clingage of fuel on the tank wall as the roof is lowered during fuel withdrawal (U.S. EPA, AP-42, 1998).

3. Source Apportionment Techniques

Within the context of this Study, the concept of "source apportionment" comprises a wide assortment of techniques including (a.) receptor modeling, (b.) spatial gradient analysis, (c.) time series analysis, (d.) emissions inventory development and (f.) air dispersion modeling. Because there is considerable "overlap" between these methods and for ease in assimilating this information, these four techniques are consolidated into two broad categories: (a.) receptor modeling and (b.) dispersion modeling in this Literature Search.

This nomenclature, although consistent with the Technical *Workplan*, is somewhat of a departure from conventional applications defined by U.S. EPA that classifies "source apportionment" and "receptor modeling" as being synonymous. In summary, receptor modeling (e.g. source apportionment) uses ambient air quality data to determine where the emissions are coming from, distinguishes the likely source(s) of air pollutants, and involves the applications of spatial gradient analysis, time series analysis and emissions inventory development to achieve this aim. By comparison, dispersion modeling forecasts the dispersion of emissions from the source(s), the resultant ambient pollutant concentrations and their spatio-temporal distribution. In many cases, dispersion modeling also employs time series analysis and emissions inventories to accomplish these goals.

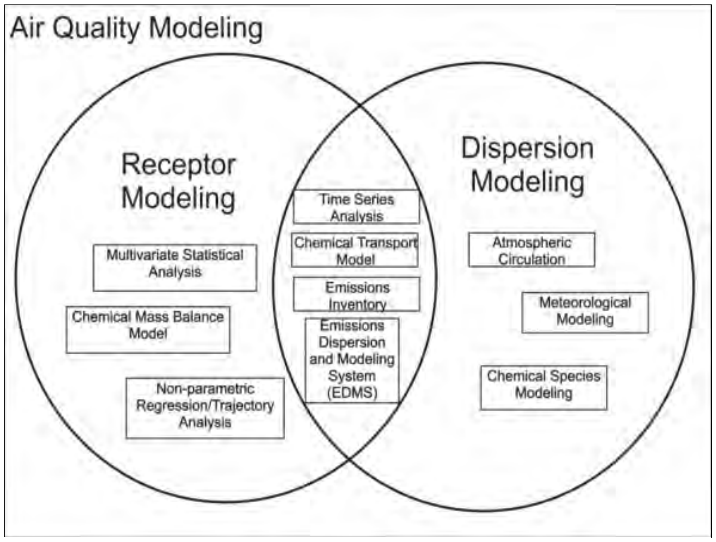

Figure 19 - Venn Diagram of Air Quality Modeling Relationships

For clarity, Figure 19 simply illustrates the relationships and overlap between receptor modeling and dispersion modeling within the domain of this Study. Summary explanations of these techniques follow based on information collected in support of this Literature Search. Consistent with the Principle Objectives of this Study, the emphasis is on airport-related applications (including LAX) and those that apply to the Los Angeles area.

a. Receptor Modeling Techniques

Multivariate statistical analyses are often employed in receptor modeling due to their unique ability to discern similarities and differences in large, varied data sets with many sets of variables. EPA's UNMIX model is often employed because it is adapted to resolve the dimensionality of a complex data set (i.e. series of pollutants from variable sources) by defining the most likely statistical boundaries, or "edge points". However, non-multivariate techniques such as non-parametric regression analysis and chemical mass balance models are still successfully and routinely employed in receptor modeling, and are discussed in detail below.

Non-Parametric Regression Analysis

Non-parametric regression analysis is a useful tool in receptor modeling in airport applications because it can account for the complex interplay of variables influencing the composition and behavior of an aircraft emissions plume.

Among the latest (and considered by many to be the most advanced) source apportionment techniques is non-parametric regression analysis. Non-parametric regression analysis is generally defined by the mathematical relation of a "dependent variable" to "predictor variables" without any *a priori* (i.e., formed or conceived beforehand) classification or assumptions on the data set. This technique is potentially useful in analyzing airport emissions due to the non-linearity of aircraft engine plume emissions within the standard aircraft landing/takeoff (LTO) cycle, wind dispersion influences, and fuel composition similarities between aircraft and other nearby emissions sources.

This statistical method was first utilized in support of an airport-related air quality assessment at LAX (Yu et al., 2004). In this application, the "dependent variable" was defined as the concentration of a given pollutant and the selected "predictor variables" were average reported wind speed and direction. In both cases, concentrations of CO, CO_2, NO/NO_2, SO_2 and meteorological data for the period August 1997 to March 1998 were based on data collected 200 meters east of runway 25R at LAX; a runway that is dominated by aircraft take-offs (Fanning et al., 2007).

The results of the regression analysis demonstrated that the highest pollutant concentrations were in the wind direction of a nearby highway, which implicates ground vehicle traffic as the most likely dominant emissions source. The exception being SO_2 levels which were concentrated at higher wind speeds, descriptive of a source elevated above ground level, as well as in the approximate lateral direction of runway 25R. Because aircraft emit more SO_2 than ground vehicles, the authors associated this signal with aircraft plumes (Yu et al., 2004).

Yu, et al. (2004) also used this same receptor modeling methodology to apportion the aircraft emissions at Hong Kong International Airport. Similar trends were observed with SO_2 and $PM_{2.5}$, but since the monitoring source was considerably farther away from the runway, and since motor vehicle traffic is much lighter relative to LAX, the relationship was not as strong. Nevertheless, this study is considered significant because it further establishes wind-correlated SO_2 measurements as potentially viable tracers for aircraft emissions.

Following the report of Yu, et al. (2004), researchers additionally employed non-parametric regression analysis to London Heathrow International Airport in order to differentiate aircraft-related NO_x concentrations from other confounding NO_x sources (such as on-airport vehicle traffic). In this application, graphic organization of the NO_x concentration and wind velocity data into model grid cells were normalized using non-parametric "smoothing" techniques. Based on this assessment of runway orientation and prevailing wind directions, aircraft plumes could successfully be distinguished from other sources as far away as 2600m from the airport. Relationships between wind speed and NO_x (inverse) and sulfur compounds (direct) were also observed. Again, this furthers the application of this technique in the recognition of aircraft plumes from surrounding plumes based upon differences in vertical mixing and plume buoyancy (Carslaw et al., 2006).

Differences in fleet mix, engine-airframe pairings, fuel type and usage, operational parameters and engine condition can significantly affect composition and concentrations of pollutants in an aircraft emissions plume.

Time Series Analyses

In general statistical terminology, a "time series" is a sequence of data points, typically measured at successive times, and spaced at (often uniform) time intervals. Time series *analysis* comprises methods that attempt to understand such time series, often either to understand the underlying context of the data points (i.e., where did they come from? what generated them?), or to make forecasts (i.e., predictions). Two examples of using time series analysis to assess airport-related emissions that are cited in this Literature Search are briefly discussed below.

At London Heathrow International Airport, NO_x measurements taken in 2005 were calibrated in time series to heavy-aircraft take-offs, based upon the offset between the first major NO_x peak and the first take-off (Carslaw et al., 2008). Algorithms were then used to join each departure to the nearest peak concentration, coupled with other statistical treatments to provide the best correlative fit between the sets of measurements. When corrected for the prevailing southerly wind direction, the time series analysis revealed that diurnal changes in aircraft traffic between runways could be discerned. Additionally, mean travel times of exhaust plumes to the measurement site were calculated to be 54 seconds. Moreover, larger aircraft comprised 78 percent of the departure NO_x emissions and 58 percent of the concentration. Importantly, airframe/engine couplings did not always vary consistently, stressing the importance of operational factors and service profiles in aircraft emissions monitoring and apportionment.

Herndon, et al. (2006) also employed time series analysis to assess aircraft emissions data collected from a mobile air monitoring platform during idle, taxi, landing/approach, engine start and take-off at Boston-Logan International Airport. From this study it was reported that during a seven-minute period, a Boeing 737 emitted the most nitrogen during take-off, whereas the idle plume was enriched in carbonyls, aromatic hydrocarbons and alkenes. It was further concluded that idle and taxiway acceleration exhaust contains higher concentrations of hydrocarbons than landing or take-off exhaust.

> Chemical mass balance receptor models depend on the presence and relative abundances of source-specific "tracer" pollutants to properly characterize emissions sources, and function best when both gas and solid phase air pollutants are considered.

The development of an emissions inventory in association with this study similarly shows that reactive nitrogen (NO_y) and methane-corrected hydrocarbon emissions indices both agree well with ICAO's published emissions indices. When normalized to formaldehyde, Herndon, et al. (2006) also derived emissions indices in good agreement with Spicer, et al. (1994)'s CFM56 engine data.

Chemical Mass Balance (CMB) Model

Another widely used application of receptor modeling is the Chemical Mass Balance (CMB) model, which consists of an algorithm conveying concentrations of a chemical species at each given receptor as a linear sum of products. Each linear sum is specific to the fractional contributions of a species in relation to each defined source profile. This type of model is sensitive to distortions that can occur through SMCR (source, message, channel, receiver) transformations, defined as distortions propagating in a signal as it travels from the source, is converted to a message, travels through a message channel and finally is recorded by the receiver (Kim et al., 2000). Species that best fit a given model are those that do not change significantly between source and receptor (Fujita et al., 1994); specifically, those species that are not altered between their emissions source and the sampling device or detection instrument by which they are collected or measured can serve as tracer species for a given source (Kim et al., 2000).

CMB models tend to be dependent upon mass fractions of a given species emitted by a specific source, and this relationship is influenced by compound transport, evaporation, deposition and transformation. These processes must be applied as weighting factors in the model in order to receive accurate source emissions factors or contributions (Kim et al., 2000). Additionally, uncertainties in the model can be propagated by choosing poorly-fitted source profiles, either in terms of profiles lacking complete characterization (Fujita et al., 1994), profiles with spatiotemporally-correlated sources (Kim et al., 2000), or profiles that are too general or composites (Schauer et al., 2002).

Air dispersion modeling techniques have been applied to LAX in numerous instances to help determine the potential impact of airport operations on local air quality.

Plume age is considered a control on the goodness of fit of a given species in the model; recently emitted plumes are best characterized by species with short lifetimes in ambient air such as xylenes and alkenes, and become more poorly defined by these compounds in the model as the emissions in the plume disperse and react in the ambient air (Fujita et al., 1994). Generally speaking, species can be assigned unrealistic significance in an apportionment model if they and their assigned source profiles are not well characterized, as in the case of using only gas-phase or only particulate-phase compounds to define the model (Schauer et al., 2002).

CMB receptor models used to source apportion emissions in Southern California ambient air reveal that motor vehicle exhaust and roadway sources are the largest contributors to poor air quality in the area, followed by photochemical transformation products (Schauer et al., 2002; Kim et al., 2000). The data also indicate that diesel exhaust contributes greatly to PM_{10} emissions where gasoline exhaust and vapors contribute significantly to VOC or NMHC concentrations (Schauer et al., 2002; Fujita et al., 1994). Nearly 81 percent of the total roadway contribution is comprised of organic compounds according to some models (Kim et al., 2000). Other models (Schauer et al., 2002) are unable to attribute a majority of the organic compound mass to primary sources, and given that this portion increases with distance inland, it most readily corresponds to secondary aerosol formation.

b. Air Dispersion Modeling

Dispersion modeling is useful in assessing air quality impacts when there are many similarly-profiled point, line and area emission sources, as in the case of an airport. Many different dispersion models exist and possess differing strengths and weaknesses. For example, CALPUFF[5] is a non-steady state dispersion model that incorporates multiple layers and multiple species with up to hundreds of kilometers of accurate resolution. The MM5 Mesoscale Meteorological Model[6] is another application geared towards assessment of long range lateral atmospheric transport. On the other hand, steady-state modeling applications such as AERMOD[7] integrate planetary boundary layer turbulence structure and scaling, assessing elevation and terrain components of air pollutant dispersion (http://www.epa.gov). Dispersion modeling techniques have been applied to LAX in numerous instances to help determine the potential impact of LAX operations on local air quality.

EDMS is a modeling application developed and endorsed by both the FAA and EPA for the modeling and analysis of aircraft engine emissions at airports and air bases.

Applications of Dispersion Modeling at LAX and Other Airports

Notably, the Emissions Dispersion and Modeling System (EDMS) is commonly used at LAX and at other airports for general conformity determination with state and federal air quality regulations such as the Clean Air Act, state and federal implementation plans, and other regulatory applications. EDMS is a modeling application developed by the FAA in conjunction with the USAF, routinely utilized in dispersion modeling, emissions characterization and impact analysis at many airports and air bases. Limitations in the model that impact its consistency are best summarized by its lack of ability to define input parameters that most accurately estimate aircraft time in mode, as well as non-parameterization of atmospheric variability that can impact pollutant concentrations (Pehrson et al., 2001). As is the case with any model, definitions of pollutants and sources in EDMS have impact on the attained results (Unal et al., 2005). Nonetheless, if adjusted for background concentrations of air pollutants,

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[5] http://www.src.com/calpuff/calpuff1.htm

[6] http://www.mmm.ucar.edu/mm5/

[7] http://www.epa.gov/scram001/dispersion_prefrec.htm#aermod

EDMS has shown to provide reasonable estimates of aircraft emissions when compared against actual monitored values (Pehrson et al., 2001).

LAX has employed EDMS to assess the potential environmental impacts associated with the realization of the Proposed Master Plan Improvements (2004). EDMS was populated with fleet mix, ground support equipment and stationary source emissions and operational data in order to forecast non-PM emissions for the airport through 2015, given various non-action and improvement plan scenarios. Through the use of EDMS it was possible to ascertain which improvement plan was the most environmentally sustainable to use in further developing the airport. Additionally, the results from EDMS were used in preparation of numerous environmental documents outlining the impact of the airport and its developments on the regional air quality and attainment status with respect to state and federal regulations (LAX Proposed Master Plan Improvements, Alternative D General Conformity Determination, 2004).

Dispersion modeling helps deduce where the highest concentrations of specific pollutants will accumulate in a regional air basin, arising from atmospheric transport and chemical transformations.

EDMS has also been utilized in a similar fashion to ascertain the impact of aircraft emissions at Hartsfield-Jackson Atlanta International Airport on ozone and $PM_{2.5}$ concentrations in the surrounding region. Importantly, it was concluded that the airport had the most significant impact on PM and ozone in areas closest to the airport, exceeding that of ground support equipment. The impact of the airport on modeled emissions significantly decreased with distance from the airport (Unal et al., 2005).

In another case involving LAX, the three-dimensional high resolution Surface Meteorology and Ozone Generation (SMOG)[8] model was coupled with the Meteorological Mesoscale model (MM5) and populated with LA basin domains of varying resolution: the coarsest horizontal grid resolution was 8.1 km and the finest was 0.9 km (Fanning et al., 2007). Near source measurements taken during the same study were calibrated to estimate black carbon emissions in the model, averaged over five minute intervals. Emissions factors for BC were calculated using the standard aircraft LTO operational mode parameters but also incorporated an additional mode to account for reverse thrust during landing procedures. Consistent with the prevailing weather patterns in the area, BC emissions are modeled to drift around LAX and concentrate in the early morning. With initiation of the midday sea breeze, the modeled BC plume is transported downwind to the surrounding communities; at night when the land

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[8] http://www.atmos.ucla.edu/~turco/page7.html

breeze sets up, the plume is diffused and drifts back toward the airport and the Pacific coast (Fanning et al., 2007).

In a similar application, an emissions inventory of the Paris regional airport criteria pollutant emissions developed by Pison and Menut (2004) was incorporated into the CHIMERE Chemical Transport Model (CTM)[9] to simulate ozone formation on the ground and at altitude in the Paris area over a four day period in August, 1998. Horizontal grid resolution of the model was set at 25 x 25 km and the vertical component was parameterized into five intervals reaching 3100m altitude. Based on the simulation, it was found that aircraft emissions have the greatest negative impact on ozone concentrations at nighttime, at ground level and in proximity to the emissions sources, while the strongest positive impacts on ozone concentrations were displayed during the daytime, in rural areas and at altitude.

Regional Applications

On a more regional level, Lu, et al. (2005) employed the coupled SMOG/MM5 model to assess concentrations, distribution patterns and seasonal or diurnal variations in naphthalene and naphthoquinones in the South Coast Air Basin. In this application, an emissions inventory was constructed for comparison against actual ambient air concentrations. The model's input parameters included a 5-45km horizontal resolution range (restricted to 5 km^2 for the emissions inventory), tropospheric vertical resolution up to 250 hPa (hectopascal, a unit of pressure measurement that decreases with increasing altitude) and emissions measurements from the SCAQMD (1997). Reportedly, site- and seasonally-averaged concentrations simulated by the model were in good agreement with actual measurements in the area. The model's emissions inventory also estimated that 44 percent of the compounds are attributable to gasoline exhaust. Moreover, peak emissions of naphthalene occurred in proximity to high traffic volume corridors, while naphthoquinone concentrations increased with distance downwind from these sources. Large gradients owing to the prevailing wind patterns were also predicted along the coast.

Regional air quality modeling of the South Coast Air Basin was also conducted during the recent MATES III study (SCAQMD, 2008). In this case, the entire basin was modeled using a grid resolution of 2 km^2 with the Comprehensive Air Quality Model with Extensions (CAMx)[10] including reactive trace modeling capability, combined with the Mesoscale Meteorological model (MM5). This coupling facilitated the replication of episodic ozone and annual $PM_{2.5}$

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[9] http://www.lmd.polytechnique.fr/chimere/

[10] http://www.camx.com/

concentrations using single atmosphere gas and particle-phase chemistry, as well as vertical diffusion and dispersion characterization necessary for more accurate ground level concentration estimates. Reportedly, the model performed best in terms of the estimation of elemental carbon size fractions and concentrations as well as for gaseous species, yet tended to incorrectly estimate total suspended particles and metal concentrations. The site-specific results of the model and their application to local ambient air quality are discussed in detail in the "Air Quality in the Study Area" section of this Literature Search document.

Global Applications

Air dispersion modeling has also been routinely employed to assess the effect of aircraft emissions on global atmospheric composition. For example, the NOXAR (Nitrogen Oxides and Ozone along Air Routes)[11] project involved mobile platform monitoring of commercial aircraft while in flight in order to better characterize the timing and impact of aircraft NO_x emissions on O_3 concentrations in the troposphere (Dias-Lalcaca et al., 1998). The measurement apparatus was installed on a Boeing 747 and catalogued 540 flights from Zurich to Chicago, Hong Kong or Beijing between 1995 and 1996. From this study, it was reported that some of the highest ozone and NO_x concentrations temporally correlate to passage through atmospheric troughs where stratospheric air aloft is carried downward into the troposphere (Dias-Lalcaca et al., 1998).

Aircraft NOx emissions tend to deplete ozone in the stratosphere where it's needed to shield the earth from incoming solar radiation, and enrich ozone in the troposphere, having implications on global warming trends and overall human health.

Emissions inventories are also commonly used to globally assess aircraft emissions related to differences in fleet mix, aircraft engine pairings and other airport operational parameters. Gardner et al., (1997) developed a global aircraft NO_x emissions inventory in 1997 in conjunction with an initiative to assess the impact of aircraft emissions aloft on the depletion of stratospheric ozone and formation of tropospheric ozone. The computer simulation was based on general circulation models where NO_x emissions were the focus of the model output, but water vapor, CO, CO_2, SO_2, particulate matter and hydrocarbons were also included. The results estimated global fuel burn to be 165.5 teragrams (Tg) per year (1 Tg = 10^{12} grams) and global NO_x emissions to be 2.78 Tg yr^{-1}. It is estimated that 60 percent of aircraft NO_x emissions occur between 10 and 12km altitude.

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[11] http://www.iac.ethz.ch/en/research/chemie/tpeter/Noxar.html

Finally, an emissions inventory of a Boeing 747 was constructed based on average measurements of unburned hydrocarbon, carbon monoxide and NO_x from a series of flights from London to Tokyo (Lee et al., 1996). The model used a combination of three applications characterizing aircraft parameters such as fuel weight, time in mode and other operational parameters; engine simulations describing time-calibrated speed parameters, altitude and fuel flow inputs; and thermodynamic properties. Qualitative results of the model show that CO and unburned HC emissions decrease with increasing Mach number, while NOx varies directly with Mach number due to the associated increasing combustor outlet temperatures. Similarly, CO and HC emissions decreased when the cruise altitude was varied rather than maintaining a constant cruise altitude, while NOx emissions increased.

Application to Aircraft Engine Monitoring

Air dispersion modeling of aircraft exhaust plumes is useful when determining the ideal instrument placement to best capture the most characteristic (highest) emissions concentrations. Koutsourakis et al., (2006) employed a three-dimensional unsteady state computational fluid dynamics model to Boeing 737 and 747 exhaust plumes during take-off. Incorporation of engine diameters and mass flows, ICAO published NO_x emissions indices and wind direction into the model allowed for detailed characterization of the exhaust plumes.

During take-off, the area before the brake-release point was modeled to have the highest NO_x concentrations, and those concentrations were sustained there until long after the take-off event. Jet momentum is the primary control on dispersion of the plume behind the plane, while wind only alters dispersion at directions perpendicular to the take-off plane.

This dispersion modeling technique was also able to characterize interference between plumes emitted from different engines on the same aircraft. Given all of these conditions, it was concluded that the best instrument placement is diagonal to the plume at 1 m height, as close to the brake release point as possible.

SECTION III - Summary of Findings and Their Application to the Study

This section contains concluding remarks about the information contained in the report along with summary statements about the outcome and use of the Literature Survey. The Principle Aim of this information is restated as follows:

Principle Aim of the Literature Survey

Determine the feasibility of achieving the Study's Objectives following the air quality monitoring/sampling and source apportionment program.

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Again, the Primary Objective of the Study is to develop detailed information on the potential impacts of LAX-related emissions on air quality in neighborhoods that surround the airport. Overall, the results of this survey indicate that employing a combination of air quality monitoring, sampling and results analysis can feasibly achieve the objective and aim of this project.

In response to this intended purpose and consistent with the three primary research topics, the following themes and findings from the Literature Survey are considered central to advancing the Study's Objectives:

A. Ambient Air Monitoring

Air quality monitoring data in the Los Angeles area (including the neighborhoods surrounding LAX) indicates that the pollutants of primary concern are O_3, $PM_{10/2.5/0.1}$, NO_2 and a variety of HAPs.

This widespread occurrence of the pollutants of primary concern also makes it difficult to establish the source(s) of the emissions, based air monitoring data alone. Fortunately, air monitoring data recently collected in the vicinities of LAX and other U.S. and European airports have enabled researchers to identify compounds that aid in assessing the potential effects of aircraft emissions. Principal among these are NO_2, black carbon, $PM_{0.1}$ and formaldehyde; although other candidate compounds are similarly regarded.

According to these findings, there is an existing and growing body of work which indicates that air quality monitoring will help achieve the Study's objectives. This observation is especially applicable to the goal of collecting meaningful air quality data on airport-related pollutants in the neighborhoods that surround LAX.

B. Emission Source Characterization

The principle sources of air emissions at most large commercial airports (including LAX) comprise aircraft, GSE, motor vehicles, fuel storage/transfer facilities and a variety of stationary sources (i.e., live-fire training facility, steam boilers, emergency generators, aircraft maintenance facilities, etc.). The vast majority of these emissions are products of fuel combustion and characteristically include CO, CO_2, NO/NO_2, SOx, water vapor, various forms and sizes of PM, and a wide assortment of hydrocarbon-based compounds.

Evaporative and working losses of hydrocarbons also occur as do emissions of fugitive dust from wind erosion. Construction activities (e.g., heavy equipment, site clearing and demolition, storage of raw materials, concrete/asphalt production, etc.) constitute temporary sources of emissions.

Emission factors presently exist for most of these sources and work is underway to improve and supplement these databases. The most significant of this research are recently completed and ongoing studies aimed at measuring emissions from aircraft engines. Early outcomes emerging from this work have contributed to important advancements in the characterizations of these emissions that occur in both the gaseous and particulate phases.

This information and data are considered "key" to achieving the Study's objectives, particularly in support of the efforts designed to quantify the impacts of LAX-related emissions in the adjoining neighborhoods.

C. Source Apportionment Techniques

For the purposes of this Study, the concept of "source apportionment" comprises a wide assortment of techniques including (a.) receptor modeling, (b.) spatial gradient analysis, (c.) time series analysis, (d.) emissions inventory development and (e.) air dispersion modeling. While each of these are distinct from one another and represent highly specialized and technical applications of data collection, statistical analyses and computer simulations, there is considerable overlap between the various applications. This is especially apparent when applied to studies involving multiple emission sources, many of which have similar emission characteristics, such as an airport.

Again, there is ample experience and an emerging body of work using source apportionment techniques at airports in general, and at LAX and in the Los Angeles area in particular, that strongly supports their successful application to this Study. Examples include techniques involving non-parametric regression analysis that help to identify emission source contributions to air monitoring data at down-wind locations; time series analyses that enable better correlations between air monitoring data and emission events; and the combined applications of emissions inventories, air dispersion modeling and chemical mass balance methods to compute the types and amounts of emissions generated and predict where they travel.

Further refinement of dispersion modeling techniques and acquisition of related data is essential in accurately assessing ambient air quality within the Los Angeles area and around LAX. Primarily, the U.S. National Environmental Policy Act establishes conditions where dispersion modeling is a necessary and applicable component of emissions inventories prepared during an environmental impact assessment. Secondly, dispersion modeling is helpful in distinguishing pollutant trends with the purpose of better characterizing emissions sources and pollutant reactivity in the atmosphere. Lastly, dispersion modeling allows one not only to determine likely concentrations and geographic spread of pollutants in a given area, it can also inform air quality practitioners as to the appropriate sampling and assessment methodologies necessary to accurately sample, analyze and characterize pollutants and pollutant trends in the ambient air.

As discussed in this report, EDMS and other dispersion modeling applications have been employed at LAX as well as at other airports worldwide to better inform development decisions, and to differentiate the relationships between the full spectrum of sources and pollutants typically present at an airport. Dispersion modeling techniques have been especially useful in assessing the impact of aircraft emissions on atmospheric chemistry both at ground level and aloft.

Finally, dispersion modeling has demonstrated utility in determining the best methodology to employ when monitoring aircraft engine and other source emissions specific to the selected measurement machinery. One dispersion modeling study has concluded, for example, that given specific machinery parameters and environmental conditions, it is beneficial to measure aircraft exhaust plumes diagonal to the plume direction at 1m height, as close to the brake release point as possible.

D. Identification and Assessment of Information and Data Gaps

This Literature Survey discusses advances in the areas of air quality monitoring and source apportionment techniques as well as the acquisition and interpretation of related data and findings pertaining to the SCAB, airports in general and LAX in particular. This section discusses areas where the state of knowledge in these topic areas has improved, as well as where data and information is still lacking.

1. Advances in Knowledge since the Compilation of the LAWA Technical Work Plan

Advances in air quality monitoring relevant to the Study’s objectives pertain mainly to the acquisition of data and better characterization of both on-airport sources and other emissions sources of interest in and around the SCAB. For example, important advancements in mode-specific particulate matter and gas phase emissions characterization for commercial aircraft have been accomplished through myriad studies occurring at airports around the world. Through these studies it is now known that aircraft engine and airframe pairings, service and maintenance profiles and fuel types can greatly affect the composition and concentration of criteria and non-criteria pollutants in aircraft exhaust plumes. Moreover, these and other studies have shown that the composition and concentrations of pollutants can differ between different components of an LTO cycle—mainly that aircraft engines emit significantly greater amounts of pollutants during engine idle and taxi operations.

Understanding of particulate matter emissions from emission sources both at LAX and in the surrounding areas has also been advanced, lending information about how size and composition of particulates can vary with source, fuel type and engine parameters.

The complex relationships of reactive oxygenated compounds such as NOx and their implications on tropospheric O_3 formation and stratospheric O_3 depletion have similarly been meaningfully expanded. Additionally, non-criteria pollutants such as gas phase hydrocarbons, including HAPs, have been much better described for aircraft and other sources as a result of current research.

SCAQMD's MATES III study (2008) and other important monitoring studies discussed in this report have made comprehensive contributions to the development of geographically specific air quality measurements for neighborhoods around LAX, and have aided in identifying pollutants of concern in a geographic context. Combined with existing toxicological data, this information will be critical in refining the accuracy and applicability of human health risk assessments related to air quality.

Highway emissions in the SCAB as well as marine emissions from the Port of Los Angeles are implicated as being significantly detrimental to overall air quality in the area, so the further understanding and increase in available data pertaining to these sources is especially important in terms of this Study's objectives.

The refinement of dispersion analysis and modeling methodologies, as well as the increase in the number of studies directly applicable to LAX and the SCAB, are another important area of advancement since the compilation of the Technical WorkPlan. Namely, there exists much better documentation with regard to pollutant dispersion throughout the SCAB relative to the locations and concentrations of the pollutant sources, which pollutants are endemic to those sources, and the meteorological factors influencing how they travel through the ambient air. As a result of these efforts and refinements, neighborhoods such as Compton, Downtown Los Angeles and Long Beach have been identified as areas with the greatest densities of pollutants directly emitted from sources, while more rural areas such as Rubidoux and Azusa have linked to higher threshold levels of other pollutants forming via atmospheric transformation as they move further from their emissions sources.

Moreover, pertinent information has also been recently obtained showing seasonal and diurnal variations in pollutant concentrations throughout the area, further heightening the important role that atmospheric and meteorological conditions play in mediating pollutant concentrations in the ambient air. Analysis of these chemical gradients and patterns will be useful in targeting areas of greatest concern in the SCAB, as well as developing agenda and strategies to limit deleterious effects to humans and the environment in the future.

Advances in source apportionment techniques and methodologies in part coincide with the advances in dispersion modeling and analysis. Tracer species for highway and airport sources have been better identified and the accuracy of source apportionment techniques such as Chemical Mass Balance receptor modeling has been improved. Additionally, the use of mobile platform measurements has allowed for higher resolution assessments of pollutant gradients and the identification of "hot spots", which in conjunction with refinement of tracer species identification has facilitated the apportionment of pollutants to specific sources.

Information presented in this report not only outlines refinements in receptor modeling like Chemical Mass Balance model, but introduces the use of non-parametric smoothing and regression analysis as techniques that can better diagnose the likely sources of emissions in a local or regional context. Time series analysis has also been more regularly employed as a means by which air quality practitioners can better understand the complex relationship between pollutant emission, evolution and transport from source to receptor.

2. Remaining Data Gaps since the Compilation of the LAWA Technical Work Plan

While many advances have been made pertaining to the emissions monitoring and characterization, dispersion modeling and source apportionment techniques pertaining to various on-and-off airport sources, the following discussion suggests areas that are still relevant and yet remain poorly developed.

Aircraft engine testing and exhaust plume sampling have been rather extensively improved, both in terms of methodological refinement, incorporation of new instruments and techniques, pollutant characterization and trend recognition. However, due to security concerns the role of military aircraft in ambient air quality is still poorly understood. Additionally, piston and turboshaft engine emissions studies are still sparse, and what data is available tends not to be particularly comprehensive or complete. A better understanding of auxiliary power unit emissions is also critical and yet lacking, especially because these sources are in operation during the operational intervals (idle and taxi) correlated by recent research to the highest levels of aircraft-related HAP emissions to the ambient air. Consequently, it is essential to understand how much auxiliary power units contribute to total emissions during these operational modes, and if emissions from these sources could in any way be differentiated from emissions from the aircraft engines.

Aircraft and other vehicle fugitive dust particulate matter monitoring and apportionment studies remain lacking, and a much more robust and applicable data set is needed if these sources are to be well apportioned in a regional context. Industrial and commercial fuel characterization, including jet fuel, natural gas, gasoline and diesel, are also essential to the identification of tracer species with which to define receptor models used for source apportionment. Finally, the cannon of peer-reviewed literature pertaining to airport and industrial stationary sources such as solvent degreasing operations and general solvent use, power generation, fire training, and fuel storage, remains underdeveloped.

Speciated hydrocarbon emissions profiles specific to airport sources need to be developed or refined to accurately inform emissions estimates both in the context of LAX and surrounding areas. Currently, information on speciated hydrocarbon emissions are generally not included in emissions inventories due to the fact that modeling applications used to conduct the inventories do not incorporate detailed information for these non-criteria pollutants. Speciated profiles and their incorporation into modeling and emissions assessment protocols are critical to better understand the characteristics and general reactivity of compounds already targeted as especially detrimental to human health or highly reactive in the atmosphere (such as formaldehyde and naphthalene).

Finally, dispersion and receptor modeling results pertaining to LAX and the SCAB need to be stringently validated with additional air quality monitoring data in order to assess their applicability. At the time of this writing, many more regionally applicable modeling studies have been conducted, yet the validation of the results have largely not occurred.

It is important to note that many of the existing knowledge gaps discussed in this section are consistent with knowledge gaps cited in other reports. For example, the Airport Cooperative Research Program (ACRP) also recommends that knowledge of APUs be advanced, both in terms of fuel consumption and operational mode-specific PM measurements. The Program's research efforts also conclude that aircraft brake and tire PM emissions currently cannot be differentiated from motor vehicle emissions, are note well characterized, and hence are not well represented in airport emissions inventories. Additionally, the ACRP reports that the relationship between nonvolatile PM emissions and engine service, maintenance and fuel usage is inadequate.

Also reported by ACRP is that the study of volatile PM evolution (soot agglomeration) lacks appropriate measurement instrumentation and specifically geared computer modeling applications. Outside of the role of fuel sulfur content, information on fuel characterization and contribution to PM (i.e. lubrication oil emissions) is quite lacking.

Finally, this report agrees with ACRP findings that gas-phase speciated hydrocarbon emissions at airports are poorly understood and inadequately accounted for in sanctioned emissions models and inventories. Moreover, the impacts of these hydrocarbons (namely HAPs) on human health and exposure toxicity are unformulated (ACRP sensu Webb et al., 2008 and Wood et al., 2008).

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APPENDIX A – ANNOTATED BIBLIOGRAPHY MATRIX

Category	Sub-category	Keywords	Title	Author(s)	Source/Publication	Volume/Issue Location	Date	Relevance Score (1-5)
Air Quality Monitoring	Emissions Testing and Profiling	Subsonic Aircraft, Turbofan, Carbonyl, PM, PAH, OC, EC, Dioxin	Characterization of Chemical and Particulate Emissions from Aircraft Engines	Agrawal, H. , A.A. Sawant, K. Jansen, J.W. Miller, D.R. Cocker III	Atmospheric Environment	42: 4380-4392	2008	5.0
Air Quality Monitoring	Emissions Testing and Profiling	Turbofan, B757, NMHC, HC, JP-5, Sulfur, Alkyl Nitrates, CO, CO2, Subsonic Aircraft	Hydrocarbon Emissions from a Modern Commercial Airliner	Anderson, B.E., Chen G., and D.R. Blake	Atmospheric Environment	40: 3601-3612	2006	4.6
Air Quality Monitoring	Emissions and Fuel Testing	IOMAS, SO3, H2SO4, Chemiion, RR M45H,	Jet Engine Exhaust Chemiion Measurements: Implications for Gaseous SO3 and H2SO4	Arnold, F., Stilp, TH., Busen, R., and U. Schumann	Atmospheric Environment	32 (18): 3073-3077	1998	3.8
Air Quality Monitoring	Emissions Testing and Profiling	PM, Metal, LAX, South Coast Air Basin, Soot	Evaluating Particulate Emissions from Jet Engines: Analysis of Chemical and Physical Characteristics and Potential Impacts on Coastal Environments and Human Health	Boyle, K.	Transportation Research record No. 1517 – Aviation, National Academy Press	no. 1517	1996	4.8
Air Quality Monitoring	Emissions Testing and Profiling	Light-Duty, Passenger Vehicles, HC, NOX, CO, CO2, repair, PM, On-road	Particulate Emission rates from In-Use High Emitting Vehicles Recruited in Orange County, California	Cadle, S.H., P.A. Mulawa, J. Ball, C. Donase, A. Weibel, J.C. Sagebiel, K.T. Knapp and R. Snow	Environmental Science and Technology	31(12): 3405-3412	1997	3.2
Air Quality Monitoring	Emissions Testing and Profiling	C-130H, Military, Supersonic Aircraft, Turboprop, NOX, CO, CO2, SOX, PM, UFP	Probing Emissions of Military Cargo Aircraft: Description of a Joint Field Measurement Strategic Environmental Research and Development Program	Cheng, M.D., Corporan, E., DeWitt, M.J., Spicer, C.W., Holdren, M.W., Cowen, K.A., Laskin, A., Harris, D.B., Shores, R.C., Kagann, R., and R. Hashmonay	Journal of the Air & Waste Management Association	58: 787-796	2008	3.8
Air Quality Monitoring	Emissions Testing and Profiling, Pollutant Characterization	PAH, Quinones, Diesel, Los Angeles, South Coast Air Basin	Determination of Four Quinones in Diesel Exhaust Particles, SRM 1649a, and Atmospheric PM2.5	Cho, A.K., Stefano, E.D., You, Y., Rodriguez, C.E., Schmitz, D.A., Kumagai, Y., Miguel, A.H., Fernandez, A.E., Kobayashi, T., Avol, E.,	Aerosol Science and Technology	38 (S1): 68-81	2004	4.4

				and J.R. Froines				
Air Quality Monitoring	Emissions Testing and Profiling	PM, Lead, VOC, Georgia	Destin Airport Air Sampling Project Executive Summary	City of Destin, Tetra Tech, Inc.	n/a	n/a	2007	3.8
Air Quality Monitoring	Emissions Testing and Profiling	O'Hare, VOC, PAH, TAPs, HAPs	Preliminary Study and Analysis of Toxic Air Pollutant Emissions from O'Hare International airport and the Resulting Health Risks Created by These Toxic Emissions in the Surrounding Residential Communities, Volumes I-IV	City of Park Ridge	n/a	n/a	2000	4.6
Air Quality Monitoring	Emissions Testing and Profiling	CO, NOX, PM, JP-8, Turboprop, Supersonic Aircraft, Military, Smoke	Characterization of Particulate Matter and Gaseous Emissions of a C-130H Aircraft	Corporan, E., Quick, A., and M.J. DeWitt	Journal of the Air and Waste Management Association	58: 474-483	2008	4.2
Air Quality Monitoring	Climatological Data Collection	NOXAR, NOX, O3, Subsonic Aircraft, Troposphere, Stratosphere	An Automated System for the Measurement of Nitrogen Oxides and Ozone Concentrations from a Passenger Aircraft: Instrumentation and First Results of the NOXAR Project	Dias-Lalcaca, P., D. Brunner, W. Imfeld, W. Moser and J. Staehelin	Environmental Science and Technology	32: 3228-3236	1998	2.6
Air Quality Monitoring	Emissions Testing and Profiling	Heavy-Duty, Trucks, Diesel, NOX, BC, On-road	A Fuel-Based Inventory for Heavy-Duty Diesel Truck Emissions	Dreher, D.B. and R.A. Harley	Journal of the Air and Waste Management Association	48: 352-358	1998	3.4
Air Quality Monitoring	Emissions Testing and Profiling	PAH, Los Angeles, South Coast Air Basin, PM	Seasonal and Spatial Variation of Polycyclic Aromatic Hydrocarbons in Vapor-Phase and PM2.5 in Southern California Urban and Rural Communities	Eiguren-Fernandez, A.E., Miguel, A.H., Froines, M.J., Thurairatnam, S., and E.L. Avol	Aerosol Science and Technology	38: 447-455	2004	4.6
Air Quality Monitoring	Emissions Testing and Profiling, Emissions Modeling	LAX, Subsonic Aircraft, BC, PM2.5, UFP, VOC, PAH,	Monitoring and Modeling of Ultrafine Particles and Black Carbon at the Los Angeles International Airport	Fanning, E., R.C. Yu, R. Lu and J. Froines	Report to CARB and CalEPA, ARB Contract #04-325	79 pp.	2007	4.8
Air Quality Monitoring	Pollutant Characterization	PAH, VOC, SVOC, HC, Los Angeles, South Coast Air Basin	Air Quality Model Evaluation Data for Organics. 5. C6-C22 Nonpolar and Semipolar Aromatic Compounds	Fraser, M.P., Cass, G.R., Simoneit, B.R.T., and R.A. Rasmussen	Environmental Science and Technology	32: 1760-1770	1998	5.0

Air Quality Monitoring	Emissions Modeling	Subsonic Aircraft, NOX, O3, Stratosphere, Troposphere, AERONOX, Turbofan	The ANCAT/EC Global Inventory of NOx Emissions from Aircraft	Gardner, R.M., K. Adams, T. Cook, F. Deidewig, S. Ernedal, R. Falk, E. Fleuti, E. Herms, C.E. Johnson, M. Lecht, D.S. Lee, M. Leech, D. Lister, B. Masse, M. Metcalfe, P. Newton, A. Schmitt, C. Vandenbergh and R. Van Drimmelen	Atmospheric Environment	31(12): 1751-1766	1997	3.4
Air Quality Monitoring	Emissions Modeling	Subsonic Aircraft, Supersonic Aircraft, NOX, O3, H2O Vapor, Stratosphere, Troposphere, Cruise, Turbofan, Turbojet	Impact of Aircraft Emissions on Tropospheric and Stratospheric Ozone. Part I: Chemistry and 2-D Model Results	Groob, J.-U., C. Bruhl and T. Peter	Atmospheric Environment	32(18): 3173-3184	1998	3.2
Air Quality Monitoring	Emissions Testing and Profiling	FTIR, Spectroscopy, JP-5, CO, NO, N20, CO2, Bypass Engine, Subsonic Aircraft	Determination of Major Combustion Products in Aircraft Exhausts by FTIR Emission Spectroscopy	Heland, J. and K. Schafer	Atmospheric Environment	32(18): 3067-3072	1998	4.0
Air Quality Monitoring	Emissions Testing and Profiling	Subsonic Aircraft, Taxi, Landing, Take-off, PM, PAH, BC, Turbofan	Particulate Emissions from In-Use Commercial Aircraft	Herndon, S.C., T. B. Onasch, B.P. Frank, L.C. Marr, J. T. Jayne, M.R. Canagaratna, J. Grygas, T. Lanni, B.E. Anderson, D. Worsnop and R.C Miake-Lye	Aerosol Science and Technology	39: 799-809	2005	4.2
Air Quality Monitoring	Emissions Testing and Profiling	NO2, CO2, NOY, HC, Carbonyl, Subsonic Aircraft, B737, Turbofan, Turboprop, Jet, PM, PAH	Hydrocarbon Emissions from In-Use Commercial Aircraft during Airport Operations	Herndon, S.C., Rogers, T., Dunlea, E.J., Jayne, J.T., Miake-Lye, R., and B. Knighton	Environmental Science and Technology	40 (14): 4406-4413	2006	4.6
Air Quality Monitoring	Emissions Testing and Profiling	Hartsfield-Jackson Atlanta, Subsonic Aircraft, CO, CO2, NO, NO2, Formaldehyde, PM, ICAO	Commercial Aircraft Engine Emissions Characterization of In-Use Aircraft at Hartsfield-Jackson Atlanta International Airport	Herndon, S.C., Jayne, J.T., Lobo, P., Onasch, T.B., Fleming, G., Hagen, D.E., Whitefield, P.D., and R.C. Miake-Lye	Environmental Science and Technology	42(6): 1877-1883	2008	4.6

Air Quality Monitoring	Emissions Testing and Profiling	O'Hare, HAPs	Chicago O'Hare Airport Air Toxic Monitoring Program, June-December, Final Report, Bureau of Air	Illinois Environmental Protection Agency	n/a	n/a	2002	4.4
Air Quality Monitoring	Emissions Testing and Profiling, Engine Testing	Gas Turbine, Jet Kerosene, PM	Development of Techniques to Characterize Particulates Emitted from Gas Turbine Exhausts	Johnson, M.P., Hilton, M., Waterman, D.R., and J.D. Black	Measurement Science and Technology	14: 1146-1150	2003	3.6
Air Quality Monitoring	Emissions Testing and Profiling, Fuel Testing	RFG, Gasoline, San Francisco, MTBE, Carbonyl, VOC, PAH, Evaporative Loss, Headspace Vapor	Impact of California Reformulated Gasoline on Motor Vehicle Emissions. 2. Volatile Organic Compound Speciation and Reactivity	Kirchstetter, T.W., Singer, B.C., Harley, R.A., Kendall, G.R., and J.M. Hesson	Environmental Science and Technology	33: 329-336	1999	4.2
Air Quality Monitoring	Emissions Testing and Profiling, Pollutant Characterization	Boston-Logan, HC, PAH, Jet Fuel, Diesel, Gasoline, Soot	Soot Depostion Study: Logan Airport and Surrounding Communities	Ernst, D.A. and A.D. Goldman	KMC Report No. 970114 Prepared for Massport	n/a	1997	4.6
Air Quality Monitoring	Dispersion Modeling	NOX, Boeing 737, Boeing 747, CFM56-3C-1, PW4056, Turbofan	Computation of Pollutant Dispersion during an Airplane Take-Off	Koutsourakis, N., Bartzis, J.G., Venetsanos, A., and S. Rafailidis	Environmental Modeling & Software	21: 486-493	2006	4.0
Air Quality Monitoring	Emissions Modeling	HC, NOX, CO, Subsonic Aircraft, Cruise, Troposphere, Stratosphere, Turbofan	Further Considerations of Engine Emissions from Subsonic Aircraft at Cruise Altitude	Lee, S.H., M.L. Dilosquer, R. Singh and M.J. Rycroft	Atmospheric Environment	30(22):3689-3695	1996	3.4
Air Quality Monitoring	Emissions Testing and Profiling	PM2.5, EC, OC, Metal, Diesel, Gasoline, South Coast Air Basin, Los Angeles, Nitrate, Sulfate, Ammonium, Diacid	Day-of-Week Trends in Carbonaceous Aerosol Composition in the Urban Atmosphere	Lough, G.C., Schauer, J.J., and D.R. Lawson	Atmospheric Environment	40: 4137-4149	2006	4.8
Air Quality Monitoring	Emissions Testing and Profiling, Emissions Modeling	South Coast Air Basin, NAPH, PAH, Naphthoquinone, SMOG, REHEX	Naphthalene Distributions and Human Exposure in Southern California	Lu, R., Wu, J., Turco, R.P., Winer, A.M., Atkinson, R., Arey, J., Paulson, S.E., Lurmann, F.W., Miguel, and A.E. Fernandez	Atmospheric Environment	39: 489-507	2005	4.8

Air Quality Monitoring	Emissions Testing and Profiling	Boston-Logan, VOC, SVOC, Carbonyl, PAH, PM, BC, Soot	Logan International Airport Air Quality Monitoring Study Final Air Quality Work Plan, September, 2007.	Massport	n/a	n/a	2007	4.6
Air Quality Monitoring	Emissions Testing and Profiling	Boston-Logan, NO2	Boston-Logan International Airport 2007 Environmental Data Report	Massport, prepared by VHB	Report to Massachusetts Port Authority Economic Planning & Development Office	n/a	2007	4.4
Air Quality Monitoring	Emissions Testing and Profiling	PM2.5, VOC, Carbonyl, HAPS, Metals,	Update on Air Monitoring Near the Minneapolis St. Paul International Airport	Minnesota Pollution Control Agency	n/a	n/a	2006	4.6
Air Quality Monitoring	Dispersion Modeling	EDMS, NOx, CO, SO2	Comparison of Modeled to Monitored Air Pollutant Concentrations at a U.S. Airport	Pehrson, J., R. Diaz, W. Guo and V. Tino	Air and Waste Management Association Meeting Session AS-1c (a)	Abstract no. 157	2001?	4.2
Air Quality Monitoring	Emissions Testing and Profiling	Sulfur, H2SO4, SO2, BC, Turbofan, Subsonic Aircraft	Jet Engine Exhaust Aerosol Characterization	Petzold, A., and F.P. Schroder	Aerosol Science and Technology	28: 62-76	1998	4.2
Air Quality Monitoring	Emissions Testing and Profiling	Paris, NOx, VOC, SO2, O3, Troposphere	Quantification of the Impact of Aircraft Traffic Emissions on Tropospheric Ozone over Paris Area	Pison, I., and L. Menut	Atmospheric Environment	38: 971-983	2004	4.0
Air Quality Monitoring	Emissions Testing and Profiling, Emissions Inventory	South Coast Air Basin, PM, SO2, NOX, CO, TOG, Port of Los Angeles, Marine Emissions	Port-Wide Baseline Air Emissions Inventory Executive Summary	Port of Los Angeles, prepared by Starcrest Consulting Group, LLC	http://www.portoflosangeles.org/DOC/REPORT_Final_BAEI_ExecSum.pdf	24 pp.	2005	4.0
Air Quality Monitoring	Emissions Testing and Profiling	Seattle-Tacoma, VOC, TAP, CO	Final Report: Air Quality Survey, Seattle-Tacoma International Airport, Port of Seattle, 1995	McGulley, F and J Gilman	n/a	n/a	1995	4.6
Air Quality Monitoring	Emissions Testing and Profiling	PM, BC, VOC, TF Green, PAH,	Air Quality Monitoring Work Plan, Prepared in Support of the State of Rhode Island Permanent Air Quality Monitoring Act, October 29, 2007	Rhode Island Airport Corporation	n/a	n/a	2007	4.6
Air Quality Monitoring	Emissions Testing and Profiling	TF Green, PM2.5, HAPS, Formaldehyde	Ambient Air Toxics in Neighborhoods Abutting T.F. Green Airport and Comparison Sites, Final Report, April 2008	Rhode Island Department of Environmental Management	n/a	n/a	2008	4.6

Air Quality Monitoring	Emissions Testing and Profiling	Passenger Vehicles, Spark Ignition, PM, Gasoline, Diesel, LPG, On-road	Submicrometer and Supermicrometer Particulate Emission from Spark Ignition Vehicles	Ristovski, Z.D., L. Morawska, N.D. Bofinger, and J. Hitchins	Environmental Science and Technology	32(24):3845-3852	1998	3.6
Air Quality Monitoring	Emissions Testing and Profiling	JP-5, Turboprop, Turboshaft, Supersonic Aircraft, PAH, BC, VOC, F-18, Military	Real-Time Measurements of Jet Aircraft Engine Exhaust	Rogers, F., Arnott, P., Zielinska, B., Sagebiel, J., Kelly, K.E., Wagner, D., Lightly, J.S., and A.F. Sarofim	Journal of the Air and Waste Management Association	55: 583-593	2005	4.0
Air Quality Monitoring	Emissions Testing and Profiling	Boiler, No.2 Distillate Fuel Oil, EC, PAH, Alkane, Carboxylic Acids, Chlorine, Ketone, Quinone, Sulfur, Ammonium	Sources of Fine Organic Aerosol. 8. Boilers Burning No. 2 Distillate Fuel Oil	Rogge, W.F., Hildemann, L.M., Mazurek, M.A., and G.R. Cass	Environmental Science and Technology	31: 2731-2737	1997	4.4
Air Quality Monitoring	Emissions Testing and Profiling	LAX, South Coast Air Basin, VOC, PM, CO, Halogenates	Air Monitoring Study in the Area of Los Angeles International Airport	South Coast Air Quality Management District (SCAQMD)	South Coast Air Quality Management District	n/a	2000	5.0
Air Quality Monitoring	Dispersion Modeling	South Coast Air Basin, MATES III, VOC, PM10, PM2.5, EC, OC, Carbonyl, PAH, Metal, Diesel, Los Angeles	Draft Report for the Multiple Air Toxics Exposure Study in the South Coast Air Basin III (MATES III)—Chapter 4—Regional Modeling and Evaluation	South Coast Air Quality Management District (SCAQMD)	http://www.aqmd.gov/prdas/matesIII/matesIII.html	15 pp.	2008	5.0
Air Quality Monitoring	Emissions Testing and Profiling	South Coast Air Basin, MATES III, VOC, PM10, PM2.5, EC, OC, Carbonyl, PAH, Metal, Diesel, Los Angeles	Draft Report for the Multiple Air Toxics Exposure Study in the South Coast Air Basin III (MATES III)—Chapter 5:Microscale Study	South Coast Air Quality Management District (SCAQMD)	http://www.aqmd.gov/prdas/matesIII/matesIII.html	10 pp.	2008	5.0
Air Quality Monitoring	Emissions Testing and Profiling	South Coast Air Basin, MATES III, VOC, PM10, PM2.5, EC, OC, Carbonyl, PAH, Metal, Diesel, Los Angeles	Draft Report for the Multiple Air Toxics Exposure Study in the South Coast Air Basin III (MATES III)—Introduction and Chapter 2: Air Toxics Monitoring and Analysis	South Coast Air Quality Management District (SCAQMD)	http://www.aqmd.gov/prdas/matesIII/matesIII.html	23 pp.	2008	5.0
Air Quality Monitoring	Emissions Testing and Profiling	Vienna, Frankfurt/Main, London-Heathrow, NO, NOx, HCHO,	Aircraft Emission Measurements by Remote Sensing Methodologies at Airports	Schafer, K., Jahn, J., Sturm, P., Lechner, B., and Bacher, M.,	Atmospheric Environment	37: 5261-5271	2003	4.2

		CO2, ICAO, Subsonic Aircraft, APU						
Air Quality Monitoring	Dispersion Modeling	O3, CO2, NO, NOX, SO2, H2O Vapor, Dispersion, Subsonic Aircraft, Cruise, Stratosphere, Troposphere, Turbofan	Dilution of Aircraft Exhaust Plumes at Cruise Altitudes	Schumann, U., H. Schlager, F. Arnold, R. Baumann, P. Haschberger and O. Klemm	Atmospheric Environment	32(18): 3097-3103	1998	2.8
Air Quality Monitoring	Emissions Testing and Profiling	Zurich, NO, NO2, CO CO2, VOC	The Impact of NOx, CO and VOC Emissions on the Air Quality of Zurich Airport	Schurmann, G., Schafer, K., Jahn, C., Hoffmann, H., Bauerfeind, M., Fleuti, E., Rappengluck, B.,	Atmospheric Environment	41: 103-118	2007	4.2
Air Quality Monitoring	Emissions Testing and Profiling	Boston-Logan, Soot, Metals, Aircraft	Soot Deposition Study: Logan Airport & Surrounding Communities	Hoffnagle, G.F., Cooper, J.A., Morris, S.,	Report No. TRC Project No. 20505, Prepared for Massport	n/a	1997	4.6
Air Quality Monitoring	Emissions Testing and Profiling, Dispersion Modeling	EDMS, Smoke, PM2.5, VOC, Hartsfield-Jackson Atlanta, Subsonic Aircraft, GSE	Airport Related Emissions and Impacts on Air Quality: Application to the Atlanta International Airport	Unal, A., Hu, Y., Chang, M.E., Odman, M.T., Russell, A.G.,	Atmospheric Environment	39: 5787-5798	2005	4.6
Air Quality Monitoring	Emissions Testing and Profiling	Soot Deposition, GSE, Aircraft, PAH, Diesel, Gasoline, Jet Fuel	Ambient Deposition Study, T.F. Green Airport, Warwick Rhode Island	VHB/KM Chng	Report to Federal Aviation Administration and Rhode Island Corporation	n/a	2006	4.6
Air Quality Monitoring	Emissions Testing and Profiling, Exposure Assessment	PM2.5, NO2, CO, TF Green, OSHA	T.F. Green Airport, Rhode Island – Evaluation of Occupational Exposures to Air Quality in the Arrivals Areas	Wallace, M. and C. Hibbard	Presentation to Air and Waste Management Association	n/a	2004	4.6
Air Quality Monitoring	Emissions Testing and Profiling	Heavy-Duty, Trucks, Diesel, Biodiesel, HC, CO, NOX, PM, On-road	Emissions from Nine Heavy Trucks Fueled by Diesel and Biodiesel Blend without Engine Modification	Wang, W.G., D.W. Lyons, N.N Clark, M. Gautam and P.M. Norton	Environmental Science and Technology	34(6): 933-939	2000	2.8
Air Quality Monitoring	Prospectus/Summary Report	Supersite, EPA, PM, HC, NOX, SOX, PAH, NAAQS	Air Quality Measurements from the Fresno Supersite	Watson, J.G., J.C. Chow, J.L. Brown, D.H. Lowenthal, S. Herring, P. Ouchida, and W. Oslund	Journal of the Air and Waste Management Association	50(8): 1321-1334	2000	3.8

Air Quality Monitoring	Emissions Testing and Profiling	UFP, PM, BC, PAH, NOX, CO, CO2, South Coast Air Basin, Diesel, Highway	Mobile Platform Measurements of Ultrafine Particles and Associated Pollutant Concentrations on Freeways and Residential Streets in Los Angeles	Westerdahl, D., Fruin, S., Sax, T., Fine, P.M., and C. Sioutas	Atmospheric Environment	39: 3597-3610	2005	4.6
Air Quality Monitoring	Emissions Testing and Profiling	UFP, PM, BC, PAH, NOX, South Coast Air Basin, LAX	The Los Angeles International Airport as a Source of Ultrafine Particles and Other Pollutants to Nearby Communities	Westerdahl, D., Fruin, S.A., Fine, P.L., and C. Sioutas	Atmospheric Environment	42: 3143-3155	2008	5.0
Air Quality Monitoring	Emissions Testing and Profiling	Subsonic Aircraft, Turbofan, NOX, HONO, O3, APEX	Speciation and Chemical Evolution of Nitrogen Oxides in Aircraft Exhaust Near Airports	Wood, E.C., S. Herndon, M.T. Timko, P.E. Yelvington and R.C. Miake-Lye	Environmental Science and Technology	42(6): 1884-1891	2008	5.0
Air Quality Monitoring	Emissions Testing and Profiling	I-710, Diesel, Heavy-duty, PM, BC, CO, UFP, Los Angeles, South Coast Air Basin	Study of Ultrafine Particles Near a Major Highway with Heavy-Duty Diesel Traffic	Zhu, Y., Hinds, W.C., Kim, S., Shen, S., and C. Sioutas	Atmospheric Environment	36: 4323-4335	2002	5.0
Air Quality Monitoring	Emissions Testing and Profiling	APEX2, Turbofan, Subsonic Aircraft, Oakland, B737, PM, CO, CO2, NOx, TOG	The Development of Exhaust Speciation Profiles for Commercial Jet Engines	Lobo, P., Whitefield, P., Hagen, D., Herndon, S., Jayne, J., Wood, E., Knighton, B., Northway, M., Miake-Lye, R., Cocker, D., Sawant, A., Agrawal, H. and J.W. Miller	Prepared for the California Air Resources Board (CARB) and the California Environmental Protection Agency (CalEPA),	Contract No. 04-344	2007	4.4
Air Quality Monitoring	Knowledge Assessment, Literature Survey	PM, APU, GSE, Turbofan, Subsonic Aircraft	Airport Cooperative Research Program Report 6 – Research Needs Associated with Particulate Emissions at Airports	Webb, S., Whitefield, P., Miake-Lye, R., Timko, M. and T. Thrasher	Transportation Research Board, Washington, D.C.	n/a	2008	3.4
Air Quality Monitoring	Knowledge Assessment, Literature Survey	HAPs, Turbofan, Stationary Source, GSE, APU	Airport Cooperative Research Program Report 7 – Aircraft and Airport-Related Hazardous Air Pollutants: Research Needs and Analysis	Wood, E., Herndon, S., Miake-Lye, R., Nelson, D. and M. Seeley	Transportation Research Board, Washington, D.C.	n/a	2008	3.4
Air Quality Monitoring	Emissions Testing and Profiling	APEX2, Turbofan, Subsonic Aircraft, Oakland, B737, PM, CO, CO2, NOx, TOG	PM Emissions from Advected Aircraft Plumes at the Oakland International Airport	Whitefield, P., Lobo, P., and D. Hagen	Proceedings of the TAC-Conference, June 26 to 29, 2006, Oxford, UK	n/a	2006	4.8

Air Quality Monitoring	Emissions Testing and Profiling	Soot, Charlatte/Douglas	Charlotte / Douglas International Airport – Soot Deposition Study, prepared for the City of Charlotte Aviation Department, March 1998	KM Chng	n/a	n/a	1998	4.6
Air Quality Monitoring	Emissions Testing and Profiling	APEX, Jackson Hartfield-Atlanta, Turbofan, Subsonic Aircraft, PM, Black Carbon, Soot	Delta-Atlanta Hartsfield (UNA-UNA) Study	Lobo, P., Whitefield, P., Hagen, D., Trueblood, M., Mundis, N., Magdits, I., Herndon, S., Onasch, T., Jayne, J., Miake-Lye, R., Eberhard, W., and R. Wayson	Partnership for AiR Transporation Noise and Emissions Reduction, MIT	Report No. PARTNER-COE-2008-001	2008	4.6
Air Quality Monitoring, Source Apportionment	Emissions Testing and Profiling, Contribution Estimation	PAH, Soot, O'Hare, Jet Fuel, Gasoline	Findings Regarding Source Contribution to Soot Deposition, O'Hare International Airport and Surrounding Communities , prepared for the City of Chicago, December 1999	KM Chng	n/a	Report no. 991102	1999	4.6
Atmospheric Modeling	Contrail Formation	H20, H2SO4, Contrail, Homogeneous Condensation, Heterogeneous Condensation, Relative Humidity, Temperature	The Effects of Ambient Temperature and Relative Humidity on Particle Formation in the Jet Regime of Commercial Aircrafts: A Modeling Study	Gleitsmann, G., and R. Zellner	Atmospheric Environment	32 (18): 3079-3087	1998	3.4
Fuel Testing	Methodology	Diesel, Gasoline, JP-8, Spectroscopy, Evaporative Loss	Complete Compositional Monitoring of the Weathering of Transportation Fuels Based on Elemental Compositions from Fourier Transform Ion Cyclotron Resonance Mass Spectrometry	Rodgers, R., E.N. Blumer, M.A. Freitas and A.G. Marshall	Environmental Science and Technology	34(9):1671-1678	2000	2.8
Regulation and Development	Emissions Standards, Testing and Inventory Procedures	CFR, Aircraft, EPA, ICAO	40 CFR Part 87--Control of Air Pollution from Aircraft and Aircraft Engines; Emissions Standards and Test Procedures	U.S. Environmental Protection Agency	40 CFR Part 87	70:221	2005	--
Regulation and Development	General Conformity Determination	LAWA, FAA, CAA, LAX, Master Plan Improvements	Clean Air Act Draft General Conformity Determination--LAX Propsed Master Plan Improvements Alternative D	Federal Aviation Administration	http://www.laxmasterplan.org/pub_finalMP.cfm	n/a	2004	--

Regulation and Development	EIS/EIR	LAX, Master Plan Improvements, LAWA, EIS/EIR	Appendix LAX Master Plan Supplement to the Draft EIS/EIR:S-E Supplemental Air Quality Impact Analysis	Camp Dresser & McKee, Inc.	http://www.laxmasterplan.org/pub_finalMP.cfm	n/a	2003	--
Regulation and Development	Emissions Standards, Testing and Inventory Procedures	AP-42, Point Source, Area Source, Stationary Source	AP 42, Fifth Edition--Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources	U.S. Environmental Protection Agency	http://www.epa.gov/ttn/chief/ap42/	5th ed.	1995, rev. 1998	--
Source Apportionment	Contribution Estimation	NOX, SO2, PM10, London	Detecting and Quantifying Aircraft and Other On-Airport Contributions to Ambient Nitrogen Oxides in the Vicinity of a Large International Airport	Carslaw, D.C., Beevers, S.D., Ropkins, K., Bell, M.C.,	Atmospheric Environment	40: 5424-5434	2006	4.2
Source Apportionment	Contribution Estimation	Subsonic Aircraft, Turbofan, NOX	Near-Field Commercial Aircraft Contribution to Nitrogen Oxides by Engine, Aircraft Type, and Airline by Individual Plume Sampling	Carslaw, D. C., K. Ropkins, D. Laxen, S. Moorcroft, B. Marner and M. Williams	Environmental Science and Technology	42(6): 1871-1876	2008	4.4
Source Apportionment	Contribution Estimation	CMB, SCAQS, South Coast Air Basin, Gasoline, Vehicle Exhaust, LPG, Natural Gas, NMHC, VOC, FID, GC,	Validation of the Chemical Mass Balance Receptor Model Applied to Hydrocarbon Source Apportionment in the Southern California Air Quality Study	Fujita, E.M., Watson, J.G., Chow, J.C., and Z. Lu	Environmental Science and Technology	28 (9): 1633-1649	1994	4.2
Source Apportionment	Methodology	SAFER, VOC, TNMOC, GC, Receptor Modeling	Reported Emissions of Volatile Organic Compounds are not Consistent with Observations	Henry, R.C. and C. Spiegelman	Proceedings of the National Academy of Sciences	94: 6596-6599	1997	2.8
Source Apportionment	Contribution Estimation	SAFER, CO, O3, PM, South Coast Air Basin	Application of SAFER Model to the Los Angeles PM10 Data	Kim, B.M. and R.C. Henry	Atmospheric Environment	34: 1747-1759	2000	4.4
Source Apportionment	Contribution Estimation	South Coast Air Basin, MATES III, VOC, NOX, SOX, CO, CO2, PM, Lead, HC, SCC, On-road Source, Off-road Source, Stationary Source, Point Source, Area Source	Draft Report for the Multiple Air Toxics Exposure Study in the South Coast Air Basin III (MATES III)—Chapter 3: Development of the Toxics Emissions Inventory	South Coast Air Quality Management District (SCAQMD)	http://www.aqmd.gov/prdas/matesIII/matesIII.html	11 pp.	2008	5.0

Source Apportionment	Conribution Estimation	HC, NMOG, SVOC, VOC, PM, CMB, South Coast Air Basin, On-road Source, Area Source, Point Source, Stationary Source	Source Reconciliation of Atmospheric Gas-Phase and Particle-Phase Pollutants during a Severe Photochemical Smog Episode	Schauer, J.J., Fraser, M.P., Cass, G.R., and B.R.T. Simoneit	Environmental Science and Technology	36 (17): 3806-3814	2002	5.0
Source Apportionment	Contribution Estimation	LAX, Hong Kong, CO, NOx, SO2, O3, RSP	Identifying the Impact of Large Urban Airports on Local Air Quality by Nonparametric Regression	Yu, K.N., Cheung, Y.P, Henry, R.C.,	Atmospheric Environment	38: 4501-4507	2004	5.0

APPENDIX B – ANNOTATED BIBLIOGRAPHY

Agrawal, H., A.A. Sawant, K. Jansen, J.W. Miller, D.R. Cocker III, 2008. "Characterization of Chemical and Particulate Emissions from Aircraft Engines,"

Atmospheric Environment, 42: 4380-4392

- Two Boeing 737-300 aircraft with CFM56-3 turbofan engines and two Boeing 737-700 aircraft with CFM56-7 turbofan engines, running on Jet A fuel, were sampled for emissions in August, 2005 (Oakland International).
- Raw exhaust extracted and sampled during run-up tests on port and starboard engines ~1m from exhaust nozzle exit plane
- EPA LTO cycle was used but modified as follows:
    - 4 and 7% load points comprised Mode 1
    - 30 and 40% load points comprised Mode 2
    - 65% load point was designated Mode 3
    - 85% was the maximum load point (since full power was not feasible during ground operation) and was considered Mode 4
- Nitrogen dilution ratios typically ranged from 10 to 40.
- PM collected on 47mm 2μm pore Teflo filters and analyzed: for microbalance weight (PM), X-Ray Fluorescence Spectroscopy (XRF) for metals, and HPLC extracted ion chromatography for ions of sulfate, chloride and nitrate

- Elemental/Organic Carbon (EC/OC) analysis performed on 1.5 cm2 punches from 47mm quartz silicate filters using Thermal/Optical Carbon Aerosol Analyzer
- Carbonyls collected on DNPH covered Teflo filters and HPLC analyzed after acetonitrile extraction.
- C10 to C30 HC collected with quartz filters packed with polyurethane foam resin, extracted with methylene chloride and analyzed using GC mass spectroscopy.
- Calculated PM EI increased with increasing power. PM emissions dominated by OC at idle and EC at higher power settings
- Carbonyl component dominated by formaldehyde, acetaldehyde and acetone. Co-elution of unknown compound with acrolein peak precluded HPLC analysis of acrolein. Carbonyl EI decreased with increasing power settings
- NAPH PAHs (including NAPH and its 1-methyl and 2-methyl derivatives) dominated the PAH species measured, and the NAPH EI increased as the power setting increased. NAPH EI began to decrease at the highest engine power settings
- Dioxins were below the detectable limits of the instrumentation
- Only sulfur ions were above instrument detection limits, most of which existed as sulfate ions
- Cr(VI) concentrations were low for all engines but one, and this is attributed to either engine wear or sample contamination
- PM measured by Dektai Mass Monitor (DMM) show spikes in PM emission during change from one power setting to the next.

Anderson, B.E., Chen G., and D.R. Blake, 2006. "Hydrocarbon Emissions from a Modern Commercial Airliner," Atmospheric Environment, 40: 3601-3612.

- As part of the EXCAVATE effort (NASA Experiment to Characterize Aircraft Volatile Aerosol and Trace-species Emissions) NMHC were analyzed from a Rolls Royce RB211-535E4 turbofan engine mounted onto a Boeing 757 aircraft during run-up in January 2002

- Air was sampled at ~1m and ~10m from the right wing engine exhaust plume (diluted with nitrogen and canister sampled), corresponding to a maximum plume age of 0.2s before reaching the sampling unit
- The engine ran on two batches of JP-5 with contrasting sulfur contents (high = 1820ppm, low = 810ppm by weight). Background samples were also captured
- Analytical instruments employed included Electron Capture Detectors (ECD) for halocarbons and alkyl nitrates, Flame Ionization Detectors (FID) for hydrocarbons, Quadrupole Mass Spectrometers (MSD) for selected ion monitoring and Gas Chromatography-FID (GC-FID) for CO measurements. CO2 was recorded using Non-dispersive Infrared Spectrometers (NDIR)
- 4 power setting investigated based on cockpit-recorded engine pressure ratios
    - Ratio of 1.3 = 4-7% idle power setting
    - Ratio of 1.15 = 26% approach power setting
    - Ratio of 1.3 = 47% low-cruise power setting
    - Ratio of 1.4 = 61% high-cruise power setting
- Emissions Indices showed that NMHC varied as a function of engine power, highest concentrations at idle and decreasing with increasing engine power
- Alkenes and alkynes (mostly ethene, propene and ethyne) comprised about 70% of the total NMHC at idle; aromatics (i.e. toluene and n-heptane) occupied the majority of NMHC emissions (50%) at high-cruise
- Alkyl nitrates (namely methyl nitrate, isopropyl nitrate and 2-butyl nitrate) were concentrated at high engine power and idle settings, but were low at the medium thrust settings
    - Orders of magnitude lower than NOx reported from previous EI's, so not attributed to impact reactive nitrogen budgets in the exhaust plume
- Organic sulfur species (OCS and CS2) EIs were slightly higher than background levels but exhibited no clear trend either in terms of fuel content or engine power setting
- Methane and dimethyl sulfate returned negative EIs, implying that they are burned out of background air during fuel combustion.
- At idle, engine primarily emits species containing 2-4 carbon atoms, but at higher power settings light HC constituency is reduced and replaced with predominantly 4 or more carbon bearing NMHC compounds

Arnold, F., Stilp, TH., Busen, R., and U. Schumann, 1998. "Jet Engine Exhaust Chemiion Measurements: Implications for Gaseous SO3 and H2SO4," Atmospheric Environment, 32 (18): 3073-3077.

- Gaseous sulfuric acid reacts with H2O via bi-molecular nucleation and condensation leading to either new particles or coated soot particles. This reaction is rate controlled by the efficiency of fuel sulfur conversion to S(VI), defined as the combination of SO3 and H2SO4
- Chemiions formed during jet fuel combustion are very sensitive to GSA, and thereby can serve as tracers in detecting jet fuel combustion emissions
- Measurements taken 1.75 downstream of a jet engine (RR M45H) on the Advanced Technology Testing Aircraft System (ATTAS), for 4 power settings and associated fuel consumption rates: 7% and 53 g s-1, 18% and 99g s-1, 30% and 146 g s-1, and 57.7% and 279 g s-1
- Plume ages between 6.6 and 14 ms mere considered
- Two fuel sulfur contents (FSC) were measured: low (0.212 g kg-1) and high (2.68 g kg-1)
- Low FSC chemiion (CI) count rates are about 10,000 per second, while high FSC count rates were only 4,000 per second, implying that the detection limits of the Ion Mass Spectrometer were not adequate to capture the massive ions.
- Low FSC fuel had abundant SO3-, HNO3- and H2SO4- core ions, with low NO3- ions due to their conversion to HNO3- via protonation from GSA.
- Abundance ratio 1 (R1) of HSO4- to NO3- cores increases with increasing plume age. Abundance ratio 2 (R2) of (SO3-+H2SO4-) to HNO3- cores decreases with increasing plume age.
- Given a rate constant of 1 x 10-9 cm3 s-1, plume age of 6.6 ms and R1 of 65, an S(VI) chemiion concentration of 6.4 X 1011 cm-3 is estimated.
- Given the instrumental limitations of the Ion Mass Spectrometer, high FSC fuel S(VI) estimates could not be calculated

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Boyle, K., 1996, Evaluating Particulate Emissions from Jet Engines: Analysis of Chemical and Physical Characteristics and Potential Impacts on Coastal Environments and Human Health, Transportation Research record No. 1517 – Aviation, National Academy Press.

- The results of this study suggest that the range of particle emissions from some jet engines cluster below 1.5 um and that these emissions contain heavy metals.

- Using settling plates at field sites around LAX and under the take-off path, indicate measurable deposition.
- Analysis reported elevated levels of zinc, copper and beryllium in fallout samples.

Cadle, S.H., P.A. Mulawa, J. Ball, C. Donase, A. Weibel, J.C. Sagebiel, K.T. Knapp and R. Snow, 1997. "Particulate Emission rates from In-Use High Emitting Vehicles Recruited in Orange County, California," Environmental Science and Technology, 31(12): 3405-3412.

- Remote sensing and visual inspection used to recruit 103 light duty in-use gasoline powered vehicles from a highway in Orange County, CA.
- Vehicles tested at roadside with owner consent using IM240 chassis dynamometer cycle after 2-3 minutes of conditioning at 50 mph.
- Age range of fleet vehicles was 6 to 22 years (1995 = year zero)
- PM-10 samples collected during the tests using Teflon (mass and elementals; X-Ray Fluorescence Spectroscopy) and quartz (organic and elemental carbon; Thermal/Optical Reflectance) ultrafine particulate filters.
- HC, CO, NOx and CO2 monitored continuously in dilution tunnel during IM240 cycle.
- 71 vehicles did not pass test and were sent to repair, undergoing the CA BAR90 emissions test before and after repair until they passed. Tested again on IM240 thereafter
- 17 vehicles, dubbed "smokers," emitted visible smoke before and during testing
- Post repair vehicles showed on average 75.6% HC emission reduction, 61.5% CO reduction and 8.9% NOx reduction
- PM-10 emissions, in terms of both organic and elemental carbon, increased after repair even though HC emissions were reduced
- Removal of deposits during repair, and extended operation at idle during diagnostics and repair, are explanations offered for the increase in PM-10 emissions. Authors recommend further research.

Carslaw, D.C., Beevers, S.D., Ropkins, K., and M.C. Bell, 2006. "Detecting and Quantifying Aircraft and Other On-Airport Contributions to Ambient Nitrogen

Oxides in the Vicinity of a Large International Airport," Atmospheric Environment, 40:5424-5434.

- London-Heathrow International Airport must meet EU daughter directive NO2 limit of 40 µg m-3 by 2010, so NOx sources around the airport much be better characterized
    - Previous study (Yu et al., 2004) identified influence of road traffic sources surrounding airports as major confounding factor in assessment of impact of airport NOx emissions
    - London-Heathrow Int'l reportedly accounts for 4.9% of total NOx emissions in London
- Features of runway use at London-Heathrow (runway alternation based on arrival/departure and time of day, as well as westerly operation preference) provide opportunity to characterize it as a NOx emissions source distinct from other surrounding sources
- Study uses data from eight monitoring sites within 2km of airport boundary, but focuses on LHR2, located 180m north of the northern runway center
    - Positioned advantageously based on the prevailing southerly/southwesterly wind direction to easily distinguish it as an airport source of NOx
    - Graphical analysis involved averaging of wind speeds and directions into categories, onto which the mean NOx concentrations are applied
        - Nonparametric smoothing process applied to normalize resolution of category cells
        - Highest NOx concentrations correlated with southerly wind direction
        - Inverse relationship between wind speed (independent of direction) and concentration of NOx
        - Direct relationship between SO2 concentration and wind speed, allowing for the differentiation between buoyant plumes (such as area sources) and non-buoyant plumes (such as road traffic)
        - In cases where there was sufficient wind velocity monitoring data, NOx concentrations could be background subtracted
        - Based on runway orientation and prevailing wind directions, aircraft plumes should be detected between 110 and 150 degrees azimuth.
        - Uncertainty in the method is propagated by smaller sample sizes per wind speed-direction cells

  - Based upon differing concentration responses for varying wind speeds between monitoring sites, it is hypothesized that aircraft plumes can be differentiated from road source plumes, and that aircraft sources can be detected as far as 2600m from the airport
  - Spatiotemporal runway data statistically tested by non-parametric U-test to determine aircraft NOx signal presence
  - Unique pattern of aircraft operation at LHR2 allows for the recognition of a distinct emissions signal relative to surrounding sources, independent of meteorological or operational influences
- Available PM data shows that LHR2 contributes 4.2% to the area total PM10 between 2001-2004, reinforcing that aircraft are a more significant contributor of NOx than PM
- Contrasting wind speed dependence of road traffic and aircraft plumes

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Carslaw, D. C., K. Ropkins, D. Laxen, S. Moorcroft, B. Marner and M. Williams, 2008. "Near-Field Commercial Aircraft Contribution to Nitrogen Oxides by Engine, Aircraft Type, and Airline by Individual Plume Sampling," Environmental Science and Technology, 42(6): 1871-1876

- NOx emissions inventoried during 2005 at Heathrow International Airport using chemiluminescence analyzer with molybdenum converter (for reduction of NO2 to NO).
- For source apportionment characterization the NOx measurements were coupled with wind velocity, temperature, humidity and aircraft movement data:
  - Movement data taken from National Air Traffic Services and British Airways Authority and included airline, aircraft type, runway used, arrival/departure status and time markers
- Chemiluminescence peaks identified based on time series gradient inversion. Background source contributions (measured from a different site) subtracted out before time alignment was performed:

  - Semiautomatic approach involved calibrating the time series of heavy aircraft take-offs to the NOx measurements – using the time delay between the first take-off and first major NOx peak to establish the offset for the data set.
  - Algorithms applied to snap each aircraft departure to the nearest peak concentration within the window of ± 10s, or ±20 to 30s if necessary
- Correlation Optimized Warping (COW) approach conducted by partitioning the NOx measurement series and expanding/contracting the aircraft time series to provide the best correlative fit. The best fit used section lengths of 50s and a warping tolerance interval of ±10s
- Plumes were grouped by the 29 engine types in the study and bootstrapped to bias-correct to the 95% confidence interval.

  Uncertainty arose from difference in sample sizes per engine, meteorological stochasticity, systematic and measurement error.
- Results of time series analysis, albeit given a southerly component to the wind direction showed:
  - Discernable shift in NOx signal at switch-over from northern to southern runway traffic in a day
  - Mean travel time of an exhaust plume is 54s from northern runway to measurement site
  - Larger aircraft comprised 78% of departure emissions, 58% of concentration over study area. As % emissions increases, % concentration contribution decreases
  - Airframe type and engine fit introduced additional variability in NOx emissions
  - Same engine/same airframe couplings had different emissions (up to 41% change). Different frame /same engine couplings

varied up to 28%. Stresses influence of aircraft operational factors in actual emissions.

Cheng, M.D., Corporan, E., DeWitt, M.J., Spicer, C.W., Holdren, M.W., Cowen, K.A., Laskin, A., Harris, D.B., Shores, R.C., Kagann, R., and R. Hashmonay, 2008. "Probing Emissions of Military Cargo Aircraft: Description of a Joint Field Measurement Strategic Environmental Research and Development Program,"

Journal of the Air & Waste Management Association, 58: 787-796.

- Emissions were tested from the inboard and outboard engines of a C-130H aircraft during run-up at the Kentucky Air National Guard in Louisville during October, 2005.
- Extractive measurements were taken both at the engine exhaust plane and 15m downwind of the engine exhaust plane; Remote sensing measurements were recorded at 5m and 15m downwind of the engine exhaust plane. Both sets of measurements occurred at the following power settings:
  - Low speed ground idle = 4% engine power
  - High speed ground idle = 7% engine power
  - Flight idle = 20% engine power
  - Cruise = 41% engine power
  - Maximum power (100%)
- Instruments employed to record the extractive measurements included:
  - Condensation Particle Counter for PM # concentration
  - Tapered Element Oscillating Microbalance for PM mass concentration
  - Fourier Transform Infrared Analyzer with Molybdenum converter, as for NOx, CO, CO2 and SOx concentrations; additional Nondispersive Infrared Analyzers employed for

  CO2; Cross-filter Correlation Spectrometer for CO; Chemiluminescence Analyzer for NO/NOx
  - Scanning Mobility Particle Sizers Equipped with both long (10-640 nm) and nano (3-70 nm) Differential Mobility Analyzers to assess PM mass and size distributions
- Remote sensing accomplished using Fourier Transform Infrared Spectroscopy and Turnable Diaode Absorptive Laser Spectroscopy
- Fuel-to-air ratios were consistent between inboard and outboard engines at all power settings and ranged from 0.008 at idle to 0.02 at maximum power.
- The ratio of CO2 at the engine exhaust plane to that at the far field locations and also varied directly with engine power setting
- At all power settings, particle size distribution peaks occurred from 50-80nm. Particle diameter varied directly with engine power setting at both engine exhaust plane and far field measurement sites
- PM # concentrations varied directly with engine power setting, with a dilution corrected difference between idle and maximum of 1 x 107 cm-3. The most variability in concentrations within a single power setting was observed at low speed idle
- Particle size distributions at the far field sampling locations showed an increase in particles below 20nm in diameter. This is explained by secondary particle nucleation from sulfur compounds and organic species in the exhaust
- Dilution corrected PM mass showed agreement between engine exhaust plane and far field samples for flight idle to maximum power

settings, however there were significantly higher engine exhaust plane values relative to the far field values for the low power idle settings

  - Semi-volatile components lost to gas phase at idle explains discrepancy
- NOx/CO2 concentration ratios increase for far field and engine exhaust plane samples with increasing engine power, reflecting more NOx relative to CO2 as engine power increases

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Cho, A.K., Stefano, E.D., You, Y., Rodriguez, C.E., Schmitz, D.A., Kumagai, Y., Miguel, A.H., Fernandez, A.E., Kobayashi, T., Avol, E., and J.R. Froines, 2004. "Determination of Four Quinones in Diesel Exhaust Particles, SRM 1649a, and Atmospheric PM2.5," Aerosol Science and Technology, 38 (S1): 68-81.

- Measured concentrations of quinones commonly found in diesel fuel, both from standard reference material collected from the National Institute of Standards and Technology and in PM2.5 diesel exhaust/ambient air samples
  - Diesel exhaust particles collected during a dynamometer tests spanning three months, using a 2740 cc four-cylinder engine with standard diesel fuel. Particles collected on glass fiber filters in a constant-volume sampler located at the end of the dilution tunnel
  - Ambient air samples (n=17) collected in 24h periods from Atascadero (350 km northwest of Los Angeles), San Dimas (50km downwind of Los Angeles) and Riverside (50km downwind of Los Angeles), on quartz fiber filters fitted with XAD resin.

- Samples extracted using Dichloromethane and acetylized using zinc and acetic anhydride prior to GC-MS (Gas Chromatography Mass Spectrometer) derivitization
- In the diesel exhaust particles, concentrations of the three-ring quinones (9,10-Phenanthraquinone and 9,10-Anthraquinone) were much higher than the more volatile two-ring 1,2 and 1,4-Naphthoquinones
- In the internal standard, average concentrations ranged from 0.19 µg/g for 1,2-Naphthoquinone to 2.03 µg/g for 9,10-Anthraquinone
- Los Angeles Area Ambient Air Results:
    - Elevated 9,10-Anthraquinone levels (between 20-200 pg/m3) were reported for all three sample sites

- Naphthoquinone and 9,10-Phenanthraquinone concentrations were slightly lower in Atascadero, but 9,10-Anthraquinone levels were similar to the other sites
- Authors acknowledge secondary formation of 9,10-Anthroquinone on the collection filters as attributing to the elevated levels
- Profiles of 1,4-Naphthoquinone and 9,10-Phenanthraquinone were similar in San Dimas and Riverside, and are explained by vehicle emissions and formation during regional atmospheric transport as the dominant and likely source contributors
- Concentrations of naphthoquinones on quartz filters were lower than the 9,10-Phenanthraquinone and 9,10-Anthraquinone levels, which is counterintuitive because NAPH concentrations greatly exceed those of Phenanthrene and Anthracene in the ambient air.
    - Explained by test of vapor phase quinones trapped under XAD collection resin: the naphthoquinones were predominantly occurring in vapor phase and preferentially trapped beneath the resin at high concentrations, which explains the anomalous concentration results

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City of Destin, 2007, "Destin Airport Air Sampling Project Executive Summary", prepared by Tetra Tech, Inc.

- Air monitoring was conducted in the vicinity of this GA airport over a five-day period in April of 2007. Samples of total suspended particulate matter (TSP), lead and organics (i.e., VOCs) were collected at three sites in the immediate vicinity of the airport and two "background" sites. Wind direction data was also collected. The stated purpose of the study was two-fold: (1.) to identify "markers" of avgas emissions and (2.) determine if ambient concentrations of these parameters up- and down-wind of the airport differ significantly.
- The treatment of the results is comprehensive but difficult to understand and the findings, therefore, are inconclusive. However, it appears that based on this study, the selected parameters and/or measurement methods do not provide a strong statistical link to emissions from this GA airport. It is not clear if this outcome is due to the low levels of contaminates in the ambient air, the sensitivity of the methods or the influence of background levels.
- Notably, a local newspaper article in June, 2008 reported that a follow-up study will be conducted during the July 4th holiday weekend.

City of Park Ridge, 2000, *Preliminary Study and Analysis of Toxic Air Pollutant Emissions from O'Hare International airport and the Resulting Health Risks Created by These Toxic Emissions in the Surrounding Residential Communities*, Volumes I-IV.

- The City of Park Ridge, with financial assistance from the communities of Des Plains, Niles and Itasca, commissioned this multi-faceted study of air toxic emissions from O'Hare International Airport. The results of this assessment are published as a four-volume set.
- Volume I – *Executive Summary and Background*

    - Includes introduction and purpose statement of study; summarization of results, findings and conclusions; and background information of the regulation of TAPs and human health risk assessments.
- Volume II – *Preliminary Modeling Evaluation of Risks Associated with Emissions From Chicago O'Hare Airport, by Environ Corp*.
    - Provides criticism of *Findings Regarding Aircraft Emissions, O'Hare International Airport and Surrounding Communities*.
- Volume III – *Preliminary Downward Site Sampling Investigation for Air Toxic EmissioFrom O'Hare International Airport*, by Mostardi-Platt Assoc.
    - Sampling and testing of air samples upwind and downwind of O'Hare using composite, grab and wipe samples.
    - Over 200 VOC species found, 92 identified and 78 in increased levels downwind of the airport.
    - Wipe samples did not reveal any PAHs.
    - Concludes that the airport contributes to the elevated levels of VOCs downwind.
- Volume IV – *Preliminary Risk Evaluation of Mostardi-Platt Park Ridge Project Data Monitoring Adjacent to O'Hare Airport*, by Environ, Inc.
    - Preliminary evaluation of potential risks associated with inhalation exposures to TAPs measured near O'Hare International Airport.
    - The chemicals that contribute most significantly are aldehydes, benzene and naphthalene.

Corporan, E., Quick, A., and M.J. DeWitt, 2008. "Characterization of Particulate Matter and Gaseous Emissions of a C-130H Aircraft," Journal of the Air and Waste Management Association, 58: 474-483.

- Characterizes nonvolatile and gaseous PM emissions of two T56-A-15 turboprop engines on C-130H military aircraft at Kentucky Air National Guard 123rd Airlift Wing.
- Sampled from the inboard and outboard engines on the aircraft's right wing, fueled with JP-8
- Power settings: low-speed idle, high-speed idle, flight idle, cruise and maximum power
    - PM measurements were nitrogen diluted using 10:1 ratio derived from CO concentrations at 1:1 dilution, to prevent water condensation, particle loss and instrument saturation
    - CPC (Condensation Particle Counter) measured particle number, SMPS fitted with a long Differential Mobility Analyzer (DMA) and CPC to count particles in 7-300nm range. Additionally, a Laser Particle Counter was used to quantify particles >300nm, however it was found that the contributions of this size range were negligible.
    - Smoke sampled on paper filters and measured using TEOM (Tapered Element Oscillating Microbalance) to quantify nonvolatile particles
    - Gaseous PM recorded using Fourier Transform Infrared (FTIR) based equipment
    - Particle number (PN) counts were both dilution corrected and corrected to account for losses in the sample line, based on

results from a previous study showing losses ranged 40-60%.

Corrected PN ranged from 6.4 x 107 to 14.3 x 107 #/cm3

  - PN emissions indices calculated accounting for variations in fuel/air ratio (F/A)

- F/A ranged from 0.0085 at high-speed idle to 0.021 at maximum

  power
- PN EI was higher for idle settings than high power settings.

  Low-speed idle EI differed significantly between engines

  - Particle size distributions were lognormal for all power settings, with a mean between 50 and 70 nm. Curves shift to the right as engine power increases, suggesting both production of larger particles and total combustion of smaller particles and

    semi-volatile aerosols

  - Dilution corrected PM mass concentrations ranged from 10-25

    mg/m3 and were lowest for the low-speed idle setting

  - Dilution and loss corrected PM mass EI averaged between 1.6-3.5 g/kg fuel, and were comparable to PN EI except for the low-speed idle condition
  - Smoke number (SN) counts ranged from 42-45 for all conditions except low-speed idle, which had a SN of 31
  - CO concentrations 7x higher at low-speed idle setting. NOx concentrations similar at idle, but increase with increasing F/A ratio at higher power setting
  - EI for CO decrease with increasing engine power; NOx EI increase with increasing power

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Dias-Lalcaca, P., D. Brunner, W. Imfeld, W. Moser and J. Staehelin, 1998. “An Automated System for the Measurement of Nitrogen Oxides and Ozone Concentrations from a Passenger Aircraft: Instrumentation and First Results of the NOXAR Project,” Environmental Science and Technology, 32: 3228-3236.

- Commercial aircraft can be used as measuring platforms for NOx and O3 concentrations in the troposphere and stratosphere.

- Study describes system instrumentation and measurement parameters of fully automated system used in NOXAR project.
    - NO chemiluminescence signal detected by mixing sample gas with internally generated O3 at constant temperature and pressure. Exhaust gas passed through ozone scrubber before analysis
    - NO2 measured by amount of photolytic decomposition to NO (producing O3)
    - O3 measured on basis of UV absorption
        - NOXAR (Nitrogen Oxides and Ozone along Air Routes) project involved a 1 year measurement period from the described device, installed on a Swissair B-747 subsonic aircraft with the following flight routes (540 grand total flights) between May 1995 and May 1996:
            - Zurich to New York/Atlanta/Boston/Chicago – 269 total flights
            - Zurich to Bombay/Hong Kong – 145 total flights
            - Zurich to Shanghai/Beijing – 129 total flights
    - Instrument checked and calibrated every 3 hours.
    - Sample resolution was 3 seconds for nitrogen species and 4 s for ozone, translating into a spatial separation of 700 to 1000 m.
    - O3 measurement uncertainties arose due to loss of gas from collection chamber degradation, as well as humidity difference between sample and reference standard gas. Checks against MOZAIC (Measurement of Ozone on Airbus In-service Aircraft) data for an A340 Airbus showed good agreement, discounting the effects of the uncertainty.
    - NO measurement uncertainties were corrected using a time-offset function.

  - NO2 measurements were contaminated due to technical difficulty, and so were calculated using the reaction rate constant of NO and O3, measurements of NO and O3, and a standard photolysis rate for NO2
  - Data from a Zurich to Atlanta flight on May 10, 1996 is shown and discussed:
- NOx data are presented as 2 minute averages except in areas of sharp peaks, wherein presentation of the 3 s resolution better captures the temporal variability.
- Compared against potential vorticity and temperature data, showing that high O3 and NOx concentrations measured by the instrument coincide with two troughs, marking areas where stratospheric air aloft is carried downward into the troposphere

- Short-lived NOx peaks are attributed to the sampling of exhaust

  plumes from other aircraft in the flight corridor.

Dreher, D.B. and R.A. Harley, 1998. "A Fuel-Based Inventory for Heavy-Duty Diesel Truck Emissions," Journal of the Air and Waste Management Association, 48: 352-358.

- MOBILE, MVEI 7G and other programs estimate emissions from a travel-based method. Heavy-duty diesel vehicle activity is spatially and temporally distinct from light-duty gasoline vehicle travel activity. Light-duty vehicle regulations are enforced in terms of emissions mass per unit distance, whereas heavy-duty emissions are regulated by unit of break work engine output.
- Conversion or refinement of methodology should occur for heavy-duty diesel vehicles to more accurately estimate emissions
- Study develops fuel-based methodology to be used in heavy-duty diesel vehicle emissions estimates
- Available fuel consumption data used to temporally apportion emissions estimates based on vehicle activity
- Emissions factors normalized to fuel consumption
- Vehicle emissions estimated by factoring vehicle activity and emissions factors by unit volume of fuel burned Traffic count data, weigh-in data and diesel fuel sales for San Francisco Bay area, as well as in situ heavy-duty diesel truck background emissions measurements

(corrected for presence of light duty vehicles) were used to apply the method.

- Diesel truck activity comprised 128% of weekly average on weekdays, but only 24% – 39% in weekends
- Fuel based inventory estimates exceed conventional estimates of MVEI 7G by as much as 2.3 times for NOx and 4.5 times for black carbon particulate emissions
- Weekday/weekend emissions differential for this class of vehicle could help explain higher ambient O3 concentrations and OC/BC ratios on the weekends in this area.

Eiguren-Fernandez, A.E., Miguel, A.H., Froines, M.J., Thurairatnam, S., and E.L. Avol , 2004. "Seasonal and Spatial Variation of Polycyclic Aromatic Hydrocarbons in Vapor-Phase and PM2.5 in Southern California Urban and Rural Communities," Aerosol Science and Technology, 38: 447-455.

- Air was sampled for PAH both in vapor phase and in PM2.5 particle phase, at six communities around Southern California. Four communities were between 40-100 km downwind and east of LA (San Dimas, upland, Mira Loma, Riverside) and two were rural and located 100+ km northwest of LA (Lompoc and Atascadero).
- Samples collected on "sandwiches" of two quartz fiber filters and XAD resin between two polyurethane foams. Samples were cleaned and extracted using hexane, methanol and methyl chloride, and analyzed with HPLC for PAH and elemental carbon.

- Vapor phase PAH comprised 99.9% of the total mass, although concentrations of those vapor and particle phase compounds were similar. Total concentrations ranged from ~260 to ~607 ng m-3.
- Lompoc had lowest concentrations of vapor phase PAH, and concentrations at all other sites were comparable to one another
- NAPH comprised 91% of the total PAH mass, and were present in concentrations three orders of magnitude higher than the others
    - Lompoc also had lowest concentrations of particle phase PAH, with all other sites returning comparable values relative to one another
- Benzo[ghi]perylene, characteristic to gasoline exhaust, dominated the particle phase PAH mass at all sites
    - Data was also grouped according to temperature to evaluate the effects of seasonality on PAH concentrations
- NAPH, Acenaphthalene, Fluorine, Phenanthrene were found mostly in vapor phase; semi-volatile PAHs (i.e. Fluoranthene, Pyrene, Benz[a]anthracene and Chrysene) were found in both phases; PAH with lower vapor pressures (i.e. Benzo[b/k]fluoranthene, Benzo[a]pyrene, Indeno[1,2,3-cd]pyrene, Dibenz[a,h]anthracene and Benzo[ghi]perylene) were found more commonly in particle phase
- Low molecular weight compounds did not vary with temperature; particle phase concentrations showed an inverse relationship with temperature
    - Attributed to cold ambient temperature, less temperature inversions at lower elevations and depression of photochemical reaction rates
    - Temperature effect on PAH concentrations was less for vapor phase constituents than particle phase constituents

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Ernst, D.A. and A.D.., Goldman, A.D., 1997. “Soot Deposition Study: Logan Airport and Surrounding Communities,” Report No. KMC Report No. 970114.

Prepared for Massachusetts Port Authority, Boston, MA, by KM Chung Environmental Inc., Waltham, MA.

- Soot sampling program and source apportionment study to evaluate atmospheric fallout of VOCs in the vicinity of the airport and in adjoining neighborhoods.
- Sampling collected at four sites: one on the airport (near runway end) and three in nearby communities surrounding the airport.
- Focused on PAHs and used chemical fingerprinting profiles from jet fuel aircraft exhaust for source identification.
- Results suggest that soot deposition in the communities around the airport results from general urban contamination rather than from aircraft sources at the airport.

Fanning, E., R.C. Yu, R. Lu and J. Froines, 2007. "Monitoring and Modeling of Ultrafine Particles and Black Carbon at the Los Angeles International Airport,"

Report to CARB and CalEPA, ARB Contract #04-325, 79 pp.

- Previous research implies arterial traffic and airport emissions (PM) affect communities on east side of LAX than on north and south sides due to prevailing wind direction; efforts have not been able to adequately distinguish airport from surrounding area arterial traffic emissions.
- Aims of Study:
    - Measure UFP number concentration, PM2.5 and BC mass concentrations at near source and at upwind site for background comparison. Measurements taken in summer and winter to investigate seasonal effects on emissions.
    - UFP and BC number and mass concentrations, respectively,

      600m downwind of take-off emissions
    - Relate effects of dispersed aircraft pollutants to community exposure levels
    - Attempt dispersion modeling of LAX aircraft emissions, with emphasis on BC

- Aim #1 above accomplished by measuring near source (blast fence 140 m downwind of runway 25R) emissions against background (upwind residential area north of LAX) levels. Performed during September 2005 and March 2006 for the near source area, and only during September for the background source
    - BC measured via aethalometer (880 nm) on 5 and 10 minute sampling interval. PM2.5 measured on Beta Attenuation Mass Monitors on 30 and 60 minute intervals. UFP concentrations and particle size distributions recorded using scanning mobility particle sizers (6.15-289 nm, 102 size bins) and condensation particle counters (7-200 nm particle sizes) on 1 second and 2 minute intervals. PAH and VOC concentrations sampled with canister and cartridge or Tisch filter sampler, approximately every 24 hours
    - Chemically analyzed using HPLC, capillary column GC depending on compound.
    - Area meteorologically described as sea-breeze dominated with associated moderate temperatures and high relative humidity. Wildfires occurring during study interval were shown to influence measurements at background site.
    - UFP size distributions at blast fence: 6.15-225 nm in summer, peaking at 14nm, and 7.64-289 nm in winter, peaking at 16.3nm. Background levels display much lower concentrations than the blast fence site and are more evenly distributed.

- UFP concentration spikes successfully correlated to runway activity
- Size specific particle concentrations at blast fence had 15nm particle concentration baseline of 60-150 #/cm3, and up to 28,000 #/cm3 during take-off events
    - During take-off cycle, 30nm particles at blast fence increased from baseline of 40 #/cm3 to ~2800 #/cm3; exponential decay function quantified for time after take-off event, but is highly dependent on particle size, type of aircraft and meteorological variability.
- Summer and winter concentrations of BC at blast fence were comparable and significantly lower at the background site
- Average PM2.5 mass concentrations were significantly higher at the blast fence than the background
- NAPH totaled 85% of vapor phase PAH's at both sites, but concentrations were higher at the blast fence. Semivolatile particle-phase PAH was higher at the blast fence, and higher molecular weights were found at hconcentrations at the background site. This might imply that the background site was influenced by surrounding traffic more than originally anticipated.
- VOC profiles did not differ between the two sites, but the blast fence returned higher levels of formaldehyde and acrolein.

- Aim #2 above accomplished in a downwind study, where SMPS/CPC measurements (for UFP and BC) were taken at 5 locations ranging from 140-610m downwind from take-off predominated runway 25R, and also at 5 locations ranging 620-960m from primary landing site on (dominantly arrival) runway 25L. 15nm particle data from 25L downwind sites were sorted to exclude takeoff data, since this site was dedicated in the study to measuring landing activity.
    - Data analyzed both in terms of entire data spread for each sampling locality, but also in terms of the upper quartile of the data, which is assumed to represent concentration peaks associated with take-off events.
    - 25R 15nm data shows average concentrations decreasing slightly with distance, but a clear trend of decrease with distance is shown when evaluating only the upper quartile of the data.
    - Peaks in 15 nm concentration due to departure activity can be observed to 170m downwind of the blast fence on 25R, but time lag is apparent that increases with distance, up to 20s. Concentrations also decrease with increasing distance.
    - BC concentration decay is also observed on 25R with increasing distance downwind, although can be seen in both the entire data spread as well as the upper quartile data, unlike the UFP measurements.
    - No observable concentration trend with increasing distance downwind for 25L PM data, but BC did decrease quite significantly with increasing distance downwind.
    - As independent confirmation a small subset of SMPS/CPC measurements were taken south and east of the study sites, to assess the impact of nearby highway traffic. Traffic did contribute to background levels at downwind locations, but after time series analysis was easily discerned from the peak 15nm concentrations associated with the aircraft activity.

- Aim #3 above involved a community study, in which SMPS/CPC , aethalometer and beta attenuation mass monitoring were employed to track UFP, BC and PM2.5 respectively at six community sites: 3 directly beneath the runway R25L landing point, one 120 m north of the blast fence site, 1 300m south and 1 300m north of the blast fence site. Measurements took place in June of 2006
  - PMN10-100 was additionally calculated, involving the summation of 10 to 100nm number concentrations and performing hourly averaging.
  - Most sites had experienced prevailing winds slightly more sourtherly than LAX. This may have lessened the occurrence of aircraft plumes over these community areas.
  - For particles less than 40nm in size, all the average concentrations for the six community sites were greater than the background site (see near source study), yet less than the blast fence site. Over the 80nm size class, neighborhood concentrations were lower than even the background reference site.
  - With regard to sites directly under R25L, particles <15nm increase in concentration going from east to west, while particles 15-50nm in size increase in concentration going the same direction
  - The site 300m north of the blast fence was determined to have anomalously high concentrations of 15nm particles.
  - All six communities displayed PM2.5 and BC concentrations comparable to those found at the background reference site.
  - PMN10-100 concentrations for the communities ranged in between the maximum concentrations measured at the blast fence sight and those minima found at the background site.

- To accomplish aim #4, a 3-D high resolution coupling of the SMOG and PSU/NCAR employed:
    - Domains used for the simulation are the LA Basin with an 8.1km horizontal resolution, two transition domains to account for wind dispersion with horizontal resolutions of 2.7 and 0.9km respectively, and an LAX/community specific domain with a resolution of 0.3km.
    - Emissions of BC are estimated using ICAO values and calibrated using the near source measurements in this study. Since the measurements were averaged over 5 minute intervals, the model is also set up to report identical intervals when predicting BC emissions
    - Emissions factors are calculated using the standard LTO time in mode approach, with an added sixth operating mode to account for brief reverse thrust upon landing.
    - The model predicts drift near the vicinity of LAX in the early morning, leading to high concentrations of BC around the area. As the day progresses and the sea-breeze initiates, BC is transported east across the downwind communities. At nighttime, the land breeze causes transport, diffusion and drift back to areas around the airport, but over a much wider spatial extent than in the morning hours.

Fraser, M.P., Cass, G.R., Simoneit, B.R.T., and R.A. Rasmussen, 1998. "Air Quality Model Evaluation Data for Organics. 5. C6-C22 Nonpolar and Semipolar Aromatic Compounds," Environmental Sciences and Technology, 32: 1760-1770.

- C6 to C22 nonpolar and semipolar volatile, semivolatile and particle-phase aromatic hydrocarbons were characterized from samples taken from Claremont, Los Angeles, Azusa, Long Beach and San Nicolas Island (background site), during a photochemical smog episode occurring in summer of 1993. Spatiotemporal distributions are also investigated
- Ambient air was canister sampled to measure VOCs, and a polyurethane foam cartridge collected large particle phase OCs and SVOCs. Fine particle phase organics were collected on quartz fiber filters
- Samples analyzed using gas chromatography-mass spectrometer (GC-MC) and flame ionization detectors (GC-FID)
- Compounds were identified using mass spectral laboratory standards whenever available, and were otherwise estimated using peak retention times and fragmentation patterns
- Compounds were quantified using manual peak integration, accounting for isomers of the same compound by defining the compound based on the substitution pattern of its functional groups.
- Corrected for blowdown (evaporation of volatiles during sample preparation), extraction losses and breakthrough of certain heavier PAH compounds (i.e. NAPH) through the polyurethane foam collection cartridge
  - Single ring aromatics (i.e. benzene) constitute most of the pollutant population
  - As number of rings in a compound increases, ambient concentration decreases; concentrations deplete more quickly concerning more highly substituted species
  - Gas-phase PAH concentrations greatly exceed particle-phase concentrations, especially for lower molecular weight species

  - Vapor phase aromatic HC as well as PAH show peak concentrations around Los Angeles, associated with concentrated vehicle traffic relative to less populated sites downwind
  - Nitrated aromatics are more concentrated at the inland sites (Azusa and Claremont)
  - Peak concentrations occurring in Los Angeles decrease with inland advection to Claremont, and lowest concentrations occur during 12 and 4 pm, due to:
    - radiative heating increasing mixing depth at ground level
    - gas-phase and photochemical reactions preferentially depleting most reactive species (i.e. benzo[a]pyrene and 1,2,4-trimethylbenzene) with increasing distance downwind
  - Gas-phase PAH (i.e. cyclopental[cd]pyrene, benzo[a]pyrene and benz[a]anthracene) are more reactive with the hydroxyl radical and thus deplete more readily than particle phase PAH
  - Anthracene undergoes much more rapid reaction than phenanthrene, with peaks occurring in the morning, declining during midday and resurging during the nighttime when photochemical reactivity is suppressed
- Particles that occur due to secondary formation via photochemical reaction are dominated by nitrated aromatics and oxygenated aromatics, with concentrations increasing with distance inland. Most also show diurnal trends
- At background site (San Nicolas), oxygenated aromatics are most prominent, with negligible levels of gas-phase monoaromatics (i.e. benzene and toluene) and PAH. It is speculated that San Nicolas

receives very diluted, aged air parcels associated with long-distance transport

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Fujita, E.M., Watson, J.G., Chow, J.C., and Z. Lu, 1994. "Validation of the Chemical Mass Balance Receptor Model Applied to Hydrocarbon Source Apportionment in the Southern California Air Quality Study," Environmental Science and Technology, 28 (9): 1633-1649.

- Conducted as part of Southern California Air Quality Study (SCAQS) of 1987 on air pollutants common to the South Coast Air Basin. This study focuses on source apportionment for the NMHC portion of VOC emissions
    - NMHC defined as all HC species C2-C12 measured on GCFID (Gas Chromatography Flame Ionization Detector)
- One hour integrated canister sampling performed in Anaheim, Azusa, Burbank, Claremont, Hawthorne, Long Beach, LA and Rubidoux in summer and fall
- Applied CMB (Chemical Mass Balance) methodology to model source apportionment, using CARB's Modeling Emission Data System for source profiles. Unidentified compounds were allocated to known individual species and weighted for the degree of certainty with which that classification could be made in CMB.
    - Source types included vehicle exhaust, gasoline evaporation, liquid gasoline, gasoline vapor, solvent, biogenic and commercial/geogenic/liquefied natural gas
    - Species that best fit the model were those that did not change significantly between source and receptor, and are acetylene, alkanes, benzene and toluene. Xylenes and alkenes were fitting when emissions were fresh

  - Once fitted, CMB model applicability was tested and the source profiles were re-weighted based on the results.

- Source Contribution Estimates:
  - Variable with motor vehicle exhaust profiles. Those profiles with higher acetylene values cause lower source contributions for exhaust and higher for liquid gasoline source types
  - Profiles are collinear for vehicle exhaust, evaporative emissions and geogenic natural gas
  - Source contributions for solvents were negligible
  - Combining the natural gas profiles into one profile yielded better model performance
  - Profile with higher fractions of acetylene switched the contribution estimates from vehicle exhaust to liquid gasoline
- Major source type contributors, in descending order of impact, to NMHC over study interval are: vehicle exhaust, liquid gas, gasoline vapor and natural gas/propane gas
  - Motor vehicle exhaust ranges from 30-70% of total NMHC and were larger in fall
- Lower acetylene mass fractions in a profile cause CMB to overestimate vehicle exhaust contribution and underestimate liquid gasoline contribution
- Highest source contribution estimates for vehicle exhaust tend to overestimate concentrations of ethane and other combustion olefins relative to actual measured values; dependent upon emission control technology, maintenance and operational parameters

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Gardner, R.M., K. Adams, T. Cook, F. Deidewig, S. Ernedal, R. Falk, E. Fleuti, E. Herms, C.E. Johnson, M. Lecht, D.S. Lee, M. Leech, D. Lister, B. Masse, M. Metcalfe, P. Newton, A. Schmitt, C. Vandenbergh and R. Van Drimmelen, 1997. “The ANCAT/EC Global Inventory of NOx Emissions from Aircraft,” Atmospheric Environment, 31(12): 1751-1766

- In conjunction with the AERONOX project, a global 3-D model was used to create an inventory of NOx emissions, to ascertain the effects of aircraft NOx emissions on O3 production/depletion in the troposphere and stratosphere, respectively.
    - Resolution = 2.8° x 2.8° x 1km
- While the focus is on NOx, H2O, CO2, PM SO2, CO HCs were also modeled from 28 specific and 5 general aircraft sources for altitudes between ground level and 17 km.
- Civil aircraft movement inputs were well characterized using available air traffic control data from 44 countries (US not included) for the span of one year
    - July 1991, October 1991, January 1992 and April 1992 were used as representative months to characterize the one-year interval.

      This approach also allowed for analysis of seasonal effects on emissions.
- Military aircraft movement and fuel usage data is not available due to security reasons, therefore it was estimated as 10% of the total global usage of aircraft fuel in the scenario. The estimates were weighted based on military aircraft type and land-sea distribution.
- Fuel consumption and NOx emission ware estimated on the basis of thermodynamic model parameters including: assuming a two-shaft engine, engine/airframe combination (on the basis of fuel flow, temperature, pressure and thrust settings), take-off mass and power,

time to cruise, maximum speed in cruise, and ambient absolute humidity

- Global fuel burn = 165.5 Tg yr-1; global NOx emissions = 2.78 Tg yr-1, 60% of emissions occurred between 10 and 12 km.
- Uncertainties include:
    - No turboprop data
    - Flight profiles and routes represent optimum (unrealistic) conditions
    - Unintentional double counting of some aircraft movements
    - Gross estimations of military parameters
    - Global reference fuel relates to refinery use, not actual use
- Because of above uncertainties and the fact that NASA was privy to confidential data from private and public sectors, this model exceeds NASA model-derived consumption and emissions estimates by almost 2 times.
- Seasonal pattern in emissions is shown, which can alter the annual profile of emissions and associated O3 alteration in the stratosphere and troposphere.

Gerstle, Thomas, 1999, "Aircraft Engine and Auxiliary Power Unit Emission Testing (Vols. 1, 2, & 3)", prepared by Environmental Quality Management, March 1999.

Volume 1: Executive Summary

- Two year effort to test, characterize and evaluate exhaust emissions (including HAPs) from military aircraft engines.
- List of constituents includes: particulates, aldehydes, semivolatiles, volatile organic compounds, and total hydrocarbons.
- Eleven HAPs were identified as being the most frequently detected as combustion products.
- Suggests looking at the data to find surrogates to predict non-tested HAPs.
- Benzene, toluene, and xylene are the most significant VOCs.
- Formaldehyde is a surrogate for the aldehyde group accounting for over 90%.

- Most HAPs occur during the idle and afterburner modes.

Volume 2: Detailed Sampling Approach and Results

- Formaldehyde contributes 60 to 70% (depending on thrust setting) to the total HAP emission rates.
- Benzene makes up 10 to 15% of the HAP emission rate; combined with formaldehyde, toluene, and xylene, these four compounds represent over 90% of the VOCs.
- Provides emission factors for 18 engines at different power settings (idle, approach, intermediate, and military) fir the following 10 HAPs; formaldehyde, acetaldehyde, acrolein, toluene, isobutyraldehyde, naphthalene, benzene, ethylbenzene, xylenes, and styrene.

Volume 3: Particulate Matter Results

- Provides particulate emission factors for 17 engines at different power settings (idle, approach, intermediate, and military). Particulate emission factors are separated into condensable, filterable, and total.

Gleitsmann, G., and R. Zellner, 1998. "The Effects of Ambient Temperature and Relative Humidity on Particle Formation in the Jet Regime of Commercial Aircrafts: A Modeling Study," Atmospheric Environment, 32 (18): 3079-3087.

- Contrail formation (by H20/H2SO4 phase change condensation) from the plume of a B747 is modeled to assess the effects of ambient air temperature and humidity on soot particle homogeneous and heterogeneous condensation
- Input parameters:
    - B747 with CF6-80C2 engines at cruise
    - Varying ambient temperature between 219 and 233 K
    - Partial pressure of H2O varied between 0.02 mbar and 0.10 mbar
    - Mixing ratios of 7.06 x 10-5 and 3.53 x 10-4 for lower and upper partial pressures listed above, respectively

  - EI for soot assumed to be 0.05 g kg-1 fuel, EI for SO_2 1.0 g kg-1 fuel (corresponding to 510 ppm sulfur content)
- Particle supersaturation necessary for contrail formation occurs rapidly within the initial few hundred meters of the nozzle exit and is concentrated in the center of the plume
- Ambient temperature and particle diameter at termination of jet regime vary inversely, and the relationship is strongest at higher ambient temperatures
- Above a threshold temperature and influenced by the relative humidity, particle sizes decrease to below 62 nm, the criteria for heterogeneous nucleation of H_2O and H_2SO_4 on soot surfaces
- Relative humidity has no influence on homogeneous nucleation, and particles don't normally exceed 3.5nm via this condensation route

Groob, J.-U., C. Bruhl and T. Peter, 1998. "Impact of Aircraft Emissions on Tropospheric and Stratospheric Ozone. Part I: Chemistry and 2-D Model Results," Atmospheric Environment, 32(18): 3173-3184.

- Aircraft NO_x and H_2O vapor emissions are two-dimensionally modeled for impact on tropospheric and stratospheric O_3 concentrations based on two scenarios: a 1991 scenario involving only subsonic aircraft, and a 2015 projection scenario incorporating subsonic and supersonic aircraft (cruise parameters of Mach 2.4 and 18-21 km elevation).

- Box calculations of O3 chemistry related to aircraft emissions of NOx and H2O vapor are estimated, and conclude that NOx and H2O vapor emissions cause tropospheric O3 formation and stratospheric O3 depletion. Free radical halogenations and their effects on PSC (polar stratospheric cloud) formation and O3 chemical are also estimated for incorporation into the 2-D model.
- Steady state estimations of NOx and HOx dependence on O3 chemistry confirm a NOx mixing ratio critical threshold of 0.03 ppbv, above which O3 is consumed and below which O3 is produced.
- The 2-D model incorporated: 18 latitude points from 85°N to 85°S, with 10° latitudinal resolution; 34 pressure levels from ground to ~61 km, 72 chemical species, 126 gas-phase reactions and 52 photolytic reactions.
    - Model parameterized for temperature based on weighted averages of mean polar temperature data; particle number densities held constant
- 2 integrations of 2-D model per emission scenario (1991 and 2015): one reference integration and one aircraft emissions based integration.
- Tropospheric winter O3 levels increased by ~3% in the 1991 scenario but had to be adjusted for convection-related summer overestimation.

Stratospheric change in water vapor and PST surface area in this iteration was negligible.

- Stratospheric O_3 decreased by ~3% in the 2015 scenario (lower polar stratosphere) and a ~1.5% O_3 column decrease is predicted.
- Authors suggest that given the threshold mixing ratio value and the emissions caused range around that value, a 3-D model is better suited for further study.

Heland, J. and K. Schafer, 1998. "Determination of Major Combustion Products in Aircraft Exhausts by FTIR Emission Spectroscopy," Atmospheric Environment, 32(18): 3067-3072.

- FTIR (Fourier Transform Infrared) ground-based measurements were taken for major combustion products CO_2, H_2O, CO, NO and N_2O for a series of civil and military aircraft with differing bypass ratios, nozzle diameters, maximum thrusts and usages. Only those results that are directly comparable with existing literature are presented and discussed.

- Measurements were made on in service aircraft from 20-40 m to the nozzle exit, perpendicular to exhaust flow. Instrumentation was set to 0.2 cm^{-1} spectral resolution with integration times of 2 minutes.

  - Tests were performed during run-up, so periods of constant power settings only lasted about 15 minutes.
- Emissions indices were normalized to the amount of CO2 emitted during combustion of JP-5 fuel.

- Two military bypass engines of the same type, one test rig mounted and the other on an airplane, were tested at distance of 7.2 and 10.5m respectively.
  - H2O mixing ratios were higher than CO ratios
  - CO ratios decreased rapidly at higher engine powers
  - NO mixing ratios increased with increasing thrust
  - CO and NO EI between 45 and 75% power settings show ~25% difference between the two engines, and is attributed to differences in the degree of maintenance and engine age

- A Boeing-737 CFM46-3B engine (measured at 60cm from the nozzle exit) returned a CO EI 27% higher than Spicer et al (1994) values and up to 48% lower than ICAO published data.
  - Attributed to individually adjusted fuel to air ratios, definition of idle thrust levels between engines, and differing degrees of maintenance between all studies

- An Lufthansa Airbus A340 CFM56-5C2 engine tested (25m from nozzle exit) returned CO EI comparable to that published by ICAO and a N2O EI within previously reported ranges for associated conventional combustion processes.
- Study suggests that current emissions estimates are based on data that is not representative of the entire range of exhaust compositions,

because in-service engines of differing ages and service/maintenance profiles are not routinely tested.

Henry, R.C. and C. Spiegelman, 1997. "Reported Emissions of Volatile Organic Compounds are not Consistent with Observations," Proceedings of the National Academy of Sciences, 94: 6596-6599.

- Automated Gas Chromatography (GC) hourly measurements for 54 VOC's and TNMOC were taken during a six month period in 1993 and applied to SAFER (Source Apportionment by Factors with Explicit Restrictions) model to estimate source apportionment and source contributions for TNMOC.
- Three of the SAFER industrial categories (comprising 37% of model total apportionment) showed good statistical correlation with the receptor model results of this study.
- Results compared against emissions inventory from Texas Natural Resource Conservation Commission.
- Vehicle emissions were subtracted from TNMOC based on the establishment of an acetylene tracer, accounting for a percentage abundance of ~5.4 percent of total emissions.
- Highest TNMOC concentrations associated with east and southeastern prevailing wind directions.
- Of the three SAFER industrial categories listed above, only one chemical plant emissions data showed good agreement with this study's receptor model results. A vast majority of source and concentration data are either absent from the measurements collected in this study, or do not agree with the sourcing based on the derived wind directions.
- The authors claim that based on their model, regulatory agencies may be making inaccurate predictions based on their computer modeling and emissions inventory procedures.

Herndon, S.C., T. B. Onasch, B.P. Frank, L.C. Marr, J. T. Jayne, M.R. Canagaratna, J. Grygas, T. Lanni, B.E. Anderson, D. Worsnop and R.C Miake-Lye, 2005.

"Particulate Emissions from In-Use Commercial Aircraft," Aerosol Science and Technology 39: 799-809.

- 100 exhaust plumes from in-use commercial aircraft sampled and measured to calculate number based PM EI:
    - 31 take-off and 24 idle at JFK in 2001; 14 take-off, 13 idle, 16 taxi acceleration/approach at Logan in 2003
    - Sampled naturally diluted ambient air downwind from aircraft within two minutes of crossing engine exit plane, within 200m of active runway (although in Logan study the laboratory was moved twice).
    - JFK measurements taken using Electrical Low Pressure Impactor (ELPI); Logan measurements conducted using Diffusion Charger (DC), Photoelectric Aerosol Sampler (PAS), Condensation Particle Counter (CPC)
- EI calculated based on emission ratio of PM particle number or active surface area concentration to emitted CO2 concentration , assumed CO2 EI of 3160 g/kg fuel and the molar masses of air and CO2
- For ELPI, measurements were background corrected by subtraction of excess CO2 and normalized to a CO2 size distribution. At Logan, the number based emission ratios were derived by a correlation of CPC and CO2 measurements.
- JFK ELPI data shows a 90nm particle mode in all plumes, with a weaker 30nm mode expressed in many of the idle plumes.

  - Agreement with previous values of 60 to 80nm , although the ground-based measurements exceed those reported at altitude in the literature
  - Average EI is highly variable, but is much larger during idle than take-off

- Ratio of PAS/DC EI characterizes different types of combustion particles:
  - 1:1 ratio characterizes take-off plume particles that are EC (elemental carbon) based, most likely PAH
  - Low ratio characterizes idle plume particles dominated by condensable organic or inorganic species
- Logan CPC data compared against PAS/DC data shows that exhaust aerosols at idle are characterized by a small size mode and are composed of inorganics or black carbon coated with condensable material.
- Variability in general, and especially in terms of idle measurements, attributed to differences in engine condition, state and accordingly fuel consumption

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Herndon, S.C., Rogers, T., Dunlea, E.J., Jayne, J.T., Miake-Lye, R., and B. Knighton, 2006. “Hydrocarbon Emissions from In-Use Commercial Aircraft during Airport Operations," Environmental Sciences and Technology, 40 (14):

4406-4413.

- During May 2003, <50 ambient air diluted exhaust plumes at Logan Airport in Boston were measured in idle, taxi, landing/approach, takeoff and engine start modes
    - Mobile platform used to sample air and determine pollution ratios relative to CO2
    - Tunable infrared laser differential absorption spectroscopy (TILDAS) employed to measure formaldehyde and NO2, CO2 measured using Nondispersive Infrared Absorption device, NOy (reactive nitrogen species including HONO, HNO3, PAN converted to NO by molybdenum catalyst) measured, and the following HCs were measured by Proton-Transfer Reaction Mass Spectrometer:
        - Methanol, acetaldehyde, acetone, benzene (including C2 and C3 benzenes), toluene, butenes/acrolein (under same mass # designation), acetone/propenal/glyoxal (also under same mass # designation)
- Time series data over a 7 minute period, displaying a taxiing B737 exhaust plume, takeoff plume, and an idling regional jet plume shows:
        - Takeoff plume displayed largest reactive nitrogen (NOy) to CO2 ratio, implying that the greatest amount of nitrogen is emitted during takeoff
        - Idle plume enriched in HC such as formaldehyde, acetaldehyde, aromatics, butenes/acrolein and acetone/propenal/glyoxal

- Measured NOy emission index for the takeoff plume is 19.5 ± 3.9 g kg-1 fuel, which is in good agreement with the ICAO's CFM56 engine EI range of 17 to 31 g kg-1 fuel
- Idle and taxiway acceleration exhaust contains higher concentrations of HC than landing and takeoff exhaust
- The methane corrected HC EI from this study for idle plumes is 2.9 g kg-1 fuel; the 25-75th percentile of ICAO's unburned HC EI ranges from 3.8-5.1 g kg-1 fuel
- When normalized to formaldehyde, a ubiquitous carbonyl in aircraft exhaust, the range of EI for all measured HCs range from 0.6 (toluene/HCHO) to 0.26 (acetaldehyde/HCHO), in good agreement with Spicer et al 1994 results for the CFM56 engine data

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Herndon, S.C., Jayne, J.T., Lobo, P., Onasch, T.B., Fleming, G., Hagen, D.E., Whitefield, P.D., and R.C. Miake-Lye, 2008. "Commercial Aircraft Engine Emissions Characterization of In-Use Aircraft at Hartsfield-Jackson Atlanta

International Airport," Environmental Sciences and Technology, 42(6):

1877-1883.

- Measurement s conducted at Hartsfield-Jackson Atlanta International Airport in September 2004, cataloging aircraft emissions of CO, CO2, NO, NO2 and HCHO based on standard LTO operations, for comparison against ICAO published databank emissions data
- Mobile laboratories stationed 366m from active runways (between 9L and 9R), and 105m from runway 27R, included instruments:
  - Nondispersive infrared absorption – CO2 measurements
  - Tunable infrared differential absorption spectroscopy (TILDAS) – NO2, NO, CO and HCHO measurements
  - Condensation Particle Counter – PM number concentration
  - Multi-angle absorption photometer – Black Carbon measurements
  - Mass Spectrometer – Aerosol characterization
  - Particulate spectrometer – PM size distribution
  - Differential Mobility Analyzer – aerosol size distribution
- Soot mode particle size between 60 and 80 nm observed
- Particle mass loading inversely related to particle number loading
- CO and NOx at idle
  - CO emissions index exceeds ICAO predictions by 50%; ranging from 17.6 to 39.2 g kg-1
  - NOx emission index 15% lower than ICAO prediction
- ICAO overestimates NOx emissions by ~18% at takeoff, attributable to reduced thrust practices
- HCHO emissions comparable to ICAO predictions
- Idle plumes > takeoff plumes for particle number emissions indices

- BC emissions index greater at higher power settings, and greater than that previously determined for CFM56 engines
- HCHO and CO emissions order of magnitude larger at idle than at takeoff

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Hoffnagle, G.F., Cooper, J.A., Morris, S., 1997. Soot deposition study: Logan Airport and surrounding communities. Report No. TRC Project No. 20505. Prepared for MASSPORT, Logan International Airport, East Boston, MA, by TRC Environmental Corporation, Windsor, CT.

- Particle deposition sampling program and source apportionment study to evaluate atmospheric fallout of trace metals in the vicinity of the airport and in adjoining neighborhoods.
- Collected atmospheric fallout in Petri dishes at nine sites both on and off the airport over a several week period.

- Sampling sites included ends-of-runways and nearby residential

  neighborhoods.
- Tested for the following compounds:
- Sulfur, chlorine, calcium, tin, chromium, manganese, iron, nickel, copper, zinc, lead and selenium.
- Also used chemical profiles for jet engine exhaust, motor vehicle brake and tire ware and marine aerosols for chemical fingerprinting.
- Many variables, primarily meteorological, make the direct correlation between source emissions and ambient concentrations very difficult.
- Concludes that soil and/or road dust represents about 92% of the collected deposition with marine aerosols representing 2.3 % and the airport less than 1% in the neighboring communities.

Illinois Environmental Protection Agency (IEPA), 2002, *Chicago O'Hare Airport Air Toxic Monitoring Program, June-December,* Final Report, Bureau of Air.

- This air monitoring program was designed and conducted to determine if the emissions associated with O'Hare airport have a measurable impact on air quality in areas adjacent to the airport. Conducted as part of the *National Integrated Urban Air Toxics Strategy* ("National Strategy") under the Federal CAA, the study involved:

  - Sampling on 16 days over six month period (June – December, 2000); 5 days with upwind and 5 with downwind conditions.
  - Two sites near O'Hare in Bensenville and Schiller Park (one upwind and one downwind, plus two in industrialized area of Chicago) with a focus on Urban Air Toxic compounds and HAPs.
  - Average levels at O'Hare were comparable with levels at other Chicago sites.
  - While downwind concentrations were higher, the levels are still in the "typical urban" range and lower than levels found in other large urban areas.

Johnson, M.P., Hilton, M., Waterman, D.R., and J.D. Black, 2003. "Development of Techniques to Characterize Particulates Emitted from Gas Turbine Exhausts,"

Measurement Science and Technology, 14: 1146-1150.

- Phoenix 30.3 gas turbine engine powered with jet kerosene and 5% 2-stroke oil was tested under idle to take-off settings
  - Smaller exit nozzle diameter than commercial or military aircraft, but operates in a similar fashion. Combustor pressure of 3 bar can be reached in comparison to the 40 bar pressure attainable for civil aircraft
  - SMPS (scanning mobility particle sizer) used to measure PM from 10 to 1000 nm, counted using condensation particle counter (CPC)
  - After in situ heating of soot particles from the exhaust plume, particles were irradiated with an infrared laser and measured for visible light re-radiation using laser induced incandescence technology (LII)
  - Particle structure and morphology assessed using transmission electron microscopy (TEM)

- Compared to commercial aircraft exhaust, the gas turbine engine exhaust had slightly larger particles and number concentrations,

  corresponding to a geometric mean size of 110 nm and 7.6 x 106 cm-3

  number concentration
- TEM showed fractal like agglomerates formed from coagulation of 40nm particles, explained by soot formation
- Engine was most inefficient at idle conditions, displaying a large volume of large particles at the low combustor pressure
- Geometric mean size varies inversely with engine power; number concentration varies directly but to a very small degree
  - Increased engine pressure associated with higher power settings precipitates a fall in particle volume and hence mass
- As dilution ratio increased, geometric mean shifts to smaller diameters (50nm)and the distribution becomes bimodal (peaks at 170 and 40 nm)

Kim, B.M. and R.C. Henry, 2000. "Application of SAFER Model to the Los

Angeles PM10 Data," Atmospheric Environment, 34: 1747-1759

- SAFER (source apportionment by factors with explicit restrictions) model applied to PM10 data collected in 1986 from the South Coast Air Basin (SCAB) to be used in a Chemical Mass Balance (CMB) model.
- CMB is most reliable if source compositions are accurate, but due to source variance based on time, location, raw material and fuel type there is inherent uncertainty in estimating these compositions.
  - CMB is dependent upon the mass fraction of a given species emitted by a given source. Since this relationship varies due to compound transport, evaporation, deposition and chemical transformation, it must be weighted accordingly and hence produces uncertainty in source composition estimates.
- SAFER is a multivariate model that can be applied to ambient data to estimate source compositions, accounting for the above variables.
  - Uses principal components analysis with SMCR (source/message/channel/receiver) distortion assumptions by means of adding explicit and additional physical constraints, in

  - order to remove the presence of unrealistic (< zero) model output
  - Additional physical constraints (APC) applied to SAFER included CO as a tracer for motor vehicle sources and O3 for secondary source tracing. Stoichiometric relationships between compounds vary based on source and area and hence are also applied as APCs.
- Methodology applied to PM10 data from two coastal sites within study area and five inland sites, including LA. Parameters were reduced to two gas species (CO and O3) and 24 elemental species. Sources defined as: roadway (motor vehicle and road dust), secondary (compounds arising from transport and transformation), marine and crustal
- Estimated source contributions agree well with existing profiles, especially in terms of those compounds not applied as APCs in the model.
- Source contributions:
  - Roadway: range from 20 to 34 µg/m-3, 81% organic carbon origination
  - Secondary: range from 17.75 to 31.40 µg/m-3, spatial variability with distance downwind from polluted area, main source of nitrates and sulfates. 32% of sulfates are from the other three (primary source) categories
  - Marine: undetectable to 2.50 µg/m-3, spatial trend—decreases with distance from coast
  - Crustal: range from 4.06 to 8.13 µg/m-3

Kirchstetter, T.W., Singer, B.C., Harley, R.A., Kendall, G.R., and J.M. Hesson, 1999. “Impact of California Reformulated Gasoline on Motor Vehicle Emissions.

2. Volatile Organic Compound Speciation and Reactivity," Environmental Sciences & Technology, 33: 329-336.

- This study sought to test the effect of change-over to reformulated gasoline (RFG) consequent to phase 2 of the California RFG program between summer of 1995 and 1996
- Liquid gasoline speciation accomplished by preparing composite liquid samples of the top five brands of premium and regular gasoline and measuring them by GC-FID (Gas Chromatography-Flame Ionization Detector)
- Sampling site was the middle bore of the Caldecott tunnel in the San Francisco Bay area, for 10 or more days each summer for the years 1994-1997. Measurements were preferentially conducted during times of high traffic volume.
- Fleet composition visually recorded by traffic counts and license plate cross referencing, average and instantaneous speeds recorded using instrumented drive-through methods
  - ~8400 vehicles per 2-h sampling period at average speed of 60 km h-1, mostly light duty vehicles, mostly gasoline powered,

estimated 95% of fleet were originally equipped with catalytic converters

- VOC concentrations measured within ~50 meters of tunnel exit, in clean background air provided by intake fans into the tunnel, which was then background subtracted from the measurements
    - 2 hr canister sampling for HC and MTBE (methyl-tert-butyl ether); carbonyls were measured with aid of ozone scrubber upstream, and collected using DNPH (2,4-dinitrophenylhydrazine) silica cartridges
- Carbonyls extracted with acetonitrile and measured using HPLC
- Changes (in weight %) from 1995 to 1996:
    - Aromatic HCs decreased by 15%
    - Benzene decreased by 2%
    - Alkenes decreased by 3.1% (mostly C5 and C6)
    - Oxygenates experienced offset increase (to alkene decrease) of 10% attributed to addition of MTBE to fuel
    - Isoalkanes also experienced offset 8% increase, mostly comprised by increases of highly branched octanes 2,2,4-trimethylpentane and 2,3,4-trimethylpentane
    - MTBE in headspace vapors increased by 15.3%, alkenes and aromatics decreased
    - Total aromatics, unidentified fractions and benzene decreased in tunnel NMOC emissions decreased as MTBE and its derivative isobutene increased and cycloalkanes/isoalkanes increased
- Linear relationship between mass fractions and NMOC in whole gasoline suggest significant amount of NMOC in tunnel is contributed by unburned gasoline

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KM Chng, 1998, *Charlotte/Douglas International Airport – Soot Deposition Study*, prepared for the City of Charlotte Aviation Department, March.

- The approach to this short-term monitoring program was very similar to the work conducted near Boston Logan and Chicago O'Hare. The results and conclusions were also similar and revealed that jet fuel indicators were not found in the samples collected and that regional emissions of these pollutants are more likely the source, both on and off the airport.

KM Chng, 1999, *Findings Regarding Source Contribution to Soot Deposition, O'Hare International Airport and Surrounding Communities*, prepared for the City of Chicago, December 1999, KM Chng Report No. 991102.

- Air monitoring program conducted in the vicinity of O'Hare on behalf of the City of Chicago and focusing on atmospheric fallout:
  - Six sites (one background) over 30 days (August – September, 1999).
  - Soot and particulate samples collected on 8"X10" glass plates.
  - Compared with Jet-A fuel, gasoline, "swipe" samples from aircraft (B 737) and motor vehicle exhaust & typical urban dust sample form National Institute of Science & Technology (NIST).
  - Analyzed using "advanced chemical fingerprinting" (gas chromatography/mass spectrometry (GC/MS) and a "source ratio analysis" (a.k.a. double-ratio plots) of certain polycyclic aromatic hydrocarbons (PAHs). Source-specific ratios of certain PAHs provide information on the source of the petroleum and combustion products.)
  - Samples collected near O'Hare bore little chemical resemblance to either unburned jet fuel or soot from jet exhaust.

  - Instead they were chemically similar to particles from burning heavy fuels and motor vehicle exhaust and the NIST sample.
  - Concluded that the contamination is from regional background pollution rather than jet fuel or aircraft engine exhaust from aircraft using the airport.

Koutsourakis, N., Bartzis, J.G., Venetsanos, A., and S. Rafailidis, 2006.

"Computation of Pollutant Dispersion during an Airplane Take-Off,"

Environmental Modeling & Software, 21: 486-493.

- Uses ADREA-HF, a three-dimensional unsteady state computational fluid dynamics code, to accomplish modeling of NOx from the plumes of a Boeing 737 (2 CFM56-3C-1 engines) and a Boeing 747 (2 PW4056 engines) during takeoff. The ultimate end of this study is to determine where to place remote optical measurement devices to best capture the highest concentrations of emissions associated with commercial airport takeoffs
  - Take-off lengths for fully loaded planes during standard conditions are assumed to be 2000m for the 737 and 2500m for the 747, with an acceleration of 1.6m/s2 applied to both aircraft. Hence, 737's take off after 50s at a speed of 80m/s and 747's take off after 56s at a speed of 90m/s
  - Also incorporated are engine diameters and mass flows to determine takeoff velocity for both aircraft

        - CFM56-3C-1 engine diameter = 60 inches, mass flow = 322 kg/s, velocity of 147 m/s
        - PW4056 engine diameter = 94 inches, mass flow = 773 kg/s, velocity of 144 m/s
    - Using ICAO emissions indices for NOx, 0.74 x 10-6 kg NOx/kg exhaust and 0.85 x 10-6 kg NOx/kg exhaust are calculated for the 737 and 747 respectively
    - Wind direction from N, E, SE, SW, S and W were simulated for the 737 model, but only E and SE for the 747 model, assuming a free flow velocity of 2.5 m/s at 10m height
- Ideal instrument placement is concluded to be diagonal to the plume at 1m height, and close to the brake release point, based on the following simulation results:
    - Area before brake-release point has highest concentrations of NOx based on model, and concentrations are sustained therein throughout and after takeoff.
    - Jet momentum during takeoff is primary dispersion behind plane, and wind only plays significant role in helping dispersion at directions perpendicular to the plane
    - In cases where the wing jets are spaced far apart, as with the 747, individual jet plumes interfere with one another much less than if they're close together.

Lee, S.H., M.L. Dilosquer, R. Singh and M.J. Rycroft, 1996. "Further Considerations of Engine Emissions from Subsonic Aircraft at Cruise Altitude," Atmospheric Environment, 30(22):3689-3695

- 80% of fuel consumed is in troposphere, 20% in polar stratosphere, subsonic medium to long range flights comprise ~70 percent of this consumption total.
- These atmospheric layers have low temperatures and large residence times for emissions, thereby increasing environmental impact
- Study combines 3 computer models to simulate Boeing 747-400 emissions data on flight-paths from London to Tokyo at cruise altitude:
    - FAST (Flight Analysis of Subsonic Transports) calculates aircraft fuel weight, time spent in phase and range flown during climb, cruise, descent and reverse phases
    - TURBOMATCH engine simulation uses Mach number, altitude, fuel flow inputs to calculate net thrust and specific fuel consumption per phase
    - APPEM (Analysis and Prediction for Pollutant Emissions) models combustion parameters based on thermodynamic condition inputs, runs multiple iterations combined with engine simulation to calculate EI and total emissions (Unburned HC, CO and NOx).
- 8 Scenarios modeled, characterized using four different Mach numbers (0.75 – 0.88), as well as steady (10.5 km) and increasing (9.8 – 12.1 km) cruise altitudes
- CO and unburned HC emissions decreased with increasing Mach number; NOx emissions increased with increasing combustor outlet temperatures and increasing Mach numbers.
- Scenarios modeled with increasing cruise altitudes (9.8 – 12.1 km) showed reduction in CO and UHC emissions, while NOx emissions increased due to the effect of the combustion outlet temperature
- Authors suggest optimum cruise profile occurs at Mach number 0.85 and increasing rather than steady altitude

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Lobo, P., Whitefield, P., Hagen, D., Trueblood, M., Mundis, N., Magdits, I., Herndon, S., Onasch, T., Jayne, J., Miake-Lye, R., Eberhard, W., and R. Wayson, 2008. "Delta-Atlanta Hartsfield (UNA-UNA) Study". Report No. PARTNER-COE-2008-001

- Aircraft exhaust plumes were probe sampled at the exhaust nozzle exit and within the plume close to the nozzle exit, and analyzed using ultraviolet remote sensing and aerosol mass spectrometer for:
    - Particulate matter size distribution, number density, mass fraction, total concentration

        - Number based geometric mean diameter, mass based geometric mean diameter, number based emissions index, mass based emissions index were calculated
        - 4 commercial airline airframes and engines commonly in use at Hartsfield Jackson-Atlanta international airport were tested throughout LTO thrust settings and additional intermediate settings
    - Number based geometric mean diameter of particles increases with engine power setting and ranges from 20 to 40 nanometers.
    - Mass based geometric mean diameter is lowest at 30% engine power and highest at the lowest and highest engine power settings. Number based emissions index displays the same trend, although highest at increasing power. Mass based emissions index also displays the same trend, but increases rapidly with increasing power
    - Most engines displayed the 40-80 nanometer soot mode and variable black carbon emissions indices
    - Overall, increasing emissions with increasing engine power. Comparison of monotypic aircraft displayed less difference in emissions than comparison of different types of aircraft
    - General conclusions:
        - Extensive secondary volatile aerosol formation occurs during plume advection
        - Black carbon component is strongly related to engine model
        - Number based EI: $3 \times 10^{16} - 2 \times 10^{17}$ particles/kg fuel
        - Mass based EI: 0.1 – 0.35 g/kg fuel

Lobo, P., Whitefield, P., Hagen, D., Herndon, S., Jayne, J., Wood, E., Knighton, B., Northway, M., Miake-Lye, R., Cocker, D., Sawant, A., Agrawal, H. and J.W. Miller, 2007. "The Development of Exhaust Speciation Profiles for Commercial Jet Engines". Prepared for the California Air Resources Board (CARB) and the California Environmental Protection Agency (CalEPA), Contract No. 04-344

- As a part of the APEX 2 study in 2005 at Oakland International Airport, B737 aircraft with CFM-56 engines burning Jet A fuel were tested to develop TOG and PM speciation profiles
    - Emissions of CO, CO_2, NO_x, PM mass, speciated PM and hydrocarbons sampled at six thrust settings: 4%, 7%, 30%, 40%, 65% and 85% power. Measurements were taken from both engines during run-up at the ground run-up enclosure.

  - Plumes were sampled at 1m, 3m and 50m downwind of the exit plane on the starboard side of the craft, and 1m downwind on the port side.
  - PM size distributions from 5 nanometers to 1 micrometer were measured and evaluated in terms of: number and mass based geometric mean diameters, total concentrations, mass and number based emissions indices. Aerosol Mass Spectrometry and Multi-Angle Absorption Photometry were employed to measure these variables
  - Gas phase emissions measured using Tunable Infrared Laser Differential Absorption Spectroscopy (TILDAS) and Proton-Transfer Reaction Mass Spectroscopy (PTR-MS) for hydrocarbons
  - Chemiluminescence measurements for NO
  - CO_2 measurements conducted using non-dispersive infrared absorption sensing, and CO_2 used as a standard to calculate emissions indices
  - DNPH cartridges used to qualitatively assess carbonyl and light hydrocarbon content
    - Light hydrocarbons and carbonyls emissions factors could not be calculated due to loss during sampling
  - Size distributions at engine exit plane were lognormal, with direct relationships observed between emissions and engine power
  - Close to exit plane, mean sizes decreased and number based emissions indices increased with increasing engine power
  - HC emissions indices decrease with increasing engine power
  - The three major carbonyls in HC emissions were formaldehyde, acetaldehyde and acetone
- Suggestions for future study:
  - Different engine/airframe pairings
  - Engine operating conditions should be better characterized (e.g. fuel flow rate)
  - On-site and real time analysis
  - Larger sample sizes needed to assess engine variability
  - Better sampling of TOG/VOC for more specific speciated emissions indices

Lough, G.C., Schauer, J.J., and D.R. Lawson, 2006. "Day-of-Week Trends in Carbonaceous Aerosol Composition in the Urban Atmosphere," Atmospheric Environment, 40: 4137-4149.

- Daily 24-h samples of PM collected in central LA and Azusa (downwind) during July 2001, composited based on day of week and site (e.g. Monday Azusa samples were composited), to observe weekly variations in concentration and constituency between urban and suburban representative areas
- Collected using PM2.5 cyclones and 90 mm quartz fiber filters, for 24-h duration. Filter punches were extracted for GC analysis, but additional samples were also analyzed for gravimetric mass, ionic species (using ion chromatography) and ionic species (using X-ray fluorescence spectroscopy)
    - Analysis involved EC/OC, nitrate, sulfate, ammonium and metals
- A general trend of increase in PM2.5 from Monday through Friday was observed, decreasing over the weekend to the Sunday minimum, due in majority to the changes in OC concentration

- Sunday-Friday difference in OC concentration was 2.5. and 3.5 µg m-3, for LA and Azusa respectively
- Average daily sulfate concentrations ranged from 3.9 ± 0.06 – 5.1 ± 2.0 µg m-3 in Azusa and 4.4 ± 1.8 µg m-3 – 6.7 ± 1.8 µg m-3 in LA.
    - Nitrates: 0.54 ± 0.18 µg m-3 – 0.82 ± 0.48 µg m-3 in Azusa to 0.26 ± 0.08 µg m-3 – 0.67 ± 0.59 µg m-3 in LA.
    - Ammonium: 1.2 ± 0.5 µg m-3 – 1.8 ± 0.8 µg m-3 in Azusa to 1.2 ± 0.9 µg m-3 – 2.1 ± 0.6 µg m-3 in LA.
- Weekly difference in EC/OC is not meteorologically influenced since there exists no trend in the above secondary compounds, likely attributed to weekly motor vehicle activity patterns
- Average day of week EC concentrations ranged from 0.51 ± 0.14 µg m-3 – 2.09 ± 0.46 µg m-3 in Azusa to 0.41 ± 0.12 µg m-3 – 1.51

± 0.76 µg m-3 in LA, although the data spread make the average not statistically significant between sites
    - EC/OC ratio increases throughout week, showing that day of week trends relate to mobile source activity and concentration of diesel activity during the weekdays
  - Tracer species like hopanes, steranes (up to 2.4 ng m-3)and PAH (0.6 ng m-3) peak during Thursday and Friday, implying a connection to zenith of traffic activity on those days
  - Other tracers such as aliphatic and aromatic diacids (forming secondarily through atmospheric photochemistry) patterns reflect regional photochemical PM formation, and have highest concentrations between Wednesday and Saturday at both sites
    - Volatile precursor species accumulate throughout the week when traffic is heavy and secondary photochemical compounds subsequently develop on weekends when traffic is light
- Metals in ambient PM show some weak trends in Azusa more than LA, and are attributed to crustal or geogenic sources due to associated industry (such as cement production) in Azusa.

Lu, R., Wu, J., Turco, R.P., Winer, A.M., Atkinson, R., Arey, J., Paulson, S.E., Lurmann, F.W., Miguel, and A.E. Fernandez, 2005. “Naphthalene Distributions and Human Exposure in Southern California,” Atmospheric Environment, 39: 489-507.

- Uses SMOG (Surface Meteorology and Ozone Generation) and REHEX (Regional Human Exposure) models to assess NAPH concentrations in South Coast Air Basin during 2003, in order to:

- Simulate concentrations, distribution patterns and seasonal/diurnal variations of NAPH and its atmospherically derived products (naphthoquinones), based on documented measurements by Southern California Particle Center and Supersite Children's Health Study (CHS), as well as those reported from USC/UCR.
    - SMOG incorporates MM5 (mesoscale meteorological model) multiple spatial grid nesting technique (5-45 km horizontal resolution, tropospheric resolution up to 250 hPa) and SCAQMD 1997 emissions inventory
    - Chemical model components focus on hydroxyl decomposition/photochemical NOx of NAPH to naphthoquinones
    - Measurements from the CHS sites agreed well with the model's predicted 5-day averaged concentrations (ranging from 109 ng m-3 at Riverside to 158 ng m-3 at San Dimas in the summer, and 181 ng m-3 at Long Beach to 314 ng m-3 at Upland in the winter)
    - Measurements strongly influenced by local emissions sources and prevailing wind patterns, local plumes not resolved due to coarse resolution (5km grid)
    - Peak NAPH emissions correspond to areas of highest vehicle emissions, i.e. along transportation corridors
    - Naphthoquinones concentrated inland along mountain slopes

    - Large NAPH gradients occur along coast owing to wind patterns
    - Winter concentrations exceed summer concentrations
    - Boundary layer mixing relegates highest concentrations to early morning and nighttime

  - Model-derived emissions inventory for the area using existing SCAQMD data, speciated with CARB's profiles for point, area on and off-road sources. On-road emissions estimated with CARB's EMFAC 2002 emissions factors
    - Grid resolution was 5km2
    - 745 kg day-1 attributed to gasoline evaporation and engine exhaust – 44% of emission total. Diesel exhaust contributes ~9% of total. Total emissions approximate 1700 kg day-1
    - NAPH to benzene ratios calculated to confirm emissions factors for NAPH
    - Canister/XAD-PUF sampled for benzene and NAPH at south exit of Sepulveda tunnel near LAX, at 1-h intervals. Analyzed using HPLC and GC.
    - Modeled NAPH:Benzene ratios were in good agreement with existing emissions inventories
- REHEX model defined using following attributes:

  - 24-h time activity patterns from Consolidated Human Activity Database
  - 2000 Census data, allocated using ARCGIS into street-segmented population distributions
  - Ambient NAPH concentrations from SMOG model
  - Measured ratio of Indoor to Outdoor NAPH concentrations and assumed in-vehicle to ambient NAPH concentrations
- REHEX estimated that mean hourly exposures exceed population-weighted outdoor concentrations by 80%
  - Indoor sources and in-vehicle concentrations accounted for up to 44% of total exposure
  - NAPH exposures are estimated to be up to 2000 ng m-3 for one or more hours for winter and summer, but the amount of people exposed to this threshold is much higher in winter owing to the higher ambient concentrations

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Massport, 2007, Logan International Airport Air Quality Monitoring Study Final Air Quality Work Plan, September, 2007.

- As part of the Massachusetts Environmental Policy Act (MEPA) Certificate on the *Final Environmental Impact Report* (EIR) for the Logan

Airside Improvements Project (LAIP*)*, the purpose of the study is to monitor air quality conditions (with a focus on "air toxics") under the flight paths and in the neighborhood surrounding Logan Airport before and after the new Centerfield Taxiway is in place.

- The study will be completed by the Massachusetts Port Authority (Massport); the owners and operators of Logan, under consultation with the Massachusetts Departments of Public Health (DPH) and Environmental Protection (DEP). The primary components of the Work Plan comprise the following:
- For this analysis, the establishment of "primary" sites in select areas of particular interest coupled with "satellite" sites located nearby enables the collection of appropriate data in a more cost-effective manner and over a wider study area. The target compounds for this study are specifically selected as they represent the primary forms of combustion products or evaporative emissions from airport related sources, and include.
    - Volatile Organic Compounds (VOCs);
    - Carbonyls; and
    - Semi-volatile Organic Compounds (SVOCs) / Polycyclic Aromatic Hydrocarbons (PAHs)
- Although not classifiable as HAPs, particulate matter (PM) and soot (as black carbon) serve as indicators (or "surrogates") to the presence of fuel combustion products and are also included as target compounds for this study.
- The study will take place over the next five years and over two distinct phases: a 12-month baseline period and a 12-month follow-up period. Following the completion of the Centerfield Taxiway construction, the follow-up monitoring program will be performed.

Massport, 2007, "Boston-Logan International Airport 2007 Environmental Data Report", prepared for the Massachusetts Port Authority Economic Planning & Development Office, prepared by VHB.

- This document is filed annually with the Massachusetts Office of Energy and Environmental Affairs and contains the summary statistics of the on-going NO_2 monitoring program at Logan Airport. This program has been in place since 1982 and involves the collection of NO_2 data on the airport and in adjoining neighborhoods. The samples are collected using passive diffusion tubes over a one week period, every month of the year. The results are expressed as annual averages, provide comparisons to historic trends as well as the results from nearby stations operated by the Department of Environmental Protection.

McGulley, Frick and Gilman, January, 1995, *Final Report: Air Quality Survey*,

Seattle-Tacoma International Airport, Port of Seattle

- Air monitoring study of carbon monoxide (CO) and select volatile

  organic compounds (VOCs) around Sea-Tac International Airport

  conducted on behalf of the Port of Seattle in 1993. Samples were collected both on and off the airport site and under differing airport operational and meteorological conditions. The CO levels were within air quality standards and the VOCs were within the ranges expected in urban areas. Other details included:

- Sampled VOC/TAPs using EPA-approved methods in and around the

  AOA. (A remote sensing infrared spectrometer was also used but did not provide quantitative data.)

  - Benzene detected in every sample and freon, toluene, ethylbenzene, xylene, and 1,2,4-trimethylbenzene were found in all but a few samples.
  - Ethyl alcohol (ethanol), acetone, isopropyl alcohol, butane, isopentane, and pentane were found in almost every sample. MEK, MIBK, hexane, and benzaldehyde occurred less frequently.
  - Ratios of several key VOCs were indicative of automobile exhaust and did not resemble the VOC profiles associated with aircraft emissions.

Minnesota Pollution Control Agency, 2006, "Update on Air Monitoring Near the Minneapolis St. Paul International Airport."

- Conducted in the summer of 2005 by the Minnesota Pollution Control Agency (MPCA), this six-month study involved the collection and analysis of PM2.5 and HAPs (e.g., VOCs, carbonyls and metals) at two on- and two off-site locations, including a school. The report includes a good statistical treatment and presentation of the data which is also included in the Appendices in tabular form.
- The findings indicated that formaldehyde was the only compound that occurred over health benchmarks, but these levels did not differ significantly from other locations in the Minneapolis/St. Paul area. It was also speculated that the elevated levels may be associated with a school remodeling project at one of the sampling sites. The levels of PM2.5 and the other VOCs were also comparable to conditions elsewhere and were well within federal and state guidelines.

O'Brien, R. J. and M.D. Wade. "Air Emission Inventory Guidance Document for Mobile Sources at Air Force Base Installations", Air Force Institute for

Environmental, Safety and Occupational and Environmental Health Risk Analysis Directorate, Brooks Air Force Base, prepared by Karta Technologies, Inc., January 2002.

- This document serves as a guidance document for the preparation of mobile source air emission inventories at Air Force installations.
- The report provides methodologies and emission factor for calculating criteria and HAP emissions from the most common types of mobile sources such as ground support equipment, aircraft, on-road vehicles, and nonroad equipment.

O'Brien, R.J. et al., "Air Emission Inventory Guidance Document for Stationary Sources at Air Force Base Installations", Occupational and Environmental Health Directorate, Brooks Air Force Base, prepared by Karta Technologies, Inc., August 21, 1998.

- The purpose of this document is to provide a uniform approach to estimate pollutant emissions from the most common types of stationary sources found at Air Force installations. The document details methodologies for calculating criteria pollutant and HAP emissions from these processes.
- A sample of the emission sources included in the document are abrasive blasting, aircraft engine testing, asphalt paving operations, fire fighter training, fuel transfer, landfills, solvent cleaning machines, internal combustion engines, surface coating, and welding.

Pehrson, J., R. Diaz, W. Guo and V. Tino, 2001?, Comparison of Modeled to Monitored Air Pollutant Concentrations at a U.S. Airport. Air and Waste

Management Association Meeting Session AS-1c (A) – Abstract 157.

- Study compares real-time monitored hourly concentrations of NO, NOx, NO2, SO2 and PM10 taken 600m downwind of the take-off runway at an undisclosed U.S. airport with modeled emissions derived using the Emissions Dispersion Modeling System (EDMS).
- Aircraft departure information was used only when there was little variation from the prevailing wind direction, since that runway was oriented parallel.
- Ground support equipment not factored in model
- Default aircraft times in mode were used in EDMS during simulation
- Simulation conducted hourly for 68 hours and background corrected
- Monitored-to modeled concentrations were in general good agreement, although poorly spatiotemporally correlated.
  - Limitations arose from
    - lack of ability to input taxi and queue directions as well as queue length as parameters in EDMS
    - inability to account for atmospheric variability

Petzold, A., and F.P. Schroder, 1998. "Jet Engine Exhaust Aerosol Characterization," Aerosol Sciences and Technology, 28: 62-76.

- Rolls Royce/SNECMA M45H Mk501 turbofan engine operated at 11, 30 and 66% power fueled with sulfur free fuel, and at 11, 20, 30 and 71% power fueled with high sulfur fuel (3000 ppm by addition of dibutylsulfide)
- Sampled by line at a distance of 1.5m behind engine exhaust exit nozzle, yielding plume ages between 5 and 15 ms depending on power setting. Sampling time was between 1 and 5 minutes depending on power setting

- BC mass collected on glass fiber filter and solvent extracted (toluene/2-propanol) and heated under nitrogen. BC that was volatilized during the process was measured as CO2
    - Optical analysis of particles performed using aethalometer and reflectometer
    - Particle size distributions recorded using optical spectrometers and condensation particle counter
- SO42-, SO2 and H2SO4 collected and measured using ion chromatography
- Losses from sample line observed and characterized:
    - SO2 and aerosols with particle diameters less than 0.02 µm were lost during sample transmission
    - Gaseous H2SO4 lost almost completely, so SO42- mass concentrations should be considered an upper limit for true concentrations
- BC formation is independent of fuel sulfur content
    - Ratio BC to TC is greatly influenced by combustion, and varies directly with power setting
    - BC to TC ratio varies inversely with fuel to air ratio
- Rate of SO2 conversion to H2O4 independent of power setting
    - Ratio of SO42- to SO2 varies only slightly with power setting, while ratio of SO42- to BC varies inversely with power
- Relationship between EI of BC and power setting is nearly linear, and is not influenced by fuel sulfur content

  - EI of TC varies little with engine power, and particulate sulfate EI is completely independent of power setting

- Particle size distributions are lognormal at idle and bimodal at take-off thrust.
  - Second larger mode at take-off thrust is attributed to soot coagulation
- BC mass concentrations are 0.25-0.28 mg m-3 at idle and 5.4-5.6 mg m-3 at takeoff; at maximum power 63% of total mass of BC shifts to larger particle mode
- EI BC is 4 x 1014 kg-1 at idle and 1.7 x1015 kg-1 at take-off

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Pison, I., and L. Menut, 2004. "Quantification of the Impact of Aircraft Traffic Emissions on Tropospheric Ozone over Paris Area," Atmospheric Environment, 38: 971-983.

- Chemical Transport Models (CTMs) are useful for modeling the concentrations of surface level pollutants such as ozone, but meteorological factors and the complexity of pollutant interaction lead to uncertainty in model estimation.
  - Study constructs an emissions inventory of aircraft emissions from three airports within 30km of the Paris city center, based

on August, 1998 emissions of NO, NO2, CO, SO2, CH4 and 10 non-methane VOCs

    - Le Bourget national airport, Roissy-Charles-de-Gaulle and Orly International Airports
    - Total mass of VOC, CO, NOx, CO2 and SO2 partitioned by LTO cycles: approach, climb-out, idle/taxi and take-off
    - Total emissions input data temporally de-aggregated and speciated, averaged based on three typical days of each calendar month, hourly variations and spatial activity variations, using monthly, daily and hourly activity data from the two international airports
- Uses CHIMERE model, CTM constructed for simulation of photo-oxidant quantities within the atmospheric boundary layer
    - Model resolution = 25 x 25 km cells in a 150 x 150 km domain representing Paris; five vertical intervals representing altitudes up to 3100m
- Emissions inventory results predict aircraft contribution to emissions in model domain is 15.3% NOx and 2.1% VOC.
    - High VOC to NOx ratio in model signifies VOCs reacting with hydroxyl radical and speeding up O3 production,

    - low ratio signifies NOx reacting with hydroxyls and slowing down O3 formation.
    - Up to 50m altitude, VOCs are highest in morning and at night. Between 50 and 3100m altitude, NOx is highest in the morning and is dominated by VOC throughout the rest of the day
  - Results of model based on input of emissions inventory:
    - Aircraft emissions showed greatest negative impact on O3 in the absence of photochemical activity (i.e. nighttime) at ground level and near-source, while the strongest positive impact was shown during the daytime in rural areas and at altitude.
    - Impact of aircraft NOx emissions exceeds impact of VOC emissions at ground level, except during local pollution events like the one observed on August 7th, 1998.

Port of Los Angeles, 2005. "Port-Wide Baseline Air Emissions Inventory Executive Summary", prepared by Starcrest Consulting Group, LLC http://www.portoflosangeles.org/DOC/REPORT_Final_BAEI_ExecSum.pdf, 24 pp.

- Outlines methodology and results from the 2001 baseline air emissions inventory (NO_x, CO, $PM_{2.5}$, PM_{10}, SO_2 and TOG) for in-port and regional (South Coast Air Basin wide totals involving transport of port-related freight) contributions from the following source categories:
  - Ocean-going vessels – auto carriers, bulk carriers, containerships, cruise ships, general cargo ships, ocean-going tugboats, refrigerated vessels, roll-on-and-off ships, bulk liquid tankers
    - Consulted local, national and international activity data sources and previous emissions inventories to estimate emissions
    - Implemented a Vessel Boarding Program that allowed confirmation of vessel fleet composition, characteristics and operational data
  - Harbor craft – assist tugboats, towboats, push boats, ferries, excursion vessels, crew boats, work boats, government vessels,

dredges and support, commercial fishing and recreational vessels
    - Operational data obtained via craft operator and marina manager interviews
  - Cargo handling equipment
    - Emissions estimates derived using CARB's OFFROAD model, supplemented by activity data obtained by operator and manager interview
  - Railroad locomotives – line haul and switching operations
    - Switching operation emissions estimates were based on time spend in throttle notch settings
      - on-board observations of shift operations and dataloggers
    - Line haul operations used surrogate fuel usage data to derive emissions estimates
  - Heavy-duty vehicles – on-road and on-terminal operations
    - On-road activity data developed by trip generation and travel demand models
    - On-terminal activity data obtained by observation and interview
    - Emissions factors calculated using EMFAC 2002
- Regional contributions in tons per year/day show:
  - Ocean-going vessels are the most significant sources of NO_x (36%), PM_{10} (56%) $PM_{2.5}$ (53%) and SO_2 (86%)
  - Harbor craft contribute most to TOG (34%) and CO (41%) emissions
  - Heavy duty vehicles also contribute significantly to NO_x concentrations (23%)

Rhode Island Airport Corporation, 2007, "Air Quality Monitoring Work Plan, Prepared in Support of the State of Rhode Island Permanent Air Quality Monitoring Act", October 29, 2007.

- Under Section 1-7-1 of the State of Rhode Island General Law (*The Permanent Air Quality Monitoring Act*), the Rhode Island Airport

Corporation (RIAC) implemented a long-term air quality monitoring program in the vicinity of T.F. Green Airport in Warwick. The following is a summary description of the program

- The monitoring program involves the monitoring of ambient levels of particulate matter (PM) - including PM2.5, PM0.1 and black carbon; volatile organic compounds (VOCs) - including benzene and 1,3 butadiene; semi-volatile organic compounds - including naphthalene; carbonyls - including formaldehyde and acetaldehyde; and polycyclic aromatic hydrocarbons (PAHs) - including those that are bound to PM.
- Monitoring is conducted four stations located in residential areas north (*Lydick Ave.*), south (*Fieldview Dr.*), east (*Pembroke Ave.*) and west (*Fire Station No. 8*) of the airport. When taken together and based on annual meteorological conditions, these sites are situated downwind, upwind and cross-wind to the airport. "Background" conditions will be determined from data collected by the Rhode Island Department of Environmental Management (RI DEM) at sites loca
- The program began in early 2008 and is expected to run for 15 years. The results are to be reported upon annually beginning in late 2008.

Rhode Island Department of Environmental Management, 2008, "Ambient Air Toxics in Neighborhoods Abutting T.F. Green Airport and Comparison Sites", Final Report, April, 2008.

- Conducted by the Rhode Island Department of Environmental Management (RIDEM) at four locations (three in neighborhoods adjoining the airport and one "background" site), the objectives of this 16-month program were as follows:
  - Characterize ambient air toxics in neighborhoods around the airport,
  - Compare the results to other areas in the state,
  - Establish a baseline of air monitoring data that can be used to evaluate the effects of changes at the airport, and
  - Identify future monitoring needs and provide additional recommendations.
- The results of this program concluded the following:
  - Levels of PM2.5 and HAPs are within standards or short-term benchmarks.
  - Levels of HAPs exceed long-term benchmarks but do not differ from other locations statewide.
  - Slightly elevated BC and formaldehyde levels occur downwind from airport.

Ristovski, Z.D., L. Morawska, N.D. Bofinger, and J. Hitchins, 1998. "Submicrometer and Supermicrometer Particulate Emission from Spark Ignition Vehicles," Environmental Science and Technology, 32(24):3845-3852

- A paucity of PM emissions data exists for gasoline spark ignition engines relative to diesel engines, because emissions from the former are released at much lower rates and levels.
- Exhaust from 11 unleaded gasoline powered vehicles (two makes), 2 LPG powered vehicles and 1 leaded gasoline powered vehicle was analyzed for: Particle Size Distribution, Count Median Diameters (CMD) Number Concentration and Particle Emissions per Kilometer
    - Five test modes applied using chassis dynamometer: steady cycle ASM methodology at 25, 40 and 80 km/hr (modes 1,2 and 3), and idle modes in both drive and neutral (modes 4 and 5)
    - Measurements taken using SMPS (Scanning Mobility Particle Sizer) in the range of 0.015 – 0.7 microns and APS (Aerodynamic Particle Sizer) in the range of 0.5 – 30 microns. The data is reported in terms of SMPS parameters.
- In Mode 2 (40 km/hr), vehicles run on leaded and unleaded gasoline had similar particle size distributions; LPG fueled vehicles tested in this mode possessed a size distribution higher than the other categories
- Count Median Diameter (CMD) measurements showed mode dependency and no clear trend in particle emissions.
- Number concentration data:
    - In the SMPS size range, leaded gasoline vehicles had particle number concentrations more than 200 times higher than the unleaded vehicles, while LPG vehicles had slightly higher number concentrations than unleaded vehicles.
    - Leaded gasoline powered vehicles possessed concentrations one order of magnitude higher than all other classes
    - Number concentration maxima occurred in Mode 2 for unleaded vehicles and Mode 3 for LPG and leaded fueled vehicles
- Total Particle Emissions (SMPS) per kilometer data:
    - Unleaded gas fueled cars with new engines emitted much less than the older unleaded vehicles
    - Unleaded gas vehicles had higher emissions at lower speeds. The reverse was true for LPG vehicles.
    - Submicrometer emissions for LPG were higher than gasoline fueled cars. Significant because LPG is supposed to be a cleaner fuel than unleaded gasoline.

Rodgers, R., E.N. Blumer, M.A. Freitas and A.G. Marshall, 2000. "Complete Compositional Monitoring of the Weathering of Transportation Fuels Based on

Elemental Compositions from Fourier Transform Ion Cyclotron Resonance Mass Spectrometry," Environmental Science and Technology, 34(9):1671-1678

- Hydrocarbon diversity of transportation fuels and transportation methods lead to loss of speciose quantity into surrounding environment.
- Volatilization and washout cause changes (i.e. weathering) in the fuel composition over time.
- GC mass spectrometry lacks mass spectral and chromatographic resolution to identify chemical analytes resulting from such weathering and decomposition processes
- Application of Fourier Transform Ion Cyclotron Resonance Mass Spectrometry (FTICR) to neat samples of diesel, JP-8 and gasoline, as well as to artificially weathered samples
  - Artificial weathering accomplished via controlled evaporative loss of mass; for example 50% weathered diesel fuel is evaporated until 50% of the original weight remains.
- Applicable to airport air quality due to evaporative loss from stationary sources such as storage tanks, as well as from GSE and other on-road equipment
- Relative abundances of species shifts toward higher mass species in all fuel types; the magnitude of the shift corresponds to the amount of evaporative loss in the sample. The magnitude of these shifts can be used to identify unknown hydrocarbon species in weathered fuels or fuel emissions.
- Diesel and JP-8 fuels contain more chemical compounds in both the weathered and unweathered fractions than gasoline, reflecting the greater compositional diversity of these fuels relative to gasoline.

- Distinguishing between geometric isomers of the HC constituency is still not possible via FTICR

Rogers, F., Arnott, P., Zielinska, B., Sagebiel, J., Kelly, K.E., Wagner, D., Lightly, J.S., and A.F. Sarofim, 2005. "Real-Time Measurements of Jet Aircraft Engine Exhaust," Journal of the Air and Waste Management Association, 55:583-593.

- Tests were conducted on jet engine exhaust emissions at North Island Naval Base in San Diego, CA in January and February 2002.
    - Five flightline tests on F404 jet engines installed on two F-18 twin engine aircrafts (65-80% power settings), and one dismounted T700 turboshaft engine tested via dynamometer (67-98% power settings)
    - All engines burned JP-5, 86.9% carbon by weight
    - Photoelectric Aerosol Sensor (PAS) used to measure PAHs: phenanthrene, fluoranthrene, pyrene, benzo(b)naptho(2,1-d)thiophene, benzo(c)phenanthrene,

    benz(a)anthracene, chrysene +tryphenylene, benzo(b+j+k)fluoranthrene, benzo(e/a)pyrene,

    indeno(1,2,3-cd)pyrene, benzo(ghi)perylene,

    dibenzo(ah+ac)anthracene and coronene
  - Photoacoustic Analyzer (PA) measured light absorbing particles such as BB
  - DT Particle Mass Monitor used to measure mass concentration
  - SMPS (Scanning Mobility Particle Sizer) measured particle size distributions
  - Gundel Denuder Sampler used to measure PAH and other VOCs in gas and condensed phases, but only on T700 test
  - Microorifice Uniform Deposit Impactor (MOUDI) recorded

    non-real time PM and carbon measurements, only on T700 test

  - Canister sampling for CO2, CO, CH4
- Engine power settings and measured PM PAH, BC and mass concentration showed a clear and consistent inverse relationship for the F404 engine tests. The T700 test displayed a direct rather than inverse relationship
- Phenanthrene, Fluoranthene and Pyrene were present in the highest concentrations of all the PAHs measured in the T700 test. Total carbon emission factors calculated for this study from T700 engines is 0.24 g/kg fuel
- Changing power settings caused short lived maxima on some of the instruments used in this study

- SMPS size distribution data recorded peak particle size at 20-40 nm

- Light absorbing particles comprised less than 10% of the total particle load for F404 engine, and nearly 100% for the T700 engine

Rogge, W.F., Hildemann, L.M., Mazurek, M.A., and G.R. Cass, 1997. "Sources of Fine Organic Aerosol. 8. Boilers Burning No. 2 Distillate Fuel Oil,"

Environmental Science & Technology, 31: 2731-2737.

- Industrial boiler burning no.2 distillate fuel oil, operating in steady-state at ~60% capacity, was tested for PM emissions
    - Five tests ranging from 185-375 minutes over a period of 3 weeks
        - Results from test # 2 (7.1% excess oxygen) and #5 (5.6% excess oxygen) reported
        - Lower amount of excess oxygen increased EC emissions in test 5
- Collected on quartz and Teflon filters from dilution tunnel sampling system, analyzed using GC-MS (Gas chromatography-Mass Spectrometry)
- PM emission rates dependent upon amount of excess oxygen, fuel batch and operating conditions
- PM mass emission rates ranged from 5-13 µg/kJ fuel burned, with an average of 9.4 ± 1.5 µg/kJ.
- Total emissions = 32% sulfur, 29% EC, 6% each of ammonium and organic matter
    - The portion of organic matter (6% of total) resolved ranged between 29.8 and 31.8%, the identifiable potion of which varied greatly between tests 2 and 5 (62.8 and 31.4% respectively)

- Composition dominated by carboxylic acids, namely n-alkanoic acids, and concentrations were fuel batch dependent
- Highest emissions were from C16 palmitic acid and C18 stearic acid; main portion of acids present had mass equal to or less than stearic acid
- PAH and oxygenated PAH more prominent in test 2 than in test 5 (8.6 v. 3.1%), signaling the influence of fuel batch and operating conditions
- Chrysene/triphenylene (co-eluting on GC) had the highest emission rates
- Chlorinated organics comprise 5.8-16.4% of organic mass emitted
- N-alkanes ranged from C19 to C23, with C21 and C23 most dominant
- Originated directly from fuel n-alkanes or as biproducts from combustive cracking
- Chlorine-substituted aromatics were identified, and correlated to PAH formation, since PAH and Chlorinated compounds were always found in high concentrations in conjunction with one another

    - Polycyclic Aromatic Ketones/Quinones (Anthraquinone and 2-methylfluoren-9-one were more abundant) present in emissions
    - Exhaust aerosol contained a significant amount of the hopane compound 17α,18α,21β(H)-28,30-bisnorhopane

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South Coast Air Quality Management District, 2000a, *Air Monitoring Study in the Area of Los Angeles International Airport, Part I.*

- Air monitoring study of VOCs and PM conducted in the vicinity of LAX in response to concerns of residents pertaining to aircraft emissions and airport expansion.
    - Conducted over three days in September 1999 at 7 sites near the airport.
    - Not possible to characterize or differentiate the VOC contribution from either the airport or the major arterials.
    - VOCs collected near major arterials were similar concentrations as those collected in the basin during the MATES II study.
    - Key contaminants detected were benzene, butadiene, and elemental carbon.
    - All key contaminants were lower at residential sites than at Aviation and Felton School sites.
    - Fallout samples depict greater abundance of larger than PM10 sized combusted oil soot particles than other Basin locations.
    - Higher elemental carbon at the LAX Aviation Blvd. site is suggestive of an influence from airport operations, though it cannot be determined whether it is from aircraft or trucks servicing the airport, or both.
    - Combusted oil soot particles were generally greater than 50 microns in size, suggest aircraft as the source of these larger soot particles.
    - Most chlorinated VOCs were not found at levels above method detection limits (0.1 ppbv). The levels of hydrocarbons found were generally lower than the levels detected in the MATES II program. The only chlorinated hydrocarbon species consistently

  - detected were perchlororthylene, methylene chloride and chloromethane. Perchlororthylene is associated with dry cleaning and the other two compounds with parts cleaning.
  - Limited number of samples taken and are not appropriate to do a risk assessment.

South Coast Air Quality Management District, 2000b, *Air Monitoring Study at Los Angeles International Airport Terminals*, Part II.

Companion to Part I study (and initial 1998 study), focusing on the LAX main terminal area. Conducted during November, 1999 in the passenger loading and unloading areas.

  - Sampling occurred one week prior to and during the Thanksgiving Day week: one of the busiest weeks at LAX and typical period of stagnant atmosphere.
  - Most chlorinated VOCs were not found at levels above the method detection limits (usually 0.1 ppb).
  - Halocarbons generally lower than the levels detected in the MATES II study.
  - Above average concentrations for benzene and 1,3-butadiene as compared to basin wide averages.
  - Key pollutants detected were carbon monoxide, benzene, 1,3-butadiene, and elemental carbon.
  - Elemental carbon concentrations were higher at all terminals then other harbor area measurements.
  - Mobile source emissions cause higher levels of benzene, 1,3-butadiene, elemental carbon, and CO than comparable studies in the South Coast Air Basin.
  - Based on meteorological conditions and the peak traffic, these measurements likely represent near-worst case at LAX.

South Coast Air Quality Management District, 2000c, *Inglewood Particulate Fallout Study Under and Near the Flight Path to Los Angeles International Airport*, Rudy Eden.

- Air monitoring study conducted in the vicinity of LAX to evaluate atmospheric fallout in neighborhood located under and near the airport flight paths:
  - Conducted during the weeks of April 28 and May 30, 2000 within the Inglewood area; at 14 locations, primarily residences.

- Quartz fiber filters were used to sample for fallout mass, organic carbon (OC), and elemental carbon (EC), and total carbon determinations.
- Glass plates were also used to collect deposition or fallout samples.
- Combusted oil soot particles were not present in abundance in the majority of samples collected, but no conclusions can be drawn because of limited sample period.
- No discernable pattern of either carbon mass or total fallout mass under LAX's flight path.
- Concentration and growth of gasoline and diesel powered vehicle traffic in and around the airport is an emission concern.

South Coast Air Quality Management District, 1998, *Air Monitoring Study at Los Angeles International Airport*.
Short term air quality monitoring study at LAX for 3 weekends in May and June 1998:

- Performed sampling and testing of CO, PM and VOCs at two curbside locations to address worker exposures.
- Maximum concentration levels compared to ambient levels at other, off-airport monitoring stations.
- VOCs indicative of auto exhaust (ethylene, propane, isopentane, benzene, toluene).
- The curbside samples contained VOC values two to four times higher off-site stations.

South Coast Air Quality Management District (SCAQMD), 2008. Draft Report for the Multiple Air Toxics Exposure Study in the South Coast Air Basin III (MATES III)—Introduction and Chapter 2: Air Toxics Monitoring and Analysis. http://www.aqmd.gov/prdas/matesIII/matesIII.html Accessed June 12, 2008

- MATES III was performed over two years, from April – March 2005 and 2006, consisting of a monitoring program, emissions inventory of air toxics and model geared toward characterizing risk across the South Coast Air Basin. It serves as an update and comparison to the

  MATES II study performed in 1988-1989

- Air toxics monitoring encompassed select VOCs, metals, and PAHs considered most contributory to human health risk and area non-attainment status as derived from the MATES II study, as well as PM10, PM2.5, and organic and elemental carbon
    - Acrolein was selected but not investigated due to lack of available and suitable technology to accurately measure it at the onset of the MATES III study
    - Ten sites were selected, within which a 24-hour integrated sampling schedule was adapted for carbonyls, PM and VOCs. Three additional 8-hour integrated canister samples were attained the provide higher resolution of VOC levels
- Sample sites selected to cover a broad spectrum of areas representing differing land use, environmental justice and source proximity attributes:
    - Anaheim, Burbank, Compton, Fontana, Huntington Park, North Long Beach, Los Angeles, Pico Rivera, Rubidoux and Wilmington
- Microscale sites also selected using the same criteria above in addition to MATES II high-risk areas, community concern and potential for neighborhood emission gradients
    - Movable monitoring platforms utilized, and each microscale site was coupled with a nearby fixed site to test the presence of gradients
    - Sampling intervals were restricted to only a few months, ranging between July 2005 and January 2006.
- VOC's were canister sampled and analyzed using GC mass spectrometry; Carbonyls were collected on DNPH

(2,4-dinitrophenylhedrazine) cartridges and analyzed using HPLC;

Cr(VI) was captured on cellusose filters and measured using ion chromatography; EC/OC, metals and the PM size fractions were collected using a variety of PM, quartz and Teflon filters, and measured for mass using microbalances, metal constituency using x-ray fluorescence spectroscopy, and ion constituency using ion chromatography

  - Diesel PM estimated using MATES II EC data, 2005 Emissions Inventory EC and PM2.5 data, CMB (Chemical Mass Balance) model and Positive Matrix Factorization (PMF) source apportionment results
  - 1,3-butadiene and benzene, two mobile source contributors, were reduced from MATES II measurements by 50% and 73%, respectively, likely caused by increased use of RFG since MATES II
  - Study does not account for MTBE (methyl-tert-butyl ether), a compound of concern associated with use of RFG
  - Perchloroethylene and methylene chloride, associated with industrial solvents and dry cleaning, reduced by 78% and 53%, respectively, since MATES II
  - Arsenic and Cadmium levels have decreased since MATES II; Lead and Nickel concentrations were much lower than the established AAQS; Cr(VI) decreased in Burbank and Huntington Park but increased in Rubidoux.
    - Removing Rubidoux from the analysis, Cr(IV) values decreased by about 13%
- EC in PM10 decreased roughly 28% from MATES II after accounting for measurement differences

    - Huntington Park and Wilmington possessed the highest concentrations out of all sites
- PM2.5 levels averaged higher for year 2 of the study than for year 1
- The CMB model for estimating Diesel PM2.5, as well as the 2005 inventory used to create it, estimate Diesel PM2.5 levels higher than those of MATES II, signifying either an underestimation in MATES II or an increase in levels since MATES II
- NAPH and other PAHs for the 3 sites (Los Angeles, Wilmington and Rubidoux) measured show a dominance of NAPH over all other PAHs:
    - LA displayed the highest concentrations of NAPH and Rubidoux the lowest. Wilmington possessed the highest non-NAPH PAH concentrations
- Compton and Huntington Park ranked highest in 1,3-butadiene levels
- Compton, Huntington Park and Burbank ranked highest in Benzene concentrations
- Compton and Burbank Perchlorethylene concentrations exceeded all other areas measured
- North Long Beach had the highest, and most highly variable, concentrations of Methylene Chloride
- Burbank, Central LA, Fontana, Huntington Park and North Long Beach displayed significantly higher concentrations of Formaldehyde than the average concentrations for all sites measured.
- Burbank, Central LA, and Fontana displayed significantly higher concentrations of Acetaldehyde than the study site average
- Huntington Park, Wilmington and Pico Rivera Arsenic levels exceeded the study average concentration
- Huntington Park, Wilmington , Fontana and North Long Beach exceeded the study averages of Lead and/or Nickel
- Compton, and especially Rubidoux, as stated above, are still areas of concern for Cr(VI) based on exceeding the average of all study sites

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South Coast Air Quality Management District (SCAQMD), 2008. Draft Report for the Multiple Air Toxics Exposure Study in the South Coast Air Basin III (MATES

III)—Chapter 3: Development of the Toxics Emissions Inventory.
http://www.aqmd.gov/prdas/matesIII/matesIII.html Accessed June 12, 2008

- Information for emissions inventory amassed SCAQMD, CARB, California DOT, and Southern California Association of Governments (SCAG)
- Four components of inventory:
    - Point sources—facilities with emissions above SCAQMD determined threshold levels
        - >4 tons per year of VOC, NOx, SOx, or PM; or >100 tons of CO per year
    - Area sources—facilities with emissions below SCAQMD determined threshold levels but in summation represent significant emissions sources (gas stations, residential heating, auto repair shops, etc)
    - On-road mobile sources—highway vehicle traffic
    - Off-road mobile sources—other vehicles not regularly on highway (i.e. planes, trains, ships, construction equipment, etc)
- All toxic emissions calculated by using CARB speciation profiles
- Point source emissions data categorized using EPA Source Classification Codes (SCCs) in conjunction with the facility's registered permits with SCAQMD to determine which SCC code best fits the source
- Area source emissions are spatially partitioned using a grid resolution of 2 km2 and the following spatial surrogates: demography and employment, housing type and total, rural land cover, forest cover, railway cover and the distribution of roads and arterials
- On-road mobile source emissions are based on CARB's EMissions FACtors v2.3 (EMFAC) program in conjunction with traffic volume and speed data amassed from SCAG, and incorporated into the Direct Travel Impact Model (DTIM)

  - EMFAC estimates concentrations of HC, CO, NOx, PM, Pb, SOx and CO2 from 1970-2040, defining values for all gas/diesel/electric vehicles manufactured since 1965. Considers: air temperature and humidity, fleet mix and growth rate, vehicle age distribution, fuel properties, vehicle miles traveled and altitude.
    - Groups vehicles into passenger cars, light trucks, medium/light-heavy/medium-heavy/heavy-heavy duty trucks, motorcycles, buses and motor homes. Broadest categories are further classified by vehicle weight
  - DTIM4, a processing system component of DTIM, links gridded on-road emissions to transportation network data and meteorological data per grid unit.

- Most categories off off-road mobile source emissions are handled using CARB's OFF-ROAD computer model, except ships, aircraft, locomotives and recreational vehicles. The study references separate methodology for these components but does not describe them in detail.
- For all investigated source types, acetaldehyde, acetone, formaldehyde, methyl ethyl ketone, diesel particulate, EC/OC are the largest contributors

- When weighted in terms of carcinogenic risk, the most significant pollutants are diesel particulate emissions, 1,2-butadiene, benzene and perchloroethylene
- On-road and off-road mobile sources are the largest contributors to the carcinogenic risk, with stationary sources contributing the remainder
- On-road, point and area source carcinogenic emissions have decreased between 13 and 65 percent since MATES II

South Coast Air Quality Management District (SCAQMD), 2008. Draft Report for the Multiple Air Toxics Exposure Study in the South Coast Air Basin III (MATES III)—Chapter 4—Regional Modeling and Evaluation. http://www.aqmd.gov/prdas/matesIII/matesIII.html Accessed June 12, 2008

- Comprehensive Air Quality Model with Extensions (CAMx), augmented with a Reactive Tracer Modeling Capability (RTRAC) was used for dispersion modeling of gaseous and aerosol toxics in the South Coast Air Basin
    - Domain included the entire basin and its coastal shipping lanes, and was gridded with a 2 km2 resolution
    - MM5 (mesoscale meteorological model) employed to create hourly meteorological fields based on the established grid, coupled with National Weather Service initializations to create dispersion profile
        - CAMx with MM5 uses single atmosphere gas and particle chemistry to replicate episodic O3 and annual PM2.5 concentrations
    - Modeling assumptions and differences from those used in MATES II included:
        - vertical diffusion characterization via MM5, increasing vertical dispersion and producing lower ground level concentration

        - Incorporation of heavy-duty diesel truck travel into the model
- Model estimations pertaining to those compounds outlined in Chapter 3 of this study to contribute most to deleterious health effects as well as overall emissions (1,3-butadiene, benzene, diesel particulate and formaldehyde) are investigated :
    - Diesel particulate concentration tracks major arterial highways and exhibits "hot spots" of 4.8 µg/m3 in central Los Angeles and 8.5 µg/m3 in the Ports of Los Angeles and Long Beach
    - Formaldehyde concentrations also express the localized hot spot phenomenon downwind of the basin (Santa Clarita and Crestline), otherwise concentrating in the western and central basin
        - Hotspots also coincide with areas of high O3 formation, suggesting that the formaldehyde emissions in these areas are photochemically derived and thus secondary
- Model simulations performed best in terms of EC2.5, EC10 and gaseous species. Total Suspended Particles and arsenic were most frequently overestimated, while Cr(VI), lead and Cadmium were generally under-predicted.

- When risk-weighted, the model shows that Los Angeles County assumes the greatest risk, followed by Orange County. Riverside, San Bernardino and areas along the Eastern basin show lowest associated risks
        - Most significant contributors to overall risk and carcinogenic effects are (from highest to lowest) diesel

        particulate, benzene, 1,3-butadiene and secondary formaldehyde
    - Highest simulated risk in terms of specific study areas was concentrated in Wilmington, Los Angeles, Long Beach and Compton
  - Population weighted risk assessment shows a 17% decrease from those values reported in MATES II. South Central Los Angeles, the Ports of Los Angeles and Long Beach are continued areas of concerns based on the results of MATES II and III

South Coast Air Quality Management District (SCAQMD), 2008. Draft Report for the Multiple Air Toxics Exposure Study in the South Coast Air Basin III (MATES III)—Chapter 5:Microscale Study. http://www.aqmd.gov/prdas/matesIII/matesIII.html Accessed June 12, 2008

- Employed movable platform monitoring to test the presence of pollutant gradients between communities. Sampling usually spanned 4-8 weeks and took place over July 2005 to September 2006. Sites chosen to best characterize the range of the following attributes:
  - Proximity to emissions sources
  - Gradient potential
  - Risk profiling from MATES II
  - Environmental/geographic equity
  - Community concern
- Microscale site/Fixed Site pairings are as follows
  - Commerce/Huntington Park
  - Indio/Rubidoux
  - San Bernardino/Fontana
  - Sun Valley/Burbank
  - Santa Ana/Anaheim
- Only those compounds having statistically significant higher concentrations in the microscale sites relative to the fixed sites, and only those above the method detection limits of the instruments used (see Chapter 2 review) are reported below.

- There were no statistically significant differences in concentration between Commerce and Huntington Park
- Manganese levels in PM10 (not PM2.5) were statistically significantly higher in Indio relative to Rubidoux, and higher in the eastern portion of the district. These differences are thought to be geogenic.
- San Bernardino significantly exceeded Fontana for the following pollutants, and the causality is thought to be traffic related: acetaldehyde, benzene, carbon tetrachloride, formaldehyde, methyl ethyl ketone, methylene chloride, toluene and o-xylene
- Sun Valley's concentrations of 1,2-dichlorobenzene, 1,3-butadiene and hexavalent chromium were determined to be statistically significantly higher than those in Burbank. Cr differential attributed to large amount of plating operations in Sun Valley
- Vehicle emission related pollutants benzene, ethylbenzene, toluene, trichloroethylene, (m+p+o)-zylenes, 1,4-dichlorobenzene, 1,3-butadiene were present in higher concentrations in Santa Ana than in Anaheim. Copper in PM2.5 was also higher, but not in PM10

Schafer, K., Jahn, J., Sturm, P., Lechner, B., and Bacher, M., 2003. "Aircraft Emission Measurements by Remote Sensing Methodologies at Airports,"

Atmospheric Environment, 37: 5261-5271.

- Anthologizes measurement campaigns at London-Heathrow, Frankfurt/Main and Vienna International Airports undertaken from 1999-2001
    - Used Fourier Transform Infrared Spectrometry (FTIR) and Differential Optical Absorption Spectroscopy (DOAS) to measure CO, CO_2, ethene, ethyne, HCHO, NO and NO_2 from engines during run-up
    - Stresses the importance of factoring in APU emissions when constructing inventories, since they are typically run for much longer intervals of time than main engines
    - NO_x emissions are lower than ICAO predictions by ~50%, while CO indices are generally higher
    - Engine-airframe pairings produced significant variability in measurements
    - Turbofan engine revolution causes idle power settings to fluctuate considerably.

Schauer, J.J., Fraser, M.P., Cass, G.R., and B.R.T. Simoneit, 2002. "Source Reconciliation of Atmospheric Gas-Phase and Particle-Phase Pollutants during a Severe Photochemical Smog Episode," Environmental Sciences & Technology, 36 (17): 3806-3814.

- Study combines gas phase, particle phase and semivolatile pollutants from ambient air and South Coast Air Basin site-specific measurements, taken during a 1993 summer photochemical smog episode, into Chemical Mass Balance model to assess source contributions
    - South Coast Air Basin Sites (in order of distance from coast): Long Beach, downtown Los Angeles, Azusa and Claremont
    - Ambient air was canister sampled, particles collected on quartz, glass or teflon fibers and polyurethane foam, and measured for the following compounds using the following instruments:
        - Gas-phase HC and NMOG = gas chromatography-flame ionization detection
        - Particle mass = gravimetrically analysis
        - Trace metals = x-ray fluorescence analysis
        - Inorganic ions = ion chromatography and colorimetry
        - Individual fine particle and SVOCs measured by gas chromatography-mass spectrometry

  - Source samples from the sites above were measured using similar instruments with the addition of a XAD resin denuder in conjunction with the Teflon/polyurethane filters, and were collected using line and dilution sampling

- Sources for CMB were defined as gasoline-powered motor vehicles, diesel engines, meat cooking operations, paved road dust, gasoline headspace vapor, whole gasoline vapors, natural gas leakage, tire wear debris, vegetative detritus and solvent applications
    - Gasoline used for vehicle and vapor source profiles was 1995 RFG composite, and was corrected for benzene and MTBE to a 1993-comparable mix
    - Composite profile for solvents used, summing emissions from solvents, degreasing agents and coatings, including alkanes, olefins, aromatics and halogenated compounds
- Gasoline powered motor vehicles are major contributor to VOC apportionment, comprising > ½ of VOC totals at all sites, followed by whole gasoline and headspace vapors. Natural gas, meat cooking and diesel exhaust also contribute but to very small degrees
- Ratio of apportioned/estimated VOCs to measured VOCs increases with increasing distance from the Long Beach/Los Angeles sites, where VOC emissions are greatest
- Motor vehicle exhaust is largest contributor to fine particulate organic compound concentrations, followed by meat cooking and road dust, then vegetative debris and tire wear debris
  - A significant portion of organic compound mass cannot be apportioned to the primary sources in the study
    - This portion increases with increasing distance inland, and is attributed to secondary organic aerosol formation from photochemical reactions
    - Secondary inorganic ion concentrations decrease with increasing distance inland, because ships and refineries on coast are primary emissions sources
- Primary contribution to PM concentrations by diesel exhaust is highest at Long Beach and Los Angeles and decreases in the more rural areas sampled

- Diesel and gasoline vehicle exhaust composes nearly all of the SVOC apportioned concentrations, with additional small contributions from meat cooking

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Schumann, U., H. Schlager, F. Arnold, R. Baumann, P. Haschberger and O. Klemm, 1998. "Dilution of Aircraft Exhaust Plumes at Cruise Altitudes," Atmospheric Environment, 32(18): 3097-3103

- Aircraft emissions from exhaust plumes at cruise altitudes impact tropospheric and lower stratospheric O3 concentrations
- Dispersion modeling based on plume dilution, expressed in bulk plume dilution ratio, N. Data set includes CO2, NO, NOy SO2, H2O vapor and temperature data from 70 plumes emitted from a variety of commercial subsonic aircraft types. Plume ages range from seconds to 95 minutes, with extrapolation to millisecond fractions.
    - Dilution ratio (N) relates the air mass of exhaust per unit burned fuel mixing with the surrounding air mass, per unit flight distance
- Data is interpolated based on the derived ratio expression: N = 7000(t/t0)0.8, where time zero reflects the reference scale of 1 second
    - This interpolation fits best for plumes existing between at "t" of 1 and 50 seconds.
    - Dilution data based on derived ratio for all aircraft types studied fall within the same magnitude of range for a specified plume age.
    - Dilution can occur much more quickly than expression forecasts if there are strongly turbulent events in these atmospheric layers
    - NOx can be used as an emissions tracer for the time interval listed.
    - Water vapor and temperature measurements confirm the dilution ratio for plume ages ranging from 0.5 to 17 seconds. Water vapor and temperature values correlate.

Shumway, L.A., "Trace Element and polycyclic Aromatic Hydrocarbon Analyses of Jet Engine Fuels: Jet A, JP5, and JP8", 2000, US Navy, Technical Report 1845, December 2000.

- Samples of commercial Jet A fuel, JP8 fuel, and JP5 fuel were analyzed for elements and polycyclic aromatic hydrocarbons (PAHs).
- Elements not detected in any fuels were antimony, arsenic, cadmium, cobalt, gallium, gold, indium, mercury, molybdenum, palladium,

platinum, rhodium, ruthenium, silver, tellurium, thallium, thorium, uranium, and zinc.

- Elements which were detected in atleast one of the fuels included aluminum, barium, calcium, chromium, copper, iron, lead, magnesium, manganese, nickel, niobium, potassium, scandium, selenium, strontium, sulfur, tin, titanium, vanadium, and zirconium.
- There were no high molecular weight PAHs in the fuels. Jet A and JP8 had more PAHs than JP5. Jet A fuel had more mid-range molecular weight PAHs than the JP5 or JP8.

Schurmann, G., Schafer, K., Jahn, C., Hoffmann, H., Bauerfeind, M., Fleuti, E., Rappengluck, B., (2007), "The Impact of NOx, CO and VOC emissions on the Air Quality of Zurich Airport", Atmospheric Environment, 41 (2007) 103 – 118.

- Conducted over a 15-day period during the summer of 2004, this study was undertaken by the airport operator (e.g., Unique) and involved the measurements of NO, NO2, CO, CO2 and VOCs along the taxiway and apron areas at the main terminal. Samples were collected using continuous-running instruments (for NO2) combined with open path spectrophotomety and canisters (for VOCs). Several conclusions derived from this study comprise the following: CO levels are highest on the taxiway due to aircraft exhaust; NO levels are highest on the apron due to GSE emissions; NO2 levels are dictated by "background" levels, including the airfield; and VOC emissions are characterized by short-chain alkenes. Comparisons to ICAO emission rates for some aircraft indicate that the measurements from this study are higher. (Notably, air monitoring for NO2 has been underway at Zurich

Airport for several years as part of a permanent installation using both continuously-operating equipment and open path technology.)

Spicer, C.W. et al., 1999, "Chemical Composition and Photochemical Reactivity of Exhaust from Aircraft Turbine Engines", Annals Geophysicae 12, 944-955.

A well cited and authoritative report on the measurement of hydrocarbon compounds in aircraft exhaust conducted in the late 1980's:

- Exhaust sampling of the military GE TF-39 (DC-10) and CFM56-3 (Boeing 737-300) engines.
- Sampling conducted using a four-arm, 12-port sampling probe mounted in the exhaust just behind the engine.
- At idle, the predominant (30 to 40%) hydrocarbon species were ethane, propene, acetylene, methane, acetaldehyde, and formaldehyde; other compounds were the remnants of unburned fuels.
- Total hydrocarbons and unburned fuel emission were greatly reduced at 30 to 80% thrust, with the exception of methane.

Unal, A., Hu, Y., Chang, M.E., Odman, M.T., Russell, A.G., 2005. "Airport Related Emissions and Impacts on Air Quality: Application to the Atlanta International Airport," Atmospheric Environment, 39:5787-5798.

- Particulate and gas-phase emissions modeled based on data from Hartsfield-Jackson Atlanta International Airport

- PM2.5 emissions estimated using first-order approximation, defined by smoke numbers and fuel flow rates using SMOKE modeling system; EDMS used to approximate gas-phase emissions, accounting for aircraft and GSE
- One inventory prepared using engine-specific smoke numbers; the other prepared by regressing mode-specific smoke numbers from surrogate data
    - 70 tons per year PM2.5 using first method, 2.5 times larger than modeled emissions using mode-specific data
    - Airport emissions found to be fractional contribution to ambient air pollution, compared to much more dominant vehicle traffic
- Maximum modeled impact on ozone was 56 ppb, on PM2.5 was 25 µg m-3, minimum was 20 ppb and 4.4 µg m-3 respectively, depending on engine-specific (maximum) or mode-specific (minimum) model
- Airport impact decreases with increasing distance from airport, and aircraft impact on ozone and PM exceeds GSE in areas proximal to airport.

VHB/KM Chng, 2006, "Ambient Deposition Study, T.F. Green Airport, Warwick Rhode Island", prepared for the Federal Aviation Administration and Rhode Island Corporation.

- Conducted in 2006 is conjunction with an environmental assessment for the airport, this short-term study involved the collection of soot deposition samples at four sites in the vicinity of the airport. The samples were analyzed and compared to references samples of jet, gasoline and diesel fuels; swipes from aircraft, GSE and motor vehicle engines; and urban dust.
- Using methods of advanced "chemical fingerprinting" combined with the assessments of PAH distributions, the presence of select "bio-markers", and comparison to urban dust, it was concluded that the atmospheric deposition near the airport has little resemblance to airport sources and was largely a result of contamination from regional background pollution.

Wallace, M. and C. Hibbard, (2004), "T.F. Green Airport, Rhode Island – Evaluation of Occupational Exposures to Air Quality in the Arrivals Areas", Presentation to the Air & Waste Management Association.

- Air monitoring was conducted to measure ambient levels of CO, PM2.5 and NO2 in the vicinity of the main terminal arrival curbsides. Taken over a seven-day period and over the Labor Day weekend, the results were well within OSHA guidelines for these pollutants. CO levels appeared to be influenced by motor vehicle traffic volumes.

Wang, W.G., D.W. Lyons, N.N Clark, M. Gautam and P.M. Norton, 2000. "Emissions from Nine Heavy Trucks Fueled by Diesel and Biodiesel Blend without Engine Modification," Environmental Science and Technology, 34(6):

933-939

- Previous research concluded biodiesel blend fuels (B20 and B35, soyate or canola methyl esters [SME or CME]) significantly reduce HC, CO and PM emissions in heavy trucks. NOx emissions marginally to significantly increase but can be controlled by altering engine optimum calibrations such as retarded injection timing.
- This study tests nine heavy trucks with either Cummins 885 or DDC series 60 engines without engine modification, using B35 and no.2 diesel fuels, to determine emissions of CO, NOx, PM and HC differences between fuel and engine type.
- WVU chassis dynamometer controls two truck cycles during test: short 5 peak truck cycle and longer 5 mile cycle each with peak speed acceleration intervals ranging from 20 -40 mph. Longer cycle uses highest possible acceleration to steady peak speeds.
- Comparative emissions analysis shows:
    - Reduction in CO emissions by average of 12% using B35, although DDC-60 engines emitted more
    - NOx emissions increased in Cummins 885 engines using B35 but marginally decreased in DDC-60 engines
    - HC emissions decreased for both engines using B35, but DDC-60 engines produced much lower overall HC emissions

  - PM emissions from B35 fuel reduced by as much as 25%
  - Most significant characteristic of B35 fuel in reducing emissions (especially CO and PM) is higher oxygen content, facilitating more complete combustion and less accumulation of incomplete combustion related compounds (i.e. black soot and CO)

  - The 5-mile WVU test generally has higher recorded emissions,

    because much more fuel is injected and used during this test relative to the shorter 5 peak cycle test

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Watson, J.G., J.C. Chow, J.L. Brown, D.H. Lowenthal, S. Herring, P. Ouchida, and W. Oslund, 2000. "Air Quality Measurements from the Fresno Supersite,"

Journal of the Air and Waste Management Association, 50(8): 1321-1334

- A summary report with regards to the Fresno, CA supersite (EPA), outlining its objectives, methods and applications of short duration

  in-situ measurements of the following air pollutants: PM2.5, PM10,

  SO42-, NO3, CO, O3, NOx, reactive nitrogen species, HCs and PAHs.

  The ultimate goal of this effort is to better inform regulatory agencies to pertinent health issues related to these pollutants.

- Will also evaluate non-routine monitoring methodology and its

  comparability to methods in practice.
- Identifies observables in common with other supersite localities.

- PM2.5 annual averages from 1991-1996 ranged from 18 to 24 µg/m3,

  24 hour averages ranging from 56 to 93 µg/m3 – NAAQS

  non-attainment.

- QA/QC standards and the preparation of SOPs are evaluated in this program to determine the applicability to other supersite locations.
- Outlines spatially and temporally significant hypotheses and how they relate to the in situ measurement procedures and the overall public health agenda.
- Shows example data from Christmas Day, 1999:
  - Variations in concentrations attributed to emissions amounts and dispersion differentials occurring throughout any given day in the area.

  - Midday mass maxima coincide with the NO3- maxima;

    late-evening maxima coincide with elevated PAH and black

    carbon measurements.
- Acknowledges that short term data collection is not sufficient to adequately assess NAAQS attainment issues, and advocates a revision of the testing duration and methodology for better comparability.

Webb, S., Whitefield, P., Miake-Lye, R., Timko, M. and T. Thrasher, 2008. "Airport Cooperative Research Program Report 6 – Research Needs Associated with Particulate Emissions at Airports" Transportation Research Board, Washington, D.C.

- This report summarizes apparent knowledge gaps with regards to PM and PM sources at airports:
  - Aircraft Nonvolatile PM Knowledge:
    - Exhaust at exit plane contains nonvolatile PM, gases, precursors for volatile PM such as sulfates and organics. Soot

    agglomeration occurs on precursors and volatile PM forms as plume ages and evolves
    - Nonvolatile PM number based emissions index ranges from 10^{14} to 10^{16} particles/kg fuel
    - Nonvolatile PM mass based emissions index ranges from 0.01-0.5 g/kg fuel
    - Lognormal size distributions with number based geometric mean diameters ranging between 20 and 80 nanometers
    - Nonvolatile PM is largely composed of elemental carbon
    - Nonvolatile PM is most abundant at higher engine power settings
- Aircraft Nonvolatile PM Knowledge Gaps:
    - Variability between engines, and little knowledge about how service, maintenance and fuel composition affects PM emissions and structure
- Aircraft Volatile PM Knowledge:
    - Sulfates and organics are precursors, or agglomeration nuclei
    - Sources are partially combusted fuels and engine lubricants
    - Appears as totally volatile particles, coated non-volatile particles and coated ambient particles
    - Characteristics highly dependent on fuel sulfur content
    - Volatile PM most concentrated in aged/advected plumes or cooled exhaust, and concentration is also dependent on temperature, relative humidity and background concentrations of other pollutants
- Aircraft Volatile PM Knowledge Gaps:
    - Exact knowledge of how volatile PM evolves in plume and in sampling lines, and how atmospheric variables listed above influence formation
    - Lack of models and instrumentation geared toward specifically volatile PM
    - Contribution of lubrication oils to volatile PM emissions in not well known, nor is impact of fuel composition outside of fuel sulfur content
- PM knowledge concerning other airport sources:
    - GSE well characterized, diesel GSE contribute much more significantly than gas GSE, and new federal regulations on fuel sulfur content will reduce PM emissions as much as 90%
- PM knowledge gaps concerning other airport sources:
    - GSE operations are highly variable between airports and times in mode are not well characterized

        - Population age is difficult to determine for GSE
        - APU PM data is extremely lacking, especially with regards to the no load, environmental control condition and engine start condition operational modes
        - APU fuel consumption not well defined
        - Brake and tire emissions during landing have not been studied and currently there is no way to differentiate between these emissions and brake and tire emissions from vehicles on the ground

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Westerdahl, D., Fruin, S., Sax, T., Fine, P.M., and C. Sioutas, 2005. "Mobile Platform Measurements of Ultrafine Particles and Associated Pollutant Concentrations on Freeways and Residential Streets in Los Angeles,"

Atmospheric Environment, 39: 3597-3610.

- UFP particle count and size (SMPS/CPC augmented with differential mobility scanners, 10s to 1 min resolution), particle length (measured by Electrical Aerosol Detector [EAD]), 2s resolution) BC concentrations (aethalometer, 1 minute resolution), PAH concentrations (aerosol sensors, 2s resolution), NOX concentrations (chemiluminescence

  analyzers, 20s resolution) and CO/CO2 concentrations(Q-Trak

  monitors, 10s resolution) were measured in April 2003 on a Los Angeles Roadway network fixed route, via mobile platform:
    - Start point was USC site on I-110

  - Followed I-110 up to the Pasadena stop, connected via I-5/ I-10 to I-710, following the I-710 to the Long Beach Stop
  - Route encompassed ~120km and was both GPS and video recorded
  - Heavy-Duty truck traffic is highly concentrated on I-710 and prohibited on I-110, and mixed on I-5/I-10

- Pollutant concentrations were lowest in Long Beach and Pasadena residential areas, intermediate at the USC location, and highest at the three freeway segments
  - UFP, NO, BC concentrations on freeways exceeded residential levels up to 20x, as well as CO2 if it is background subtracted. Concentrations of these pollutants also increase with the presence of diesel truck traffic
  - PM2.5 varied less spatially but increased in the presence of high-emitting vehicles
  - CO and CO2 increased with proximity to all vehicle types on the road, and concentrations were highest on the freeways

- Non-parametric Spearman's correlation coefficients (ρ2) showed strong correlations between UFP, EAD particle length, BC, NO and PAH 10s averages (ρ2=0.9), implying strong dependence on diesel traffic volumes. CO and CO2 showed weaker correlation (ρ2=0.6), which is interpreted as reduced dependence on diesel traffic volumes.

- Time series plots reveal abrupt concentration changes between freeway and residential areas, and imply steep UFP concentration gradients near freeways
    - UFP and NO concentrations co-vary, although NO decreases in residential areas. NO_2 ranged from 25 ppb in residential areas to 100 ppb on the I-710
    - CO and CO_2 dependent on proximity to traffic density
- UFP size distributions for I-710 have a mode occurring at ~0.02µm, an accumulation mode of 0.1-1.0 µm is expressed for the I-110 data, and concentrations associated with the distributions are much lower on I-110. This is attributed to the prohibition of diesel vehicle traffic on I-110.

Westerdahl, D., Fruin, S.A., Fine, P.L., and C. Sioutas, 2008. "The Los Angeles International Airport as a Source of Ultrafine Particles and Other Pollutants to Nearby Communities," Atmospheric Environment, 42: 3143-3155.

- UFP particle count and size (SMPS/CPC augmented with differential mobility scanners, 10s to 1 min resolution), BC concentrations (aethalometer, 1 minute resoltion), PAH concentrations (aerosol sensors, 2s resolution) and NOX concentrations (chemiluminescence analyzers, 20s resolution) were measured at sites around LAX in April 2003 via mobile platform.
    - Site A was a coastal site 500m upwind of the airport, for background reference purposes
    - Site B was northeast of the north runway (landing dominated) and 500m downwind.
    - Site C was representative of the taxiway area and was located 100m downwind of south runway
    - Site D was 100m south downwind of the south (takeoff dominated) runway.
        - A single takeoff event was observed during the study at this site
    - Site E (particle count measurements only, August 2004) was 900m downwind of the south runway
    - Measurements along freeways 105 and 710 were also measured for comparison.
- Particle count data reveal lowest counts at site A, low counts at site B (although excursions corresponding to aircrafts passing overhead are observed, high excursions of particle counts and BC at site C, also corresponding to aircraft activity. Site D, which captured the takeoff event, exhibited a 10s peak with 4.8 million counts per cm-3, along with elevated NOx and BC.
- Aircraft-heavy areas showed lower PM-PAH counts, and BC and NOx levels co-varied
- Mean measurements were all lowest at the coast and increased with increasing distance downwind. All studied compounds increased in count and concentration in conjunction with the takeoff event at site D.

- Particle size distribution is bimodal with peaks at 12nm and 80-90 nm. Peaks with respect to mass occur at 20 nm and 150 nm.
- The takeoff observed at site D added ~27.3 µg m-3
- Coastal air possesses lower levels of the approximate particle size range of 7-60 nm relative to the other sites in the study. Of the other sites, most differentiation is evident in the fine fraction of 7-40 nm.
- Between the coast and its most proximal downwind airport sites, there is ~100 fold increase in particle counts, a 134-fold increase in NOx and a 12 fold increase in BC.

Whitefield, P., Lobo, P., and D. Hagen, 2006. "PM Emissions from Advected Aircraft Plumes at the Oakland International Airport". Proceedings of the TAC-Conference, June 26 to 29, 2006, Oxford, UK.

- The APEX2 campaign was undertaken at the Oakland International Airport in 2005 and had two main research objectives
  - Dedicated engine emissions testing performed during run-up
  - Emissions sampling associated with a runway study
    - Advected exhaust plumes of over 300 B737 aircraft emissions were sampled during normal LTO cycles
    - Mobile laboratories stationed downwind on the eastern end of the runway to characterize and speciate advected PM and other combustion gases, as well as to measure CO2

        - Size distribution and total concentration measured by spectrometer and differential mobility analyzer
        - Condensation particle counters measured number concentrations
        - CO2 detection
        - Ambient meteorological conditions recorded
    - Ambient PM and CO2 concentrations background subtracted from plume measurements; peaks in ambient levels around 9am and 4pm are attributed to rush hour vehicular traffic activity in the area
    - Number based geometric mean diameters were similar for all engines between taxi and take-off
    - Mass based geometric mean diameters were much higher for take-off plumes than for taxi plumes, relating to increasing diameters with increasing power setting
    - Mass based EI's for older technology B737's (300 series) were much higher for take-off than during taxi, however no statistical trends were observed for number based EI's or for newer B737's (700 series)

Wood, E.C., S. Herndon, M.T. Timko, P.E. Yelvington and R.C. Miake-Lye, 2008.

"Speciation and Chemical Evolution of Nitrogen Oxides in Aircraft Exhaust Near

Airports," Environmental Science and Technology, 42(6): 1884-1891

- Presents results pertaining to APEX2 and APEX3 experiments:
    - APEX2 – Oakland International Airport, August 2005. Four

      Boeing 737 aircraft with CFM56 turbofan engines. 200 in-use

    aircraft exhaust plumes measured during landing, taxi and take-off operations.
  - APEX3 – Cleveland Hopkins International Airport, October/November 2006. Nine airplanes with larger span of frame and engines characterized.
- APEX2: NO_2 measured with quantum cascade tunable infrared laser differential absorption spectrometer (QC-TILDAS), NO measured via chemiluminescence analyzer
- APEX3: NO measured using lead-salt TILDAS, NO_y and HONO (nitrous acid) measured with coupled chemiluminescence analyzer and molybdenum converter, O_3 measured with photometer at 254nm, CO_2 recorded using IR absorption photometers
- Measurements taken through dedicated engine tests during run-up as well as from advected plumes
- EI calculated for NO, NO_2 HONO and NO_y as NO_2 mass equivlalents for ease of comparison.
- EI NO and NO_x increase with increasing engine power
  - NO_2 fraction of NO_x decreases with power, but displays small increases with power in the interval settings of 4-7% and 65-100%

- NO is converted to NO_2 very rapidly in low thrust exhaust plumes, but O_3 measurements remain constant, so it is not an ozone catalyzed transformation nor does it have anything to do with ozone chemistry
    - NO EI is lower in advected plume than during any of the dedicated engine tests
- NO_2 emissions comprise ~25% of NO_x released below 3000 feet and 50% of NO_x below 500 feet.
- HONO is highly variable depending on engine type, state and thrust setting, but can comprise up to 7% of aircraft exhaust emissions.

Wood, E., Herndon, S., Miake-Lye, R., Nelson, D. and M. Seeley, 2008. "Airport Cooperative Research Program Report 7 – Aircraft and Airport-Related Hazardous Air Pollutants: Research Needs and Analysis" Transportation Research Board, Washington, D.C.

- This report summarizes the state of the knowledge with respect to hazardous air pollutants at and around airports, and prioritizes a research agenda necessary to bridge knowledge gaps:
    - The FAA's EDMS currently estimates HAPs emissions using the assumption that the aircraft is operating at 7% engine thrust setting
        - Aircraft HAPs emissions of gas-phase hydrocarbons, including HAPs, are highest at taxi and idle power settings with less than 7% thrust levels
        - As a result, emissions inventories prepared using EDMS likely underestimate HAP emissions
    - Consensus between studies that report aircraft HAPs is not yet achieved, and these results are lacking detailed contextual information regarding toxicity. Nonetheless, most current studies identify the following HAPs:
        - Acrolein, formaldehyde, 1,2-butadiene, naphthalene, acetaldehyde, benzene, ethylbenzene, toluene, xylenes, lead, propenal
        - Additional hydrocarbons that haven't been evaluated for toxicity, and yet are still common to airport emissions include: crotonaldehyde, glyoxal, methylglyoxal and propionaldehyde
    - HAPs of interest from stationary sources, ground access vehicles and ground support equipment include benzene and 1,3-butadiene, and are especially ubiquitous from gasoline powered sources
    - Suggested Research Agenda:

  - "Identify the effects of ambient conditions…and engine technology on HAP emissions at various idle/taxi power settings"
  - Determine actual thrust values at airports during idle conditions
  - Characterize HAPs emissions from piston aircraft, and other general aviation types of aircraft
  - Determine which emissions and emissions sources most significantly affect potential receptors in a given area

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Yu, K.N., Cheung, Y.P, Henry, R.C., 2004. "Identifying the Impact of Large Urban Airports on Local Air Quality by Nonparametric Regression," Atmospheric Environment, 38: 4501-4507.

- Non-linearity of plume emissions during aircraft operational modes, wind dispersion and fuel compositional similarities with other nearby sources make it difficult to discern aircraft contributions to ambient air pollution from other sources.
- Study uses non-parametric regression on hourly wind speed and direction data to distinguish aircraft source pollution based on emissions data at Los Angeles International Airport (LAX) and Hong Kong International Airport (HKIA)
  - LAX data was collected between August 1997 and March 1998, and included hourly concentration measurements of CO, CO2, NO, NO2 and meteorological data 200m east of runway 25R.
  - Continuous measurements of NO, NO2, O3, CO, SO2 and respirable suspended particles (RSP) were collected at a monitoring station ~3km southeast of HKIA

    - Non-parametric statistical regression relates to quantification of the relationship between dependent and predictor variables without any a priori classification or assumptions
        - Dependent variable = concentration of a measured pollutant
        - Predictor variables = average hourly wind speed and direction.
        - Regression parameters were subjectively smoothed
        - Outliers in air quality data can generate large uncertainties in the regression analysis
- LAX results
    - Direction of maximum CO, NO, NO2 and NOx is in direction of nearby highway, reflecting influence of ground vehicle traffic on these emissions
    - SO2 emissions show highest concentrations at high wind speeds and around the direction of 270° azimuth, which coincides with the lateral direction of the nearby runway.
        - Aircraft emit orders of magnitude more SO2 than ground vehicles, so this signal is attributed to aircraft plumes
- HKIA results
    - Monitor farther away from runway, so SO2 is more diffuse in all directions.
        - Aircraft plays larger role in elevated ambient CO than at LAX because vehicle traffic is not dense
        - Highest concentrations correspond to wind speeds of 5-10 km/h, signifying that they are being transported from an elevated source
        - Elevated RSP concentrations correlate to high SO2 concentrations.
- Authors propose that wind correlated SO2 concentrations be used as tracer for aircraft plumes near airports

Zhu, Y., Hinds, W.C., Kim, S., Shen, S., and C. Sioutas, 2002. "Study of Ultrafine Particles Near a Major Highway with Heavy-Duty Diesel Traffic," Atmospheric Environment, 36:4323-4335.

- Study evaluates UFP in proximity to I-710 in Los Angeles during October, 2001, and compares to study published by same author that inventories UFP on the heavy-duty traffic restricted I-405.
    - Measures particle concentration in 6 to 220 nm size range along with CO and BC as a function of distance upwind or downwind of the I-710
        - Wind speed and direction were recorded alongside manual traffic counts to assess traffic density and vehicle mix
- 80% of time during sampling period wind blew from the east, from the freeway directly at the sampling site
        - Sampling site was oriented perpendicular to and level with freeway
        - Diesel traffic represents about 30% of the vehicles on the I-710, but on the I-405 they constitute less than 5%
        - Particle number concentrations and size distributions (between 6 and 220 nm) were recorded using scanning mobility particle sizer and condensation particle counter

    - CPC counts and number concentrations were normalized to the average for the measurement period
    - BC measured via aethalometer and CO measured by calibrated CO monitor
- Between 17 and 20m downwind the particle size mode was 10 nm, with a modal concentration of 3.2 x 105 cm-3 at 17m and 2.4 x 105 cm-3 at 20m. A second mode was recorded at 20nm, predominantly at the 17 and 20m sampling intervals
- With increasing distance the 10 nm mode increased to the larger size range and the concentration continued to decrease, while the 20 nm mode only exhibited the shift to the larger size range with increasing distance
    - Relationship between number/concentration and distance is attributed to particle coagulation
    - Suggest that people living or working within 100m downwind of this major traffic source, or people that regularly commute, have a much higher UFP exposure chance
- Total particle number concentration in the range of 6-25 nm comprised nearly 70% of the total UFP up until 100m, after which it dropped significantly
    - Number concentrations in the size ranges of 25-50 nm and 50-100nm leveled off between 17 and 150m
- 60% of PM emission on I-710 is attributed to diesel traffic
- BC and CO concentrations decreased quickly with increasing distance from traffic sources

- BC concentration is much higher near diesel dominated I-710 than I-405, particle number concentration on I-405 is higher than on I-710

APPENDIX C

LAWA TECHNICAL WORK PLAN SUMMARY OF CURRENT KNOWLEDGE AND KNOWLEDGE GAPS

A combination of emissions and meteorology affect ambient concentrations of particles and gases. LAX is located in the most intensely studied outdoor pollution laboratory in the world. More than 1000 scientific papers and reports have reported on a wide variety of pollution-related issues in the SoCAB since the 1950s. However, as the area has urbanized, as pollution controls have been implemented, and as scientific knowledge has progressed, much of the previous information is no longer relevant to today's situation. This section briefly summarizes current knowledge about emissions, meteorology, and ambient concentrations relevant to the Study objectives.

A.1 EMISSIONS

Table A-1 provides criteria emission data for the South Coast Air Basin for 1997 and 1996.

Table A-1 SoCAB and LAX Emission Inventories

	Annual Emissions (1000 tons)				
1997	**CO**	**VOC**	**NO_x**	**SO_2**	**PM_{10}**
SoCAB Total[1]	1,830	364	366	25.7	155
Total Aircraft[1]	32.2	5.21	6.52	0.376	0.299
LAX Aircraft[2]	5.39	1.26	4.44	0.193	n/a
1996					
SoCAB Total[3]	2,300	402	402	28.1	172
SoCAB Aircraft[3]	31.8	5.48	5.48	-[3]	-[3]
LA County[3]	1,350	245	245	23.4	83.95
LA County Aircraft[3]	20.1	3.28	3.65	-[3]	-[3]
LAX Aircraft[4]	4.85	1.13	3.72	0.166	0.051
LAX Complex[4]	16.6	2.07	5.18	0.183	0.159

[1] From the 1997 AQMP, Appendix III, Table A-4. Total aircraft includes commercial and military aircraft.

[2] From the South Coast Aircraft Emission Inventory: Baseline for 1997. To be consistent the SO2 emissions provided are the unadjusted SO2 emissions.

[3] From CARB, accuracy is low due to one and two significant digit integer raw data. LA County totals do not include the part of the county outsite of the SoCAB.

[4] From the draft EIS/EIR. The aircraft emissions do not include APU emissions, which are included in the other aircraft total.

The 1996 emission inventories for the SoCAB indicate that LAX aircraft emissions are approximately: 0.2 percent of the regional CO emissions; 0.3 percent of the regional VOC emissions; 0.9 percent of the regional NOx emissions; 0.6 percent of the regional SO2 emissions; and 0.03 percent of the regional PM10 emissions. The LAX complex emissions, which include vehicle emissions on LAX roadways, are approximately: 0.7 percent of the regional CO emissions; 0.5 percent of the VOC emissions; 1.3 percent of the regional NOx emissions; 0.7

percent of the regional SO2 emissions; and 0.09 percent of the regional PM10 emissions. The LAX complex covers 5.71 square miles or approximately 0.05 percent of the approximate 12,000 square mile SoCAB. Therefore, depending on the pollutant, the emission density from LAX is approximately 2 to 30 times higher than the average emission density in the SoCAB and approximately x to xx times higher than the average emission density in the SoCAB portion of Los Angeles County.

A.1.1 Site Specific Emission Sources

LAX has a number of emissions sources. The predominant emission sources are mobile sources mainly comprised of aircraft, GSE, and on-road vehicle emissions. LAX also has other on-site stationary emission sources including; a number of maintenance facilities, cargo facilities, an on-site central utility plant (CUP), an onsite fuel farm and several smaller fuel storage sites, several flight kitchens, numerous restaurants, various HVAC and hot water natural gas fired heaters, a fire fighting training facility, and various emergency engine-generators. In addition, there are several significant area sources at the airport, including; road dust/break wear/tire wear from on-airport vehicles and aircraft, aircraft and GSE refueling, intermittent soil/groundwater remediation efforts and fuel spills, and facility construction and maintenance.

Aircraft Operations and Emissions

LAX normally operates in an east to west direction (runways 24 and 25) with departures going to the west out over the ocean and arrivals coming in from east. In order to minimize noise during the overnight hours of 2400 to 0630 arrivals are routed from the west (runways 06 and 07), unless prohibited by weather conditions. When necessary due to weather all operations operate in a west to east direction. The use of the inboard runways is maximized for departures and the outboard runways maximized for arrivals. The most recent airfield operations data is summarized in **Table A-2**:

Table A-2 Average Daily LAX Operations Data – July 1, 1999 to June 30, 2000

Runway	**Departures**		**Arrivals**	
East to West	Number	Percentage	Number	Percentage
24L	453	44.6	40	3.9
24R	42	4.1	441	43.4
25L	71	7.0	436	42.9
25R	409	40.3	38	3.7
West to East				
06L	1	0.1	11	1.1
06R	19	1.9	23	2.3
07L	15	1.5	11	1.1
07R	5	0.5	17	1.7
Total	1016	100	1017	100

Source: LAWA Noise Management Section 7/14/00.

VOC emissions of jet engines at idle and several power levels are reported by Spicer et al. (1984, 1994). This work was done for the military and thus reports emissions for JP-4, JP-5, and JP-8 fuels. Only the JP-8 fuel is similar to commercial jet fuel however, in this Study the JP-8 was derived from oil shale, so it may not be equivalent to ordinary Jet A1. Although this work gives much information unavailable elsewhere, it is of limited value for accurate receptor modeling since the fuels are not the same as commercial fuel and the engines are older than many now in service. For receptor modeling it is important to find a chemical fingerprint that is characteristic of jet aircraft emissions, that distinguishes it from other major sources, and is relatively stable for various loads, and engines. Aircraft VOC emissions are very high in ethene, ethyne, and propene as well as high carbon number species (>C_{10}) from unburned fuel. This distinguishes jets from automobiles, which have low emissions of these species, and from refinery emissions, which are high in other VOCs. However, these species may not be enough to distinguish jet from diesel VOCs, which have a similar VOC fingerprint. Only more detailed analysis of samples obtained during a pilot field study can tell if it is possible to distinguish jets from diesel VOCs. One possibility for separating these sources is if jets and diesels contain different inorganic additives that can be seen in the particulates.

There is even less information on particulate emissions of aircraft at idle, landing, and takeoff conditions than VOC emissions, especially speciated particulated emissions. Spicer et al. (1984) gives some data on polyaromatic hydrocarbons (PAHs) but because of fuel and engine differences, these are probably not closely related to ordinary commercial jet emissions. The work of Fordyce and Shelbley (1974) is good but much too old to be applicable today. The interest in global climate change and possible effects of jet aircraft on particles in the stratosphere have led to a number of recent studies of particulate emissions of jets under high altitude cruise conditions. These however, have little utility for the proposed Study. Source-dominated samples taken at the end of a runway, for example or a taxiway, could be analyzed and provide chemical fingerprints of the particles from jet aircraft.

Stationary Sources

Several airlines, and other entities, operate maintenance facilities at LAX. Notable facilities include those operated by United Airlines, American Airlines, Federal Express, Trans World Airlines, Continental Airlines, US Air, Northwest and Delta Airlines, as well as, the United States Coast Guard and LAWA. Small maintenance facilities located on-airport includes those at car rental facilities, the United States Coast Guard, and Westchester Golf Course. General emission sources at the maintenance facilities include emergency generators and other engines (fueled by diesel, gasoline, propane, and natural gas), surface coating operations, degreasing operations, fuel storage/vehicle refueling, and welding. In recent years the operations at several of the airlines operated facilities have decreased as airlines have consolidated maintenance activities at other airports. In particular, operations at the Delta and Continental Airlines facilities have been reduced. Also, the use of solvents, particularly chlorinated solvents, has been reduced substantially. With the possible exception of aerosol can use, there are no known sources that currently use chlorinated solvents on-airport.

Over two dozen separate cargo facilities operate on-airport. These facilities operate on the southeast area of the airport adjacent to Century Blvd., Aviation Blvd., and Imperial Hwy.

Some of these facilities are mainly warehouse facilities with no significant emission sources. Other cargo facilities have site specific emission sources such as engine driven light stands. However, the overall emission potential from cargo facilities, other than their associated aircraft and GSE emissions, are small in comparison with other on-site emission sources.

The Central Utility Plant is comprised of two gas turbines, two auxiliary boilers, five HCFC-based chiller units, two lithium bromide adsorption coolers, a cooling tower, and ancillary equipment. The major emission source is the two gas turbines. The gas turbines are almost exclusively fired on natural gas. The cooling tower, which has a high efficiency mist eliminator, is a relatively small particulate emission source. No significant emissions of these materials are expected due to reaction in the water and the low drift fraction.

The LAXFUEL fuel farm is located west of the CTA. Jet A is the primary fuel stored at the fuel farm. The fuel farm emission sources are comprised of 15 Jet A storage tanks, one small waste oil tank, one small diesel tank, and four large diesel power emergency generators. LAXFUEL routes incoming (pipeline) Jet A through a clay-based filter system to remove impurities. No Jet A1 is currently used or stored at LAX. The Jet A storage tanks are internal floating roof tanks. The emergency generators are tested monthly, and are used in the advent of a power loss or fire.

There are a number of other fuel storage tanks located on-site. The largest of these sites is the Mercury Aviation site that stores Jet A, Diesel, and automotive gasoline in underground tanks. Other on-site facilities with fuel storage include: National and Avis rental car facilities (automotive gasoline and diesel); airline terminal, cargo, and maintenance facilities (automotive gasoline, diesel, propane, and CNG); Garrett Aviation (aviation gasoline and Jet A); Westchester Golf Course (gasoline, propane and diesel); LAX maintenance (gasoline, diesel, propane); and the on-site LAFD fire stations (diesel).

There are several flight kitchens located on-site including; LSG Skychefs (two locations), Chelsea Catering, Nikko Inflight Catering, Ogden Food Services, and Dobbs International. The emission sources at these facilities are mainly comprised of natural gas combustion sources (cooking and boilers) and cooking emissions (grease and char). The LSG Skychef facility on World Way West also has a natural gas fueled cogeneration IC engine, operated by Ridgewood Energy.

There are a number of restaurants operating within the main passenger terminals, the CTA, and other areas on-site. Emissions from restaurants are mainly comprised of natural gas combustion for cooking, deep fat frying emissions, and charbroiling emissions. In addition, wood combustion is employed in a few of the CTA restaurants. Restaurants are the only known wood combustion source located on-site.

Most of the buildings located on-airport have natural gas fired comfort heating and/or hot water heaters. These heaters are operated as necessary based on building use and the season of the year.

The fire fighting training facility is located in the southwest corner of the airport adjacent to the corner of Pershing and Imperial. Fire fighting training is performed by putting out controlled fires within a mock aircraft frame. The fires set are generally fueled by Jet A. Fire fighting training only occurs a few hours a year during certain wind conditions (offshore winds).

There are a number of miscellaneous emergency engine generators located around the airfield. FAA alone has 11 emergency engine generators. These equipment are mainly fired with diesel; however, some are fueled with gasoline, propane, and natural gas. Emergency generators are periodically tested for a few minutes up to an hour, otherwise they are only used in case of emergency power loss or fire.

Area Sources

Road dust is formed by vehicles driving in the CTA, the ramp areas, and on the AOA. Road dust is caused by vehicle tire wear, break wear, and mainly through the re-suspension of fine dust that is on the road being traveled. Aircraft also cause road dust during travel on the tarmac, taxiways, and runways. A particularly visible source of road dust emission is the tire wear caused during aircraft landing.

Aircraft, GSE, and other vehicle refueling occur all over the airfield. Aircraft, primarily fueled by the LAXFUEL hydrant system, are also fueled by tank truck. An aviation gasoline tank at Garrett Aviation is used to fuel piston engine aircraft. Aviation gasoline still contains lead for anti-knock. Currently, LAXFUEL does not inject additives into Jet A .[3] No vapor recovery is used during aircraft refueling (Jet A or aviation gasoline). GSE are refueled with diesel, gasoline, propane or CNG. Diesel and gasoline fueled GSE can be refueled by tank truck or at numerous tank dispensing stations located on the airport. Gasoline refueling is performed using vapor recovery systems (i.e. vapor balance return). There are negligible emissions associated with propane and LNG refueling when performed properly. Propane is dispensed from a number of tanks located on-airport. The CNG refueling facility is located within the United Airlines Maintenance complex.

The soil and groundwater has been contaminated by a number of airport users over the years. Remedial activities occur periodically to clean up these contaminated sites. These activities cause air pollution through the direct or controlled release of gasoline, diesel and Jet A vapors or through the use of combustion related remediation technologies (such as thermal oxidizers).

Emissions from facility demolition/construction and maintenance occur periodically all over the airport grounds. Emission sources include indoor and outdoor painting, sandblasting, and internal combustion driven construction equipment.

A.2 CLIMATE AND METEOROLOGY

Meteorology affects the transport of emissions between source and receptors, as well as the time during which pollutants age. Both of these phenomena are important to receptor modeling owing to their influence on reactive components in source profiles.

Southern California is in the semi-permanent high pressure zone of the eastern Pacific. During summer, average temperatures are ~25 °C, with maximum daily readings often exceeding 35 °C. Precipitation events are rare. Winters are cooler with average temperatures of ~15 °C. Minimum temperatures are normally ~5 °C but can drop below freezing at inland locations when cold fronts pass through. Precipitation is frequent from December through March, with monthly averages of 5 to 8 cm. Summertime sunrise and sunset are approximately 0500 and 1900 PST and wintertime sunrise and sunset are approximately 0700 and 1700 PST.

Frequent and persistent temperature inversions are caused by subsidence of descending air which warms when it is compressed over cool, moist marine air. These inversions often occur during periods of maximum solar radiation which create daytime mixed layers of ~1,000 m thickness, though the top of this layer can be lower during extreme ozone episodes (Blumenthal et al., 1978). Relative humidities depend on the origin of the air mass and the time of day, and can exceed 50% throughout the SoCAB with the intrusion of a marine layer near the surface. Relative humidities are higher near the coast than farther inland (Smith et al., 1984).

Smith et al. (1972) and Keith and Selik (1977) describe wind flow patterns in the SoCAB. During summer, the sea breeze is strong during the day with a weak land-sea breeze at night. Owing to the high summer temperatures and extensive urbanization in the 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 with depths as low as ~50 m. Surface layers usually couple to the mixed layer within a few hours after sunrise each day. Summertime flow patterns are from the west and south during the morning, switching to predominantly westerly winds by the afternoon.

During winter, land surface temperatures fall below those of the ocean, and easterly nocturnal winds are more pronounced than during the summer. A mild sea breeze is only established later in the day when temperatures approach their maxima. Wintertime flow patterns are much less predictable than summertime flows and are often influenced by frontal passages punctuated by periods of stagnation. Wintertime flows are from the east and north at night, switching to westerly trajectories by afternoon.

The land/sea breeze circulation transfers air back and forth between the SoCAB and the Pacific Ocean. Cass and Shair (1984) estimated that up to 50% of the sulfate measured at Lennox was due to emissions which had been transported to sea on the previous day. When wind speeds are low, air tends to slosh back and forth within the SoCAB. The SoCAB is ventilated when air exits to the Mojave Desert and the Coachella Valley (Green et al., 1992). Using tracer gas releases, Smith and Shair (1983) have found transport routes through Soledad Canyon, Cajon Pass, and San Gorgonio Pass. They also found evidence of transport aloft from the San Fernando Valley into eastern Ventura County under certain circumstances. Emissions that originate near the coast can be transported over long distances, quickly leaving the area of their initial emission. Emissions that originate far inland can also be transported back to the coast, and even into the ocean for recirculation during subsequent days.

A.3 TRANSPORT AND TRANSFORMATION

Pollutants are transported by the prevailing winds and can recirculate in a particular area or air basin during periods of calm winds, high wind instability and regular daily wind variation (i.e. opposing diurnal and nocturnal wind patterns). All pollutants, to varying degrees, are scrubbed from the atmosphere during precipitation; some pollutants depose onto ground/water surfaces or are absorbed by the ground surface or plant matter or are absorped by water bodies; and all pollutants, to varying degrees, spread to the stratosphere.

Some pollutants, such as CO and primarily particulate, are relatively stable do not readily react or transform over time in the troposphere. Pollutants such as NO_x, VOC, SO_2 will transform overtime, or are implicated as pollutant precursors. NO_x in the form of NO will transform into NO_2, particularly in the presence of high O_3 concentrations. NO_2 and VOC are precursors to O_3 and can also form nitrate and organic secondary aerosol particulate. SO_2 is a precursor to sulfate secondary aerosol particulate. Nitrates and sulfates are the primary contributors to dry acid deposition and acid rain (i.e. HNO_3 and H_2SO_4). Atmospheric chemistry as a whole and the reaction mechanisms for the aforementioned pollutant transformations are complex. The reactions often compete within a group (i.e. nitrogen compounds) or between pollutant groups (i.e. nitrates and sulfates both scavenge ammonia aggressively). However, general trends in pollutant transformation vs. time can be established.

Most industrial sources of sulfur oxides emitted as SO_2 or SO_3. SO_2 can be converted to sulfate by reactions in gas, aerosol, and aqueous phases. The aqueous phase reaction is rapid which can cause rapid conversion of SO_2 to sulfate in fog conditions (~10% per minute for 1 ppb of H_2O_2); however, some of this converted sulfate will then depose with the fog droplets. Gas phase oxidation of SO_2 to sulfate is slower (~1 to 5% per hour).

Most anthropogenic NO_x sources, namely combustion sources, emit primarily NO (80 to 95%) and NO_2 (5 to 20%) with a trace of other NO_x compounds (N_2O, N_2O_5, etc.). NO oxidizes by several potential reaction pathways to NO_2. NO_2 has a number of reaction pathways in the atmosphere which can cause the formation of nitrate particulate, other nitrogen oxides (N_2O, N_2O_5), organic nitrogenous compounds, and react in the formation of O_3. These reactions are complex, sometimes competing, and certain reactions only occur in the presence or absence of light energy.

Fate and transport can be used to help identify source apportionment, by determining the likely average age of the pollutants being monitored and correlating that with wind direction and speed to determine the likely source. For LAX source apportionment particularly important correlations are the NO to NO_2 ratio and the daytime vs. nighttime sulfate/nitrate concentrations vs. SO_2 and NO_x concentrations. The monitoring stations are all relatively close to the emission sources at LAX; therefore, during high wind events NO will have little time to react to NO_2 prior to reaching the nearest downwind monitoring station. Sulfate and nitrate aerosol concentrations versus total particulate and organic particulate concentrations and versus SO_2 and NO_x concentrations can also help identify contributing emission sources.

A.4 AMBIENT CONCENTRATIONS

Ambient air quality monitoring data is available for areas on-site and in the vicinity of the LAX airport (SCAQMD 1997a, 1998a, 1999a; AVES Inc., 1998). The monitoring data includes data from a temporary monitoring station, and a network of continuous monitoring stations throughout the South Coast Air Basin. The ambient air quality data from these sites are discussed in this section.

An ambient monitoring study at the LAX airport was conducted from August 14th, 1997, through March 6th, 1998. The purpose of this monitoring study was to measure the concentration levels of select criteria pollutants attributable to on-airport operations, specifically aircraft operations, and those concentration levels attributable to off-airport sources. A monitoring station was located approximately 0.6 kilometers east in a prevalent downwind location of the end of the southern runway, (25R), at the approach/departure midline. Runway 25R is used primarily for departures during the daytime hours and the northern taxiway parallel to the runway has significant aircraft taxi traffic and queue lengths.

The criteria pollutants monitored in the study were carbon monoxide (CO), nitric oxide (NO), nitrogen dioxide (NO_2), total nitrogen oxides (NO_x), sulfur dioxide (SO_2), and particulate matter with an equivalent aerodynamic diameter of less than 10 microns (PM_{10}). The duration of the ambient monitoring study covered half of the summer NO_x season and the majority of the winter CO season. The criteria pollutants CO, NO, NO_x, and SO_2 were monitored continuously, while the 24-hr PM_{10} concentrations were collected every other day using a continuous volumetric flow PM_{10} sampler. The NO_2 concentrations were determined by subtracting NO measurements from the NO_x measurements following the EPA reference method RFNA0677-021.

The maximum concentrations for each criteria pollutant sampled during the ambient monitoring period is presented in **Table A-3** - Ambient Air Quality at SCAQMD and On-Airport Monitoring Station Locations. The results show an exceedance of 24-hour PM_{10} CAAQS, without any violations of federal and state standards for the remaining non-annual measurements of the criteria pollutants. The conclusion of the monitoring study indicates that for annual measurements of NO_x, SO_2, and PM_{10}, the site is in attainment of the NAAQS and most likely exceeds the annual PM_{10} CAAQS. An important finding of the monitoring study is that the highest CO and NO_x levels occur when the wind direction is off-airport, roughly 45 to 135 degrees (see Section A.4.1). The finding implies that the highest concentration levels of criteria pollutants are attributable to non-airport sources. The conclusion of the monitoring study states that the likely contributors to high concentrations at the on-airport site are mobile sources from the two nearby freeways, I-405 and I-105, and the surrounding arterial roadways.[2]

The data from the on-airport monitoring site is valuable for the LAX Source Apportionment Study. Since the wind direction was monitored in addition to the criteria pollutant levels, the monitoring data can be used to attribute aircraft sources as well as nearby sources to the resulting concentration levels at the monitoring site. The limitation of the monitoring study results is that the data collected is less than a year's worth of data.

In addition to the on-airport monitoring site, the SCAQMD maintains a network of criteria pollutant monitoring stations throughout the air basin that operate continuously. The SCAQMD monitoring station closest to the LAX airport is the monitoring station 094 in Hawthorne. The address of the Hawthorne monitoring site is 5234 West 120th Street near La Cienega Blvd. The monitoring site is approximately 3.8 kilometers from the LAX central terminal area. The highest reported CO, O_3, NO_2, SO_2, PM_{10}, lead, and sulfate concentration levels for 1997, 1998, and 1999 are presented in **Table A-3** - Ambient Air Quality. The ambient air quality data at the Hawthorne site is useful for the LAX Source Apportionment Study because it characterizes the ambient air quality near the airport. The limitation of the Hawthorne data is that the contribution of sources surrounding the site to the criteria pollutant levels cannot be determined from the available data. Since the reported concentration levels are annual averages and maximums, the concentrations cannot be assigned to available weather data, which is used to identify contributing sources.

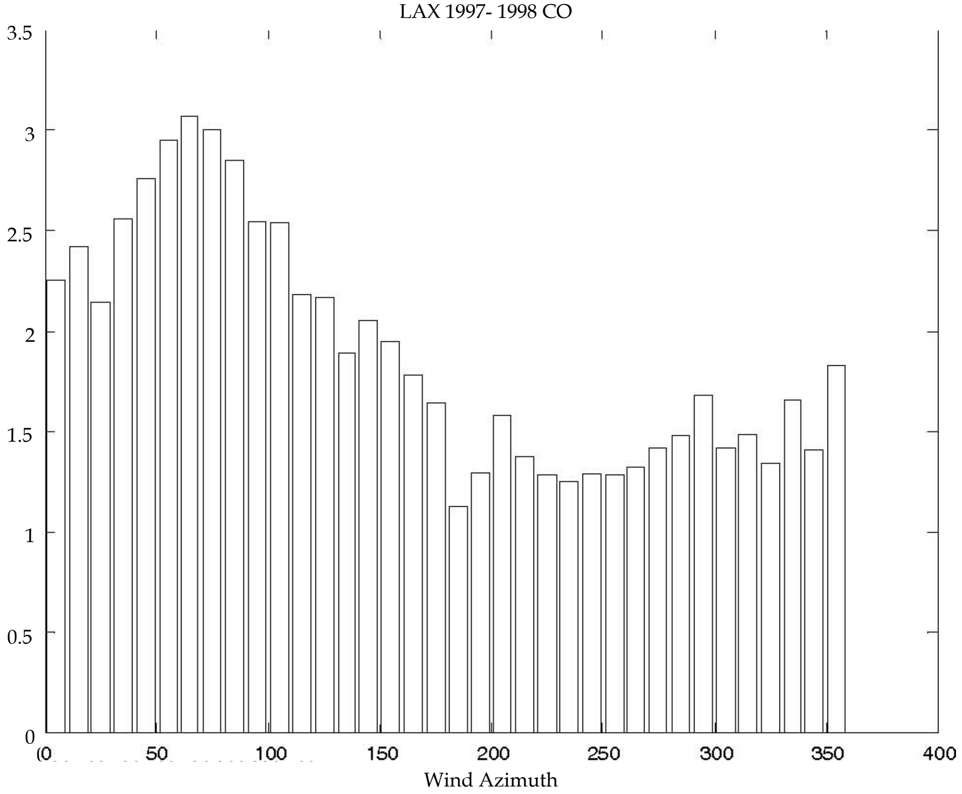
Table A-3 Ambient Air Quality at SCAQMD and On-Airport Monitoring Station Locations

Criteria Pollutant	Period	SCAQMD Monitoring Station 094			LAX Monitoring Station	Federal and State Standards	
		1997	1998	1999	1997-1998	NAAQS	CAAQS
Carbon Monoxide, CO	1 hour	12	11	10	10.6	35	20
	8 hour	10.3	9.4	8.4	8.6	9.5	9
Ozone, O_3	1 hour	0.11	0.09	0.15		0.12	0.09
	8 hour	0.09	0.07	0.09		0.08	N/A
Nitrogen Dioxide, NO_2	1 hour	0.17	0.15	0.13	0.15	N/A	0.25
	AAM	0.028	0.0295	0.0295	0.038**	0.053	N/A
Sulfur Dioxide, SO_2	1 hour	0.1	0.03	0.09	0.021	N/A	0.25
	3 hour				0.017	0.5	N/A
	24 hour	0.015	0.014	0.02	0.007	0.14	0.04
	AAM	0.0014	0.0039	0.004		0.03	N/A
Particulate Matter, PM_{10}	AAM	35.5*	32.7	35.6	36.3**	50	N/A
	AGM	33.8*	30.3	33.4	33.9**	N/A	30
	24 hour	79*	66	69	80.2	150	50

* Less than 12 full months of data. May not be representative.
** Not a true annual average

1997-1998 LAX Ambient Monitoring Study Wind Direction Analysis of Gas Concentration Data

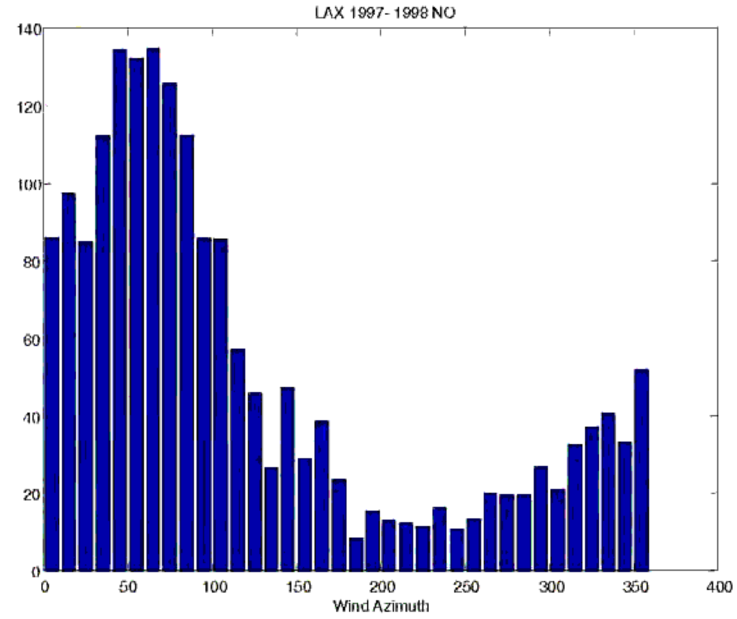
CO, NO, NO_2, and SO_2 data from the 1997-1998 sampling program were examined. The wind direction dependence of the concentrations of the various gases was determined as follows. The average concentration of the pollutant gas in question was determined for each of 36 10-degree wind direction sectors centered on 5, 15, 25, etc. degrees azimuth angle. A bar chart of the average concentration in each wind sector for CO is given below.

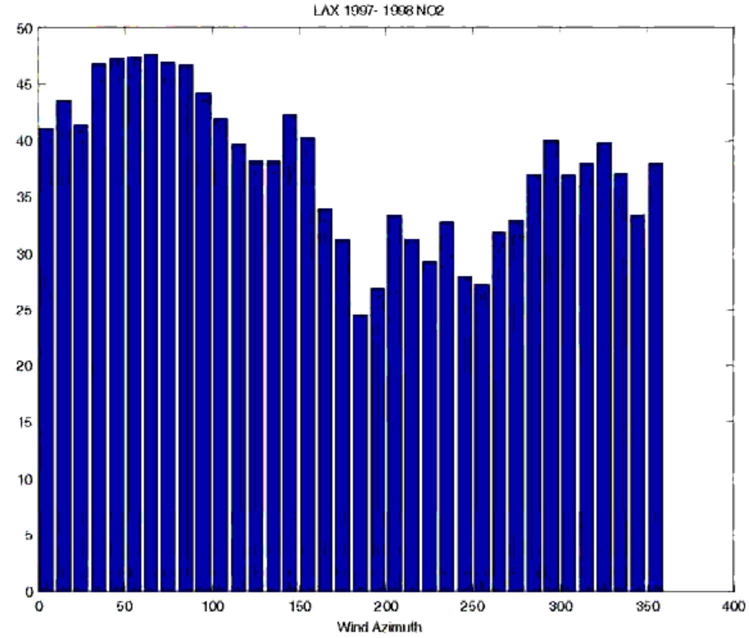


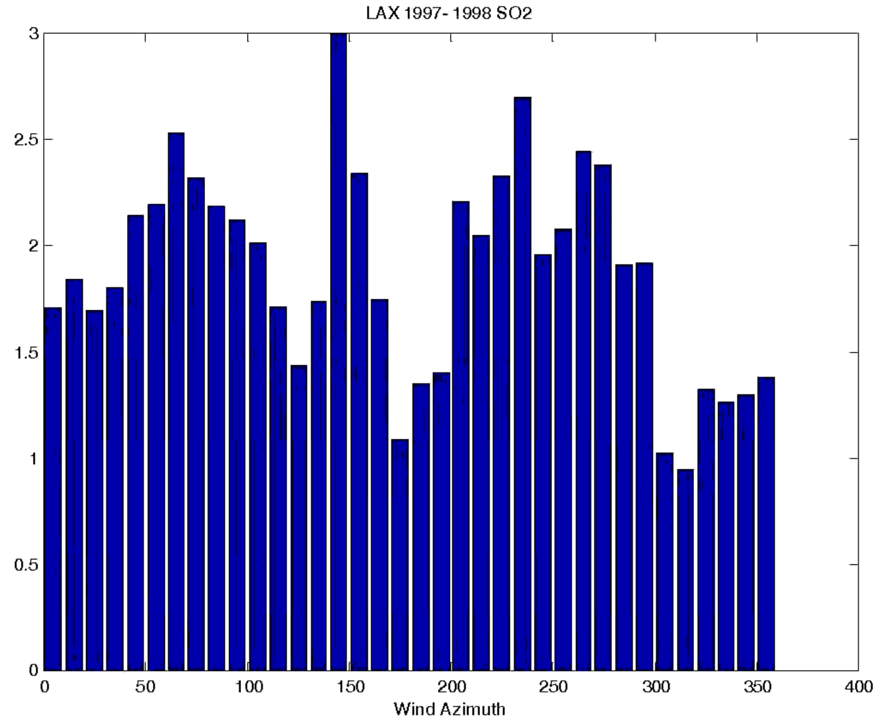
The highest average CO is centered around 55 degrees from North. This is the direction centered between the 405 Freeway and Century Boulevard, the two most heavily used roads in the area.

The NO wind direction plot is given below. The traffic peak is a bit more to the north at about 45 or 50 degrees and there is a stronger dependence on wind direction than for CO. The NO_2 plot follows the NO plot and is more similar to the CO plot than the NO plot. The SO_2 plot is very interesting and is shown after the NO_2 plot.

Unlike the vehicle-dominated plots of CO, NO, and NO_2, there are four peaks in the SO_2 wind direction plot: a broad peak centered at 65, a sharp peak at 145, and two overlapping peaks one centered about 220, and one centered at 270. The first broad peak at about 65 degrees azimuth maybe related to vehicles since it is broad and peaks where the NO and CO peak. The peak in the direction of 220 may be related to the El Segundo refinery, which is in that direction. The peak at 270 is probably from airport operations. However, the peak at 145 does not have a known source at this time. Since it is a sharp peak, it is probably a nearby source. This needs to be investigated.


LAX 1997- 1998 NO
140
120
100
80
60
40
20
0
0
50
100
150
200
250
300
350
400
Wind Azimuth


LAX 1997- 1998 NO2
50
45
40
35
30
25
20
15
10
5
0
0
50
100
150
200
250
300
350
400
Wind Azimuth



A.5 IMPLICATIONS OF CURRENT KNOWLEDGE FOR STUDY DESIGN

- Need to measure a variety of components, not just pollutants of concern, to understand source contributions.
- Need a multi-station network to estimate extent of pollution cloud.
- Need short sample durations to identify intermittent events and changes throughout the day, week, and year.
- Need samples corresponding to on-shore and off-shore flows.
- Need to reconcile and improve emissions estimates, both on- and off-airport.

APPENDIX D

LAWA TECHNICAL WORK PLAN BIBLIOGRAPHY OF PRIOR STUDIES

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APPENDIX E

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Module D — Off-Airport Inventory

Identify Other Potentially Significant Emission Sources in the Study Area

(Task 3)

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Mr. Bill Piazza of the Los Angeles Unified School District for his support in providing information about and navigation explanation of the Freeway Performance Measurement System (PeMS) website database.

EXECUTIVE SUMMARY

The purpose of this task was to provide an analysis of the off-airport emissions and on-airport tenant emissions, focusing on finding emission data sources and performing a criteria pollutant emission estimate for use in the scoping level source modeling analysis (Task 8). Additionally, a review of the data availability for non-criteria pollutants was performed.

This analysis task demonstrates that the majority of the criteria emission sources within the study area and west of the study area (marine emissions) are available through a number of separate emission database sources. However, there are constituent gaps in the available inventories, such as carbon dioxide and air toxics constituents; as well as, problems or gaps in data available for certain source types, such as harborcraft and pleasurecraft marine emissions and source specific emissions and stack parameters for the Chevron El Segundo Refinery.

The identification of which emission sources are the most significant for the Air Quality and Source Apportionment study needs to be determined in concert with the source-oriented modeling analysis task (Task 8), where additional information regarding the relative significance of the off-airport emission sources is provided. From a mass emissions perspective there are significant NO_x, CO, and $PM_{10}/PM_{2.5}$ emissions from the on-road vehicles, off-road vehicles, and major stationary sources (Chevron, Scattergood, El Segundo Power Plant, etc.) within the study area. For VOC emissions area sources and aggregated small point sources within the study are also numerically significant. For SO_x emissions only the major stationary sources and the marine traffic emission are significant emission sources.

It has also been determined that real-time data for freeway and major shipping lane traffic can be acquired to provide real-time activity levels to determine real-time emissions from these two source categories. However, the effort to acquire and format this data for determination of real-time emissions will be time consuming in comparison with using predictive models.

Additionally, is was determined that there are issues with the accuracy of some of the emission database sources, which are related to the age of the inventories, the assumptions and bases used to create for the inventories, and the provided locations of the emission sources. Therefore, additional interface with the agencies responsible for maintaining these emission inventory databases will be needed, and some work in this regard has already begun including providing corrected El Segundo Buoy location data to the ARB for their Marine Model Version 2.1.

In summary, while this study shows that there are available predictive and real-time data sources to provide a complete off-airport emission estimate, more work is necessary to finalize the methods and databases selected to provide the off-airport emissions for the final study.

SECTION 1

INTRODUCTION

The purpose of this report is to provide documentation on the effort, methods, and results for the identification and inventory of other significant emission sources within the study area (i.e., off-airport emissions and on-airport tenant emissions).

Scope of Effort

This effort included an inventory of off-airport onshore emission sources within the defined study area, and major offshore emission sources located west of the study area. Additionally, on-airport third party (tenant) emissions were inventoried as part of this effort. The general types of emission sources identified and inventoried are shown in Table 1.

TABLE 1

EMISSION SOURCES IDENTIFIED AND INVENTORIED

Emission Sources Inventoried
Stationary Sources (a)
On-Road Traffic
Off-Road Equipment
Area Sources
Aggregated Stationary Sources (b)
Marine Emissions

(a) Those stationary sources having available separate emission source data, including on-airport tenant emission sources not otherwise included in the on-airport emissions estimate.

(b) Aggregated stationary sources are those small point sources, such as restaurants, gas stations, etc. that do not have available separate emission source data.

The physical extent of the onshore and offshore emission inventory is described in Section 2. The emission inventory completed as part of this task included the determination of off-airport emissions and on-airport tenant emissions, but did not include on-airport aircraft, GSE, traffic emissions, or LAWA emissions which were determined separately in Task 5. However, the other on-airport emissions estimates were used as necessary to complete the emissions estimates provided here-in, specifically to ensure that all emission sources were accounted for to the extent possible and to ensure that on-airport emission sources were not double counted.

The data collection included, as available, criteria pollutants, air toxic compounds, and carbon dioxide. Availability of data for these pollutants varied, with criteria pollutant data being available or calculated, although the particulate and organic compound emissions data was not consistently reported[1], air toxics emissions data availability was more limited and available data appears incomplete, and carbon dioxide emissions data was often not available. Due to schedule and budget limitations, after collection, only the criteria pollutant data was processed and evaluated in detail.

Summary of Results

The emissions inventory indicates that there are a number of potentially significant emission sources that need to be considered in the study area. However, certain emission sources are more or less critical for certain pollutants. For example, marine emissions are critical for SOx emissions impact determination, but would be significantly less critical for CO emissions impacts. The actual impacts of each source are also a function of their location and emission dispersion characteristics, so the emissions inventory alone cannot determine the potential contribution to ambient air quality impacts for each of the emission source types. This initial emissions inventory evaluation has determined that all of the emission sources listed in Table 1 should be modeled to determine if their impacts may be significant within any part of the study area.

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[1] In the different emission databases particulate emissions are variously reported as PM10, PM2.5, total suspended particulate (TSP), or combinations thereof. In the different emission databases organic compound emissions are variously reported as total organic gases (TOG), volatile organic compounds (VOC), hydrocarbon (HC), reactive organic compounds (ROG), or combinations thereof.

SECTION 2

EMISSIONS DATA SOURCES

A review of available public database information was made and the most relevant public agencies were contacted. This includes contact with the South Coast Air Quality Management District (SCAQMD), the California Air Resources Board (ARB), the Southern California Association of Governments (SCAG), and the United States Environmental Protection Agency (USEPA).

Summary of Emission Data Sources Used

The following data sources were used to determine the criteria pollutant emissions that were forwarded for modeling.

TABLE 2

EMISSION DATA SOURCES

Emission Source	**Data Source**
Stationary Sources	ARB – CHAPIS SCAQMD - Online AER Data Site Specific CEMS Data (a)
On-Road Traffic	SCAG – Transportation Model PEMS – Caltrans/UC Berkeley
Off-Road (onshore)	ARB – CHAPIS
Area Source	ARB – CHAPIS
Aggregated Point Source	ARB – CHAPIS
Marine Emissions	ARB – Marine Model Version 2.1 ARB – Harborcraft Model
On-Airport Tenant Sources	ARB – CHAPIS (b) SCAQMD- Online AER Data Master Plan On-Airport Stationary Source Emission Inventory

---

(a) Scattergood and El Segundo Power Plants.
(b) CHAPIS = Community Health Air Pollution System

Section 3 describes in more detail how these data sources were used and adjusted to provide emissions data for the modeling analyses.

Online Literature Search

Prior to contacting any agencies an online literature search was performed. That search found the following potentially useful data sources:

- AIRS facility emissions data from EPA
- CHAPIS facility and area wide emissions data from ARB
- AER facility emissions and equipment data from SCAQMD

A review of the information obtained from each public agency contacted is provided below. A more thorough technical explanation of the compilation and use of the emission source data from each data source will be explained further in Section 3.

United States Environmental Protection Agency

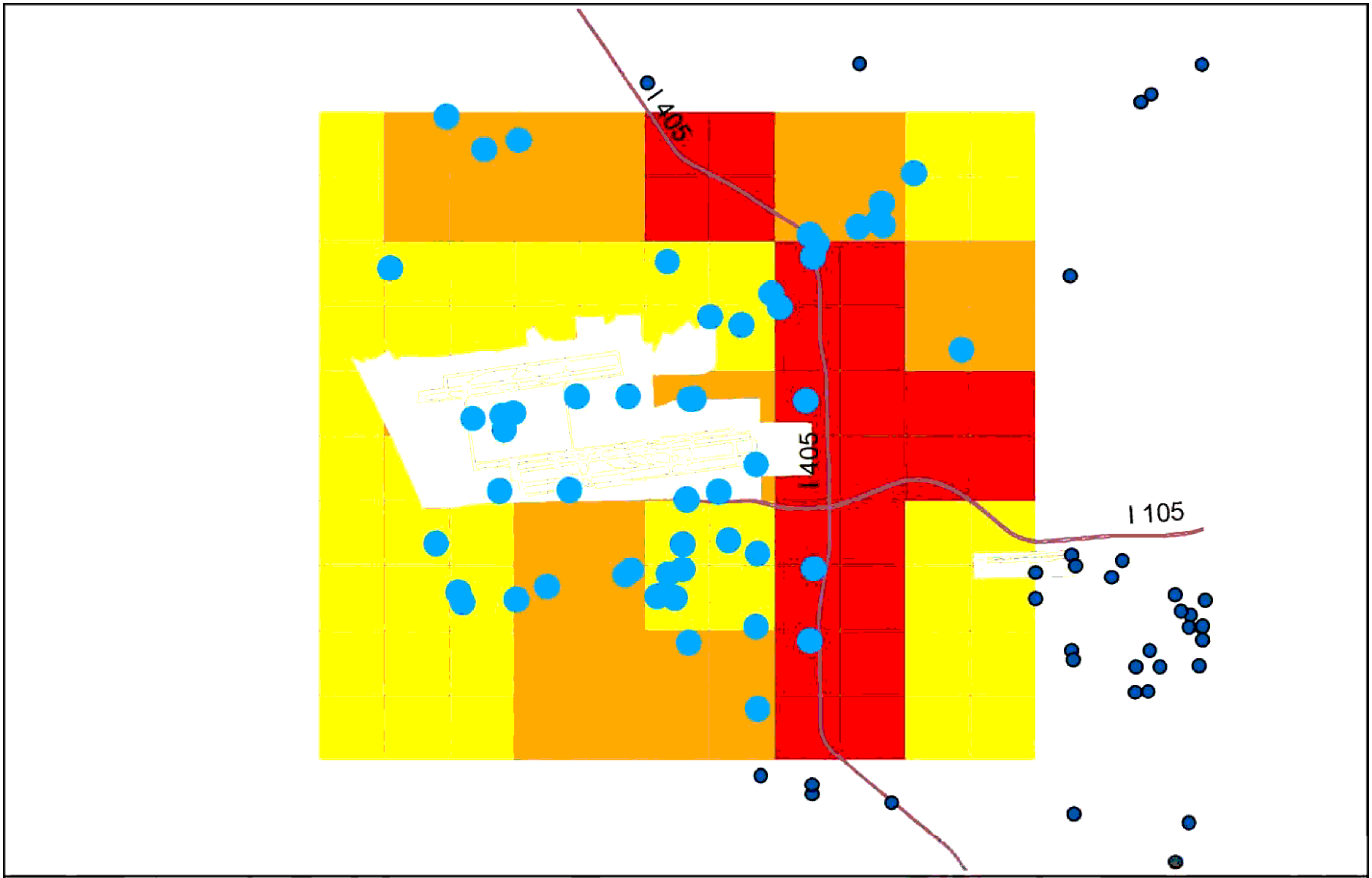
Contact was made with EPA Region IX personnel to identify potential USEPA emission source data sources, other than those already known. That contact was not aware of information that was useful beyond what is available in the AIRS Database (USEPA 2008a).

Later it was discovered that the TTN area of the USEPA website contains emissions data (older date than available from other sources) and more importantly emission source specific stack data for the Chevron El Segundo (USEPA 2008b).

California Air Resources Board

The California Air Resources Board (ARB) was contacted to determine available emissions data that could be retrieved from their online CHAPIS database (ARB 2008a). It was later learned that ARB also has marine emissions models. Information from the CHAPIS database, in the form of source separated major stationary source data and one square kilometer data for aggregated on-road emissions, off-road emissions, area source emissions, and minor point source emissions was collected (ARB 2008b). The general area of the CHAPIS emissions data supplied by ARB is shown in Figure 1, where the locations of the one kilometer squares are shown in colors indicating the comparative emission rate from each square, and where the source separated major stationary sources are shown as the blue dots, with the larger blue dots indicating ARB's interpretation of which of the major stationary sources may be within the LAX Study Area. This data was culled as necessary to better fit the actual shape of the defined study area and the coordinates of the data were also corrected as necessary.

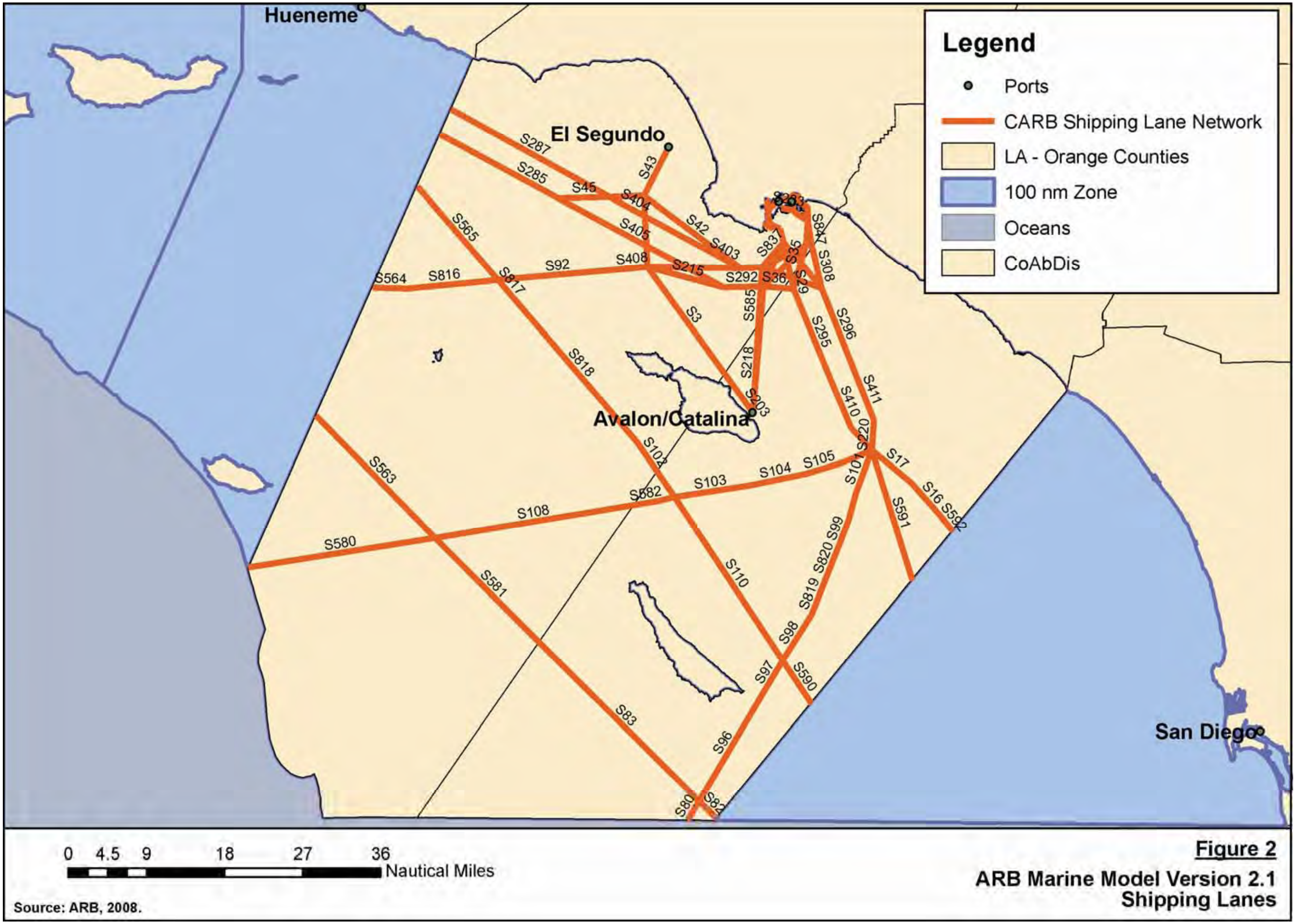
Information for marine sources, both major shipping lanes and the El Segundo product loading/unloading buoys, and harbor craft was also collected from ARB (ARB 2008c). The data was provided electronically from ARB for the study area and defined offshore area which is shown in Figure 2.



Source: ARB, 2008.

Figure 1

CHAPIS 1-Kilometer and Stationary Source Data



Source: ARB, 2008.

Figure 2

ARB Marine Model Version 2.1
Shipping Lanes

South Coast Air Quality Management District

After discussion with the SCAQMD TWG contact person, a formal and written data request was prepared and submitted to SCAQMD on April 18th, 2008. A formal acknowledgment letter of the receipt of this data request was received on April 24th, 2008. It was later determined that SCAQMD could not provide the requested information, in part because they considered it proprietary, and it was suggested to use the already identified FIND database, that contains Annual Emission Report (AER) data and other source data, as a potential source of information. Point source data, where available, was collected from the FIND database (SCAQMD 2008a).

SCAQMD was later contacted to again request limited information for stack parameters for modeling a few of the largest point sources (Chevron Refinery, Scattergood Power Plant, and El Segundo Refinery). SCAQMD also considered that information proprietary and could not release the information.

Southern California Association of Governments

SCAG was contacted to determine the potential to obtain on-road data for the study area. A separate model run was completed by SCAG using the SCAG Transportation Model for summer 2008 (SCAG 2008). This model includes output of traffic volumes, link coordinates, traffic times for each link, and vehicle class information. The output of this model was provided in electronic format. Data for a total of 1726 links were provided. A graphical representation of the provided SCAG link data is shown in Figure 3. These SCAG links constitute only a portion of the roadways in the study area, but do cover most of the major roadways. The SCAG links cover an extent that is somewhat greater than the study area, particularly for the 405 and 105 freeways.

Los Angeles Department of Water and Power

LADWP was contacted and agreed to supply available hourly emissions and fuel use data for the Scattergood Power Plant. Actual hourly emissions and fuel use data during June and July 2008 was collected for the three power boilers at the Scattergood Power Plant (LADWP 2008). This data was provided in electronic format. Stack parameters for the existing two boiler stacks was collected from information available on the SCAQMD CEQA projects website (SCAQMD 2008b).

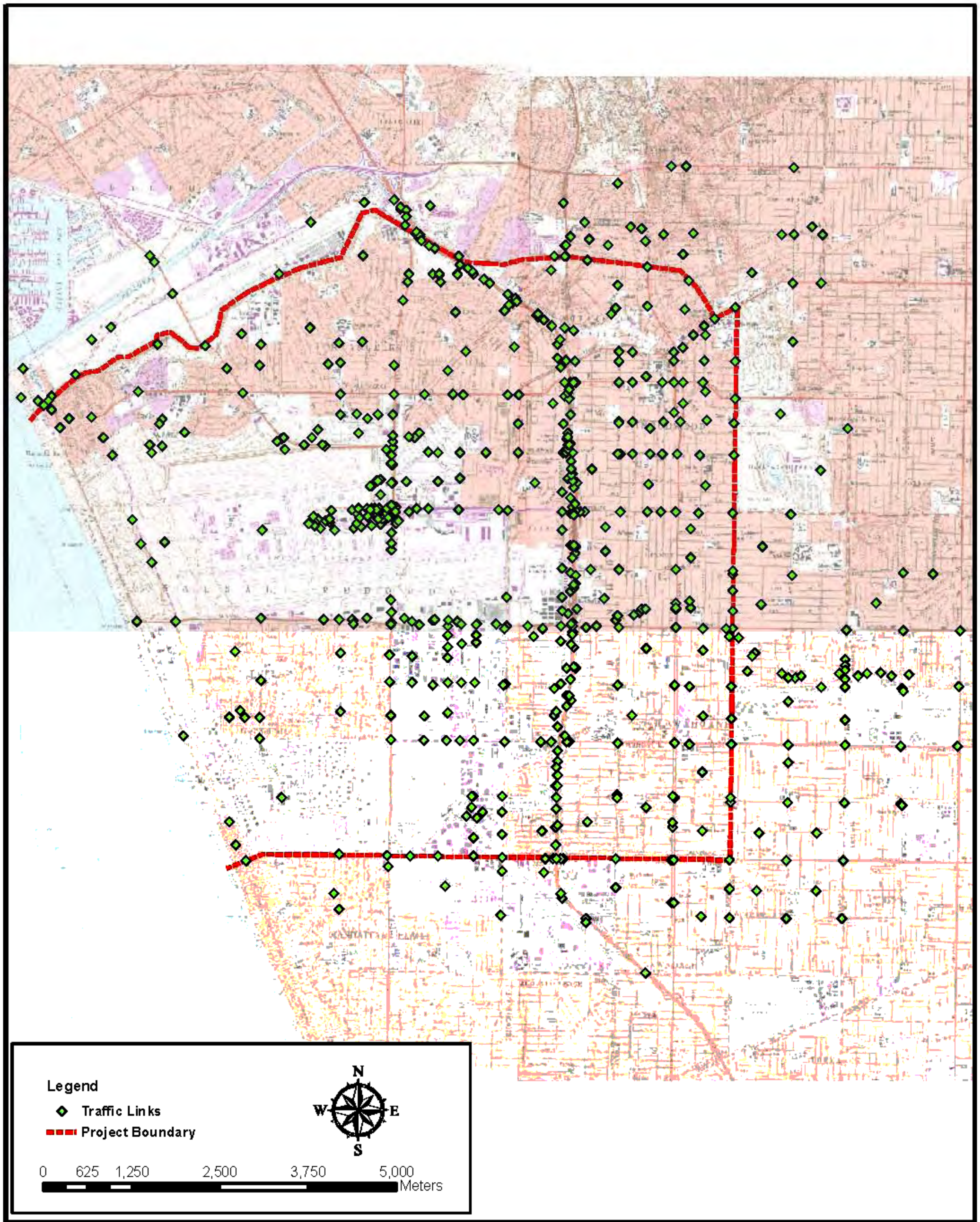


Figure 3

SCAG Link Data

Source: SCAG, 2008.

NRG Energy Inc.

NRG was contacted and agreed to supply available hourly emissions and fuel use data for the El Segundo Power Plant. Actual hourly emissions and fuel use data during June and July 2008 was collected for the two power boilers at the El Segundo Power Plant (NRG 2008). This data was provided in electronic format. Stack parameters for the existing boiler stacks was collected from information available from the California Energy Commission El Segundo Power Plant siting case records (NRG 2001).

Chevron Corporation

The Chevron Corporation was contacted to inquire about obtaining source specific emission sources. Chevron's environmental contact person stated that the requested data was not public and that they were not at liberty to supply the requested information.

United States Geological Survey

The El Segundo marine terminal location was found to be improperly described in the ARB marine data as approximately five miles offshore and improperly described in other regulatory/marine industry websites as being essentially in the surf zone. The USGS Global Visualization Viewer (USGS 2008) was used to find aerial photographs with vessels in place at the El Segundo marine terminal, which was then overlaid onto USGS maps to determine reasonably accurate locations for vessels hotelling at these buoys.

Freeway Performance Measurement System (PeMS)

Late in the emissions data retrieval period this traffic data resource was identified to the Technical Working Group. The data available includes real-time traffic data, including; traffic volume, separate truck volume, and traffic speed at specific sensor locations (UCB 2008). The sensors cover the 405 and 105 freeway area inside the study boundary. A selected number of links were collected to compare with the SCAG model's forecasted traffic data.

SECTION 3

EMISSIONS DATA AND DATA ADJUSTMENTS

The following provides a summary of the collected emissions data and the data adjustments performed for each of the emission source types. Data was collected for all available pollutants (criteria, air toxics, CO_2); however, for this phase of the study due to schedule and budget limitations only the criteria pollutant data were processed beyond their initial collection.

The locations of the emission sources provided for the modeling analyses are shown in Figure 4.

Stationary Sources

Stationary source emissions data were collected from several sources: including the USEPA AIRS database, from ARB through a compilation of available specific point source data in the CHAPIS data base, and collected online at the SCAQMD Facility Information Detail (FIND) website. The most recent year of FIND emissions data (2006) was collected where available for sources within the study boundary. The AIRS data information was determined to be dated in comparison with the other emission sources and was not used.

Additionally, on-airport emissions estimates originally prepared for the LAX Master Plan were collected from John Pehrson of CDM and used to determine emissions for on-airport emission sources not included in the ARB or SCAQMD data (CDM 2000).

No adjustments were made to the stationary sources data obtained from ARB or SCAQMD; and the 2006 SCAQMD AER data where available for a particular source was directed to be used for the modeling analysis. Several sources identified in the Master Plan emissions inventory, and not included in the SCAQMD and ARB data were found. Several of these were for sources that no longer exist at the airport or have been replaced by other similar sources (such is the case for airline catering facilities, where approximately five no longer existing on the site, with two new facilities taking their place). Adjustments to the emissions data were made based on similar facilities for known new emission sources (such as for the new Flying Foods and Gate Gourmet catering facilities) as determined through a review of LAWA supplied tenant information (LAWA 2008).

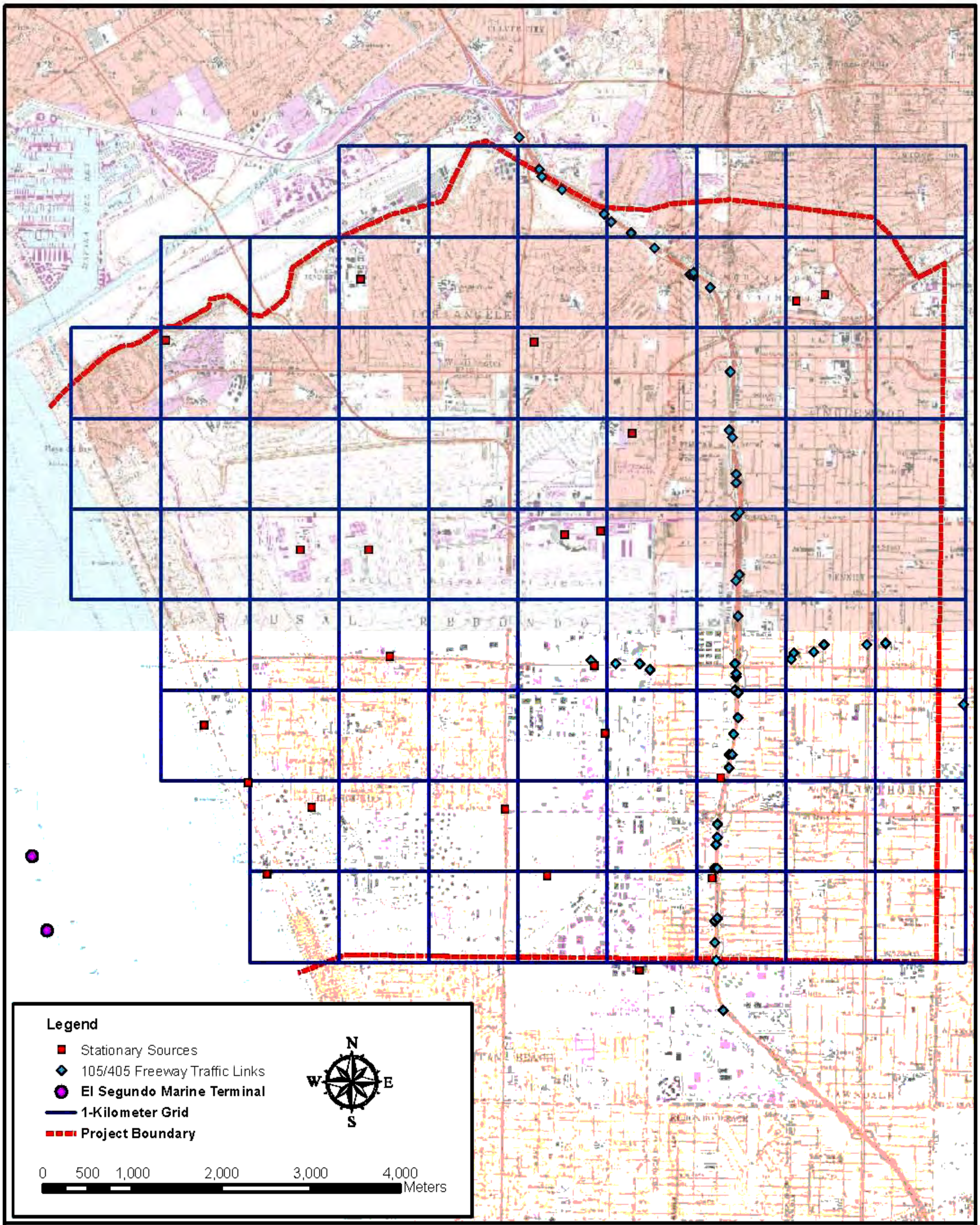


Figure 4

Modeling Input Emission Data Locations

Source: Aspen Environmental Group, 2008.

It was determined that only facilities with emissions (total of the criteria pollutants) over five tons per year were going to be modeled. There were a few sources that were found to be above 5 tons of criteria pollutant emissions using the ARB, SCAQMD or Master Plan data that were not modeled due to one of the following reasons:

- Emission source was primarily a GSE supplier, so the emissions should be accounted for in the on-airport GSE emissions.
- Emissions for general aircraft refueling, based on a review of the relatively high on-airport area source ROG data in the CHAPIS database seemed to be already accounted for.
- Did not have emissions over 5 tons per year in any one location (CTA restaurants)
- Facilities that after further review of the FIND database were found to have reduced their emission potential by giving up permits for their major emission sources and obtained ERCs for the shutdown.

After screening there were a total of twenty two facilities, sixteen off-airport, and six on-airport to be modeled separately. These facilities are listed in Table 3.

TABLE 3

STATIONARY SOURCE LIST

Stationary Sources to be Modeled

Off-Airport Sources	**On-Airport Sources**
Chevron Products Company	United Airlines Inc.
Scattergood Generating Facility	American Airlines Inc.
So Cal Gas Playa Vista	Garrett Aviation Services Inc.
El Segundo Power Plant	LAXFUEL Corp
Raytheon Company	LSG Skychefs
Northrop Grumman Corp, Aircraft Div	U.S. Post Office
Northrop Grumman Space & Missions Systems	
Boeing Satellite Systems Inc	
The Aerospace Corp	
Loyola Marymount	
Vought Aircraft Industries	
Hyperion WWTP	
Insync Media Inc	
Merle Norman Cosmetics	
Electroply Inc	
Marvin Engineering Co Inc.	

Of the stationary source emissions identified for the modeling analyses, approximately 99.9 percent of the SOx emissions, 95 percent of the CO emissions, 94 percent of the NOx and PM2.5 emissions, 93 percent of the PM10 emissions, and 85 percent of the VOC emissions were from four sources (Chevron El Segundo Refinery, Scattergood Power Plant, El Segundo Power Plant, and So Cal Gas Playa Vista), with the Chevron El Segundo Refinery dominating over the other three facilities in all pollutants other than CO. A summary of the total point source emissions is presented in Section 4.

On-Road Emissions Sources

On-road emissions were collected from ARB (CHAPIS) for the 1-kilometer squares that make up the study area, and SCAG traffic link information was collected for summer 2008 for the major links that run through the study area. For modeling purposes, emissions for the 405 and 105 freeways, based on the SCAG data, were calculated. The EMFAC2007 model was used to determine emission factors for the different vehicle classes (ARB 2006). PM2.5 fractions were determined using the latest California Emission Inventory Development and Reporting System (CEIDARS) particulate size fractions data (SCAQMD 2008c). Emissions were determined for each of the 405 and 105 freeway links that overlay the study area. Additionally, paved road dust emissions (PM10 and PM2.5) where determined using USEPA AP-42 Section 13.2.1 calculations (USEPA 2008c).

Several adjustments were made to the on-road emissions. First the ARB data was corrected from 2001 to 2008 using linear interpolation of the ARB emissions estimates for the Los Angeles County, using only the control basis (ARB 2008d). Correcting for both the growth and control basis was not considered reasonable for this area as it is generally built-out and there has been very little population growth in the area. In order to interpolate properly the specific emissions category is used and the emissions from 2001 to 2008 are linearly interpolated using the year 2000 county emissions estimate and the forecast year 2010 emissions estimate.

The second adjustment was the subtraction of the EDMS on-airport on-road emissions data. This subtraction also required the additional step of setting negative values to zero. An issue with this data is that the EDMS model uses fuel sulfur contents that do not meet California fuel standards.

The last adjustment was subtracting the calculated SCAG 405 and 105 link emissions data from the appropriate ARB square kilometer data. This subtraction also required two additional steps, first the paved road fugitive emissions were not subtracted as the ARB on-road emissions data clearly does not include fugitive dust, and second, emissions level smoothing was performed over the 1-kilometer cells that were adjacent to the cells that overlaid the freeways. This second smoothing step was required to address emissions level/location issues within the ARB data (please see Figure 1 that shows emissions in many of the 1-kilometer squares surrounding the freeways to be unreasonably high) and avoid 405/105 emissions subtractions that result in negative values.

Collected PeMS traffic data was compared to the SCAG model traffic data for a couple of selected links. In general, the SCAG model data predicted higher traffic counts than the PeMS data and slower traffic speeds. However, due to the unusually high traffic speeds (expected rush hour slowing was often not seen in the PeMS data) reported in the PeMS data for the links surveyed, and difficulty determining PeMS data accuracy, no adjustments to traffic flow based on the lower PeMS traffic volume data were incorporated at this time.

Off-Road Emissions Sources

Off-road emissions were obtained from ARB CHAPIS data. The criteria pollutant emissions were updated from 2001 to 2008 using linear interpolation of the ARB emissions estimates for the basin, using only the control basis (see additional explanation under on-road sources). Additionally, the on-airport GSE emissions, after they were spatially identified, were subtracted from the appropriate 1-kilometer squares. Emissions that were then determined to be negative after this subtraction were set to zero. An issue with this data is that the EDMS model uses fuel sulfur contents that do not meet California fuel standards.

Area Emissions Sources

Area source emissions were obtained from ARB CHAPIS data. The criteria pollutant emissions were updated from 2001 to 2008 using linear interpolation of the ARB emissions estimates for the basin, using only the control basis (see additional explanation under on-road sources). No further adjustments were made to these emissions. After review of the emissions data it appeared that the CHAPIS data would account for the refueling fugitive emissions at the airport as the ROG emissions attributed to the 1-kilometer squares that overlay the airport are significantly higher than surrounding areas.

Aggregated Stationary Source Emissions

Aggregated stationary source emissions were obtained from ARB CHAPIS data. The emissions data included criteria pollutants and selected air toxic pollutants. The criteria pollutant emissions were updated from 2001 to 2008 using linear interpolation of the ARB emissions estimates for the basin, using only the control basis (see additional explanation under on-road sources).

An additional adjustment was made to the on-airport emissions in specific 1-kilometer squares by subtracting the non-cooling tower emissions for the non-CHAPIS listed stationary sources determined for modeling by the Master Plan data (LSG Skychefs and U.S. Post Office). The cooling tower emissions were not subtracted as SCAQMD does not account for cooling tower emissions in its emissions estimates, so the emissions estimates SCAQMD provided to ARB for CHAPIS would not include these emissions.

Marine Emissions

The marine emissions were collected from the ARB based on output from their Marine Model Version 2.1 and Harborcraft Model. The emissions from the Marine Model Version 2.1 are shipping lane link specific for 2008, as adjusted by ARB, and are daily average emissions that include criteria pollutant emissions, greenhouse gas emissions (CO_2, methane, and N_2O) and fuel use. No adjustments were made to these emissions estimates, but the number of shipping lane links used for modeling was limited to the shipping lanes north of Point Vicente, south of the extended Los Angeles County border, and east of the Channel Islands. Those specific shipping lane links, see Figure 2 for reference, are as follows:

- S42, S43, S44, S92, S285, S287, S403, S404, S405, S408, S564, S816, and the El Segundo Buoys.

The emissions from the Harborcraft Model are daily average emissions that include criteria pollutant emissions, CO_2, and methane. The harborcraft emissions were attributed to large areas extending out from the entire air basin in three separate intervals, state waters and two outer continental shelf intervals. While, the emissions were significant in total (daily NOx emissions were over 17 tons) there was no way to attribute emissions to the area directly west of the study area, which are likely to be lower than average considering the high emissions that would likely be attributed to the Los Angeles/Long Beach port complex. Therefore, harborcraft emissions were not included further in the study area emissions inventory and harborcraft emissions were not provided for the dispersion modeling analyses.

Available Data Summary

The emissions data provided by the various agencies or collected from online sources did not always include all of the emissions data desired. The limitations on the available pollutant information are summarized in Table 4.

TABLE 4

INITIALLY AVAILABLE POLLUTANT DATA

Emissions Data Source	Criteria	Air Toxics	CO2
CHAPIS (a)			
On-Road Emissions	YES	YES	NO
Off-Road Emissions	YES	YES	NO
Area Source Emissions	YES	YES	NO
Aggregated Point Source Emissions	YES	YES	NO
SCAQMD AER Stationary Source Emissions (a)	YES	YES	NO
El Segundo/Scattergood Power Plant CEMS Data	YES	NO	YES
SCAG Calculated On-Road Emissions	YES	NO	YES
ARB Marine Emissions	YES	NO	YES
Master Plan On-Airport Data (a)	YES	YES	NO

(a) Air toxics data may not be complete.

Some of the air toxics data, while not initially collected may be available or can be determined through particulate and organic emission profiles, or other source specific emission factors. The missing CO_2 data will be difficult to determine with the exception of the Master Plan On-Airport emission sources which generally have fuel use data along with the emissions data.

SECTION 4

EMISSIONS DATA SUMMARY

The emissions data, representing the emissions provided for modeling, is summarized in Table 5. This emissions summary does not include airport operation emissions, including LAWA's on-airport point and area emission sources.

TABLE 5

EMISSIONS DATA SUMMARY (average tons/day)

Emissions Sources	NOx	CO	VOC	SOx	PM10	PM2.5
Major Point Source (a)	2.85	4.37	2.12	1.20	0.91	0.78
On-Road Traffic						
Non Freeway Traffic Subset	3.07	28.95	3.01	0.07	0.25	0.17
405/105 Freeway Traffic Subset	3.26	9.20	0.83	0.01	1.59	0.18
Off-Road	3.62	10.09	1.22	0.06	0.20	0.18
Area Source	0.28	0.51	2.03	0.00	0.16	0.04
Aggregated Point Source	0.49	0.36	1.17	0.01	0.03	0.02
Marine Emissions (b)	0.50	0.04	0.02	1.73	0.10	0.10
Totals	**14.07**	**53.52**	**10.4**	**3.08**	**3.24**	**1.47**

(a) Comprises the off-airport and on-airport tenant emissions that were modeled separately.

(b) Comprises only the emissions from the specific marine traffic links and El Segundo Marine Terminal buoys that are identified in Section 3.

The emissions shown above in Table 5 also do not include marine emissions outside of the Channel Islands or north of the extended Los Angeles County border or south of Point Vicente, or any harborcraft marine emissions.

MODELING INPUT DATA

Along with the emissions data, the locations and other modeling inputs for the different emission sources were provided for modeling as follows:

- For the CHAPIS on-road, off-road, area source, and aggregate point source data the southwest corner location in NAD83 UTM was provided for each of the 80 1-kilometer squares that were used to cover the project area.

- For the Scattergood and El Segundo Power Plants specific stack parameter input data was provided, including NAD83 UTM locations for the stacks.

- Latitude and longitude data was provided for each of the other stationary sources (except Chevron), along with a general description of the emission sources occurring at each of the stationary sources to be modeled.

- For the 405/105 freeway emissions, the location and initial width of each volume source, using USEPA procedures based on total roadway width and using a two width separation, were provided to the modeling group for each of 52 freeway links, with a total of 2252 volume sources.

- For the marine sources the specific El Segundo Buoy locations were provided along with the start and end point of each of the shipping lanes in NAD83 UTM.

- Temporal file data available on the USEPA website was compiled and appropriate temporal files were forwarded for the modeling runs (USEPA 2008d).

SECTION 5

LIMITATIONS AND POTENTIAL IMPROVEMENTS

There are limitations and/or inconsistencies in the data collected and processed for this Demonstration Project phase of the project. There are also certain areas in the emissions estimate or determination of modeling parameters that may be able to be improved with additional work in later project phases.

Limitations and Inconsistencies

There are a few limitations in the available data and some inconsistencies between different sets of data. A summary of these are as follows:

- The on-road emissions data from CHAPIS does not include road dust emissions, and may not include brake wear and tire wear emissions. The on-airport on-road emissions data determined through the use of EDMS does not include road dust emissions. The emissions calculated as part of this study from the SCAG link data includes road dust (AP-42 Section 13.2.2 calculation), break wear and tire wear.

- The ARB 1-kilometer square emissions data was noted to be for 2001 and was therefore corrected to a 2008 basis. The method used for this correction, while determined in consultation with ARB, is limited and likely caused some errors, particularly for on-road SOx which while still low is clearly too high as compared with the 405/105 freeway SOx emissions.

- The EDMS emissions data needs to be improved so that subtracting emissions from the on-airport traffic does not cause negative SOx emissions (i.e. the fuel sulfur assumptions in EDMS for on-road traffic are not correct for California fuel standards). The same is true for GSE emissions, with additional correction likely needed for other pollutants (such as CO and NOx) with emissions estimates that are likely too high. The use of federal emissions estimating models that are tied into EDMS (MOBILE6 and NONROAD), rather than the use of California models (EMFAC2007 and OFFROAD) will overestimate emissions for California on-road and off-road sources.

- There may be issues or problems with the assumed locations for some of the emissions sources, including: the SCAG link locations, the ARB 1-kilometer squares, the stationary sources, and marine traffic links. In general, the data appears to be a good fit, but much of the data was originally received in obscure or agency specific coordinate systems that needed to be corrected to standard coordinates, which could have introduced errors that need to be resolved through GIS analysis. Additionally, there may be errors in the supplied location data that have not yet been discovered. One specific example is that there is a SCAG 405 freeway link that causes the northbound lanes to cross the southbound lanes and then cross back in the next link.

- The emissions data is inconsistent in regards to the available pollutants. To complete the air toxics emissions estimate ARB particulate and organic source profiles, or similar, will need to be used for several emission source types. The amount of missing carbon dioxide emissions data, along with the source types from which it is missing, makes the completion of a reasonably accurate carbon dioxide emissions estimate for the study area very difficult, if not impossible at this time.

Potential Improvements

There are areas where the data could be improved depending on the available timeline and budget allowed for data collection and processing. These potential improvements include the following:

- Obtain updated stationary source emissions data from SCAQMD. This would include their help to identify sources that are new in the area and that have left the area since the 2006 AER. This is most important for the Chevron El Segundo Refinery.

- Determine if the CHAPIS 1-kilometer square data can be updated from the 2001 basis. ARB would have to work with SCAQMD to obtain the data necessary for this update. It would also be useful to obtain information from SCAQMD staff on the exact assumptions used to create the emissions for each CHAPIS emissions category given to ARB (on-road, off-road, area, aggregate point sources), so that any double or non-counting can be determined and corrected.

- Obtain and use PeMS data, if it can be determined it is accurate, to determine real-time hourly traffic emissions. There are many issues with using PeMS data including limited vehicle type information, the high cost of downloading and processing the data, and the schedule lag associated with the use of real-time data.

- Obtain and use real-time marine traffic data for the major shipping routes of concern and the El Segundo Buoys. Additionally, the collection of appropriate ship emission factor data would be needed to determine emissions using the marine traffic data. The use of this data would have the same cost and schedule issues as the use of the PeMS data.

- Obtain, if possible, harborcraft and pleasurecraft marine emissions west of LAX, review quantity and determine viability and necessity for inclusion in the modeling analysis.

- Perform additional review of the USEPA TTN website stationary source data to determine if additional improvements in stationary source stack parameters can be made.

SECTION 6

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Module E — Fuel Analysis

Sample and Characterize Mobile Source Fuels Used On and Around the Airport
(Task 4)

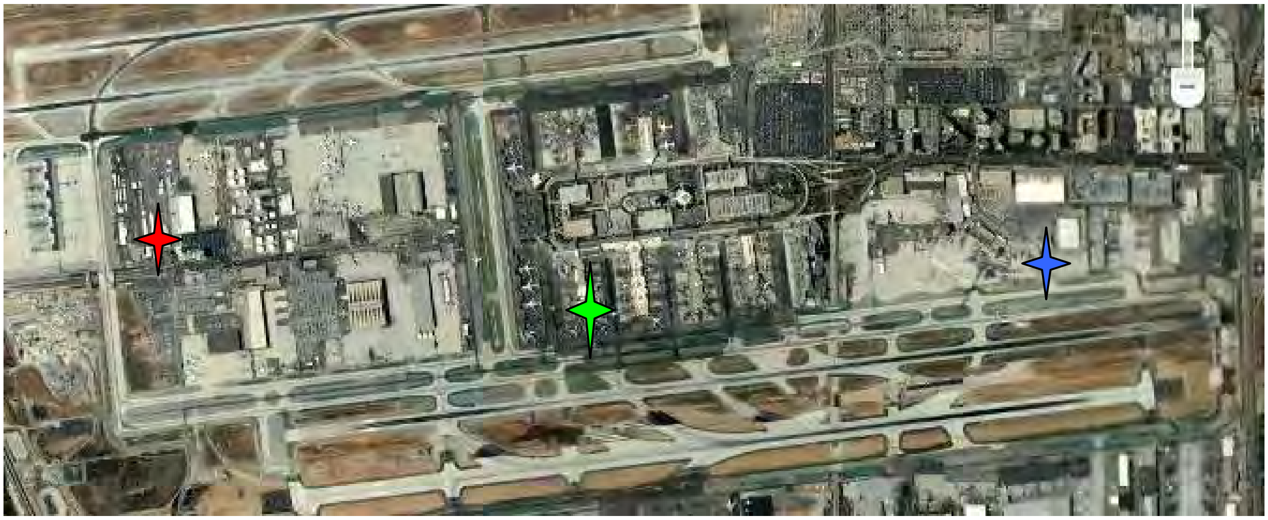
Introduction

The purpose of this task was to determine a baseline chemical makeup of the fuels being used at LAX International Airport ("the Airport" or LAX) during the timeframe of the Air Quality and Source Apportionment Study (AQSAS) Technology and Methodology Feasibility Demonstration Project ("Demonstration Project"). This fuel sampling and analysis, together with other data, will facilitate receptor modeling efforts and will supplement an understanding of the chemical composition of exhaust produced by mobile emissions sources at the Airport.

On July 16, 2008, the Study Team collected four (4) liquid fuel samples at the Airport, including one sample each of jet fuel (Jet-A) and gasoline, as well as two samples of diesel fuel. There is currently no Aviation Gasoline refueling performed at LAX.

The Jet-A sample was collected from a hydrant fuel truck as it was refueling an aircraft on the east side of Terminal 4. One diesel (diesel A) and one unleaded gasoline sample were collected at the Construction/Maintenance Yard located on the west side of the Airport, and one diesel (diesel B) sample was collected at the Aircraft & GSE Maintenance area located on the east side of the airport. Sample collection locations are depicted in Figure 1. Multiple headspace-free sampling jars were used for sample collection and were labeled in the field.

Figure 1
SAMPLE COLLECTION LOCATIONS
AQSAS Demonstration Project
Los Angeles International Airport



After collection, samples were preserved and transported to the Study Team's participating laboratory, Atmospheric Analysis & Consulting (AAC). One sampling container of each of the fuels was retained for analysis at AAC while others were transported to subcontracted laboratories, American Environmental Testing Laboratory (AETL), Corelab and Saybolt.

As called for in the Scope of Services, each of the fuel samples was analyzed by the following methodologies:

- ASTM D-5623 (Speciated Sulfur compounds),
- EPA 8260/8082 (Volatile Organic Compounds, Halogenated Hydrocarbons, Poly Chlorinated Biphenyls),
- ASTM D-6729/6733 & Gas Chromatography/Mass Spectroscopy (Detailed Hydrocarbon Analysis, Composition/Breakdown, Markers/Additives), and
- EPA TO-15/TO-12 PAMS (Headspace analysis for Volatile Organic Compounds and Hydrocarbons).

No problems were encountered during receiving, preparation and/or analysis of these samples. Upon receipt of the data from the subcontracted laboratories, AAC performed an independent Quality Assurance/Quality Control evaluation of the data packages and all data was transferred to Electronic Data Deliverable format. Appendix A of this report contains all of the hardcopies, as received, from the subcontracted labs as well as AAC's analysis results.

Fuel Analysis (VOC Composition)

The volatile organic compound (VOC) measurements are used to support the receptor modeling efforts of the AQSAS. The working hypothesis is that the compounds seen in the fuel are characteristic of what is seen in the unburned hydrocarbon component of exhaust. In some instances this can be observed in gasoline and diesel engines, and it is hypothesized to be possible for aircraft turbine engines.

Table 1 shows the results of one fuel analysis method, EPA Reference Method 8260. The concentrations of the trimethylbenzenes and xylenes are much higher in Jet-A than in diesel, and could potentially delineate jet aircraft emissions from diesel emissions. However, gasoline also has very high concentrations of these species. The most reliable source apportionment requires species that are dominated by Jet-A and allow for differentiation of gasoline and diesel fuel (i.e., species that have much higher concentrations in Jet-A and diesel than in gasoline).

The fuel samples were also analyzed by gas chromatograph / mass spectrometry (GC/MS), maximizing the number of chemical species that can be uniquely identified and measured. The major and minor VOC species and classes of VOCs (concentrations > 1%) in Jet-A fuel are seen in Table 2. The high carbon number species, dodecane and above (10 or more carbons) are seen to be very low in gasoline, but not in Jet-A or diesel fuel and if present in the emissions, can be used in receptor modeling of VOCs to separate gasoline from Jet-A and diesel fuel. It is important to note that these results come from a single sample at each of the four locations and do not reflect or quantify variability in the fuel compositions.

In order to support CMB modeling, species that are high in Jet-A compared to diesel must be identified and quantified. The ratio of Jet-A to diesel species is shown in Table 2, and a number of species have much higher concentrations in Jet-A than diesel. Note that there are three dimethyl- 2, 3-dihydro-1H-indenes that have concentrations of about 1 percent in Jet-A that are very low in diesel fuel. These explain most of the total indene concentration in Jet-A of about 3.1 percent. Total indenes in the diesel fuels are 0.7 and 1.5 percent. The two largest indene species in diesel A and B are also shown in Table 2. These are quite different from the Jet-A indene species; thus, emission measurements of dimethyl-2,3-dihydro-1H-indenes are potentially dominated by jet aircraft VOC emissions.

Table 1

8260 VOC FUEL CONCENTRATION
AQSAS - Demonstration Project
Los Angeles International Airport

Analyte	Jet-A Wt %	DIESEL (1) Wt %	Jet-A/ Diesel (1)	DIESEL (2) Wt %	Jet-A/ Diesel (2)	Unleaded Gasoline Wt %
Benzene	0.00160	0.00176	0.9	0.00366	0.4	0.80000
n-Butylbenzene	0.04820	0.00100	48.2	0.00100	48.2	0.00400
sec-Butylbenzene	0.02420	0.00424	5.7	0.00300	8.1	0.01380
Ethylbenzene	0.05220	0.01060	4.9	0.01250	4.2	1.18000
Isopropylbenzene	0.02130	0.00252	8.5	0.00206	10.3	0.06900
p-Isopropyltoluene	0.03080	0.00273	11.3	0.00213	14.5	0.00410
Naphthalene	0.03840	0.00153	25.1	0.00161	23.9	0.03850
n-Propylbenzene	0.06020	0.00760	7.9	0.00540	11.1	0.24400
Toluene (Methyl benzene)	0.04500	0.01920	2.3	0.04600	1.0	6.60000
1,2,4-Trimethylbenzene	0.41000	0.06480	6.3	0.04840	8.5	2.55000
1,3,5-Trimethylbenzene	0.09600	0.01560	6.2	0.01210	7.9	0.48300
o-Xylene	0.11500	0.01890	6.1	0.02300	5.0	2.20000
m,p-Xylenes	0.19000	0.03920	4.8	0.05440	3.5	5.94000

Note: Number of significant digits is not indicative of analytical certainties.
Two samples of diesel fuel were taken on the day of fuel sampling.

Table 2

GC/MS FUEL COMPOSITION
AQSAS - Demonstration Project
Los Angeles International Airport

Analyte	Jet-A Wt. %	Diesel (A)		Diesel (B)		UNL. GAS. Wt. %
		Wt. %	Ratio with Jet-A	Wt. %	Ratio with Jet-A	
Cyclic Paraffins (Naphthenics)	27.4	34.6	0.8	34.4	0.8	7.08
Isoparaffins	27.1	35.6	0.8	36.3	0.7	41.91
Mono-Aromatics	15.6	1.4	11.1	1.5	10.4	0
Di-Aromatics	14.2	6.7	2.1	6.9	2.1	0
Total Aromatics	29.8	8.1	3.7	8.4	3.5	31.69
Paraffins	11	14.4	0.8	14.5	0.8	7.32
Indenes	3.1	0.7	4.4	1.5	2.1	0.02
Aldehydes	1.2	1.8	0.7	2.5	0.5	0
Dodecane	2.01	1.02	2	1.15	1.7	0.05
Undecane	1.97	0.67	2.9	0.69	2.9	0.11
Tridecane	1.6	1.22	1.3	1.24	1.3	0.02
Undecane, 2,6-Dimethyl-	1.51	0.57	2.6	0.54	2.8	0
Trans-Anti-1-Methyl-Decahydrona…	1.33	0.5	2.7	0.51	2.6	0
Naphthalene, DECAHYDRO-2-METHYL-	1.21	0.01	121	0.66	1.8	0
Cyclohexane, 2-Butyl-1, 1, 3-Trim…	1.2	0.01	120	0.17	7.1	0
Tetradecane	1.19	1.49	0.8	1.45	0.8	0
Decane	1.1	0.26	4.2	0.28	3.9	0.11
Naphthalene, 1,2,3,4-Tetrahydro…	1.16	0.47	2.5	0.81	1.4	0
1h-Indene, 2,3-Dihydro-1,6-Dime…	1.06	0.01	106	0.01	106	0
1h-Indene, 2,3-Dihydro-1,3-Dime…	1	0.01	100	0.01	100	0
1h-Indene, 2,3-Dihydro-4-Methyl-	0.85	0.01	85	0.01	85	0
Additional indene related species:						
1H-Indene, 2, 3-dihydro-4, 7-dime…				0.48		
1H-Indene, 2,3-dihydro-4,5,7-tr…				0.33		
1H-Indene, 2,3-Dihydro-1,1,3-TR…		0.32				
1H-Indene, 2,3-Dihydro-1,1,5-TR…		0.16				

Appendix A

ATMOSPHERIC ANALYSIS & CONSULTING, INC.
1534 Eastman Avenue, Suite A
Ventura, California 93003
Phone (805) 650-1642 Fax (805) 650-1644
E-mail: aacLab@earthlink.net

AAC Project No. 08045 7

Page 1 of 1

CHAIN OF CUSTODY/ ANALYSIS REQUEST FORM

Client Name: Jacob's Consultancy

Project Name: LAWA

Project Mgr (Print Name): Darcy Zarubiak

Project Number: NA

Sampler's Name (Print Name): Marcus Hueppe

Sampler's Signature: Marcus Hueppe

AAC Sample No.	Date Sampled	Time Sampled	Sample Type	Client Sample ID/Description	Type/No. of Containers	① ASTM-D5623	② EPA 8260	② Halogenated Hydrocarbons + PCBs	② Composition/break down Markers/Additives	③ Detailed Hydrocarbon Analysis	④ Headspace Analysis
33841	7/16/08	9:25am	Liq Fuel	Construction/Maintanance Yard (Unleaded Gasoline)	GL Jar / 2	X	X	X	X	X	X
33842	7/16/08	9:28am	Liq Fuel	Construction/Maintanance Yard (Diesel)	GL Jar / 2	X	X	X	X	X	X
33843	7/16/08	10:38am	Liq Fuel	Aircraft + GSE Maint. (Diesel)	GL Jar / 2	X	X	X	X	X	X
33844	7/16/08	11:04am	Liq Fuel	Aircraft + GSE Maint (Jet A)	GL Jar / 2	X	X	X	X	X	X

Send report:
Hardcopy : Jacob's Con..
EDD: weston
Attn:
Phone#:
Fax#

Send Invoice to:
Jacob's Consultancy
6688 North Central Expressway
Dallas, TX 75206
Attn: Darcy Zarubiak
P.O. #

Turnaround Time
24-Hr ____ 48-Hr ____
5 Day ____ Normal X
Other (Specify) ____

Special Instructions/remarks:
① Sub to CoreLab
② Sub to AETL
③ Sub to Saybolt
④ keep at AAC

Relinquished by (Signature): Marcus Hueppe	Print Name: Marcus Hueppe	Date/Time 7/16/08 1300	Received by (signature):	Print Name
Relinquished by (Signature):	Print Name:	Date/Time	Received by (signature):	Print Name

Speciated Sulfur Compounds
ASTM D-5623
Hardcopy Report

Core Lab
PETROLEUM SERVICES

8210 Mosley Rd.
Houston, TX 77075
713 943-9776 Telephone
713 943-3846 Facsimile

CORE LABORATORIES

MARCUS HEUPPE
ATMOSPHERIC ANALYSIS & CONSULTING
1534 EASTMAN AVE, SUITE A
VENTURA, CA 93003

Sample Number: 182760-001
Sample Date: 7/16/08 9:25:00 AM
Date Reported: 7/25/08
Date Received: 7/22/08
Sample ID: 080457-33841
Description: Unleaded Gasoilne

Analytical Report

Test	Result	Units	Method	Date	Analyst
Sulfur Speciation					
Hydrogen Sulfide	< 0.2	ppm wt Sulfur	ASTM D-5623	7/24/08	JB
Carbonyl Sulfide	< 0.2	ppm wt Sulfur			
Methyl Mercaptan	< 0.2	ppm wt Sulfur			
Ethyl Mercaptan	0.9	ppm wt Sulfur			
Dimethyl Sulfide	< 0.2	ppm wt Sulfur			
Carbon Disulfide	< 0.2	ppm wt Sulfur			
Isopropyl Mercaptan	0.2	ppm wt Sulfur			
Ethylene Sulfide	< 0.2	ppm wt Sulfur			
tert-Butyl Mercaptan	< 0.2	ppm wt Sulfur			
N-Propyl Mercaptan	0.4	ppm wt Sulfur			
Ethyl Methyl Sulfide	< 0.2	ppm wt Sulfur			
Propylene Sulfide	< 0.2	ppm wt Sulfur			
Thiophene	3.6	ppm wt Sulfur			
Methyl-Isopropyl-Sulfide	< 0.2	ppm wt Sulfur			
sec-Butyl Mercaptan	< 0.2	ppm wt Sulfur			
Isobutyl Mercaptan	< 0.2	ppm wt Sulfur			
Ethyl Sulfide	< 0.2	ppm wt Sulfur			
N-Butyl Mercaptan	< 0.2	ppm wt Sulfur			
Dimethyl Disulfide	< 0.2	ppm wt Sulfur			
2-Methyl Thiophene	0.9	ppm wt Sulfur			
3-Methyl Thiophene	1.1	ppm wt Sulfur			
Diisopropyl Sulfide	< 0.2	ppm wt Sulfur			
Tetra-Hydro Thiophene	0.2	ppm wt Sulfur			
Ethyl Methyl Disulfide	< 0.2	ppm wt Sulfur			
2-Methyl-Tetra-Hydro-Thiophene	0.2	ppm wt Sulfur			
2-Ethyl Thiophene	0.3	ppm wt Sulfur			
2,5-Dimethyl Thiophene	< 0.2	ppm wt Sulfur			

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Sample Number: 182760-001
Sample Date: 7/16/08 9:25:00 AM
Date Reported: 7/25/08
Date Received: 7/22/08
Sample ID: 080457-33841
Description: Unleaded Gasoilne

Analytical Report

Test	Result	Units	Method	Date	Analyst
3-Ethyl Thiophene	0.3	ppm wt Sulfur			
2,4 & 2,3-Dimethyl Thiophene	0.2	ppm wt Sulfur			
3,4-Dimethyl Thiophene	< 0.2	ppm wt Sulfur			
Diethyl Disulfide	< 0.2	ppm wt Sulfur			
Methyl Ethyl Thiophenes	0.2	ppm wt Sulfur			
Trimethyl Thiophenes	0.3	ppm wt Sulfur			
Tetramethyl Thiophenes	0.5	ppm wt Sulfur			
Benzothiophene	0.2	ppm wt Sulfur			
Methyl Benzothiophenes	< 0.2	ppm wt Sulfur			
Dimethyl Benzothiophenes	< 0.2	ppm wt Sulfur			
Trimethyl Benzothiophenes	< 0.2	ppm wt Sulfur			
Tetramethyl Benzothiophenes	< 0.2	ppm wt Sulfur			
Dibenzothiophene	< 0.2	ppm wt Sulfur			
4-Methyl Dibenzothiophene	< 0.2	ppm wt Sulfur			
3-Methyl DBZT + 2-Methyl DBZT	< 0.2	ppm wt Sulfur			
1-Methyl Dibenzothiophene	< 0.2	ppm wt Sulfur			
4,6-Dimethyl Dibenzothiophene	< 0.2	ppm wt Sulfur			
Dimethyl Dibenzothiophenes	< 0.2	ppm wt Sulfur			
Trimethyl Dibenzothiophenes	< 0.2	ppm wt Sulfur			
Tetramethyl Dibenzothiophenes	< 0.2	ppm wt Sulfur			
Unidentified Volatile Sulfur	< 0.2	ppm wt Sulfur			

Approved By: ______________________
M. Jean Waits
Supervising Chemist

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1534 EASTMAN AVE, SUITE A
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Sample Number: 182760-002
Sample Date: 7/16/08 9:28:00 AM
Date Reported: 7/25/08
Date Received: 7/22/08
Sample ID: 080457-33842
Description: Diesel (a)

Analytical Report

Test	Result	Units	Method	Date	Analyst
Sulfur Speciation					
Hydrogen Sulfide	< 0.2	ppm wt Sulfur	ASTM D-5623	7/24/08	JB
Carbonyl Sulfide	< 0.2	ppm wt Sulfur			
Methyl Mercaptan	< 0.2	ppm wt Sulfur			
Ethyl Mercaptan	< 0.2	ppm wt Sulfur			
Dimethyl Sulfide	< 0.2	ppm wt Sulfur			
Carbon Disulfide	< 0.2	ppm wt Sulfur			
Isopropyl Mercaptan	< 0.2	ppm wt Sulfur			
Ethylene Sulfide	< 0.2	ppm wt Sulfur			
tert-Butyl Mercaptan	< 0.2	ppm wt Sulfur			
N-Propyl Mercaptan	< 0.2	ppm wt Sulfur			
Ethyl Methyl Sulfide	< 0.2	ppm wt Sulfur			
Propylene Sulfide	< 0.2	ppm wt Sulfur			
Thiophene	< 0.2	ppm wt Sulfur			
Methyl-Isopropyl-Sulfide	< 0.2	ppm wt Sulfur			
sec-Butyl Mercaptan	< 0.2	ppm wt Sulfur			
Isobutyl Mercaptan	< 0.2	ppm wt Sulfur			
Ethyl Sulfide	< 0.2	ppm wt Sulfur			
N-Butyl Mercaptan	< 0.2	ppm wt Sulfur			
Dimethyl Disulfide	< 0.2	ppm wt Sulfur			
2-Methyl Thiophene	< 0.2	ppm wt Sulfur			
3-Methyl Thiophene	< 0.2	ppm wt Sulfur			
Diisopropyl Sulfide	< 0.2	ppm wt Sulfur			
Tetra-Hydro Thiophene	< 0.2	ppm wt Sulfur			
Ethyl Methyl Disulfide	< 0.2	ppm wt Sulfur			
2-Methyl-Tetra-Hydro-Thiophene	< 0.2	ppm wt Sulfur			
2-Ethyl Thiophene	< 0.2	ppm wt Sulfur			
2,5-Dimethyl Thiophene	< 0.2	ppm wt Sulfur			

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1534 EASTMAN AVE, SUITE A
VENTURA, CA 93003

Sample Number:	182760-002
Sample Date:	7/16/08 9:28:00 AM
Date Reported:	7/25/08
Date Received:	7/22/08
Sample ID:	080457-33842
Description:	Diesel (a)

Analytical Report

Test	Result	Units	Method	Date	Analyst
3-Ethyl Thiophene	< 0.2	ppm wt Sulfur			
2,4 & 2,3-Dimethyl Thiophene	< 0.2	ppm wt Sulfur			
3,4-Dimethyl Thiophene	< 0.2	ppm wt Sulfur			
Diethyl Disulfide	< 0.2	ppm wt Sulfur			
Methyl Ethyl Thiophenes	< 0.2	ppm wt Sulfur			
Trimethyl Thiophenes	< 0.2	ppm wt Sulfur			
Tetramethyl Thiophenes	< 0.2	ppm wt Sulfur			
Benzothiophene	< 0.2	ppm wt Sulfur			
Methyl Benzothiophenes	< 0.2	ppm wt Sulfur			
Dimethyl Benzothiophenes	< 0.2	ppm wt Sulfur			
Trimethyl Benzothiophenes	< 0.2	ppm wt Sulfur			
Tetramethyl Benzothiophenes	< 0.2	ppm wt Sulfur			
Dibenzothiophene	< 0.2	ppm wt Sulfur			
4-Methyl Dibenzothiophene	< 0.2	ppm wt Sulfur			
3-Methyl DBZT + 2-Methyl DBZT	< 0.2	ppm wt Sulfur			
1-Methyl Dibenzothiophene	< 0.2	ppm wt Sulfur			
4,6-Dimethyl Dibenzothiophene	< 0.2	ppm wt Sulfur			
Dimethyl Dibenzothiophenes	< 0.2	ppm wt Sulfur			
Trimethyl Dibenzothiophenes	< 0.2	ppm wt Sulfur			
Tetramethyl Dibenzothiophenes	< 0.2	ppm wt Sulfur			
Unidentified Volatile Sulfur	< 0.2	ppm wt Sulfur			

Approved By: ______________________

M. Dean Waits
Supervising Chemist

Core Lab
PETROLEUM SERVICES

8210 Mosley Rd.
Houston, TX 77075
713 943-9776 Telephone
713 943-3846 Facsimile

CORE LABORATORIES

MARCUS HEUPPE
ATMOSPHERIC ANALYSIS & CONSULTING
1534 EASTMAN AVE, SUITE A
VENTURA, CA 93003

Sample Number:	182760-003
Sample Date:	7/16/08 10:38:00 AM
Date Reported:	7/25/08
Date Received:	7/22/08
Sample ID:	080457-33843
Description:	Diesel (b)

Analytical Report

Test	Result	Units	Method	Date	Analyst
Sulfur Speciation					
Hydrogen Sulfide	< 0.2	ppm wt Sulfur	ASTM D-5623	7/24/08	JB
Carbonyl Sulfide	< 0.2	ppm wt Sulfur			
Methyl Mercaptan	< 0.2	ppm wt Sulfur			
Ethyl Mercaptan	< 0.2	ppm wt Sulfur			
Dimethyl Sulfide	< 0.2	ppm wt Sulfur			
Carbon Disulfide	< 0.2	ppm wt Sulfur			
Isopropyl Mercaptan	< 0.2	ppm wt Sulfur			
Ethylene Sulfide	< 0.2	ppm wt Sulfur			
tert-Butyl Mercaptan	< 0.2	ppm wt Sulfur			
N-Propyl Mercaptan	< 0.2	ppm wt Sulfur			
Ethyl Methyl Sulfide	< 0.2	ppm wt Sulfur			
Propylene Sulfide	< 0.2	ppm wt Sulfur			
Thiophene	< 0.2	ppm wt Sulfur			
Methyl-Isopropyl-Sulfide	< 0.2	ppm wt Sulfur			
sec-Butyl Mercaptan	< 0.2	ppm wt Sulfur			
Isobutyl Mercaptan	< 0.2	ppm wt Sulfur			
Ethyl Sulfide	< 0.2	ppm wt Sulfur			
N-Butyl Mercaptan	< 0.2	ppm wt Sulfur			
Dimethyl Disulfide	< 0.2	ppm wt Sulfur			
2-Methyl Thiophene	< 0.2	ppm wt Sulfur			
3-Methyl Thiophene	< 0.2	ppm wt Sulfur			
Diisopropyl Sulfide	< 0.2	ppm wt Sulfur			
Tetra-Hydro Thiophene	< 0.2	ppm wt Sulfur			
Ethyl Methyl Disulfide	< 0.2	ppm wt Sulfur			
2-Methyl-Tetra-Hydro-Thiophene	< 0.2	ppm wt Sulfur			
2-Ethyl Thiophene	< 0.2	ppm wt Sulfur			
2,5-Dimethyl Thiophene	< 0.2	ppm wt Sulfur			

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1534 EASTMAN AVE, SUITE A
VENTURA, CA 93003

Sample Number:	182760-003
Sample Date:	7/16/08 10:38:00 AM
Date Reported:	7/25/08
Date Received:	7/22/08
Sample ID:	080457-33843
Description:	Diesel (b)

Analytical Report

Test	Result	Units	Method	Date	Analyst
3-Ethyl Thiophene	< 0.2	ppm wt Sulfur			
2,4 & 2,3-Dimethyl Thiophene	< 0.2	ppm wt Sulfur			
3,4-Dimethyl Thiophene	< 0.2	ppm wt Sulfur			
Diethyl Disulfide	< 0.2	ppm wt Sulfur			
Methyl Ethyl Thiophenes	< 0.2	ppm wt Sulfur			
Trimethyl Thiophenes	< 0.2	ppm wt Sulfur			
Tetramethyl Thiophenes	< 0.2	ppm wt Sulfur			
Benzothiophene	< 0.2	ppm wt Sulfur			
Methyl Benzothiophenes	< 0.2	ppm wt Sulfur			
Dimethyl Benzothiophenes	< 0.2	ppm wt Sulfur			
Trimethyl Benzothiophenes	< 0.2	ppm wt Sulfur			
Tetramethyl Benzothiophenes	< 0.2	ppm wt Sulfur			
Dibenzothiophene	< 0.2	ppm wt Sulfur			
4-Methyl Dibenzothiophene	< 0.2	ppm wt Sulfur			
3-Methyl DBZT + 2-Methyl DBZT	< 0.2	ppm wt Sulfur			
1-Methyl Dibenzothiophene	< 0.2	ppm wt Sulfur			
4,6-Dimethyl Dibenzothiophene	< 0.2	ppm wt Sulfur			
Dimethyl Dibenzothiophenes	< 0.2	ppm wt Sulfur			
Trimethyl Dibenzothiophenes	< 0.2	ppm wt Sulfur			
Tetramethyl Dibenzothiophenes	< 0.2	ppm wt Sulfur			
Unidentified Volatile Sulfur	< 0.2	ppm wt Sulfur			

Approved By:

M. Jean Waits
Supervising Chemist

Core Lab
PETROLEUM SERVICES

8210 Mosley Rd.
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CORE LABORATORIES

MARCUS HEUPPE
ATMOSPHERIC ANALYSIS & CONSULTING
1534 EASTMAN AVE, SUITE A
VENTURA, CA 93003

Sample Number: 182760-004
Sample Date: 7/16/08 11:04:00 AM
Date Reported: 7/25/08
Date Received: 7/22/08
Sample ID: 080457-33844
Description: Jet A

Analytical Report

Test	Result	Units	Method	Date	Analyst
Sulfur Speciation					
Hydrogen Sulfide	< 0.2	ppm wt Sulfur	ASTM D-5623	7/24/08	JB
Carbonyl Sulfide	< 0.2	ppm wt Sulfur			
Methyl Mercaptan	< 0.2	ppm wt Sulfur			
Ethyl Mercaptan	< 0.2	ppm wt Sulfur			
Dimethyl Sulfide	< 0.2	ppm wt Sulfur			
Carbon Disulfide	< 0.2	ppm wt Sulfur			
Isopropyl Mercaptan	< 0.2	ppm wt Sulfur			
Ethylene Sulfide	< 0.2	ppm wt Sulfur			
tert-Butyl Mercaptan	< 0.2	ppm wt Sulfur			
N-Propyl Mercaptan	< 0.2	ppm wt Sulfur			
Ethyl Methyl Sulfide	< 0.2	ppm wt Sulfur			
Propylene Sulfide	< 0.2	ppm wt Sulfur			
Thiophene	< 0.2	ppm wt Sulfur			
Methyl-Isopropyl-Sulfide	< 0.2	ppm wt Sulfur			
sec-Butyl Mercaptan	< 0.2	ppm wt Sulfur			
Isobutyl Mercaptan	< 0.2	ppm wt Sulfur			
Ethyl Sulfide	< 0.2	ppm wt Sulfur			
N-Butyl Mercaptan	< 0.2	ppm wt Sulfur			
Dimethyl Disulfide	< 0.2	ppm wt Sulfur			
2-Methyl Thiophene	< 0.2	ppm wt Sulfur			
3-Methyl Thiophene	< 0.2	ppm wt Sulfur			
Diisopropyl Sulfide	< 0.2	ppm wt Sulfur			
Tetra-Hydro Thiophene	< 0.2	ppm wt Sulfur			
Ethyl Methyl Disulfide	0.2	ppm wt Sulfur			
2-Methyl-Tetra-Hydro-Thiophene	< 0.2	ppm wt Sulfur			
2-Ethyl Thiophene	< 0.2	ppm wt Sulfur			
2,5-Dimethyl Thiophene	< 0.2	ppm wt Sulfur			

Core Lab
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CORE LABORATORIES

MARCUS HEUPPE
ATMOSPHERIC ANALYSIS & CONSULTING
1534 EASTMAN AVE, SUITE A
VENTURA, CA 93003

Sample Number: 182760-004
Sample Date: 7/16/08 11:04:00 AM
Date Reported: 7/25/08
Date Received: 7/22/08
Sample ID: 080457-33844
Description: Jet A

Analytical Report

Test	Result	Units	Method	Date	Analyst
3-Ethyl Thiophene	0.4	ppm wt Sulfur			
2,4 & 2,3-Dimethyl Thiophene	0.2	ppm wt Sulfur			
3,4-Dimethyl Thiophene	0.3	ppm wt Sulfur			
Diethyl Disulfide	0.6	ppm wt Sulfur			
Methyl Ethyl Thiophenes	5.9	ppm wt Sulfur			
Trimethyl Thiophenes	2.5	ppm wt Sulfur			
Tetramethyl Thiophenes	30	ppm wt Sulfur			
Benzothiophene	5.7	ppm wt Sulfur			
Methyl Benzothiophenes	18	ppm wt Sulfur			
Dimethyl Benzothiophenes	55	ppm wt Sulfur			
Trimethyl Benzothiophenes	80	ppm wt Sulfur			
Tetramethyl Benzothiophenes	10	ppm wt Sulfur			
Dibenzothiophene	0.6	ppm wt Sulfur			
4-Methyl Dibenzothiophene	< 0.2	ppm wt Sulfur			
3-Methyl DBZT + 2-Methyl DBZT	< 0.2	ppm wt Sulfur			
1-Methyl Dibenzothiophene	< 0.2	ppm wt Sulfur			
4,6-Dimethyl Dibenzothiophene	< 0.2	ppm wt Sulfur			
Dimethyl Dibenzothiophenes	< 0.2	ppm wt Sulfur			
Trimethyl Dibenzothiophenes	< 0.2	ppm wt Sulfur			
Tetramethyl Dibenzothiophenes	< 0.2	ppm wt Sulfur			
Unidentified Volatile Sulfur	176	ppm wt Sulfur			

Approved By: MWaits
M. Jean Waits
Supervising Chemist

8210 Mosley Rd.
Houston. TX 77075

CORE LABORATORIES

QA Report

Tuesday, August 19, 2008

Job Number: 182760

Test: **Sulfur Speciation-Gasoline**

Method: ASTM D-5623

QA TYPE: LCS

STD ID	Analysis	Units	Ref. Value	Result	% Rec.	RPD	Date
2047.172 - 1	Ethyl Mercaptan	ppm wt S	105	92	88	-13	7/25/08
2047.172 - 1	Dimethyl Sulfide	ppm wt S	118	117	99	-1	7/25/08
2047.172 - 1	Isopropyl Mercaptan	ppm wt S	148	155	105	5	7/25/08
2047.172 - 1	N-Propyl Mercaptan	ppm wt S	147	161	110	9	7/25/08
2047.172 - 1	Thiophene	ppm wt S	172	188	109	9	7/25/08

QA TYPE: CCV = Calibration Verification Standard, ERS = External Reference Material, LCS = Laboratory Control Sample, DUP = Sample Duplicate, BLK = Method Blank, MS = Matrix Spike

ATMOSPHERIC ANALYSIS & CONSULTING, INC.
1534 Eastman Avenue, Suite A
Ventura, California 93003
Phone (805) 650-1642 Fax (805) 650-1644
E-mail: aacLab@earthlink.net

AAC Project No. 080457

Page 1 of 1

CHAIN OF CUSTODY/ ANALYSIS REQUEST FORM

Client Name AAC

Project Name LAWA

Project Mgr Marcus Hueppe

Project Number 080457

Sampler's Name NA

Sampler's Signature NA

AAC Sample No.	Date Sampled	Time Sampled	Sample Type	Client Sample ID/Description	Type/No. of Containers	ASTM D-5623					
080457-33841	07/16/08	925	Liq Fuel	Unleaded Gasoline	VOA / 1	X					
080457-33842	07/16/08	928	Liq Fuel	Diesel (a)	VOA / 1	X					
080457-33843	07/16/08	1038	Liq Fuel	Diesel (b)	VOA / 1	X					
080457-33844	07/16/08	1104	Liq Fuel	Jet A	VOA / 1	X					

Analysis Requested

Send report:
AAC
1534 Eastman Ave. Suite A
Ventura, CA 93003

Attn: Marcus Hueppe

Phone#: 805-6501642
Fax# 805-650-1644

Send invoice to:

AAC
1534 Eastman Ave. Suite A
Ventura, CA 93003

Attn:

P.O. #

Turnaround Time
24-Hr ___ 48-Hr ___
5 Day ___ Normal X
Other (Specify) ___

Special Instructions/remarks:

Relinquished by (Signature): Marcus Hueppe	Print Name: Marcus Hueppe	Date/Time 7/21/08 0800	Received by (signature):	Print Name ANDREW Middleton 7/22/08/2330
Relinquished by (Signature):	Print Name:	Date/Time	Received by (signature):	Print Name

VOC's, Halogenated Hydrocarbons and PCB's EPA 8260/8082 Hardcopy Report

American Environmental Testing Laboratory Inc.
2834 & 2908 North Naomi Street Burbank, CA 91504 • DOHS NO: 1541, LACSD NO: 10181
Tel: (888) 288-AETL • (818) 845-8200 • Fax: (818) 845-8840 • www.aetlab.com

Ordered By

Telephone: (805) 650-1642
Attention: Marcus Hueppe

Job Number	Order Date	Client
48343	07/21/2008	AA&C

Project ID: 080457
Project Name: LAWA

Enclosed please find results of analyses of 4 liquid samples which were analyzed as specified on the attached chain of custody. If there are any questions, please do not hesitate to call.

Checked By: ______________________

Approved By: C. Razmara

Cyrus Razmara, Ph.D.
Laboratory Director

ATMOSPHERIC ANALYSIS & CONSULTING, INC.
1534 Eastman Avenue, Suite A
Ventura, California 93003
Phone (805) 650-1642 Fax (805) 650-1644
E-mail: aacLab@earthlink.net

AAC Project No. 080457

Page 1 of 1

Job # 48343

CHAIN OF CUSTODY/ ANALYSIS REQUEST FORM

Client Name AAC
Project Name LAWA
Project Mgr Marcus Hueppe
Project Number 080457
Sampler's Name NA
Sampler's Signature NA

AAC Sample No.	Date Sampled	Time Sampled	Sample Type	Client Sample ID/Description	Type/No. of Containers	EPA 8260	Halogenated Hydrocarbons	PCB's			
080457-33841	07/16/08	925	Liq Fuel	Unleaded Gasoline	VOA / 1	X	X	X		483	43.01
080457-33842	07/16/08	928	Liq Fuel	Diesel (a)	VOA / 1	X	X	X		483	43.02
080457-33843	07/16/08	1038	Liq Fuel	Diesel (b)	VOA / 1	X	X	X		483	43.03
080457-33844	07/16/08	1104	Liq Fuel	Jet A	VOA / 1	X	X	X		483	48.04

Analysis Requested

Send report:
AAC
1534 Eastman Ave. Suite A
Ventura, CA 93003

Attn: Marcus Hueppe

Phone#: 805-6501642
Fax# 805-650-1644

Send invoice to:

AAC
1534 Eastman Ave. Suite A
Ventura, CA 93003

Attn:
P.O. #

Turnaround Time
24-Hr ____ 48-Hr ____
5 Day ____ Normal X
Other (Specify) ____

Special Instructions/remarks:

Relinquished by (Signature): Marcus Hueppe	Print Name: Marcus Hueppe	Date/Time 7/21/08 0800	Received by (signature):	Print Name AG
Relinquished by (Signature):	Print Name:	Date/Time 7/21-08 1915	Received by (signature):	Print Name Julius Hernandez.

American Environmental Testing Laboratory Inc.

2834 & 2908 North Naomi Street Burbank, CA 91504 • DOHS NO: 1541, LACSD NO: 10181
Tel: (888) 288-AETL • (818) 845-8200 • Fax: (818) 845-8840 • www.aetlab.com

ANALYTICAL RESULTS

Ordered By

Atmospheric Analysis & Consulting
1534 Eastman Avenue
Suite A
Ventura, CA 93003-7760

Telephone: (805)650-1642
Attn: Marcus Hueppe
Page: 2

Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8260B), Volatile Organic Compounds by GC/MS (SW846)

QC Batch No: 0724081A1

Our Lab I.D.			Method Blank				
Client Sample I.D.							
Date Sampled							
Date Prepared			07/24/2008				
Preparation Method			5030B				
Date Analyzed			07/24/2008				
Matrix			Liquid				
Units			ug/Kg				
Dilution Factor			1				
Analytes	**MDL**	**PQL**	**Results**				
Acetone	25	50	ND				
Benzene	2.0	10.0	ND				
Bromobenzene (Phenyl bromide)	5.0	10.0	ND				
Bromochloromethane	5.0	10.0	ND				
Bromodichloromethane	5.0	10.0	ND				
Bromoform (Tribromomethane)	25	50	ND				
Bromomethane (Methyl bromide)	15	30	ND				
2-Butanone (MEK)	25	50	ND				
n-Butylbenzene	5.0	10.0	ND				
sec-Butylbenzene	5.0	10.0	ND				
tert-Butylbenzene	5.0	10.0	ND				
Carbon Disulfide	25	50	ND				
Carbon tetrachloride	5.0	10.0	ND				
Chlorobenzene	5.0	10.0	ND				
Chloroethane	15	30	ND				
2-Chloroethyl vinylether	50	50	ND				
Chloroform (Trichloromethane)	5.0	10.0	ND				
Chloromethane (Methyl chloride)	15	30	ND				
2-Chlorotoluene	5.0	10.0	ND				
4-Chlorotoluene	5.0	10.0	ND				
1,2-Dibromo-3-chloropropane (DBCP)	25	50	ND				
Dibromochloromethane	5.0	10.0	ND				
1,2-Dibromoethane (EDB)	5.0	10.0	ND				
Dibromomethane	5.0	10.0	ND				
1,2-Dichlorobenzene	5.0	10.0	ND				
1,3-Dichlorobenzene	5.0	10.0	ND				
1,4-Dichlorobenzene	5.0	10.0	ND				

ANALYTICAL RESULTS

Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8260B), Volatile Organic Compounds by GC/MS (SW846)

QC Batch No: 0724081A1

Our Lab I.D.		Method Blank				
Client Sample I.D.						
Date Sampled						
Date Prepared		07/24/2008				
Preparation Method		5030B				
Date Analyzed		07/24/2008				
Matrix		Liquid				
Units		ug/Kg				
Dilution Factor		1				

Analytes	MDL	PQL	Results				
Dichlorodifluoromethane	15	30	ND				
1,1-Dichloroethane	5.0	10.0	ND				
1,2-Dichloroethane (EDC)	5.0	10.0	ND				
1,1-Dichloroethene	5.0	10.0	ND				
cis-1,2-Dichloroethene	5.0	10.0	ND				
trans-1,2-Dichloroethene	5.0	10.0	ND				
1,2-Dichloropropane	5.0	10.0	ND				
1,3-Dichloropropane	5.0	10.0	ND				
2,2-Dichloropropane	5.0	10.0	ND				
1,1-Dichloropropene	5.0	10.0	ND				
cis-1,3-Dichloropropene	5.0	10.0	ND				
trans-1,3-Dichloropropene	5.0	10.0	ND				
Ethylbenzene	2.0	10.0	ND				
Hexachlorobutadiene	15	30	ND				
2-Hexanone	25	50	ND				
Isopropylbenzene	5.0	10.0	ND				
p-Isopropyltoluene	5.0	10.0	ND				
4-Methyl-2-pentanone (MIBK)	25	50	ND				
Methyl-tert-butyl ether (MTBE)	5.0	10.0	ND				
Methylene chloride (DCM)	25	50	ND				
Naphthalene	5.0	10.0	ND				
n-Propylbenzene	5.0	10.0	ND				
Styrene	5.0	10.0	ND				
1,1,1,2-Tetrachloroethane	5.0	10.0	ND				
1,1,2,2-Tetrachloroethane	5.0	10.0	ND				
Tetrachloroethene	5.0	10.0	ND				
Toluene (Methyl benzene)	2.0	10.0	ND				
1,2,3-Trichlorobenzene	5.0	10.0	ND				
1,2,4-Trichlorobenzene	5.0	10.0	ND				
1,1,1-Trichloroethane	5.0	10.0	ND				
1,1,2-Trichloroethane	5.0	10.0	ND				
Trichloroethene	5.0	10.0	ND				
Trichlorofluoromethane	5.0	10.0	ND				
1,2,3-Trichloropropane	5.0	10.0	ND				

ANALYTICAL RESULTS

Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8260B), Volatile Organic Compounds by GC/MS (SW846)

QC Batch No: 0724081A1

Our Lab I.D.			Method Blank				
Client Sample I.D.							
Date Sampled							
Date Prepared			07/24/2008				
Preparation Method			5030B				
Date Analyzed			07/24/2008				
Matrix			Liquid				
Units			ug/Kg				
Dilution Factor			1				
Analytes	MDL	PQL	**Results**				
1,2,4-Trimethylbenzene	5.0	10.0	ND				
1,3,5-Trimethylbenzene	5.0	10.0	ND				
Vinyl Acetate	25	50	ND				
Vinyl chloride (Chloroethene)	15	30	ND				
o-Xylene	2.0	10.0	ND				
m,p-Xylenes	2.0	20.0	ND				

Our Lab I.D.			Method Blank				
Surrogates	%Rec.Limit		% Rec.				
Bromofluorobenzene	75-125		102				
Dibromofluoromethane	75-125		96.2				
Toluene-d8	75-125		95.9				

ANALYTICAL RESULTS

Ordered By

Atmospheric Analysis & Consulting
1534 Eastman Avenue
Suite A
Ventura, CA 93003-7760

Telephone: (805)650-1642
Attn: Marcus Hueppe
Page: 5

Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8260B), Volatile Organic Compounds by GC/MS (SW846)
QC Batch No: 0724081A1

Our Lab I.D.			48343.01				
Client Sample I.D.			Unleaded Gasoline				
Date Sampled			07/16/2008				
Date Prepared			07/24/2008				
Preparation Method			5030B				
Date Analyzed			07/24/2008				
Matrix			Liquid				
Units			ug/Kg				
Dilution Factor			8000				
Analytes	**MDL**	**PQL**	**Results**				
Acetone	200000	400000	ND				
Benzene	16000	80000	8,000,000				
Bromobenzene (Phenyl bromide)	40000	80000	ND				
Bromochloromethane	40000	80000	ND				
Bromodichloromethane	40000	80000	ND				
Bromoform (Tribromomethane)	200000	400000	ND				
Bromomethane (Methyl bromide)	120000	240000	ND				
2-Butanone (MEK)	200000	400000	ND				
n-Butylbenzene	40000	80000	ND				
sec-Butylbenzene	40000	80000	138,000				
tert-Butylbenzene	40000	80000	ND				
Carbon Disulfide	200000	400000	ND				
Carbon tetrachloride	40000	80000	ND				
Chlorobenzene	40000	80000	ND				
Chloroethane	120000	240000	ND				
2-Chloroethyl vinylether	400000	400000	ND				
Chloroform (Trichloromethane)	40000	80000	ND				
Chloromethane (Methyl chloride)	120000	240000	ND				
2-Chlorotoluene	40000	80000	ND				
4-Chlorotoluene	40000	80000	ND				
1,2-Dibromo-3-chloropropane (DBCP)	200000	400000	ND				
Dibromochloromethane	40000	80000	ND				
1,2-Dibromoethane (EDB)	40000	80000	ND				
Dibromomethane	40000	80000	ND				
1,2-Dichlorobenzene	40000	80000	ND				
1,3-Dichlorobenzene	40000	80000	ND				

ANALYTICAL RESULTS

Page: 6

Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8260B), Volatile Organic Compounds by GC/MS (SW846)

QC Batch No: 0724081A1

Our Lab I.D.			48343.01				
Client Sample I.D.			Unleaded Gasoline				
Date Sampled			07/16/2008				
Date Prepared			07/24/2008				
Preparation Method			5030B				
Date Analyzed			07/24/2008				
Matrix			Liquid				
Units			ug/Kg				
Dilution Factor			8000				
Analytes	**MDL**	**PQL**	**Results**				
1,4-Dichlorobenzene	40000	80000	ND				
Dichlorodifluoromethane	120000	240000	ND				
1,1-Dichloroethane	40000	80000	ND				
1,2-Dichloroethane (EDC)	40000	80000	ND				
1,1-Dichloroethene	40000	80000	ND				
cis-1,2-Dichloroethene	40000	80000	ND				
trans-1,2-Dichloroethene	40000	80000	ND				
1,2-Dichloropropane	40000	80000	ND				
1,3-Dichloropropane	40000	80000	ND				
2,2-Dichloropropane	40000	80000	ND				
1,1-Dichloropropene	40000	80000	ND				
cis-1,3-Dichloropropene	40000	80000	ND				
trans-1,3-Dichloropropene	40000	80000	ND				
Ethylbenzene	16000	80000	11,800,000				
Hexachlorobutadiene	120000	240000	ND				
2-Hexanone	200000	400000	ND				
Isopropylbenzene	40000	80000	690,000				
p-Isopropyltoluene	40000	80000	41,000J				
4-Methyl-2-pentanone (MIBK)	200000	400000	ND				
Methyl-tert-butyl ether (MTBE)	40000	80000	ND				
Methylene chloride (DCM)	200000	400000	ND				
Naphthalene	40000	80000	385,000				
n-Propylbenzene	40000	80000	2,440,000				
Styrene	40000	80000	ND				
1,1,1,2-Tetrachloroethane	40000	80000	ND				
1,1,2,2-Tetrachloroethane	40000	80000	ND				
Tetrachloroethene	40000	80000	ND				
Toluene (Methyl benzene)	16000	80000	66,000,000				
1,2,3-Trichlorobenzene	40000	80000	ND				
1,2,4-Trichlorobenzene	40000	80000	ND				
1,1,1-Trichloroethane	40000	80000	ND				
1,1,2-Trichloroethane	40000	80000	ND				
Trichloroethene	40000	80000	ND				

ANALYTICAL RESULTS

Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8260B), Volatile Organic Compounds by GC/MS (SW846)

QC Batch No: 0724081A1

Our Lab I.D.			48343.01				
Client Sample I.D.			Unleaded Gasoline				
Date Sampled			07/16/2008				
Date Prepared			07/24/2008				
Preparation Method			5030B				
Date Analyzed			07/24/2008				
Matrix			Liquid				
Units			ug/Kg				
Dilution Factor			8000				
Analytes	MDL	PQL	Results				
Trichlorofluoromethane	40000	80000	ND				
1,2,3-Trichloropropane	40000	80000	ND				
1,2,4-Trimethylbenzene	40000	80000	25,500,000				
1,3,5-Trimethylbenzene	40000	80000	4,830,000				
Vinyl Acetate	200000	400000	ND				
Vinyl chloride (Chloroethene)	120000	240000	ND				
o-Xylene	16000	80000	22,000,000				
m,p-Xylenes	16000	160000	59,400,000				
Our Lab I.D.			48343.01				
Surrogates	%Rec.Limit		% Rec.				
Bromofluorobenzene	75-125		104				
Dibromofluoromethane	75-125		94.7				
Toluene-d8	75-125		98.5				

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Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8260B), Volatile Organic Compounds by GC/MS (SW846)

QC Batch No: 0727085A2

Our Lab I.D.			Method Blank				
Client Sample I.D.							
Date Sampled							
Date Prepared			07/27/2008				
Preparation Method			5030B				
Date Analyzed			07/28/2008				
Matrix			Liquid				
Units			ug/Kg				
Dilution Factor			1				
Analytes	MDL	PQL	Results				
Acetone	25	50	ND				
Benzene	2.0	10.0	ND				
Bromobenzene (Phenyl bromide)	5.0	10.0	ND				
Bromochloromethane	5.0	10.0	ND				
Bromodichloromethane	5.0	10.0	ND				
Bromoform (Tribromomethane)	25	50	ND				
Bromomethane (Methyl bromide)	15	30	ND				
2-Butanone (MEK)	25	50	ND				
n-Butylbenzene	5.0	10.0	ND				
sec-Butylbenzene	5.0	10.0	ND				
tert-Butylbenzene	5.0	10.0	ND				
Carbon Disulfide	25	50	ND				
Carbon tetrachloride	5.0	10.0	ND				
Chlorobenzene	5.0	10.0	ND				
Chloroethane	15	30	ND				
2-Chloroethyl vinyl ether	50	50	ND				
Chloroform (Trichloromethane)	5.0	10.0	ND				
Chloromethane (Methyl chloride)	15	30	ND				
2-Chlorotoluene	5.0	10.0	ND				
4-Chlorotoluene	5.0	10.0	ND				
1,2-Dibromo-3-chloropropane (DBCP)	25	50	ND				
Dibromochloromethane	5.0	10.0	ND				
1,2-Dibromoethane (EDB)	5.0	10.0	ND				
Dibromomethane	5.0	10.0	ND				
1,2-Dichlorobenzene	5.0	10.0	ND				
1,3-Dichlorobenzene	5.0	10.0	ND				
1,4-Dichlorobenzene	5.0	10.0	ND				

ANALYTICAL RESULTS

Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8260B), Volatile Organic Compounds by GC/MS (SW846)

QC Batch No: 0727085A2

Our Lab I.D.			Method Blank				
Client Sample I.D.							
Date Sampled							
Date Prepared			07/27/2008				
Preparation Method			5030B				
Date Analyzed			07/28/2008				
Matrix			Liquid				
Units			ug/Kg				
Dilution Factor			1				
Analytes	**MDL**	**PQL**	**Results**				
Dichlorodifluoromethane	15	30	ND				
1,1-Dichloroethane	5.0	10.0	ND				
1,2-Dichloroethane (EDC)	5.0	10.0	ND				
1,1-Dichloroethene	5.0	10.0	ND				
cis-1,2-Dichloroethene	5.0	10.0	ND				
trans-1,2-Dichloroethene	5.0	10.0	ND				
1,2-Dichloropropane	5.0	10.0	ND				
1,3-Dichloropropane	5.0	10.0	ND				
2,2-Dichloropropane	5.0	10.0	ND				
1,1-Dichloropropene	5.0	10.0	ND				
cis-1,3-Dichloropropene	5.0	10.0	ND				
trans-1,3-Dichloropropene	5.0	10.0	ND				
Ethylbenzene	2.0	10.0	ND				
Hexachlorobutadiene	15	30	ND				
2-Hexanone	25	50	ND				
Isopropylbenzene	5.0	10.0	ND				
p-Isopropyltoluene	5.0	10.0	ND				
4-Methyl-2-pentanone (MIBK)	25	50	ND				
Methyl-tert-butyl ether (MTBE)	5.0	10.0	ND				
Methylene chloride (DCM)	25	50	ND				
Naphthalene	5.0	10.0	ND				
n-Propylbenzene	5.0	10.0	ND				
Styrene	5.0	10.0	ND				
1,1,1,2-Tetrachloroethane	5.0	10.0	ND				
1,1,2,2-Tetrachloroethane	5.0	10.0	ND				
Tetrachloroethene	5.0	10.0	ND				
Toluene (Methyl benzene)	2.0	10.0	ND				
1,2,3-Trichlorobenzene	5.0	10.0	ND				
1,2,4-Trichlorobenzene	5.0	10.0	ND				
1,1,1-Trichloroethane	5.0	10.0	ND				
1,1,2-Trichloroethane	5.0	10.0	ND				
Trichloroethene	5.0	10.0	ND				
Trichlorofluoromethane	5.0	10.0	ND				
1,2,3-Trichloropropane	5.0	10.0	ND				

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Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8260B), Volatile Organic Compounds by GC/MS (SW846)

QC Batch No: 0727085A2

Our Lab I.D.			Method Blank				
Client Sample I.D.							
Date Sampled							
Date Prepared			07/27/2008				
Preparation Method			5030B				
Date Analyzed			07/28/2008				
Matrix			Liquid				
Units			ug/Kg				
Dilution Factor			1				
Analytes	MDL	PQL	**Results**				
1,2,4-Trimethylbenzene	5.0	10.0	ND				
1,3,5-Trimethylbenzene	5.0	10.0	ND				
Vinyl Acetate	25	50	ND				
Vinyl chloride (Chloroethene)	15	30	ND				
o-Xylene	2.0	10.0	ND				
m,p-Xylenes	2.0	20.0	ND				
Our Lab I.D.			Method Blank				
Surrogates	%Rec.Limit		% Rec.				
Bromofluorobenzene	75-125		125				
Dibromofluoromethane	75-125		102				
Toluene-d8	75-125		107				

ANALYTICAL RESULTS

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Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8260B), Volatile Organic Compounds by GC/MS (SW846)

QC Batch No: 0727085A2

Our Lab I.D.			48343.02	48343.03			
Client Sample I.D.			Diesel (a)	Diesel (b)			
Date Sampled			07/16/2008	07/16/2008			
Date Prepared			07/27/2008	07/27/2008			
Preparation Method			5030B	5030B			
Date Analyzed			07/28/2008	07/28/2008			
Matrix			Liquid	Liquid			
Units			ug/Kg	ug/Kg			
Dilution Factor			2000	2000			
Analytes	MDL	PQL	Results	Results			
Acetone	50000	100000	ND	ND			
Benzene	4000	20000	17,600J	36,600			
Bromobenzene (Phenyl bromide)	10000	20000	ND	ND			
Bromochloromethane	10000	20000	ND	ND			
Bromodichloromethane	10000	20000	ND	ND			
Bromoform (Tribromomethane)	50000	100000	ND	ND			
Bromomethane (Methyl bromide)	30000	60000	ND	ND			
2-Butanone (MEK)	50000	100000	ND	ND			
n-Butylbenzene	10000	20000	ND	ND			
sec-Butylbenzene	10000	20000	42,400	30,000			
tert-Butylbenzene	10000	20000	ND	ND			
Carbon Disulfide	50000	100000	ND	ND			
Carbon tetrachloride	10000	20000	ND	ND			
Chlorobenzene	10000	20000	ND	ND			
Chloroethane	30000	60000	ND	ND			
2-Chloroethyl vinylether	100000	100000	ND	ND			
Chloroform (Trichloromethane)	10000	20000	ND	ND			
Chloromethane (Methyl chloride)	30000	60000	ND	ND			
2-Chlorotoluene	10000	20000	ND	ND			
4-Chlorotoluene	10000	20000	ND	ND			
1,2-Dibromo-3-chloropropane (DBCP)	50000	100000	ND	ND			
Dibromochloromethane	10000	20000	ND	ND			
1,2-Dibromoethane (EDB)	10000	20000	ND	ND			
Dibromomethane	10000	20000	ND	ND			
1,2-Dichlorobenzene	10000	20000	ND	ND			
1,3-Dichlorobenzene	10000	20000	ND	ND			
1,4-Dichlorobenzene	10000	20000	ND	ND			

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Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8260B), Volatile Organic Compounds by GC/MS (SW846)

QC Batch No: 0727085A2

Our Lab I.D.			48343.02	48343.03			
Client Sample I.D.			Diesel (a)	Diesel (b)			
Date Sampled			07/16/2008	07/16/2008			
Date Prepared			07/27/2008	07/27/2008			
Preparation Method			5030B	5030B			
Date Analyzed			07/28/2008	07/28/2008			
Matrix			Liquid	Liquid			
Units			ug/Kg	ug/Kg			
Dilution Factor			2000	2000			
Analytes	MDL	PQL	Results	Results			
Dichlorodifluoromethane	30000	60000	ND	ND			
1,1-Dichloroethane	10000	20000	ND	ND			
1,2-Dichloroethane (EDC)	10000	20000	ND	ND			
1,1-Dichloroethene	10000	20000	ND	ND			
cis-1,2-Dichloroethene	10000	20000	ND	ND			
trans-1,2-Dichloroethene	10000	20000	ND	ND			
1,2-Dichloropropane	10000	20000	ND	ND			
1,3-Dichloropropane	10000	20000	ND	ND			
2,2-Dichloropropane	10000	20000	ND	ND			
1,1-Dichloropropene	10000	20000	ND	ND			
cis-1,3-Dichloropropene	10000	20000	ND	ND			
trans-1,3-Dichloropropene	10000	20000	ND	ND			
Ethylbenzene	4000	20000	106,000	125,000			
Hexachlorobutadiene	30000	60000	ND	ND			
2-Hexanone	50000	100000	ND	ND			
Isopropylbenzene	10000	20000	25,200	20,600			
p-Isopropyltoluene	10000	20000	27,300	21,300			
4-Methyl-2-pentanone (MIBK)	50000	100000	ND	ND			
Methyl-tert-butyl ether (MTBE)	10000	20000	ND	ND			
Methylene chloride (DCM)	50000	100000	ND	ND			
Naphthalene	10000	20000	15,300J	16,100J			
n-Propylbenzene	10000	20000	76,000	54,000			
Styrene	10000	20000	ND	ND			
1,1,1,2-Tetrachloroethane	10000	20000	ND	ND			
1,1,2,2-Tetrachloroethane	10000	20000	ND	ND			
Tetrachloroethene	10000	20000	ND	ND			
Toluene (Methyl benzene)	4000	20000	192,000	460,000			
1,2,3-Trichlorobenzene	10000	20000	ND	ND			
1,2,4-Trichlorobenzene	10000	20000	ND	ND			
1,1,1-Trichloroethane	10000	20000	ND	ND			
1,1,2-Trichloroethane	10000	20000	ND	ND			
Trichloroethene	10000	20000	ND	ND			
Trichlorofluoromethane	10000	20000	ND	ND			
1,2,3-Trichloropropane	10000	20000	ND	ND			

ANALYTICAL RESULTS

Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8260B), Volatile Organic Compounds by GC/MS (SW846)

QC Batch No: 0727085A2

Our Lab I.D.			48343.02	48343.03			
Client Sample I.D.			Diesel (a)	Diesel (b)			
Date Sampled			07/16/2008	07/16/2008			
Date Prepared			07/27/2008	07/27/2008			
Preparation Method			5030B	5030B			
Date Analyzed			07/28/2008	07/28/2008			
Matrix			Liquid	Liquid			
Units			ug/Kg	ug/Kg			
Dilution Factor			2000	2000			
Analytes	MDL	PQL	**Results**	**Results**			
1,2,4-Trimethylbenzene	10000	20000	648,000	484,000			
1,3,5-Trimethylbenzene	10000	20000	156,000	121,000			
Vinyl Acetate	50000	100000	ND	ND			
Vinyl chloride (Chloroethene)	30000	60000	ND	ND			
o-Xylene	4000	20000	189,000	230,000			
m,p-Xylenes	4000	40000	392,000	544,000			
Our Lab I.D.			48343.02	48343.03			
Surrogates	**%Rec.Limit**		**% Rec.**	**% Rec.**			
Bromofluorobenzene	75-125		106	100			
Dibromofluoromethane	75-125		101	91.7			
Toluene-d8	75-125		97.4	103			

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Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8260B), Volatile Organic Compounds by GC/MS (SW846)

QC Batch No: 0724081A1

Our Lab I.D.			48343.04				
Client Sample I.D.			Jet A				
Date Sampled			07/16/2008				
Date Prepared			07/24/2008				
Preparation Method			5030B				
Date Analyzed			07/24/2008				
Matrix			Liquid				
Units			ug/Kg				
Dilution Factor			8000				
Analytes	MDL	PQL	Results				
Acetone	200000	400000	ND				
Benzene	16000	80000	ND				
Bromobenzene (Phenyl bromide)	40000	80000	ND				
Bromochloromethane	40000	80000	ND				
Bromodichloromethane	40000	80000	ND				
Bromoform (Tribromomethane)	200000	400000	ND				
Bromomethane (Methyl bromide)	120000	240000	ND				
2-Butanone (MEK)	200000	400000	ND				
n-Butylbenzene	40000	80000	482,000				
sec-Butylbenzene	40000	80000	242,000				
tert-Butylbenzene	40000	80000	ND				
Carbon Disulfide	200000	400000	ND				
Carbon tetrachloride	40000	80000	ND				
Chlorobenzene	40000	80000	ND				
Chloroethane	120000	240000	ND				
2-Chloroethyl vinylether	400000	400000	ND				
Chloroform (Trichloromethane)	40000	80000	ND				
Chloromethane (Methyl chloride)	120000	240000	ND				
2-Chlorotoluene	40000	80000	ND				
4-Chlorotoluene	40000	80000	ND				
1,2-Dibromo-3-chloropropane (DBCP)	200000	400000	ND				
Dibromochloromethane	40000	80000	ND				
1,2-Dibromoethane (EDB)	40000	80000	ND				
Dibromomethane	40000	80000	ND				
1,2-Dichlorobenzene	40000	80000	ND				
1,3-Dichlorobenzene	40000	80000	ND				
1,4-Dichlorobenzene	40000	80000	ND				

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Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8260B), Volatile Organic Compounds by GC/MS (SW846)

QC Batch No: 0724081A1

Our Lab I.D.			48343.04				
Client Sample I.D.			Jet A				
Date Sampled			07/16/2008				
Date Prepared			07/24/2008				
Preparation Method			5030B				
Date Analyzed			07/24/2008				
Matrix			Liquid				
Units			ug/Kg				
Dilution Factor			8000				
Analytes	**MDL**	**PQL**	**Results**				
Dichlorodifluoromethane	120000	240000	ND				
1,1-Dichloroethane	40000	80000	ND				
1,2-Dichloroethane (EDC)	40000	80000	ND				
1,1-Dichloroethene	40000	80000	ND				
cis-1,2-Dichloroethene	40000	80000	ND				
trans-1,2-Dichloroethene	40000	80000	ND				
1,2-Dichloropropane	40000	80000	ND				
1,3-Dichloropropane	40000	80000	ND				
2,2-Dichloropropane	40000	80000	ND				
1,1-Dichloropropene	40000	80000	ND				
cis-1,3-Dichloropropene	40000	80000	ND				
trans-1,3-Dichloropropene	40000	80000	ND				
Ethylbenzene	16000	80000	522,000				
Hexachlorobutadiene	120000	240000	ND				
2-Hexanone	200000	400000	ND				
Isopropylbenzene	40000	80000	213,000				
p-Isopropyltoluene	40000	80000	308,000				
4-Methyl-2-pentanone (MIBK)	200000	400000	ND				
Methyl-tert-butyl ether (MTBE)	40000	80000	ND				
Methylene chloride (DCM)	200000	400000	ND				
Naphthalene	40000	80000	384,000				
n-Propylbenzene	40000	80000	602,000				
Styrene	40000	80000	ND				
1,1,1,2-Tetrachloroethane	40000	80000	ND				
1,1,2,2-Tetrachloroethane	40000	80000	ND				
Tetrachloroethene	40000	80000	ND				
Toluene (Methyl benzene)	16000	80000	455,000				
1,2,3-Trichlorobenzene	40000	80000	ND				
1,2,4-Trichlorobenzene	40000	80000	ND				
1,1,1-Trichloroethane	40000	80000	ND				
1,1,2-Trichloroethane	40000	80000	ND				
Trichloroethene	40000	80000	ND				
Trichlorofluoromethane	40000	80000	ND				
1,2,3-Trichloropropane	40000	80000	ND				

ANALYTICAL RESULTS

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Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8260B), Volatile Organic Compounds by GC/MS (SW846)

QC Batch No: 0724081A1

Our Lab I.D.			48343.04				
Client Sample I.D.			Jet A				
Date Sampled			07/16/2008				
Date Prepared			07/24/2008				
Preparation Method			5030B				
Date Analyzed			07/24/2008				
Matrix			Liquid				
Units			ug/Kg				
Dilution Factor			8000				
Analytes	**MDL**	**PQL**	**Results**				
1,2,4-Trimethylbenzene	40000	80000	4,100,000				
1,3,5-Trimethylbenzene	40000	80000	960,000				
Vinyl Acetate	200000	400000	ND				
Vinyl chloride (Chloroethene)	120000	240000	ND				
o-Xylene	16000	80000	1,150,000				
m,p-Xylenes	16000	160000	1,900,000				

Comment(s):
48343.04: Analyzed under dilution due to matrix interference

Our Lab I.D.			48343.04				
Surrogates	**%Rec.Limit**		**% Rec.**				
Bromofluorobenzene	75-125		101				
Dibromofluoromethane	75-125		94.9				
Toluene-d8	75-125		96.8				

ANALYTICAL RESULTS

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Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8082), Polychlorinated Biphenyls (PCBs) by GC

QC Batch No: 072308

Our Lab I.D.			Method Blank				
Client Sample I.D.							
Date Sampled							
Date Prepared			07/23/2008				
Preparation Method			3550B				
Date Analyzed			07/23/2008				
Matrix			Liquid				
Units			ug/Kg				
Dilution Factor			1				
Analytes	MDL	PQL	**Results**				
Aroclor-1016 (PCB-1016)	25.0	50.0	ND				
Aroclor-1221 (PCB-1221)	25.0	50.0	ND				
Aroclor-1232 (PCB-1232)	25.0	50.0	ND				
Aroclor-1242 (PCB-1242)	25.0	50.0	ND				
Aroclor-1248 (PCB-1248)	25.0	50.0	ND				
Aroclor-1254 (PCB-1254)	25.0	50.0	ND				
Aroclor-1260 (PCB-1260)	25.0	50.0	ND				
Aroclor-1262 (PCB-1262)	25.0	50.0	ND				
Aroclor-1268 (PCB-1268)	25.0	50.0	ND				
Our Lab I.D.			Method Blank				
Surrogates	**%Rec.Limit**		**% Rec.**				
Tetrachloro-m-xylene	30-150		82.6				

ANALYTICAL RESULTS

Ordered By

Atmospheric Analysis & Consulting
1534 Eastman Avenue
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Attn: Marcus Hueppe
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Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8082), Polychlorinated Biphenyls (PCBs) by GC

QC Batch No: 072308

Our Lab I.D.			48343.01	48343.02	48343.03	48343.04	
Client Sample I.D.			Unleaded Gasoline	Diesel (a)	Diesel (b)	Jet A	
Date Sampled			07/16/2008	07/16/2008	07/16/2008	07/16/2008	
Date Prepared			07/23/2008	07/23/2008	07/23/2008	07/23/2008	
Preparation Method			3550B	3550B	3550B	3550B	
Date Analyzed			07/23/2008	07/23/2008	07/23/2008	07/23/2008	
Matrix			Liquid	Liquid	Liquid	Liquid	
Units			ug/Kg	ug/Kg	ug/Kg	ug/Kg	
Dilution Factor			10	10	10	10	
Analytes	MDL	PQL	**Results**	**Results**	**Results**	**Results**	
Aroclor-1016 (PCB-1016)	250	500	ND	ND	ND	ND	
Aroclor-1221 (PCB-1221)	250	500	ND	ND	ND	ND	
Aroclor-1232 (PCB-1232)	250	500	ND	ND	ND	ND	
Aroclor-1242 (PCB-1242)	250	500	ND	ND	ND	ND	
Aroclor-1248 (PCB-1248)	250	500	ND	ND	ND	ND	
Aroclor-1254 (PCB-1254)	250	500	ND	ND	ND	ND	
Aroclor-1260 (PCB-1260)	250	500	ND	ND	ND	ND	
Aroclor-1262 (PCB-1262)	250	500	ND	ND	ND	ND	
Aroclor-1268 (PCB-1268)	250	500	ND	ND	ND	ND	

Comment(s):

48343.01: Analyzed under dilution due to matrix interference 48343.02: Analyzed under dilution due to matrix interference 48343.03: Analyzed under dilution due to matrix interference 48343.04: Analyzed under dilution due to matrix interference

ANALYTICAL RESULTS

Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8082), Polychlorinated Biphenyls (PCBs) by GC

Our Lab I.D.			48343.01	48343.02	48343.03	48343.04	
Surrogates	%Rec.Limit		% Rec.	% Rec.	% Rec.	% Rec.	
Tetrachloro-m-xylene	30-150		79.2	88.1	88.5	80.2	

QUALITY CONTROL RESULTS

Ordered By

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Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8082), Polychlorinated Biphenyls (PCBs) by GC

QUALITY CONTROL REPORT

QC Batch No: 072308; Dup or Spiked Sample: B072308; LCS: Blank; QC Prepared: 07/23/2008; QC Analyzed: 07/23/2008; Units: ppb

Analytes	Sample Result	MS Concen	MS Recov	MS % REC	MS DUP Concen	MS DUP Recov	MS DUP % REC	RPD %	MS/MSD % Limit	MS RPD % Limit
Aroclor-1260 (PCB-1260)	0.0	500.00	530	106	500.00	535.00	107	<1	50-150	<50
Surrogates										
Tetrachloro-m-xylene	0.0	50.00	53.00	106	50.00	50.00	100	5.8	30-150	<20

QC Batch No: 072308; Dup or Spiked Sample: B072308; LCS: Blank; QC Prepared: 07/23/2008; QC Analyzed: 07/23/2008; Units: ppb

Analytes	LCS Concen	LCS Recov	LCS % REC	LCS/LCSD % Limit						
Aroclor-1260 (PCB-1260)	500.00	545.00	109	50-150						
Surrogates										
Tetrachloro-m-xylene	50.00	54.50	109	30-150						

QUALITY CONTROL RESULTS

Ordered By

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Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8260B), Volatile Organic Compounds by GC/MS (SW846)

QUALITY CONTROL REPORT

QC Batch No: 0724081A1; Dup or Spiked Sample: B0724081A1; LCS: Blank; QC Prepared: 07/24/2008; QC Analyzed: 07/24/2008; Units: ppb

Analytes	MS Concen	MS Recov	MS % REC	MS DUP Concen	MS DUP Recov	MS DUP % REC	RPD %	MS/MSD % Limit	MS RPD % Limit	
Benzene	50.00	49.80	99.6	50.00	51.20	102	2.38	75-125	<20	
Chlorobenzene	50.00	46.10	92.2	50.00	46.60	93.2	1.08	75-125	<20	
1,1-Dichloroethene	50.00	54.60	109	50.00	56.50	113	3.60	75-125	<20	
Methyl-tert-butyl ether (MTBE)	50.00	46.10	92.2	50.00	45.90	91.8	<1	75-125	<20	
Toluene (Methyl benzene)	50.00	46.60	93.2	50.00	47.30	94.6	1.49	75-125	<20	
Trichloroethene	50.00	59.10	118	50.00	59.20	118	<1	75-125	<20	
Surrogates										
Bromofluorobenzene	50.00	46.40	92.8	50.00	46.10	92.3	<1	75-125	<20	
Dibromofluoromethane	50.00	48.30	96.6	50.00	50.40	101	4.55	75-125	<20	
Toluene-d8	50.00	47.90	95.8	50.00	47.80	95.7	<1	75-125	<20	

QC Batch No: 0724081A1; Dup or Spiked Sample: B0724081A1; LCS: Blank; QC Prepared: 07/24/2008; QC Analyzed: 07/24/2008; Units: ppb

Analytes	LCS Concen	LCS Recov	LCS % REC	LCS/LCSD % Limit						
Benzene	50.00	49.70	99.4	75-125						
Chlorobenzene	50.00	45.70	91.4	75-125						
1,1-Dichloroethene	50.00	52.20	104	75-125						
Methyl-tert-butyl ether (MTBE)	50.00	45.80	91.6	75-125						
Toluene (Methyl benzene)	50.00	46.60	93.2	75-125						
Trichloroethene	50.00	59.00	118	75-125						
LCS										
Chloroform (Trichloromethane)	50.00	46.10	92.2	75-125						
Ethylbenzene	50.00	45.70	91.4	75-125						
1,1,1-Trichloroethane	50.00	50.10	100	75-125						
o-Xylene	50.00	46.10	92.2	75-125						
m,p-Xylenes	100.00	94.30	94.3	75-125						
Surrogates										
Bromofluorobenzene	50.00	46.50	93.1	75-125						
Dibromofluoromethane	50.00	48.10	96.1	75-125						

QUALITY CONTROL RESULTS

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Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8260B), Volatile Organic Compounds by GC/MS (SW846)

QC Batch No: 0724081A1; Dup or Spiked Sample: B0724081A1; LCS: Blank; QC Prepared: 07/24/2008; QC Analyzed: 07/24/2008; Units: ppb

Analytes	LCS Concen	LCS Recov	LCS % REC	LCS/LCSD % Limit						
Toluene-d8	50.00	47.60	95.2	75-125						

QUALITY CONTROL RESULTS

Ordered By

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Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8260B), Volatile Organic Compounds by GC/MS (SW846)

QUALITY CONTROL REPORT

QC Batch No: 0727085A2; Dup or Spiked Sample: B0727085A2; LCS: Blank; QC Prepared: 07/27/2008; QC Analyzed: 07/28/2008; Units: ppb

Analytes	MS Concen	MS Recov	MS % REC	MS DUP Concen	MS DUP Recov	MS DUP % REC	RPD %	MS/MSD % Limit	MS RPD % Limit	
Benzene	50.00	51.30	103	50.00	53.10	106	2.87	75-125	<20	
Chlorobenzene	50.00	53.00	106	50.00	53.40	107	<1	75-125	<20	
1,1-Dichloroethene	50.00	59.50	119	50.00	58.50	117	1.69	75-125	<20	
Methyl-tert-butyl ether (MTBE)	50.00	46.70	93.4	50.00	53.10	106	12.6	75-125	<20	
Toluene (Methyl benzene)	50.00	52.60	105	50.00	53.20	106	<1	75-125	<20	
Trichloroethene	50.00	63.10	126	50.00	53.80	108	15.4	75-125	<20	
Surrogates										
Bromofluorobenzene	50.00	49.80	99.6	50.00	49.30	98.6	1.00	75-125	<20	
Dibromofluoromethane	50.00	46.50	93.0	50.00	47.50	95.0	2.15	75-125	<20	
Toluene-d8	50.00	49.90	99.7	50.00	50.80	102	2.31	75-125	<20	

QC Batch No: 0727085A2; Dup or Spiked Sample: B0727085A2; LCS: Blank; QC Prepared: 07/27/2008; QC Analyzed: 07/28/2008; Units: ppb

Analytes	LCS Concen	LCS Recov	LCS % REC	LCS/LCSD % Limit						
Benzene	50.00	46.30	92.6	75-125						
Chlorobenzene	50.00	47.00	94.0	75-125						
1,1-Dichloroethene	50.00	62.10	124	75-125						
Methyl-tert-butyl ether (MTBE)	50.00	40.90	81.8	75-125						
Toluene (Methyl benzene)	50.00	47.10	94.2	75-125						
Trichloroethene	50.00	52.60	105	75-125						
LCS										
Chloroform (Trichloromethane)	50.00	38.80	77.6	75-125						
Ethylbenzene	50.00	46.10	92.2	75-125						
1,1,1-Trichloroethane	50.00	40.60	81.2	75-125						
o-Xylene	50.00	46.70	93.4	75-125						
m,p-Xylenes	100.00	94.00	94.0	75-125						
Surrogates										
Bromofluorobenzene	50.00	49.20	98.4	75-125						
Dibromofluoromethane	50.00	46.20	92.5	75-125						

QUALITY CONTROL RESULTS

Project ID: 080457
Project Name: LAWA

AETL Job Number	Submitted	Client
48343	07/21/2008	AA&C

Method: (8260B), Volatile Organic Compounds by GC/MS (SW846)

**QC Batch No: 0727085A2; Dup or Spiked Sample: B0727085A2; LCS: Blank; QC Prepared: 07/27/2008; QC Analyzed: 07/28/2008;
Units: ppb**

Analytes	LCS Concen	LCS Recov	LCS % REC	LCS/LCSD % Limit						
Toluene-d8	50.00	51.00	102	75-125						

American Environmental Testing Laboratory Inc.
2834 & 2908 North Naomi Street, Burbank, CA 91504 • DOHS NO: 1541, LACSD NO: 10181
Tel: (888) 288-AETL • (818) 845-8200 • Fax: (818) 845-8840 • www.aetlab.com

Data Qualifiers and Descriptors

Data Qualifier:

*:	In the QC section, sample results have been taken directly from the ICP reading. No preparation factor has been applied.
B:	Analyte was present in the Method Blank.
D:	Result is from a diluted analysis.
E:	Result is beyond calibration limits and is estimated.
H:	Analysis was performed over the allowed holding time due to circumstances which were beyond laboratory control.
J:	Analyte was detected . However, the analyte concentration is an estimated value, which is between the Method Detection Limit (MDL) and the Practical Quantitation Limit (PQL).
M:	Matrix spike recovery is outside control limits due to matrix interference. Laboratory Control Sample recovery was acceptable.
MCL:	Maximum Contaminant Level
NS:	No Standard Available
S6:	Surrogate recovery is outside control limits due to matrix interference.
S8:	The analysis of the sample required a dilution such that the surrogate concentration was diluted below the method acceptance criteria.
X:	Results represent LCS and LCSD data.

Definition:

%Limi:	Percent acceptable limits.
%REC:	Percent recovery.
Con.L:	Acceptable Control Limits
Conce:	Added concentration to the sample.
LCS:	Laboratory Control Sample
MDL:	Method Detection Limit is a statistically derived number which is specific for each instrument, each method, and each compound. It indicates a distinctively detectable quantity with 99% probability.

Data Qualifiers and Descriptors

MS:	Matrix Spike
MS DU:	Matrix Spike Duplicate
ND:	Analyte was not detected in the sample at or above MDL.
PQL:	Practical Quantitation Limit or ML (Minimum Level as per RWQCB) is the minimum concentration that can be quantified with more than 99% confidence. Taking into account all aspects of the entire analytical instrumentation and practice.
Recov:	Recovered concentration in the sample.
RPD:	Relative Percent Difference

Detailed Hydrocarbon Analysis, Composition/Breakdown, Markers/Additives ASTM D-6729/6733, GC/MS Hardcopy Report

Saybolt
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SAYBOLT LP
21730 S. Wilmington Avenue
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310-518-4400 Telephone
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Fast To The Point

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Certificate of Analysis

ATMOSPHERIC ANALYSIS & CONSULTING INC.
MARCUS HUEPPE
1534 EASTMAN AVENUE
VENTURA, CA 93003

		Date Sampled:	7/16/2008
Report Date:	9/30/2008	Product:	Unleaded Gasoline
Job No:	13091-00005181	Location:	Ventura, CA
Sample Number:	801240-01	Sample ID:	Sample #080457-33841
Client Ref:	AAC Project #080457	Vessel:	

Test	Method	Result	Units
Compostion Breakdown by GC/MS			
Composition Breakdown by GC/MS	GC/MS	See Attached	
Detailed Capillary Analysis			
Detailed Hydrocarbon Analysis	ASTM D-6729	See Attached	

*Analysis results are submitted by a third party laboratory. Saybolt was not present whilst the analysis was carried out, and has signed for receipt only with no liability accepted.

Approved By: Francine Hanby
Francine Hanby
Laboratory Manager

Saybolt
A CORE LABORATORIES COMPANY

Unleaded Gasoline
Lab No: 801240-01
Job No: 13091-00005181

Composition Breakdown, Gas Chromatography/Mass Spectrometer

The sample was analyzed on a gas chromatograph/mass spectrometer. A library search was performed on the collected data using the Wiley 138 Library and the NIST 98 Library. Together the libraries contain approximately 200,000 compounds.

This appears to be some gasoline blending stock.

The following is the tentative composition.

Tentatively identified Compounds Types Found	Approximate Quantification Percent by Weight
Paraffins	7.32
Isoparaffins	41.91
Cyclic paraffins (naphthenics)	7.08
Aromatics	31.69
Olefins	3.89
Alcohols	2.02
Unidentified	6.09
Total	100.00

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Saybolt LP

Unleaded Gasoline
Lab No: 801240-01
Job No: 13091-00005181 **ASTM D-6729**

Component Name	**WT %**
Methane	<0.02
Ethene	<0.02
Ethane	<0.02
Propene	<0.02
Propane	<0.02
Isobutane	<0.02
Methanol	<0.02
Isobutene	<0.02
1-Butene	<0.02
1,3-Butadiene	<0.02
n-Butane	0.22
trans-2-Butene	0.03
2,2-Dimethylpropane	<0.02
cis-2-Butene	0.03
1,2-Butadiene	<0.02
Ethanol	2.02
3-Methyl-1-butene	<0.02
Isopentane	4.1
Methyl cyclobutane	0.12
1,4-Pentadiene	<0.02
2-Butyne+(Dimethylacetylene)	<0.02
1,1-Dimethylcyclopropane	0.34
1-Pentene	<0.02
Isopropanol	<0.02
2-Methyl-1-butene	0.18
n-Pentane	2.44
2-Methyl-1,3-butadiene	<0.02
trans-2-Pentene	<0.02
3,3-Dimethyl-1-butene	<0.02
cis-2-Pentene	<0.02
tert-Butanol (TBA)	<0.02
2-Methyl-2-butene	<0.02
trans-1,3-Pentadiene	<0.02
3-Methyl-1,2-butadiene	<0.02
Cyclopentadiene	<0.02
cis-1,3-Pentadiene	<0.02
1,2-Pentadiene	<0.02
2,2-Dimethylbutane	0.12
Cyclopentene	0.13
4-Methyl-1-pentene	<0.02
3-Methyl-1-pentene	<0.02
n-Propanol	<0.02
Cylcopentane	<0.02
2,3-Dimethylbutane	1.49
2,3-Dimethyl-1-butene	0.19
Methyl-tert-butyl ether	<0.02

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Unleaded Gasoline
Lab No: 801240-01
Job No: 13091-00005181 **ASTM D-6729**

Component Name	**WT %**
cis-4-Methyl-2-pentene	0.07
2-Methylpentane	3.6
trans-4-Methyl-2-pentene	<0.02
Methylethylketone (MEK)	<0.02
3-Methylpentane	2.09
C6-Olefin	0.08
2-Methyl-1-pentene	<0.02
1-Hexene	0.17
Methyl-sec-butyl ether	<0.02
C6-Olefin	0.17
2-Butanol	<0.02
2-Ethyl-1-butene	<0.02
n-Hexane	2.8
cis-3-Hexene	<0.02
Di-isopropylether (DIPE)	<0.02
trans-3-Hexene+Hexadiene	<0.02
1-Ethyl-2-methylcyclopropane	0.29
2-Methyl-2-pentene	<0.02
3-Methylcyclopentene	<0.02
trans-3-Methyl-2-pentene	<0.02
cis-2-hexene	0.11
3,3-Dimethyl-1-pentene	<0.02
cis-3-Methyl-2-pentene	<0.02
Ethyl-tert-butyl ether (ETBE)	<0.02
2,3-Dimethyl-1,3-butadiene	<0.02
Methylcyclopentane	2.02
2,2-Dimethylpentane	2.78
4,4-Dimethyl-1-pentene	<0.02
Isobutanol	<0.02
2,3-Dimethyl-2-butene	<0.02
2,4-Dimethylpentane	<0.02
1,3,5-Hexatriene	<0.02
1,1,2-Cyclopropane	0.05
2,2,3-Trimethylbutane	0.05
Methylcyclopentadiene	<0.02
C7-Olefin	1.94
C7-Olefin	<0.02
C7-Diolefin	<0.02
4-Methylcyclopentene	0.32
Methylenecyclopentane	<0.02
Benzene	1.28
1-Methyl-1-cyclopentene	0.05
C7-Olefin	<0.02
cis-2-Methyl-3-hexene	<0.02
3,3-Dimethylpentene+5-me	<0.02
Cyclohexane	<0.02
trans-2-Methyl-3-hexene	<0.02

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Saybolt LP

Unleaded Gasoline
Lab No: 801240-01
Job No: 13091-00005181 **ASTM D-6729**

Component Name	**WT %**
3,3-Dimethyl-1,4-pentadiene	<0.02
n-Butanol	<0.02
Dimethylcyclopentadiene	<0.02
t-2-Ethyl-3-Mehtyl-1-bute	<0.02
4-Methyl-1-hexene	<0.02
C7-Olefin	<0.02
3-Methyl-1-hexene	<0.02
4-Methyl-2-hexene	<0.02
2-Methylhexane+C7-Olefin	1.8
2,3-Dimethylpentane	4.94
Cyclohexene	<0.02
tert-Amyl-methyl ether	<0.02
C7-Olefin	<0.02
C7-Olefin	<0.02
Isopropyl cyclopentane	0.37
3-Methyhexane	<0.02
C7-Olefin	<0.02
C7-Olefin	<0.02
trans-1,3-Dimethylcyclopentane	0.39
cis-1,3-Dimethylcyclopentane	<0.02
trans-1,2-Dimethylcyclopentane	<0.02
3-Ethylpentane	<0.02
C7-Olefin	<0.02
2,2,4-Trimethylpentane	8.13
C7-Olefin	<0.02
1-Heptene	<0.02
C7-Olefin	<0.02
2,3-Dimethyl-1,3-pentadiene	<0.02
C7-Diolefin	<0.02
C7-Olefin	<0.02
C7-Diolefin	<0.02
C7-Diolefin	<0.02
C7-Olefin	<0.02
n-Heptane	1.4
cis-3-Heptene	<0.02
2-Methyl-2-hexene	<0.02
cis-3-Methyl-3-hexene	0.06
trans-3-Heptene	0.16
3-Ethyl-2-pentene	0.05
1,5-Dimethylcyclopentene	0.06
trans-2-Methyl-3-hexene	<0.02
C7-Diolefin+C7-Triolefin	<0.02
2,3-Dimethyl-2-pentene	<0.02
3-Ethylpentene	<0.02
Methylcyclohexane	0.84
C7-Olefin	0.03
1,1,3-Trimethylcyclopentene	<0.02

Unleaded Gasoline
Lab No: 801240-01
Job No: 13091-00005181 **ASTM D-6729**

Component Name	**WT %**
2,2-Dimethyhexane	<0.02
2,3,4-Trimethy-1,4-pentadiene	<0.02
3,3-Dimethyl-1,5-hexadiene	<0.02
C8-Diolefin	<0.02
C7-Olefin	<0.02
Ethylcyclopentane	0.21
3-Methylcyclohexene	<0.02
Methylcyclohexadiene	<0.02
2,2,3-Trimethylpentane	<0.02
2,5-Dimethylhexane+C8	0.85
2,4-Dimethylhexane	1.16
C7-Triolefin+C8-Olefin	<0.02
trans,cis-1,2,4-Trimethylpentane	<0.02
3,3-DMC6+C8-Olefin	<0.02
C7-Triolefin+C8-Olefin	<0.02
trans,cis-1,2-3-Trimethylcyclopentane	<0.02
C8-Olefins	<0.02
C8-Olefins	<0.02
C8-Olefins	<0.02
C8-Olefins	<0.02
2,3,4-Trimethylpentane	2.44
C7-Diolefin	<0.02
Toluene	7.29
2,3,3-Trimethylpentane	2.38
C8-Olefin	<0.02
C8-Diolefin	<0.02
C8-Olefin	<0.02
C8-Olefin	<0.02
C8-Olefin	<0.02
C8-Diolefin+C8-Olefin	<0.02
2,3-Dimethylhexane	0.76
2-Methyl-3-ethylpentane	<0.02
1,1,2-Trimethylcyclopentane	<0.02
C8-Diolein+C8-Paraffin	<0.02
C8-Olefins	<0.02
C8-Olefins	<0.02
2-Methylheptane	0.79
4-Methylheptane	<0.02
C8-Diolefin+C7-Olefin	<0.02
C8-Olefins	<0.02
cis-1,4-Dimethylcyclohexane	0.26
trans-1,4-Dimethylcyclohexane	0.09
3-Methylheptane	<0.02
3-Ethylhexane	<0.02
C8-Diolefin	<0.02
C8-Olefins	<0.02
C8-Olefin	

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Unleaded Gasoline
Lab No: 801240-01
Job No: 13091-00005181 **ASTM D-6729**

Component Name	**WT %**
1,1-Dimethylcyclohexane	<0.02
C8-Olefin	<0.02
C8-Olefin	<0.02
cis-1-Ethyl-3-methylcyclohexane	0.12
2,2,5-Trimethylhexane	1.2
trans-1-Ethyl-3-methylcylcopentane	0.09
trans-1-Ethyl-2-methylcylcopentane	0.12
1-methyl-1-ethylcyclopentane	<0.02
1-Octene	<0.02
C8-Olefin	<0.02
trans-1,2-dimethylcyclohexane	<0.02
C8-Olefins	<0.02
C8-Olefin	<0.02
C8-Olefins	<0.02
trans-3-C8-Olefin	<0.02
trans-1,3-Dimethylcyclohexane	0.14
cis-1,4-Dimethylcyclohexane	<0.02
n-Octane	0.75
C8-Olefin	<0.02
C8-Olefin	<0.02
trans-2-Octene	<0.02
Isopropylcyclopentane	<0.02
C9-Olefin	<0.02
C9-Olefin	<0.02
C9-Olefin	<0.02
C9-Olefin	<0.02
2,2,4-Trimethylhexane	<0.02
2,4,4-Trimethylhexane	<0.02
C9-Olefins	<0.02
2,3,5-Trimethylhexane	0.22
cis-2-Octene	<0.02
2,2,3,4-Tetramethycyclopentane	<0.02
2,2-Dimethyheptane	<0.02
cis-1,2-dimethylcyclohexane	<0.02
2,4-Dimethyheptane	0.15
C9-Olefin	<0.02
C9-Olefin	<0.02
Ethylcyclohexane	0.14
Propylcyclopentane	<0.02
2-Methyl-4-ethylhexane	<0.02
2,6-Dimethyheptane	0.2
C9-Olefin	<0.02
1,1,4-Trimethylcyclohexane	<0.02
C9-Olefins	<0.02
C9-Olefins	<0.02
1,1,3-Trimethylcyclohexane	0.17
2,5 & 3,5-Dimethylheptane	0.23

Unleaded Gasoline
Lab No: 801240-01
Job No: 13091-00005181 **ASTM D-6729**

Component Name	**WT %**
C9-Olefins	<0.02
3,3-Dimethylheptane	<0.02
C9-Isoparaffin	<0.02
C9-Olefins	<0.02
2,3,3-Trimethylhexane	<0.02
C9-Olefins	<0.02
Ethylbenzene	1.62
C9-Olefins	<0.02
trans-1,2,4-Trimethylcyclohexane	0.1
C9-Olefins	<0.02
2,3,4-Trimethylhexane	<0.02
C9-Olefin	<0.02
3,3,4-Trimethylhexane	0.05
m-Xylene	4.6
p-Xylene	2.18
2,3-Dimethylheptane	0.17
3,5-Dimethylheptane	0.22
3,4-Dimethylheptane	<0.02
C9-Olefin	0.14
3-Methyl-3-ethylhexane	<0.02
C9-Olefin	<0.02
4-Ethylheptane	<0.02
4-Methycyclooctane+C9-Olefin	<0.02
2-Methyloctane	0.25
C9-Olefin	<0.02
C9-Isoparaffin	<0.02
C9-Olefin	<0.02
3-Ethylheptane	0.27
3-Methyloctane	<0.02
C9-Isoparaffin	<0.02
cis-1,2-4-Trimethylcyclohexane	<0.02
1,1,2-Trimethylcyclohexane	<0.02
o-Xylene	2.55
C9-Olefin	0.05
C9-Isoparaffin	<0.02
C9-Isoparaffin	<0.02
C9-Olefin	<0.02
trans-1-Ethyl-4-methylcyclohexane	0.09
cis-1-Ethyl-4-methylcyclohexane	0.06
C9-Isoparaffin	<0.02
1-Nonene	<0.02
Isobutylcyclopentane	<0.02
C9-Isoparaffin	<0.02
trans-3-Nonene	<0.02
cis-3-Nonene	<0.02
C9-Isoparaffin	<0.02
n-Nonane	0.3

Unleaded Gasoline
Lab No: 801240-01
Job No: 13091-00005181 **ASTM D-6729**

Component Name	**WT %**
C10-Olefin	<0.02
trans-2-Nonene	<0.02
1-Methyl-1-ethylcyclohexane	<0.02
1-Methyl-2-propylcyclopentane	<0.02
C10-Olefin	<0.02
C10-Isoparaffin	0.33
C10-Isoparaffin	<0.02
Isopropylbenzene	<0.02
cis-2-Nonene	<0.02
tert-Butylcyclopentane	<0.02
C9-Olefins	<0.02
Nonene	<0.02
Isopropylcyclohexane	<0.02
3,3,5-Timethylheptane	0.29
2,2-Dimethyloctane	<0.02
2,4-Dimethyloctane	<0.02
1-Methyl-4-isopropylcyclohexane	<0.02
sec-Butylcyclopentane	<0.02
Propylcyclohexane	<0.02
2,5-Dimethyloctane	<0.02
Butylcyclopentane	<0.02
2,6-Dimethyloctane	<0.02
3,6-Dimethyloctane	<0.02
1-Methyl-2-ethylcyclohexane	<0.02
C10-Olefin	<0.02
Propylbenzene	0.39
3,3-Dimethyloctane	<0.02
3-Methy-5-ethylheptane	<0.02
C10-Olefin	<0.02
1-Ethyl-3-methylbenzene	2.63
1-Ethyl-4-methylbenzene	0.77
Naphthene	<0.02
1,3,5-Trimethylbenzene	0.8
2,3-Dimethyloctane	<0.02
5-Methylnonane	<0.02
4-Methylnonane	<0.02
2-Methylnonane	<0.02
1-Ethyl-2-methylbenzene	<0.02
3-Ethyloctane	<0.02
Naphthene	0.08
3-Methylnonane	0.16
C10-Olefin	<0.02
C10-Isoparaffin	0.22
C10-Isoparaffin	<0.02
1,2,4-Trimethylbenzene	3.13
C10-Isoparaffin	0.07
C10-Isoparaffin	<0.02

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Lab No: 801240-01
Job No: 13091-00005181 **ASTM D-6729**

Component Name	**WT %**
Isobutylcyclohexane	<0.02
C10-Isoparaffin	<0.02
C10-Isoparaffin	<0.02
1-Decene	<0.02
C10-Isoparaffin	<0.02
C10-Isoparaffin	<0.02
C10-Aromatic	0.67
Isobutylbenzene	<0.02
trans-1-Methyl-2-propylcyclohexane	0.11
Naphthene	<0.02
C10-Isoparaffin	<0.02
C10-Isoparaffin	<0.02
sec-Butylbenzene	<0.02
n-Decane	<0.02
C11-Isoparaffin	<0.02
C11-Isoparaffin	<0.02
1,2,3-Trimethylbenzene	0.7
1-Methyl-3-isopropylbenzene	<0.02
1-Methyl-4-isopropylbenzene	<0.02
C11-Isoparaffin	<0.02
C11-Isoparaffin	<0.02
C11-Isoparaffin	<0.02
2,3-dihydroindene	<0.02
sec-Butylcyclohexane	<0.02
C11-Isoparaffin	<0.02
1-Methyl-2-isopropylbenzene	<0.02
3-Ethylnonane	<0.02
C11-Isoparaffin	<0.02
Naphthene	<0.02
C11-Isoparaffin	<0.02
1,3-Diethylbenzene	<0.02
1-Methyl-3-propylbenzene	<0.02
1,4-Diethylbenzene	<0.02
1-Methyl-4-propylbenzene	<0.02
Butylbenzene	0.09
3,5-Dimethyl-1-ethylbenzene	<0.02
1,2-Diethylbenzene	0.11
C11-Isoparaffin	<0.02
C10-Aromatic	0.59
C10-Aromatic	0.52
C10-Aromatic	0.14
1-Methyl-2-propylbenzene	<0.02
C10-Aromatic	0.86
5-Methyldecane	<0.02
4-Methyldecane	0.4
2-Methyldecane	<0.02
C11-Isoparaffin	<0.02

Unleaded Gasoline
Lab No: 801240-01
Job No: 13091-00005181 **ASTM D-6729**

Component Name	**WT %**
1,4-Dimethyl-2-ethylbenzene	<0.02
1,3-Dimethyl-4-ethylbenzene	<0.02
C11-Isoparaffin	<0.02
3-Methyldecane	<0.02
Methylindane	<0.02
1,2-dimethyl-4-ethylbenzene+Methylindane	<0.02
C11-Isoparaffin	<0.02
1,3-Dimethyl-2-ethylbenzene	<0.02
C11-Isoparaffin	<0.02
C11-Isoparaffin	<0.02
1-Methyl-4-tert-butylbenzene	<0.02
1,2-Dimethyl-3-ethylbenzene	<0.02
1-Ethyl-2-isopropylbenzene	<0.02
n-Undecane	0.11
1-Ethyl-4-isopropylbenzene	<0.02
C12-Isoparaffin	<0.02
1,2,4,5-Tetramethylbenzene	<0.02
2-Methylbutylbenzene	<0.02
1,2,3,5-Tetramethylbenzene	0.26
3-Methylbutylbenzene	<0.02
C11-Aromatic	0.07
C12-Isoparaffin	<0.02
C11-Aromatic	0.18
C11-Aromatic	0.17
Cc11-Aromatic	<0.02
1-tert-Butyl-2-methylbenzene	<0.02
C11-Aromatic	<0.02
1-Ethyl-2-propylbenzene	<0.02
C11-Aromatic	<0.02
C11-Aromatic	<0.02
C11-Aromatic	<0.02
1-Methyl-3-butylbenzene	<0.02
c11-Aromatic	<0.02
1,2,3,4-Tetramethylbenzene+C11-Aromatic	<0.02
Pentylbenzene	<0.02
trans-1-Methyl-2-(4-methylpentane)-cyclopentane	<0.02
C11-Aromatic	<0.02
C11-Aromatic	<0.02
C11-Aromatic	<0.02
C12-Isoparaffin	<0.02
1,2,3,4-Tetrahydronaphth	<0.02
1-tert-Butyl-3,5-dimethylbenzene	<0.02
Naphthalene	<0.02
1,1-Dimethylindane	<0.02
1,2-Dimethylindane	<0.02
1,6-Dimethylindane	<0.02
C11-Aromatic	<0.02

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Lab No: 801240-01
Job No: 13091-00005181   **ASTM D-6729**

Component Name	WT %
1-Ethylindane	<0.02
2-Ethylindane	<0.02
Ethyl-1,3,5-trimethylbenzene	<0.02
1,3-Dipropylbenzene	<0.02
n-Dodecane	0.05
Ethyl-1,2,4-trimethylbenzene	<0.02
C11-Aromatic	0.03
C11-Aromatic	0.06
C12-Aromatic+Ethylindane	<0.02
2,4-Dimethylindane	<0.02
4-Ethylindane	<0.02
1-tert-Butyl-4-ethylbenzene	<0.02
1,3-Dimethylindane	<0.02
1-Methyl-4-pentylbenzene	<0.02
4,7-Dimethylindane	<0.02
5,6-Dimethylindane	<0.02
C12-Aromatic	<0.02
Hexylbenzene	<0.02
C6-Benzene	<0.02
C6-Benzene	<0.02
C6-Benzene	<0.02
4,5-dimethylindane	<0.02
C6-Benzene	<0.02
2-Methylnaphthalene	<0.02
C6-Benzene	<0.02
C6-Benzene	<0.02
n-Tridecane	<0.02
1-Methylnaphthalene	<0.02
C6-Benzene	<0.02
C2-tetralin	<0.02
C6-Benzene	<0.02
C6-Benzene	<0.02
C13-Isoparaffin	<0.02
trans-7-Decene	<0.02
2,6-Dimethylnaphthalene	<0.02
2,7-Dimethylnaphthalene	<0.02
n-Tetradecane	<0.02
1,3-Dimethylnaphthalene	<0.02
1,2-Dimethylnaphthalene	<0.02
n-Pentadecane	<0.02
1,6-Dimethylnaphthalene	<0.02
1,4-Dimethylnaphthalene	<0.02
1,5-Dimethylnaphthalene	<0.02
Acenaphthalene	<0.02
Unidentified Compounds	6.09
Total	100.00

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Certificate of Analysis

ATMOSPHERIC ANALYSIS & CONSULTING INC.
MARCUS HUEPPE
1534 EASTMAN AVENUE
VENTURA, CA 93003

Date Sampled: 7/16/2008
Report Date: 9/30/2008
Job No: 13091-00005181
Sample Number: 801240-02
Client Ref: AAC Project #080457
Product: Diesel (a)
Location: Ventura, CA
Sample ID: Sample #080457-33842
Vessel:

Test	Method	Result	Units
Compostion Breakdown by GC/MS			
Composition Breakdown by GC/MS	GC/MS	See Attached	
Detailed Capillary Analysis			
Detailed Hydrocarbon Analysis	ASTM D-6733M	See Attached	

*Analysis results are submitted by a third party laboratory. Saybolt was not present whilst the analysis was carried out, and has signed for receipt only with no liability accepted.

Approved By: Francine Hanby
Francine Hanby
Laboratory Manager

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Diesel (a)
Lab No: 801240-02
Job No: 13091-00005181

Composition Breakdown, Gas Chromatography/Mass Spectrometer

The sample was analyzed on a gas chromatograph/mass spectrometer. A library search was performed on the collected data using the Wiley 138 Library and the NIST 98 Library. Together the libraries contain approximately 200,000 compounds.

We preformed a composition breakdown on the hydrocarbon material as received. These results are normalized only to the chemicals found. If heavier compounds, high molecular weight additives or polymers are present these were not seen on the gas chromatograph/mass spectrometer.

The material was found to be a diesel fuel range product with a lower than typical aromatic content. This has been indicative recently of some ultra low sulfur diesel fuels. The carbon distribution ranges forma a trace of C_4 to a trace of C_{25}, with the apex at C_{16}. The library found some small levels of chemicals identified as aldehydes, acids and ketones.

We saw the following organic compound types in the headspace material. The following is the tentative composition.

Tentatively identified Compounds	**Approximate Quantification**
Types Found	**Percent by Weight**
Paraffins	14.4
Isoparaffins	35.6
Cyclic paraffins (naphthenics)	34.6
Mono-aromatics	1.4
Di-aromatics	6.7
Poly-aromatics	2.5
Indenes	0.7
Ketones	0.9
Aldehydes	1.8
Organic acids	0.8
Esters	0.6
Total	100.00

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Diesel (a)
Lab No: 801240-02
Job No: 13091-00005181

Composition Breakdown, Gas Chromatography/Mass Spectrometer, ASTM D-6733 Modified

The sample was analyzed on a gas chromatograph/mass spectrometer. A library search was performed on the collected data using the Wiley 138 Library and the NIST 98 Library. Together the libraries contain approximately 200,000 compounds.

The organic materials are consistent with diesel fuel range hydrocarbons. The chemicals range from approximately C_5 to C_{29} with an apex around C_{16}.

The following is a list of the individual compounds identified by our libraries and their match qualities. The chemicals found have been reported in retention time order as analyzed. Please note, these are names from the libraries and may or may not be the actual name of the compound, but would be representative of the chemical type based on the spectra. Some duplication of names does occur.

The results are listed on the following pages.

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Diesel (a)
Lab No: 801240-02
Job No: 13091-00005181 **ASTM D-6733 Modified**

Tentatively identified Compounds	Approximate Quantifcation %	Match Quality
Butane, 2 methyl-	0.01	86.00
Pentane, 2-methyl-	0.01	87.00
Hexane	0.00	87.00
Cylclopentane, methyl-	0.01	90.00
Cyclohexane	0.01	93.00
Hexane, 2-methyl	0.01	90.00
Pentane, 2,3-dimethyl-	0.01	60.00
Hexane, 3-methyl	0.01	91.00
Pentane, 2,2,3,4-tetramethyl-	0.01	59.00
Cyclopentane, 1,2-dimethyl-	0.01	78.00
Heptane	0.01	94.00
Cyclohexane, methyl-	0.05	94.00
Cyclopentane, ethyl-	0.01	93.00
Cyclopentane, 1,2,3-trimethyl-	0.01	87.00
Heptane, 2-methyl-	0.01	87.00
Benzene, methyl-	0.02	94.00
Heptane, 3-methyl-	0.02	91.00
Cyclohexane, 1,3-dimethyl-, cis-	0.04	97.00
Cyclohexane, 1,3-dimethyl-, cis-	0.01	87.00
Cyclopentane,1-ethyl-3-methyl-	0.01	93.00
Cyclopentane,1-ethyl-2-methyl-	0.02	95.00
Cyclohexane, 1,2-dimethyl-, trans-	0.02	95.00
Octane	0.03	90.00
Cyclohexane, 1,3-dimethyl-, trans-	0.03	94.00
Cyclohexane, 1,2-dimethyl-, cis-	0.02	93.00
Octane, 2-methyl-	0.01	72.00
Cyclohexane, 1,3,5-trimethyl-,...	0.01	91.00
Cyclohexane, ethyl-	0.03	95.00
Cyclohexane, 1,1,3-trimethyl-	0.03	97.00
cis-3- Nonene	0.01	64.00
Cyclohexane, 1,3,5-trimethyl-	0.04	91.00
Cyclohexane, 1,3,5-trimethyl-	0.01	94.00
Heptane, 2,3-dimethyl-	0.01	74.00
Benzene, ethyl-	0.01	95.00
Octane, 4-methyl-	0.01	91.00
Decane, 2-methyl-	0.02	83.00
Benzene, 1,4-dimethyl-	0.03	97.00
Cyclopentane, 1-ethyl-3-methyl-	0.01	47.00
Octane, 3-methyl-	0.03	86.00
Cyclohexane, 1,2,3-trimethyl-,...	0.02	94.00
3-Octen-2-one, (E)-	0.02	90.00
Cyclohexane,1,2,4-trimethyl-	0.03	94.00
Cyclohexane,1,2,4-trimethyl-	0.02	94.00
Cyclopentane, 1-methyl-2-propyl-	0.02	87.00
Cyclohexane, 1-ethyl-4-methyl-	0.05	91.00

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Diesel (a)
Lab No: 801240-02
Job No: 13091-00005181

ASTM D-6733 Modified

Tentatively Identified Compounds	**Approximate Quantifcation %**	**Match Quality**
Cyclohexane, 1-ethyl-4-methyl-,...	0.02	91.00
Benzene, 1,3-dimethyl-	0.02	95.00
Nonane	0.08	91.00
Cyclohexane, 1,2,3-trimethyl-	0.02	94.00
Cyclohexane, 1,2,3-trimethyl-	0.02	60.00
Cyclohexane, 1-ethyl-4-methyl-,...	0.05	86.00
Cyclohexane, 1-ethyl-4-methyl-,...	0.02	90.00
1-Tridecanol	0.01	72.00
Bicyclo[3.3.1]nonane	0.02	93.00
Cyclohexane, (1-merthylethyl)-	0.01	95.00
Cyclohexane, 1,1-dimethyl-	0.01	59.00
Cyclohexane, 2,4-diethyl-3-methyl-	0.01	72.00
Benzene, (1-methylethyl)-	0.01	83.00
3-Trifluoroacetoxy-6-ethyldecane	0.03	43.00
Cyclohexane, 1-ethyl-2-methyl-,...	0.02	87.00
Cyclohexane, propyl-	0.04	90.00
1-Decene	0.01	53.00
Cyclopentane, butyl-	0.01	90.00
Octane, 2,6-dimethyl-	0.06	95.00
Cyclohexane, 2,3,4-trimethyl-	0.01	35.00
Cyclohexane, diethyl-	0.04	87.00
Ether, tert-butyl isopropyliden...	0.03	47.00
2-Octene, 4-ethyl-	0.01	62.00
Cyclopentane, 1-methyl-3-(2-meth...	0.01	49.00
1R,2T,4T,5C-TETRAMETHYLCYCLOHEXANE	0.03	91.00
1R,2T,4C,5T-1,2,4,5-TETRAMETHYL...	0.03	80.00
Cyclopentane, (2-methylbutyl)-	0.01	50.00
Benzene, propyl-	0.01	50.00
1H-Indene, octahydro-, trans-	0.01	93.00
1,1,2,3-TETRAMETHYLCYCLOHEXANE B	0.04	94.00
Octane, 4-ethyl-	0.01	83.00
CYCLOHEXANE, 1,2-DIETHYL	0.02	91.00
CYCLOHEXANE, 1,2-DIETHYL	0.02	87.00
Benzene, 1-ethyl-2-methyl-	0.08	74.00
Nonane, 4-methyl-	0.06	53.00
Nonane, 2-methyl-	0.04	90.00
Benzene, 1,3,5-trimethyl-	0.04	95.00
Cylcohexane, 1,1,2,3-tetramethyl-	0.01	64.00
Nonane, 3-methyl-	0.05	94.00
m-Menthane, (1S,3R)-(+)-	0.03	59.00
Cyclohexane, 1-ethyl-2,3-dimethyl-	0.05	80.00
Cyclohexane, 1,4-dimethyl-, cis-	0.03	47.00
2-Octene, 2,6-dimethyl-	0.02	47.00
Cyclohexane, 1-ethyl-2,4-dimethyl-	0.05	78.00
Cyclohexane, 1-ethyl-2,3-dimethyl-	0.01	90.00
Cyclohexane, 1-methyl-3-propyl-	0.07	87.00

Diesel (a)
Lab No: 801240-02
Job No: 13091-00005181 **ASTM D-6733 Modified**

Tentatively Identified Compounds	Approximate Quantifcation %	Match Quality
Cyclohexane, 1-methyl-3-propyl-	0.08	59.00
1H-Indene, octahydro-, cis-	0.07	80.00
3-Heptene, 4-propyl-	0.03	49.00
Benzene, 1,2,4-trimethyl-	0.08	97.00
Cyclohexane, 1-ethyl-2,3-dimethyl-	0.02	83.00
Cyclohexane, 1-methyl-2-propyl-	0.03	94.00
Cyclohexane, 1,2-dimethyl-	0.01	58.00
Cyclohexane, (3-methylbutyl)-	0.02	68.00
Decane	0.26	95.00
6-Methyl-bicyclo[4.2.0]octan-7-one	0.01	83.00
m-Menthane, (1S,3R)-(+)-	0.03	72.00
Naphthalene, decahydro-, cis-	0.01	95.00
trans -1-4-Diethylcyclohexane	0.01	58.00
Naphthalene, decahydro-, cis-	0.03	87.00
2H-Pyran, tetrahydro-4-methyl-2...	0.01	53.00
Benzene, 1-methyl-2-propyl-	0.01	83.00
Cyclohexane, 1-methyl-4-(1-meth...	0.04	55.00
Cyclopentane,1-methyl-1-(2-met...	0.08	72.00
Tetradecane, 5-methyl-	0.01	47.00
Dodecane, 3-methyl-	0.01	50.00
Benzene, 1,2,4-trimethyl-	0.09	86.00
Decane, 4-methyl-	0.14	93.00
Bicyclo[2.2.1]heptane,2,2,3-tr...	0.01	30.00
Cyclohexane, 1,1-dimethyl-2-pro...	0.01	38.00
Crotonic acid, menthyl ester	0.01	38.00
Octadecane, 1-chloo-	0.04	47.00
1-Methyl-2-methylenecyclohexane	0.03	70.00
Cyclohexane, butyl-	0.08	87.00
Cyclohexane, 1,1,3-trimentyl-	0.06	53.00
Cyclopentane, pentyl-	0.06	90.00
Cyclohexeane, butyl-	0.05	91.00
Dodecane, 3-methyl-	0.09	47.00
Naphthalene, decahydro-, cis-	0.08	90.00
1-ETHYL-2,2,6-TRIMETHYLCYCLOHEXANE	0.04	94.00
Bicyclo[5.3.0]decane	0.04	93.00
Cyclohexane, 1,2-diethyl-1-methyl-	0.07	76.00
Cyclohexane, 1,1,3-trimentyl-	0.05	60.00
Benzene, 1-methyl-3-propyl-	0.05	94.00
Naphthalene, decahydro-, trans-	0.35	96.00
Cyclohexene, 3-methyl-6-(1-meth...	0.09	59.00
Benzene, 1-ethyl-2,3-dimethyl-	0.12	91.00
Decane, 4-methyl-	0.08	91.00
Bicyclo[3.1.0]hexane-2-one-4-me...	0.03	49.00
Cyclohexane,(1,2-dimethylbutyl)-	0.08	43.00
Decane, 2-methyl-	0.13	76.00
Benzene, 1-methyl-2-propyl-	0.02	93.00

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Tentatively Identified Compounds	Approximate Quantifcation %	Match Quality
Naphthalene, decahydro-2-methyl-	0.05	79.00
cis-Decaline,2-syn-methyl-	0.04	49.00
Cyclohexane, 1,2-diethyl-3-methyl-	0.03	76.00
Decane, 3-methyl-	0.13	86.00
trans-Decalin, 2-methyl-	0.07	47.00
Benzene, 1-ethyl-2,3-dimethyl-	0.09	89.00
Benzene, 1-ethyl-2,4-dimethyl-	0.07	95.00
Naphthalene, decahydro-2-methyl-	0.02	53.00
11-Hexadecen-1-ol, (Z)-	0.04	35.00
Cyclohexane, 1,1,2-trimethyl-	0.02	43.00
Cyclopropane, 1-butyl-1-methyl-,...	0.02	55.00
Benzene, 1-ethyl-2,3-dimethyl-	0.21	89.00
Cyclohexane, 1-ethyl-4-methyl-,...	0.10	43.00
1-Methyl-2-methylenecyclohexane	0.17	42.00
1-Methyldecahydronaphthalene	0.04	42.00
trans-Decalin, 2-methyl-	0.07	62.00
Cyclohexane, 1-ethyl-2-methyl-	0.07	81.00
cis-Decalin, 2-syn-methyl-	0.09	64.00
Naphthalene, decahydro-, cis-	0.08	97.00
Undecane	0.67	91.00
Cyclodecene, 1-methyl-	0.09	83.00
2-METHYLDECALIN (PROBABLY CIS)	0.15	90.00
3,4-Dimethylcyclohexanol	0.04	43.00
Napthalene, decahydro-2-methyl-	0.58	97.00
Hexane, 2,3,4-trimethyl-	0.05	30.00
Benzene, 1-methyl-2-(1-methylet...	0.16	89.00
3-Undecene, 6-methyl-, (E)-	0.08	47.00
2,6-Dimethyldecane	0.09	53.00
Benzene, 1,2,4,5-tetramethyl-	0.17	95.00
Decane, 3,6-dimethyl-	0.02	70.00
Hexadecane	0.06	46.00
TRANS-ANTI-1-METHYL-DECAHYDRONA...	0.50	95.00
Cyclohexane, 1,2,3-trimethyl-	0.06	38.00
2-METHYLDECALIN (PROBABLY CIS)	0.07	91.00
n-Amycyclohexane	0.32	46.00
Benzene, 1-methyl-4(1-methylpr...	0.06	50.00
1H-Indene, 2,3-dihydro-5-methyl-	0.05	91.00
3-Dodecene, (E)-	0.09	53.00
Cyclodecene, 1-methyl-	0.08	46.00
Benzene, diethylmethyl	0.11	90.00
Benzene, 1-methyl-4(1-methylpr...	0.16	60.00
CIS-SYN-1-METHYL-DECAHYDRONAPHT..	0.37	94.00
Benzeneacetic acid, 4-amino-	0.10	42.00
Bicyclo[3.1.0]hexane-2-one-4-me...	0.07	55.00
Napthalene, decahydro-2-methyl-	0.25	94.00
Undecane, 5-methyl	0.19	55.00
Undecane, 4-methyl	0.41	46.00

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Tentatively Identified Compounds	**Approximate Quantifcation %**	**Match Quality**
Benzene, diethylmethyl-	0.03	95.00
Undecane, 2-methyl-	0.21	64.00
Napthalene, decahydro-2, 6-dime...	0.48	93.00
Benzene, 2,4-diethyl-1-methyl-	0.04	95.00
Napthalene, decahydro-2, 6-dime...	0.03	64.00
Decane, 3,8-dimethyl-	0.02	64.00
CIS-SYN-1-METHYL-DECAHYDRONAPHT..	0.14	93.00
Benzene, (1,1-dimethylpropyl)-	0.07	62.00
5-t-Butyl-cyclopeptene	0.07	38.00
Napthalene, decahydro-2, 3-dime...	0.29	93.00
Napthalene, decahydro-2, 6-dime...	0.18	93.00
2,6-DIMETHYL-4-OXA-ENDO-TRICYCL...	0.34	90.00
Cyclohexane, 1-methyl-3-pentyl	0.40	58.00
Naphthalene, decahydro-1, 6-dime...	0.45	86.00
3-Undecane, 5-methyl-	0.06	18.00
Benzene, (2-methyl-1-butenyl)-	0.14	56.00
Naphthalene, decahydro-2, 6-dime...	0.37	94.00
Dodecane	1.02	93.00
Naphthalene, decahydro-2, 6-dime...	0.20	98.00
Naphthalene, decahydro-2, 3-dime...	0.16	94.00
TRANS-10-METHYL-4-KETOPERHYDROA...	0.16	87.00
Naphthalene, decahydro-1, 6-dime...	0.09	76.00
Naphthalene, decahydro-2, 3-dime...	0.19	58.00
Undecane, 2, 6-dimethyl-	0.57	93.00
Pyridine,2-ethyl-, 1-oxide	0.04	25.00
3-Methyl-2-(2-oxopropyl)furan	0.06	30.00
3,5-Decadiene, 2,2-dimethyl-, (...	0.25	58.00
Cyclopentane, 2-isopropyl-1,3-d...	0.18	35.00
Cyclohexane, 2-butyl-1,1,3-trimet...	0.18	97.00
DECAHYDRO-2-ETHYL-NAPHTHALENE	0.44	94.00
3-Methyl-2-(2-oxopropyl)furan	0.12	50.00
Bicyclo[4.1.0] heptane, 3-methyl...	0.29	53.00
Bicyclo[4.1.0] heptane, 3-methyl...	0.28	60.00
trans, cis-3-Ethylbicyclo[4.4.0...	0.16	95.00
trans, cis-3-Ethylbicyclo[4.4.0...	0.15	94.00
Cyclohexane, hexyl-	0.25	83.00
1-Tridecene	0.27	55.00
Naphthalene, decahydro-1, 5 dime...	0.09	55.00
Isobenzofuran	0.14	30.00
Indan, 5,6-dimethyl-	0.47	91.00
Dodecane, 6-methyl-	0.32	60.00
Tridecane, 5-methyl-	0.26	38.00
2(1H)-Naphthalenone, octahydro...	0.18	70.00
Dodecane, 4-methyl-	0.33	55.00
Naphthalene, decahydro-1,2-dime...	0.08	25.00
3,5-Dodecadiene, 2-methyl-	0.15	55.00
Dotriacontane	0.40	38.00

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Tentatively Identified Compounds	**Approximate Quantifcation %**	**Match Quality**
Naphthalene, 1,2,3,4-tetrahydro...	0.26	95.00
1-Cyclohexylheptene	0.22	55.00
3,5-Dodecadiene, 2-methyl-	0.08	60.00
Undecane, 2,9-dimethyl-	0.31	64.00
Octane, 3,6-dimethyl-	0.43	59.00
Bicyclo[3.1.1] heptane, 2,6,6-tr...	0.15	46.00
Benzene, 1,4-dimethyl-2-(2-meth...	0.11	41.00
Cyclohexane, 1-heptyl-	0.11	38.00
1-Undecane, 8-methyl-	0.29	51.00
Naphthalene, decahydro-2, 2-dime...	0.39	50.00
1-Cyclohexanone, 2,2-methyl-5-(...	0.11	38.00
3,5-Dodecadiene, 2-methyl-	0.20	49.00
Cyclopentane, 1-methyl-3-(2-meth...	0.33	46.00
cis, trans-1, 10-Dimethylspiro[5....	0.18	43.00
Naphthalene, 1,2,3,4-tetrahydro...	0.20	86.00
1-Cyclohexylheptene	0.30	38.00
2H-Benzocyclohepten-2-one, deca...	0.23	35.00
trans, trans-2,10-Dimethylspiro[...	0.13	55.00
Tridecane	1.22	97.00
1H-Indene, 2,3-dihydro-1,1,5-tr...	0.16	43.00
Bicyclo[4.1.0]heptane, 7-pentyl-	0.29	58.00
trans, trans-2,10-Dimethylspiro[...	0.21	46.00
5,7-Dimethyloctahydrocoumarin	0.43	38.00
Cyclohexane, (2-ethyl-1-methyl...	0.13	46.00
Cyclohexane, 1-methyl-4-(1-meth...	0.11	40.00
trans, trans-2, 10-Dimethylspiro[...	0.12	50.00
Undecane, 5-ethyl-	0.28	50.00
Naphthalene, 1,2,3,4-tetrahydro...	0.18	96.00
1H-Indene, 2,3-dihydro-4,5,7-tr...	0.10	53.00
1,11-Tridedicen	0.10	43.00
Naphthalene, 1,2,3,4-tetrahydro...	0.22	64.00
Cyclododecanone, 2-methylene-	0.17	58.00
Naphthalene, 2-(1,1-dimethyleth...	0.29	55.00
cis, cis-3-Ethylbicyclo[4.4.0]d...	0.17	53.00
Cyclohexane, (2-ethyl-1-methylb...	0.13	51.00
trans, trans-2, 10-Dimethylspiro[...	0.19	55.00
1,1,6,6-Tetramethylsiro[4.4]no...	0.20	43.00
1-Cyclopentyl-4-(1-methylethyl)...	0.16	53.00
2-Hexanone, 3-cyclohexylidene-4...	0.27	60.00
Methyl ethyl cyclopentene	0.15	42.00
Heptylcyclohexane	0.31	70.00
Cyclopentane, 1-pentyl-2-propyl-	0.33	76.00
Tricyclo[4.3.1.13.8]undecane, 3...	0.15	15.00
Hexatiacontane	0.34	35.00
Tridecane, 5-methyl-	0.38	49.00
Tridecane, 4-methyl-	0.99	55.00
Tridecane, 2-methyl-	0.32	95.00

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Tentatively Identified Compounds	**Approximate Quantifcation %**	**Match Quality**
1(2H) -Naphthalenone, octahydro-...	0.33	49.00
cis-3-Ethyl-endo-tricyclo[5.2.1...	0.12	38.00
Heptacosane, 1-chloro-	0.51	49.00
Cyclopentane, (4-octyldodecyl)-	0.25	46.00
Nonane, 3,7-dimethyl-	0.77	81.00
Z-9-Tetradecenol	0.08	70.00
Cyclododecanone, 2-methylene-	0.24	38.00
3-Diisopropylamino-acrylonitrile	0.28	43.00
Cyclopentane, 2-isopropyl-1, 3-d...	0.23	46.00
Cyclopentane, 1,1,3-trimethyl-2-...	0.33	55.00
Cyclopentane, 1,1,3-trimethyl-2-...	0.25	60.00
Cyclohexane, 1-(cyclohexylmethy...	0.18	60.00
1H-Indene, 2,3-dihydro-1,1,3-tr...	0.32	95.00
Naphthalene, 1,2,3,4- tetrahydro...	0.31	56.00
Tetradecane	1.49	96.00
Tetracontane, 3,5,24-trimethyl-	0.38	58.00
2,6,10-Trimethylundeca-1,3-diene	0.45	42.00
Perhydrophenanthrene, (4a.alpha...	0.56	55.00
Octadecanoic acid, 2-oxo-, meth...	0.33	72.00
Benzocyclodecene, tetradecahydro-	0.32	43.00
1-Hentetracontanol	0.48	38.00
Cyclohexane, 1,2,4,5-tetraethyl...	0.12	38.00
11-Hexadecen-1-ol, (Z)-	0.54	27.00
Bicyclo[3.1.1]hexan-3-one, 6,6...	0.21	38.00
Bicyclo[4.1.0]heptane, 3,7,7-tr...	0.43	38.00
3-Octyne, 2,2,7-trimethyl-	0.32	64.00
Bicyclo[3.1.1]heptane, 2,6,6-tr...	0.20	64.00
Bicyclo[3.1.0]hexan-2-one, 4-me...	0.17	60.00
2(1H) -Naphthalenone, octahydro-...	0.13	64.00
Naphthalene, 1,2,3,4- tetrahydro...	0.26	96.00
Decane, 3-cyclohexyl-	0.94	58.00
Tetradecane, 5-methyl-	0.31	89.00
2(1H) -Naphthalenone, octahydro-...	0.15	42.00
Tetradecane, 4-methyl-	0.67	86.00
Dodecane, 2-methyl-8-propyl-	0.84	90.00
1-Oxaspiro[2.5] octane, 5,5-dime...	0.28	53.00
2,4,5,5,8a-Pentamethyl-4a,5,6,7....	0.30	30.00
Tetratetracontane	0.63	52.00
2,5,8-Trimethyl-1,2,3,4-tetrahy...	0.16	93.00
8.beta., 12-Epoxy-13,14,15,16,17...	0.58	91.40
Tritetracontane	0.39	43.00
Bicyclo[3.3.1]nonan-9-one, 1,2...	0.16	30.00
3-Hexen-2-one, 3-cyclohexyl-4-e...	0.40	46.00
Anthracene, tetradecahydro...	0.64	91.00
Z-9-Tetradecenol	0.53	90.00
Cyclohexane, 1,1-dimethyl-	0.26	50.00

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Tentatively Identified Compounds	**Approximate Quantifcation %**	**Match Quality**
Pentadecane	1.56	97.00
Cyclohexane, 1,2,4,5-tetraethyl...	0.43	48.00
2,5[Dimethylpyrroline	0.49	38.00
3-Hexen-2-one, 3-cyclohexyl-4-e...	0.14	38.00
7-Oxabicyclo[4.1.0]heptane, 1,5...	0.18	41.00
Perhydrophenanthrene, (4a.alpha...	0.41	64.00
3-Hexen-2-one, 3-cyclohexyl-4-e...	0.20	50.00
Cyclohexane, (2.2-dimethycyclo..	0.14	41.00
Bicyclo[3.1.0] hexan-2-one, 4-me...	0.26	46.00
Cyclohexane, 1,2,4,5-tetraethyl...	0.27	47.00
Cyclohexanone, 2,2-dimethyl-5-(...	0.22	56.00
Bicyclo[3.1.0] hexan-2-one, 4-me...	0.20	46.00
Bicyclo[3.1.1]hepane, 2,6,6-tr...	0.29	47.00
3,4-Dimethyl-1-(phenylthio)-2-p...	0.58	22.00
Phenanthrene, tetradecahydro-	0.21	50.00
cis-3-Methyl-endo-tricyclo[5.2...	0.27	42.00
Pentadecane, 7-methyl-	0.33	55.00
Octadecane, 1-bromo-	0.47	18.00
Hexyl octyl ether	0.24	43.00
TRIDECANE, 4-CYCLOHEXYL-	0.53	83.00
Tetradecane, 4,11-dimethyl-	0.35	91.00
Octadecane, 2-methyl-	0.70	68.00
Borane, diethyl(decycloxy)-	0.41	46.00
Anthracene, 9-cyclohexyltrtrade...	0.12	22.00
Tetretetracontane	0.39	52.00
Cis-3-methyl-endo-tricyclo[5.2....	0.15	42.00
1-Cyclobutanol, 1-methyl-2-(2,2...	0.17	25.00
(2,2,6-Trimethyl-bicyclo[4.1.0]...	0.35	35.00
Longifolenaldehyde	0.20	52.00
Longifolenaldehyde	0.15	53.00
2-Hexanone, 3-cyclohexylidene-4...	0.35	49.00
Cyclohexane, (2-ethy-1-methyl-...	0.56	35.00
8-Hexadecyne	0.29	35.00
Hexadecane	1.63	95.00
2-Hexanone, 3-cyclohexylidene-4...	0.19	43.00
Naphthalene, 1,2,3,4- tetrahydro...	0.47	44.00
1-Hentetracontanol	0.41	46.00
Cyclohexane, 1,1-dimethyl-	0.25	38.00
Bicyclo[7.7.0]hexadec-1(9)-ene	0.55	50.00
Bicyclo[7.7.0]hexadec-1(9)-ene	0.33	38.00
Heptadecane, 9-(2-cyclohexyleth...	0.17	53.00
CAMPHERENONE	0.34	84.00
2-Hexanedioic acid, 2-methyoxy...	0.54	60.00
CAMPHERENONE	0.05	80.00
1-Docosene	0.12	45.00
Cyclohexane, (2,2-dimethylcyclo...	0.23	30.00
Tritetracontane	0.39	49.00

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Tentatively Identified Compounds	**Approximate Quantifcation %**	**Match Quality**
PENTADECANE, 2,6,10-TRIMETHYL-	0.71	95.00
Tridecane, 5-methyl-	0.26	49.00
2-Hexanone, 3-cyclohexylidene-4...	0.24	46.00
Hexadecane, 4-methyl-	0.31	95.00
Cyclohexane, (2-methylpropyl)-	0.19	70.00
Heptadecane, 2-methyl-	0.41	86.00
Cyclotetradecane, 1,7,11-trimet...	0.16	49.00
Cyclotetradecane, 1,7,11-trimet...	0.10	49.00
2(1H)-Naphthalenone, octahydro...	0.16	41.00
Hexadecane, 3-methyl-	0.30	89.00
2-Hexanone, 3-cyclohexylidene-4...	0.20	50.00
(-)-E-Pinane	0.17	45.00
E-11,13-Dimethyl-12-tetradecen...	0.23	83.00
Longifolenaldehyde	0.15	51.00
Cyclotetradecane, 1,7,11-trimet...	0.31	50.00
Cyclohexane, (2,2-dimethylcyclo...	0.29	43.00
2-Hydroxy-4-isopropynaphthalene	0.36	25.00
Cyclotetradecane, 1,7,11-trimet...	0.20	55.00
Heptadecane	1.28	97.00
Pentadecane, 2,6,10,14-tetramet...	1.02	98.00
Tetrapentacontane, 1,54-dibromo-	0.35	50.00
5,6,6-Trimethyl-5-(3-oxobut-1-e...	0.22	38.00
Cyclohexane. 1,1-dimethyl-	0.29	35.00
1-Dodosene	0.23	58.00
(-)-E-Pinane	0.23	38.00
2(1H)-Naphthalenone, octahydro...	0.20	46.00
2(1H)-Naphthalenone, octahydro...	0.13	55.00
Cyclotetradecane, 1,7,11-trimet...	0.10	55.00
2-Hexanedioic acid, 2-methyoxy...	0.25	70.00
Z-8-Methyl-9-tetradecenoic acid	0.15	55.00
Hexadecane, 1-chloro-	0.35	55.00
Pentadecane, 2,6,10-trimethyl-	0.23	60.00
1-Butyl-2-ethyloctahydro-4,7-ep...	0.22	86.00
Octadecane, 3-methyl-	0.47	53.00
Heptadecane, 4-methyl-	0.30	96.00
Cyclopentane, (2-hexyloctyl)-	0.12	52.00
Heptadecane, 2-methyl-	0.31	89.00
Cyclotetradecane, 1,7,11-trimet...	0.24	45.00
Heptadecane, 3-methyl-	0.27	98.00
7-Hexyltridecan-1-ol	0.16	49.00
Pentadecane, 2,6,10-trimethyl-	0.10	53.00
1-Octadecene	0.09	45.00
Cyclotetradecane, 1,7,11-trimet...	0.13	50.00
E-11,13-Dimethyl-12-tetradecen...	0.32	78.00
Cyclohexane, 1,2-dimethyl-3-pen...	0.09	38.00
Cyclopentane,1-methyl-3-(2-met...	0.11	51.00

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Tentatively Identified Compounds	**Approximate Quantifcation %**	**Match Quality**
2-Dodecen-1-yl(-)succunic anhyd...	0.15	64.00
Cyclopentane, (2-hexyloctyl)-	0.19	64.00
Octadecane	1.01	98.00
Hexadecane, 1-(ethenyloxy)-	0.22	90.00
Hexadecane, 2,6,10,14-tetramethyl-	0.72	99.00
Heptadecane, 3-methyl-	0.21	45.00
Cyclotetradecane, 1,7,11-trimet...	0.21	95.00
3-Cyclopent-1-enyl-3-hydroxy-2-...	0.17	43.00
Heptadecanenitrile	0.08	52.00
Cyclotetradecane, 1,7,11-trimet...	0.21	81.00
Cyclopentane, (2-hexyloctyl)-	0.06	46.00
Cyclotetradecane, 1,7,11-trimet...	0.04	91.00
1-Pentadecene	0.33	45.00
Dodecane	0.21	87.00
Cyclotetradecane, 1,7,11-trimet...	0.14	64.00
Tetrapentacontane, 1,54-dibromo-	0.13	53.00
E-11,13-Dimethyl-12-tetradecen...	0.06	83.00
1-Hexadecanol, 2-methyl-	0.20	49.00
Cyclotetradecane, 1,7,11-trimet...	0.10	64.00
Hexadecane	0.25	81.00
Octadecane, 2-methyl-	0.30	95.00
Undecane, 2-cyclohexyl-	0.20	64.00
Octadecane, 3-methyl-	0.24	94.00
Cyclopentane, (2-hexyloctyl)...	0.14	64.00
Cyclotetradecane, 1,7,11-trimet...	0.23	70.00
Cyclotetradecane, 1,7,11-trimet...	0.10	91.00
2-Hexanedioic acid, 2-methyoxy...	0.07	60.00
Cyclotetradecane, 1,7,11-trimet...	0.04	70.00
Cyclotetradecane, 1,7,11-trimet...	0.11	64.00
Octadecane	0.35	86.00
Nonadecane	0.70	98.00
Cyclotetradecane, 1,7,11-trimet...	0.15	90.00
1-Dotriacontanol	0.16	58.00
1-Hentetracontanol	0.12	49.00
Methyl (1s*,2s*,5R*)-1,5-dimeth...	0.18	58.00
2,3-Dioxabicyclo[2.2.2]oct-7-en...	0.12	60.00
7,7-Dimethyl-6-methylidene-5-(2...	0.10	90.00
Cyclopentane, (2-hexylocty)-	0.10	86.00
2-Dodecen-1-yl(-)succinic anhyd...	0.15	55.00
2-Dodecen-1-yl(-)succinic anhyd...	0.12	55.00
Cyclotetradecane, 1,7,11-trimet...	0.18	89.00
Ethanol, 2-(dodecyloxy)-	0.25	83.00
Cyclotetradecane, 1,7,11-trimet...	0.10	90.00
Tetrapentacontane, 1,54-dibromo-	0.18	58.00
Octadecane, 3-methyl-	0.17	47.00
Cyclotetradecane, 1,7,11-trimet...	0.10	55.00
Heptadecane	0.20	84.00

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Diesel (a)
Lab No: 801240-02
Job No: 13091-00005181

ASTM D-6733 Modified

Tentatively Identified Compounds	**Approximate Quantifcation %**	**Match Quality**
Heptadecane	0.19	87.00
Cyclopentane, 1,1'-[3-(2-cyclop...	0.14	91.00
Nonadecane, 3-methyl-	0.20	95.00
2-Hexanedioic acid, 2-methyoxy...	0.11	70.00
2-Hexanedioic acid, 2-methyoxy...	0.07	60.00
Tetradecane, 2,6,10-trimethyl-	0.21	86.00
Spiro[4.5]decan-7-one, 1,8-dime...	0.12	51.00
Cyclotetradecane, 1,7,11-trimet...	0.02	95.00
Cyclotetradecane, 1,7,11-trimet...	0.06	87.00
Cyclotetradecane, 1,7,11-trimet...	0.07	70.00
Hexadecane, 2,6,10,14-tetramethyl-	0.09	70.00
Eicosane	0.57	98.00
Hexadecane, 2,6,10,14-tetramethyl-	0.07	56.00
Tetrapentacontane, 1,54-dibromo-	0.10	53.00
Cyclohexane, 1-(1,5-dimethylhex...	0.12	83.00
Cyclotetradecane, 1,7,11-trimet...	0.05	70.00
1-Nonadecene	0.15	58.00
9-Methyl-Z-10-tetradecen-1-ol a...	0.12	49.00
Cyclohexane, 1-(1,5-dimethylhex...	0.14	83.00
2-Dodecen-1-yl(-)succinic anhyd...	0.05	70.00
1-Nonadecene	0.13	49.00
Octadecane	0.18	87.00
Cyclotetradecane, 1,7,11-trimet...	0.08	64.00
Methyl (1s*,2s*,5R*)-1,5-dimeth...	0.09	74.00
1-Hentetracontanol	0.02	58.00
Decane, 1-iodo-	0.12	80.00
2-Butanone, 4-(2,6,6-trimethyl...	0.06	64.00
Octadecane	0.10	95.00
Cyclopentane, (2-hexyloctyl)-	0.03	64.00
Eicosane, 2-methyl-	0.14	95.00
E11, 13-Dimethyl-12-tetradecen...	0.07	60.00
Nonadecane	0.13	94.00
Eicosane, 9-cyclohexyl-	0.17	86.00
Cyclotetradecane, 1,7,11-trimet...	0.06	95.00
Cyclotetradecane, 1,7,11-trimet...	0.16	93.00
2-Dodecen-1-yl(-)succinic anhyd...	0.07	64.00
Octadecane, 1-chloro-	0.03	56.00
Heneicosane	0.46	94.00
1-Hentetracontanol	0.05	68.00
1-Heptacosanol	0.01	45.00
Heneicosane	0.05	74.00
Octadecanoic acid, 17-oxo-, met...	0.09	90.00
1-Docosene	0.05	64.00
Hexadecane, 1-chloro-	0.05	47.00
1,11-Dibromoundecane	0.08	51.00
E11, 13-Dimethyl-12-tetradecen...	0.02	70.00
Hexadecane, 2,6,10,14-tetramethyl-	0.11	80.00

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Diesel (a)
Lab No: 801240-02
Job No: 13091-00005181 **ASTM D-6733 Modified**

Tentativeiy Identified Compounds	**Approximate Quantifcation %**	**Match Quality**
Octadecane	0.07	80.00
Octadecane	0.04	89.00
Tetrapentacontane, 1,54-dibromo-	0.05	60.00
Hexadecanoic acid	0.07	80.00
Cyclotetradecane, 1,7,11-trimet...	0.09	94.00
Nonadecane, 2-methyl-	0.08	70.00
Octadecane, 2-methyl-	0.09	87.00
Octadecane, 1-chloro-	0.04	64.00
1,2,3,4-Tetrahydro-1,4,5-triphe...	0.06	83.00
Cyclohexane, 1,2-dimethyl-3-pen...	0.06	55.00
TRIDECANE, 6-CYCLOHEXYL-	0.07	83.00
3-(6,6-Dimethyl-5-oxohept-2-eny...	0.04	52.00
Heneicosane, 3-methyl-	0.03	56.00
(1s,2E,4s,5R,7E,11E)-Cembra-2,7...	0.03	56.00
Cyclotetradecane, 1,7,11-trimet...	0.04	60.00
Docosane	0.25	99.00
Octadecane, 1-chloro-	0.06	64.00
Nonadecane	0.03	70.00
Nonadecane	0.03	62.00
9-Methyl-Z-10-tetradecen-1-ol a...	0.01	55.00
1-Docosanethiol	0.04	95.00
2-Dodecen-1-yl (-) succinic anhyd...	0.01	68.00
2-Dodecen-1-yl (-) succinic anhyd...	0.04	59.00
2-Dodecen-1-yl (-) succinic anhyd...	0.02	60.00
Octadecane, 1-chloro-	0.07	64.00
Octadecane	0.10	93.00
Tetrapentacontane, 1,54-dibromo-	0.03	55.00
Octadecane, 1-chloro-	0.04	52.00
Nonadecane	0.05	91.00
Octadecane, 1-chloro-	0.06	80.00
Eicosane	0.05	83.00
1-Hexadecanol, 2-methyl-	0.04	60.00
Heneicosane	0.04	86.00
3-Eicosene, (E)-	0.03	64.00
1H-Indene, 5-buytl-6-hexyloctah...	0.02	51.00
Cyclohexane, 1,2,4,5-tetraethyl-	0.01	50.00
Cyclohexane, (2-methylproply)-	0.03	53.00
2,5-Furandione, 3-(dodecenyl)di...	0.02	80.00
Hexadecane, 1-(ethenyloxy)-	0.02	95.00
1-Hentetracontanol	0.02	52.00
Tricosane	0.13	98.00
1-Bromo-11-iodoundecane	0.01	49.00
5-Methyl-Z-5-docosene	0.01	58.00
Cyclohexane, 1-(1,5-dimethylhex...	0.01	83.00
6-Nitroundec-5-ene	0.04	49.00
Heptadecane,1-(ethenyloxy)-	0.05	86.00
15-Isobutyl-(13alphah)-isocopalane	0.04	62.00
Cyclohexane, 1,2,4,5-tetraethyl-	0.02	45.00

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Diesel (a)
Lab No: 801240-02
Job No: 13091-00005181

ASTM D-6733 Modified

Tentatively Identified Compounds	Approximate Quantifcation %	Match Quality
Eicosane	0.03	93.00
Eicosane, 9-cyclohexyl-	0.01	58.00
Octadecane, 3-ethyl-5-(2-ethylb...	0.01	25.00
Hexadecane, 1-chloro-	0.03	55.00
1-Bromo-11-iodoundecane	0.02	55.00
2,3-Dioxabicyclo[2.2.2] oct-7-en...	0.01	38.00
Docosane	0.02	80.00
Tricosane	0.02	95.00
E-9-Methyl-8-tridecen-2-ol, ace...	0.02	43.00
Tetrapentacontane, 1,54-dibromo-	0.02	70.00
1H-Pyrazole-1-carboxaldehyde, 4...	0.01	27.00
5-Cycloocten-1-one, 2-(4-octen-...	0.01	35.00
Hexadecane, 1-(ethenyloxy)-	0.01	81.00
13-Tetradecen-1-ol acetate	0.02	46.00
2,3-Dioxabicyclo[2.2.2] oct-7-en...	0.01	35.00
1H-Indene, 5-butyl-6-hexyloctah...	0.01	56.00
Tetracosane	0.08	98.00
Tetracosane	0.02	53.00
Cyclohexane, 1,1'-(2-methyl-1,3...	0.01	46.00
Cyclohexane, 1,1'-(2-propyl-1,3...	0.02	43.00
1H-Indene, 5-butyl-6-hexyloctah...	0.01	50.00
E-9-Methyl-8-tridecen-2-ol, ace...	0.01	38.00
17,21-Dimethylheptantriacontane	0.02	38.00
1-Dodecanol, 2-methyl-,(S)-	0.01	43.00
3-(Prop-2-enoyloxy)dodecane	0.01	32.00
Hexadecane, 1-(ethenyloxy)-	0.01	94.00
Heptadecanenitrile	0.01	35.00
Ethyl-2-butyramido-3,3,3-triflu...	0.01	42.00
Z-14-Nonacosane	0.01	30.00
Octadecane	0.01	93.00
Z-14-Nonacosane	0.01	38.00
Ethyl-2-acetamido-3,3,3-trifluo...	0.01	46.00
Eicosane	0.04	96.00
3,3,7,11-Tetramethyltricyclo[5...	0.01	35.00
Ethyl-2-butyramido-3,3,3-triflu...	0.01	37.00
1H-Indene, 2-methyl-3-phenyl-	0.01	38.00
Cyclotrisiloxane, hexamethyl	0.01	35.00
Eicosane	0.02	98.00
Eicosane	0.01	95.00
Silicic Acid, diethyl bis(trime...	0.01	37.00
Cyclotrisiloxane, hexamethyl	0.01	27.00
Eicosane	0.02	95.00
Eicosane	0.01	70.00
Eicosane	0.01	70.00
Unidentified low level compounds	0.21	-
Total	100.00	

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Certificate of Analysis

ATMOSPHERIC ANALYSIS & CONSULTING INC.
MARCUS HUEPPE
1534 EASTMAN AVENUE
VENTURA, CA 93003

Date Sampled: 7/16/2008
Product: Diesel (b)
Location: Ventura, CA
Sample ID: Sample #080457-33843
Vessel:

Report Date: 9/30/2008
Job No: 13091-00005181
Sample Number: 801240-03
Client Ref: AAC Project #080457

Test	Method	Result	Units
Compostion Breakdown by GC/MS			
Composition Breakdown by GC/MS	GC/MS	See Attached	
Detailed Capillary Analysis			
Detailed Hydrocarbon Analysis	ASTM D-6733M	See Attached	

*Analysis results are submitted by a third party laboratory. Saybolt was not present whilst the analysis was carried out, and has signed for receipt only with no liability accepted.

Approved By:
Francine Hanby
Laboratory Manager

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Diesel (b)
Lab No: 801240-03
Job No: 13091-00005181

Composition Breakdown, Gas Chromatography/Mass Spectrometer

The sample was analyzed on a gas chromatograph/mass spectrometer. A library search was performed on the collected data using the Wiley 138 Library and the NIST 98 Library. Together the libraries contain approximately 200,000 compounds.

We preformed a composition breakdown on the hydrocarbon material as received. These results are normalized only to the chemicals found. If heavier compounds, high molecular weight additives or polymers are present these were not seen on the gas chromatograph/mass spectrometer.

The material was found to be a diesel fuel range product with a lower than typical aromatic content. This has been indicative recently of some ultra low sulfur diesel fuels. The carbon distribution ranges forma a trace of C_4 to a trace of C_{25}, with the apex at C_{16}. The library found some small levels of chemicals identified as aldehydes, acids and ketones.

We saw the following organic compound types in the headspace material. The following is the tentative composition.

Tentatively identified Compounds **Types Found**	**Approximate Quantification** **Percent by Weight**
Paraffins	14.5
Isoparaffins	36.3
Cyclic paraffins (naphthenics)	34.4
Mono-aromatics	1.5
Di-aromatics	6.9
Poly-aromatics	1.3
Indenes	1.5
Ketones	0.9
Aldehydes	2.5
Organic acids	0.1
Esters	0.1
Total	100.00

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Diesel (b)
Lab No: 801240-03
Job No: 13091-00005181

Composition Breakdown, Gas Chromatography/Mass Spectrometer, ASTM D-6733 Modified

The sample was analyzed on a gas chromatograph/mass spectrometer. A library search was performed on the collected data using the Wiley 138 Library and the NIST 98 Library. Together the libraries contain approximately 200,000 compounds.

The organic materials are consistent with diesel fuel range hydrocarbons. The chemicals range from approximately C_5 to C_{29} with an apex around C_{16}.

The following is a list of the individual compounds identified by our libraries and their match qualities. The chemicals found have been reported in retention time order as analyzed. Please note, these are names from the libraries and may or may not be the actual name of the compound, but would be representative of the chemical type based on the spectra. Some duplication of names does occur.

The results are listed on the following pages.

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Diesel (b)
Lab No: 801240-03
Job No: 13091-00005181 **ASTM D-6733 Modified**

Tentatively Identified Compounds	**Approximate Quantifcation %**	**Match Quality**
Butane, 2 methyl-	0.03	91.00
Pentane	0.02	91.00
Pentane, 2-methyl-	0.01	91.00
Pentane, 3-methyl-	0.01	91.00
Hexane	0.01	90.00
Cylclopentane, methyl-	0.01	91.00
Cyclohexane	0.01	87.00
Hexane, 2-methyl	0.01	94.00
Pentane, 2,3-dimethyl-	0.01	91.00
Hexane, 3-methyl-	0.01	94.00
Cylcopentane, 1,3-dimethy-, trans-	0.01	93.00
Pentane, 2,2,3,4-tetramethyl-	0.01	64.00
Cyclopentane, 1,2-dimethyl-	0.01	94.00
Heptane	0.02	91.00
Cyclohexane, methyl-	0.05	95.00
Cyclopentane, ethyl-	0.01	94.00
Cyclopentane, 1,2,4-trimethyl-	0.01	87.00
CYCLOPENTANE, 1,2,3-TRIMETHYL-	0.01	94.00
Heptane, 2-methyl-	0.02	91.00
Benzene, methyl-	0.03	95.00
Heptane, 3-methyl-	0.02	91.00
Cyclohexane, 1,3-dimethyl-, cis-	0.04	97.00
Cyclohexane, 1,4-dimethyl-	0.01	87.00
Cyclopentane,1-ethyl-3-methyl-	0.01	96.00
CYCLOPENTANE,1-ETHYL-2-METHYL-	0.01	96.00
Cyclohexane, 1,4-dimethyl-	0.02	94.00
Octane	0.03	87.00
Cyclohexane, 1,4-dimethyl-	0.03	96.00
Cyclohexane, 1,2-dimethyl-, cis-	0.02	95.00
Heptane, 2,6-dimethyl-	0.01	62.00
Cyclohexane, 1,3,5-trimethyl-	0.01	91.00
Cyclohexane, ethyl-	0.03	94.00
Cyclohexane, 1,1,3-trimethyl-	0.04	97.00
2-Nonene, (E)-	0.01	74.00
3-Octen-2-one, (E)-	0.04	90.00
Cyclohexane, 1,3,5-trimethyl-	0.01	91.00
Heptane, 2,3-dimethyl-	0.01	74.00
Benzene, ethyl-	0.01	95.00
Octane, 4-methyl-	0.01	91.00
Octane, 2-methyl-	0.02	90.00
Benzene, 1,3-dimethyl-	0.04	97.00
Cylcopropane, 1,1,2,3-tetramethyl-	0.01	43.00
Octane, 3-methyl-	0.03	86.00
Cyclohexane, 1,2,3-trimethyl-	0.02	94.00
3-Octen-2-one, (E)-	0.02	90.00

Diesel (b)
Lab No: 801240-03
Job No: 13091-00005181

ASTM D-6733 Modified

Tentatively Identified Compounds	**Approximate Quantifcation %**	**Match Quality**
Cyclohexane,1,2,4-trimethyl-	0.03	91.00
3-Octen-2-one, (E)-	0.02	90.00
Cyclopentane, 1-methyl-2-propyl-	0.02	81.00
Cyclohexane, 1-ethyl-4-methyl-	0.05	91.00
Cyclohexane, 1-ethyl-4-methyl-	0.02	95.00
Benzene, 1,3-dimethyl-	0.03	95.00
Nonane	0.09	93.00
Cyclohexane, 1,2,3-trimethyl-	0.02	94.00
Cyclohexane, 1,2,3-trimethyl-	0.02	76.00
Cyclohexane, 1-ethyl-4-methyl-	0.05	86.00
Cyclohexane, 1-ethyl-4-methyl-	0.02	91.00
4-Tetridecene, (Z)-	0.01	53.00
1H-Indene, octahydro-, cis-	0.02	93.00
Cyclohexane, (1-merthylethyl)-	0.01	90.00
Cyclpheptane, methyl-	0.01	53.00
Cyclohexane, 1,2-diethyl-3-methyl-	0.01	72.00
Benzene, (1-methylethyl)-	0.01	86.00
2-Cyclohexen-1-ol, 3,5,5-trimethyl...	0.03	52.00
Cyclohexane, 1-ethyl-2-methyl...	0.03	90.00
Cyclohexane, propyl-	0.04	90.00
Cyclopentane, butyl-	0.02	90.00
Octane, 2,6-dimethyl-	0.05	94.00
Nonane, 4-methyl-	0.01	53.00
Cyclohexane, diethyl-	0.04	87.00
Heptane, 3-ethyl-2-methyl-	0.03	50.00
2-Octene, 4-ethyl-	0.01	64.00
1-Dodecene	0.01	50.00
1R,2T,4C,5T-1,2,4,5-Tetramethyl-...	0.03	91.00
Cyclohexane, 1,2,4-trimethyl-	0.04	64.00
Cyclohexane, 1,2,3-trimethyl-,...	0.01	58.00
Benzene, propyl-	0.01	46.00
1H-Indene, octahydro-, trans-	0.04	96.00
1,1,2,3-TETRAMETHYLCYCLOHEXANE A	0.04	95.00
Octane, 4-methyl-	0.01	78.00
Cyclohexane, 1-ethyl-2,4-dimethyl-	0.02	91.00
Cyclohexane, diethyl-	0.02	83.00
Benzene, 1-ethyl-3-methyl-	0.08	64.00
Nonane, 4-methyl-	0.06	90.00
Nonane, 2-methyl-	0.04	87.00
Benzene, 1,2,4-trimethyl-	0.04	95.00
trans-3-Decene	0.01	50.00
Nonane, 3-methyl-	0.04	95.00
Cyclohexane, 1-isopropyl-3-methyl-	0.02	58.00
Cyclohexane, 1-ethyl-2,3-dimethyl-	0.05	90.00
Cyclohexane, 1,4-dimethyl-	0.03	58.00
Cylcohexane, 1,2,4-trimethyl-	0.02	60.00

Diesel (b)
Lab No: 801240-03
Job No: 13091-00005181

ASTM D-6733 Modified

Tentatively Identified Compounds	**Approximate Quantifcation %**	**Match Quality**
Cyclohexane, 1-ethyl-2,4-dimethyl-	0.05	76.00
Cyclohexane, 1-ethyl-2,3-dimethyl-	0.01	87.00
Cyclohexane, 1-methyl-3-propyl-	0.07	90.00
1-(1-Methyl-cyclohexyl)-ethanone	0.08	59.00
1H-Indene, octahydro-, cis-	0.07	42.00
5-Decene, (E)-	0.03	46.00
Benzene, 1,3,5-trimethyl-	0.07	97.00
trans-1,4-diethylcyclohexane	0.02	90.00
Cyclohexane, 1-methyl-4-(1-methyl)-	0.03	90.00
Cyclopentane, 2-isopropyl-1-3-d...	0.01	58.00
Cyclohexane, 1,1,2-trimethyl-	0.01	64.00
Decane	0.28	95.00
Cyclohexane, 3-octyl-	0.01	64.00
m-Menthane, (1S,3R)-(+)-	0.03	62.00
Naphthalene, decahydro-, cis-	0.02	93.00
Naphthalene, decahydro-, cis-	0.04	83.00
Cyclohexane, butyl-	0.01	25.00
Benzene, (1-methylpropyl)-	0.01	70.00
Cyclohexane, ethylidene-	0.04	60.00
Cyclohexane, (2-methyl-1-propen...	0.08	58.00
Undecane, 2,4-dimethyl-	0.01	43.00
Heptadecane, 2,6-dimethyl-	0.01	53.00
Benzene, 1-ethyl-2-methyl-	0.90	74.00
Decane, 4-methyl-	0.14	93.00
Triallylsilane	0.02	52.00
Decane, 2-methyl-	0.03	45.00
Cyclohexane, 1-methyl-4-(1-meth...	0.03	60.00
Cyclohexane, butyl-	0.08	87.00
Cyclohexane, 1,1,3-trimentyl-	0.06	58.00
Cyclopentane, pentyl-	0.06	95.00
1H-Indene, octahydro-5-methyl-	0.05	94.00
1H-Indene, octahydro-5-methyl-	0.09	92.00
1-Methyl-2-methylenecyclohexane	0.08	70.00
1,1-DIMETHYL-2-PROPYLCYCLOHEXANE	0.04	96.00
1-Methyl-2-methylenecyclohexane	0.04	72.00
Cyclohexane, 1-ethyl-2-propyl-	0.07	91.00
Cyclohexane, 1,1,3-trimethyl-	0.05	60.00
Benzene, 1-methyl-3-propyl-	0.05	94.00
Naphthalene, decahydro-, trans-	0.36	98.00
Cyclohexene, 3-methyl-6-(1-methyl-)-	0.09	59.00
Benzene, 1-ethyl-2,3-dimethyl-	0.11	91.00
Decane, 4-methyl-	0.08	94.00
Naphthalene, decahydro-2-methyl-	0.03	87.00
Bicyclo[3.1.1]heptan-3-one-2,6-...	0.08	53.00
Decane, 2-methyl-	0.13	81.00
Benzene, 1-methyl-2-propyl-	0.02	91.00

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Diesel (b)
Lab No: 801240-03
Job No: 13091-00005181

ASTM D-6733 Modified

Tentatively Identified Compounds	Approximate Quantifcation %	Match Quality
Naphthalene, decahydro-2-methyl-	0.05	70.00
Cyclopropane, 1-(1-methylethyl)...	0.04	58.00
Cyclohexane, 1,2-diethyl-3-methyl-	0.03	87.00
Decane, 3-methyl-	0.13	92.00
trans-Decalin, 2-methyl-	0.07	47.00
Cyclohexane, 1-methyl-4-(1-meth...	0.09	35.00
Benzene, 1-ethyl-2,4-dimethyl-	0.06	94.00
Bicyclo[3.1.0]hexane-2-one-4-meth...	0.02	83.00
Cyclohexane, 1-methyl-4-(1-methyl)-	0.04	35.00
Cyclohexane, 1,1,3-trimethyl-	0.02	52.00
1-Decene, 5-methyl-	0.02	49.00
Benzene, 1-ethyl-2,4-dimethyl-	0.21	64.00
Cyclohexane,1-methyl-2-propyl-	0.10	47.00
1,1'-Bicyclohexyl, 2-ethyl-, trans-	0.18	47.00
Cycloheptane, methyl-	0.04	30.00
trans-Decalin, 2-methyl-	0.07	70.00
Cyclohexane, 1-ethyl-2-methyl-	0.08	70.00
cis-Decaline, 2-syn-methyl-	0.10	64.00
Naphthalene, decahydro-, cis-	0.08	98.00
Undecane	0.69	91.00
3-Cyclohexene-1-carboxaldehyde,	0.09	68.00
cis-Decaline, 2-syn-methyl-	0.15	92.00
Undecane, 5-methyl-	0.05	43.00
Naphthalene, decahydro-2-methyl-	0.58	98.00
Undecane, 5-methyl-	0.06	35.00
Benzene, 1-ethyl-2,3-dimethyl-	0.16	92.00
1-Octadecene	0.08	47.00
Undecane, 5-methyl-	0.09	64.00
Benzene, 1,2,4,5-tetramethyl-	0.18	95.00
Decane, 3,6-dimethyl-	0.02	70.00
Undecane, 5,7-dimethyl-	0.06	43.00
TRANS-ANTI-1-METHYL-DECAHYDRONAPHTHA	0.51	95.00
2,4-Hexadiene, 2,5-dimethyl-	0.07	42.00
cis-Decaline, 2-syn-methyl-	0.08	64.00
n-Amycyclohexane	0.33	46.00
Benzene, 1-methyl-4(1-methylpr...	0.07	50.00
cis, trans-1, 10-Dimethylspiro(4....	0.03	38.00
Cyclopentane, hexyl-	0.10	70.00
5-t-Butyl-cycloheptene	0.09	46.00
Benzene, diethylmethyl-	0.11	89.00
Benzene, 1-methyl-4(1-methylpr...	0.17	55.00
Napthalene, decahydro-2-methyl-	0.38	94.00
Benzene, 1,2,3,4-tetramethyl-	0.09	91.00
Bicyclo[3.1.0]hexane-2-one-4-methyl-	0.08	55.00
2-METHYLDECALIN (PROBABLY CIS)	0.26	96.00
Nonane, 4,5-dimethyl-	0.19	47.00

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ASTM D-6733 Modified

Tentatively Identified Compounds	**Approximate Quantifcation %**	**Match Quality**
Undecane, 4-methyl	0.45	60.00
Benzene, diethylmethyl	0.04	91.00
Undecane, 2-methyl	0.23	70.00
Napthalene, decahydro-2, 6-dime...	0.50	93.00
Benzene, diethylmethyl-	0.03	89.00
Napthalene, decahydro-2, 6-dime...	0.04	89.00
Decane, 3, 8-dimethyl-	0.19	64.00
CIS-SYN-1-METHYL-DECAHYDRONAPHT...	0.15	95.00
Benzene, 1-methyl-4-(1-methylpr...	0.08	91.00
5-t-Butyl-cyclopeptene	0.07	55.00
Napthalene, decahydro-2, 3-dime...	0.28	95.00
Napthalene, decahydro-2, 6-dime...	0.21	93.00
2,6-DIMETHYL-4-OXA-ENDO-TRICYCL...	0.35	90.00
Cyclohexane, 1-methyl-2-pentyl-	0.42	58.00
Naphthalene, decahydro-1, 2-dime...	0.46	52.00
Benzene, 1-methyl-4-(1-methylet...	0.05	18.00
trans, trans-1, 10-Dimethylspiro[...	0.14	30.00
Naphthalene, decahydro-2, 6-dime...	0.43	90.00
Dodecane	1.15	92.00
Naphthalene, decahydro-2, 6-dime...	0.21	98.00
Naphthalene, decahydro-1, 6-dime...	0.20	94.00
Naphthalene, decahydro-2, 6-dime...	0.17	76.00
Naphthalene, decahydro-1, 6-dime...	0.10	81.00
Naphthalene, decahydro-2, 6-dime...	0.19	81.00
Naphthalene, decahydro-1, 6-dime...	0.05	93.00
Undecane, 2, 6-dimethyl-	0.54	93.00
Cyclohexanol, dodecyl-	0.10	47.00
Naphthalene, decahydro-1, 2-dime...	0.25	90.00
2(1H)-Naphthalenone, octahydro...	0.19	50.00
Cyclohexane, 2-butyl-1, 1, 3-trim...	0.17	97.00
DECAHYDRO-2-ETHYL-NAPHTHALENE	0.45	91.00
1-Dotriacontanol	0.11	53.00
Bicyclo[4.1.0] heptane, 3-methyl...	0.31	53.00
trans, cis-1, 8-Dimethylspiro[4.5...	0.28	64.00
trans, cis-3-Ethylbicyclo[4.4.0...	0.17	93.00
DECAHYDRO-2-ETHYL-NAPHTHALENE	0.15	91.00
Cyclohexane, hexyl-	0.27	83.00
1-Tridecene	0.28	42.00
Naphthalene, decahydro-1, 5 dime...	0.23	55.00
1H-Indene, 2, 3-dihydro-4, 7-dime...	0.48	91.00
Dodecane, 6-Methyl-	0.32	55.00
Undecane, 2, 4-dimethyl-	0.27	41.00
3.5-Dodecadiene, 2-methyl-	0.18	55.00
Dodecane, 4-methyl-	0.41	60.00
Cyclododecene, 1-methyl-	0.16	43.00

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Tentatively Identified Compounds	**Approximate Quantifcation %**	**Match Quality**
Undecane, 2, 10-dimethyl-	0.41	43.00
Naphthalene, 1,2,3,4-tetrahydro...	0.25	96.00
1-Cyclohexylheptene	0.23	49.00
Bicyclo[3.1.1] heptane, 2,6,6-tr...	0.09	60.00
Dodecane, 3-methyl-	0.31	64.00
Undecane, 2, 6-dimethyl-	0.43	78.00
Cyclohexane, (2-ethyl-1-methyl...	0.14	49.00
Benzene, 1,4-dimethyl-2-(2-meth...	0.12	42.00
cis, trans-1, 9-Dimethylspiro[5.5...	0.11	49.00
7-Tetradacene, (Z)-	0.29	50.00
Naphthalene, decahydro-2, 2-dime...	0.34	59.00
3,5-Dodecadlene, 2-methyl-	0.06	46.00
5,7-Dimethyloctahydrocoumarin	0.11	38.00
cis, trans-1, 10-Dimethylspiro[5....	0.20	60.00
Cyclohexane, 1,3-dimethyl-, trans-	0.35	49.00
trans, trans-2, 10-Dimethylspiro[...	0.18	45.00
Naphthalene, 1,2,3,4-tetrahydro...	0.21	72.00
1-Cyclohexylheptene	0.30	44.00
2,4-Hexadiene, 2,5-dimethyl-	0.24	25.00
trans, trans-and trans, cis-1, 10...	0.13	55.00
Tridecane	1.24	97.00
Naphthalene, 1,2,3,4-tetrahydro...	0.13	25.00
1-Cyclohexanone, 3,5,5-trimethy...	0.35	62.00
trans, trans-2, 10-Dimethylspiro[...	0.20	50.00
Oxirane, decyl-	0.44	25.00
Cyclohexane, (2-ethyl-1-methyl...	0.13	43.00
Ketone, 1,5-dimethylbicyclo[2,1...	0.12	53.00
trans, trans-and trans, cis-1, 10...	0.11	50.00
Undecane, 5-ethyl-	0.29	50.00
2,4,6-TRIMETHYLINDANE	0.19	90.00
1,11-Tridedicen	0.19	62.00
Naphthalene, 1,2,3,4-tetrahydro...	0.22	50.00
3,5-Dodecadlene, 2-methyl-	0.18	41.00
trans, trans-3-Ethylbicyclo[4.4...	0.29	76.00
Cyclohexane, 1-methyl-4 (1-meth...	0.17	55.00
Cyclohexane, (2-ethyl-1-methylb...	0.13	39.00
7-Tetradecyne	0.21	78.00
Borane, 2-3-dimethyl-2-butyl-(...	0.20	72.00
1-Cyclopentyl-4-(1-methylethyl)...	0.15	49.00
2-Hexanone, 3-cyclohexylidene-4...	0.29	46.00
Heptylcyclohexane	0.47	70.00
Cyclopentane, 1-pentyl-2-propyl-	0.33	86.00
2-Hexanone, 3-cyclohexylidene-4...	0.15	25.00
Tetratetracontane	0.34	43.00
Tridecane, 5-methyl-	0.39	49.00
Tridecane, 4-methyl-	1.02	62.00

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Tentatively Identified Compounds	**Approximate Quantifcation %**	**Match Quality**
Tridecane, 2-methyl-	0.33	95.00
1(2H) -Naphthalenone, octahydro-...	0.32	43.00
2(1H) -Naphthalenone, octahydro-...	0.14	38.00
1,9-Tetradecadiene	0.14	49.00
Tridecane, 3-methyl-	0.39	70.00
1-Decanol, 2-hexyl-	0.23	30.00
Nonane, 3,7-dimethyl-	0.76	81.00
Z-9-Tetradecenol	0.08	70.00
1-Dodecyne	0.26	35.00
13-Oxadispiro[5.0.5.1] tridecan-...	0.29	45.00
Cyclopentane, 2-isopropyl-1, 3-d...	0.22	42.00
Cyclopentane, pentyl-	0.33	60.00
Cyclododecane, ethyl-	0.25	56.00
Cyclohexane, 1-(cyclohexylmethy...	0.20	70.00
Naphthalene, 1,2,3,4- tetrahydro...	0.29	96.00
1H-Indene, 2,3-dihydro-4,5,7-tr...	0.33	53.00
Tetradecane	1.45	96.00
Tetracontane, 3,5,24-trimethyl-	0.38	53.00
Undecane, 5-Cyclohexyl-	0.46	45.00
Anthracene, tetradecahydro-	0.56	86.00
Bicyclo[2.2.1]Heptane-2,3-diol...	0.10	25.00
Cyclononane, 1,1,4,4,7,7-hexam...	0.24	45.00
Isojasmone	0.32	58.00
3,9-Epoxyltricyclo{4.2.1.1(2,5)}...	0.42	44.00
Cyclohexane, 1,2,4,5-tetraethyl...	0.18	35.00
2(1H)-Benzocyclooctenone, decah...	0.53	35.00
Cyclopentane, 2-isopropyl-1,3-d...	0.22	38.00
Anthracene, tetrahecahydro...	0.44	55.00
3-Octyne, 2,2,7-trimethyl-	0.33	64.00
Bicyclo[3.1.0]hexan-2-one, 4-me...	0.21	55.00
Bicyclo[3.1.0]hexan-2-one, 4-me...	0.20	64.00
2(1H) -Naphthalenone, octahydro-...	0.14	53.00
Naphthalene, 1,2,3,4- tetrahydro...	0.25	93.00
Decane 3-cyclohexyl-, 3-cyclohe...	0.94	90.00
Tetradecane, 5-methyl-	0.30	89.00
2-hepten-6-one, 5-phenyl-, (Z)-	0.15	44.00
Tetradecane, 2-methyl-	0.67	46.00
Dodecane, 2-methyl-8-propyl-	0.79	90.00
Cyclohexane, 1-(cyclohexylmethy...	0.28	25.00
Cyclohexane, 1,2,4,5-tetraethyl...	0.30	25.00
Pentadecane, 3-methyl-	0.62	70.00
2,5,8-Trimethyl-1,2,3,4-tetrahy...	0.15	56.00
8.beta., 12-Epoxy-13,14,15,16,17...	0.58	91.00
Hexadecane	0.39	38.00
3-Hexen-2-one, 3-cyclohexyl-4-e...	0.13	60.00
1-Oxaspiro[.5] octane, 5,5-dime...	0.42	25.00
Phenanthrene, tetradecahydro-	0.46	89.00

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Tentatively Identified Compounds	Approximate Quantifcation %	Match Quality
2,4-Hexadiene, 2,5-dimethyl-	0.19	38.00
Z-9-Tetradecenal	0.25	90.00
Cyclohexane, 1,1-dimethyl-	0.27	46.00
Pentadecane	1.43	97.00
Cyclohexane, (2.2-dimethycyclo..	0.42	42.00
Cyclohexane, 1,1-dimethyl-	0.48	42.00
3-Hexen-2-one, 3-cyclohexyl-4-e...	0.18	50.00
2-Aziridinone, 1-tert-butyl-3-(...	0.18	38.00
7-Pentadecyne	0.41	80.00
Bicyclo[3.1.0] hexan-2-one, 4-me...	0.17	60.00
Cyclohexanone, 2,2-dimethyl-5-(...	0.17	42.00
Bicyclo[3.1.0] hexan-2-one, 4-me...	0.23	46.00
Bicyclo[3.1.0] hexan-2-one, 4-me...	0.27	55.00
Cyclohexanone, 2,2-dimethyl-5-(...	0.22	48.00
(-)-E-Pinane	0.22	41.00
Bicyclo[3.1.1] heptane, 2,6,6-tr...	0.26	47.00
3,4-Dimethyl-1-(phenylthio)-2-p...	0.58	35.00
Phenanthrene, tetradecahydro-	0.22	50.00
4,6,7,8,9,10-Hexahydro-4-iminop...	0.25	83.00
Tritetracontane	0.32	43.00
13-Tetradecenal	0.46	22.00
Tridecane, 5-methyl-	0.24	45.00
Undecane, 4-cyclohexyl-	0.55	72.00
Dodecane, 2-methyl-8-propyl-	0.30	90.00
Pentadecane, 2-methyl-	0.68	78.00
7-Oxabicyclo[4.1.0]heptane, 1,5...	0.39	46.00
2-Hexanone, 3-cyclohexylidene-4...	0.13	46.00
Decane, 3,8-dimethyl-	0.38	58.00
Cis-3-methyl-endo-tricyclo[5.2....	0.14	52.00
1-Oxaspiro[2.5] octane, 5,5-dime...	0.17	38.00
Bicyclo[2.2.1] heptane, 2,2,6-tr...	0.32	30.00
Longifolenaldehyde	0.08	58.00
Bicyclo[3.1.1] heptane, 2,6,6-tr...	0.19	53.00
Bicyclo[3.1.1] octan-3-one, 6-ex...	0.10	49.00
2-Hexanone, 3-cyclohexylidene-4...	0.33	49.00
Spiro[4.5] decan-7-one, 1,8-dime...	0.20	50.00
Bicyclo[3.1.1] heptane, 2,6,6-tr...	0.35	30.00
Bicyclo[3.1.1] heptane, 2,6,6-tr...	0.29	41.00
Hexadecane	1.47	93.00
2-Hexanone, 3-cyclohexylidene-4...	0.25	45.00
2,3-Dioxabicyclo[2.2.2] oct-7-en...	0.45	41.00
Spiro[4.5] decan-7-one, 1,8-dime...	0.36	47.00
Cyclohexanone, 1,1-dimethyl-	0.25	42.00
Bicyclo[7.7.0] hexadec-1(9)-ene	0.54	45.00
Longifolenaldehyde	0.18	55.00
2-Hexanone, 3-cyclohexylidene-4...	0.13	46.00

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ASTM D-6733 Modified

Tentatively Identified Compounds	**Approximate Quantifcation %**	**Match Quality**
Tridecanedial	0.18	53.00
Tridecanedial	0.36	38.00
Bicyclo[3.1.0] hexan-2-one, 4-me...	0.22	50.00
2-Hexenedioic acid, 2-methoxy-...	0.34	60.00
Bicyclo[3.1.0] hexan-2-one, 4-me...	0.10	55.00
CAMPHERENONE	0.25	92.00
1-Butyl-2-ethyloctahydro-4, 7-ep	0.60	86.00
PENTADECANE, 2,6,10-TRIMETHYL-	0.66	90.00
Tetradecane, 4-ethyl-	0.25	50.00
2-Hexanone, 3-cyclohexylidene-4...	0.23	50.00
Hexadecane, 4-methyl-	0.30	95.00
Cyclohexane. (2-methylpropyl)-	0.20	70.00
Pentadecane, 3-methyl-	0.39	95.00
Heptadecane, 4-methyl-	0.17	56.00
Imidazole, 4-methyl-5-[3,3,3-tr...	0.11	47.00
Bicyclo[2.2.1] heptane, 1,3,3-tr	0.13	38.00
Hexadecane, 3-methyl-	0.29	86.00
2-Dodecen-1-yl(-) succinic anhyd...	0.19	38.00
(-)-E-Pinane	0.18	53.00
5-Heptadecenal	0.21	49.00
Longifolenaldehyde	0.18	78.00
Bicyclo[2.2.1] heptane, 2,2,3-tr...	0.26	43.00
1,4-Methanonaphthalene, 6, 7-die...	0.29	38.00
2,11-Dodecadiene, 4-chloro-	0.15	43.00
(-)E-Pinane	0.03	41.00
Bicyclo[2.2.1] heptane, 2,2,3-tr...	0.19	35.00
2-Hexenedioic acid, 2-methoxy-...	0.18	83.00
Heptadecane	1.14	97.00
Pentadecane, 2,6,10,14-tetramet...	0.99	97.00
1-Hentetracontanol	0.32	52.00
1-Octadecene	0.20	46.00
Cyclohexane, 2,4-diisopropyl-1....	0.27	49.00
Cyclopentane, (2-hexyloctyl)...	0.22	43.00
2(1H)-Naphthalenone, Octahydro...	0.24	46.00
Tridecanedial	0.22	47.00
Cyclohexane, 1,2,4,5-tetraethyl...	0.09	53.00
3,3,3-Trifluoro-2-hydroxy-propi...	0.11	46.00
Cyclotetradecane, 1,7,11-trimet...	0.22	64.00
1-Nonadecane	0.19	52.00
Tritetracontane	0.35	43.00
Tetradecane, 1-chloro-	0.24	46.00
1-Butyl-2-ethyloctahydro-4, 7-ep...	0.22	92.00
Tetrapentacontane, 1, 54-dibromo-	0.50	53.00
Heptadecane, 4-methyl-	0.31	96.00
Cyclopentane, 1-butyl-2-pentyl-	0.14	80.00
Heptadecane, 2-methyl-	0.31	86.00

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ASTM D-6733 Modified

Tentatively Identified Compounds	**Approximate Quantifcation %**	**Match Quality**
Heptadecane, 3-methyl-	0.24	53.00
Heptadecane, 3-methyl-	0.28	95.00
Cyclopentane, (2-hexyloctyl)-	0.19	46.00
Decane, 5-cyclohexyl-	0.07	42.00
Cyclopentane, (2-hexyloctyl)-	0.23	50.00
Cyclopentane, (2-hexyloctyl)-	0.12	42.00
Cyclopentane, (2-hexyloctyl)-	0.18	64.00
Cyclopentane, (2-hexyloctyl)-	0.25	64.00
Cyclopentane, (2-hexyloctyl)-	0.16	50.00
2-Hexenedioic acid, 2-methoxy....	0.17	53.00
Octadecane	0.94	98.00
1-Dotriacontanol	0.23	53.00
Hexadecane, 2,6,10,14-tetramethyl-	0.72	98.00
Cyclopentane, (2-hexyloctyl)-	0.11	50.00
Cyclopentane, (2-hexyloctyl)-	0.12	55.00
Z-8-Methyl-9-tetradecenoic acid	0.11	53.00
Cyclopentane, (2-hexyloctyl)-	0.11	64.00
Cyclohexane, 1,1-dimethyl-	0.17	38.00
2,5-Furandione, 3-(dodecenyl) di...	0.07	83.00
Borane, 2,3-dimethyl-2-butyl-(...	0.12	64.00
Cyclopentane, (2-hexyloctyl)-	0.11	51.00
Cyclotetradecane, 1,7,11-trimet...	0.08	90.00
17-Pentatriacontene	0.03	46.00
Tetrapentacontane, 1,54-dibromo-	0.35	45.00
Heptadecane	0.23	87.00
Diisoamylene	0.13	42.00
9-Hydroxy-2,2-dimethyl-dec-5-en...	0.22	53.00
Tetradecane, 5-methyl-	0.19	60.00
Cylcotetradecane, 1,7,11-trimet...	0.07	55.00
Cyclotetradecane, 1,7,11-trimet...	0.03	89.00
Cyclotetradecane, 1,7,11-trimet...	0.03	59.00
Hexadecane	0.27	81.00
Heptadecane, 3-methyl	0.21	78.00
Cyclotetradecane, 1,7,11-trimet...	0.08	70.00
1-Eicosyne	0.22	70.00
Octadecane, 3-methyl-	0.25	95.00
2-Dodecen-1-yl(-)succinic anhyd...	0.15	70.00
Cyclotetradecane, 1,7,11-trimet...	0.33	90.00
2-Dodecen-1-yl(-)succinic anhyd...	0.15	64.00
Cyclotetradecane, 1,7,11-trimet...	0.09	86.00
Decane, 3,8-dimethyl	0.31	60.00
Cyclopentane, (2-hexyloctyl)-	0.07	86.00
Nonadecane	0.64	98.00
Cyclotetradecane, 1,7,11-trimet...	0.15	89.00
1-Nonadecene	0.16	49.00
E-8 Methyl-9-tetradecen-1-ol ac...	0.12	52.00

Diesel (b)
Lab No: 801240-03
Job No: 13091-00005181

ASTM D-6733 Modified

Tentatively Identified Compounds	Approximate Quantifcation %	Match Quality
Vinyl lauryl ether	0.19	45.00
2-Dodecen-1-yl(-)succinic anhyd...	0.13	50.00
7,7-Dimethyl-6-methylidene-5-(2...	0.13	90.00
Cyclotetradecane, 1,7,11-trimet...	0.09	70.00
Cyclohexane, 1,1-dimethyl-	0.24	35.00
Cyclotetradecane, 1,7,11-trimet...	0.02	72.00
Cyclotetradecane, 1,7,11-trimet...	0.17	83.00
Eicosane	0.26	86.00
Cyclotetradecane, 1,7,11-trimet...	0.09	64.00
Z-9 Tetradecenal	0.17	83.00
Tetrapentacontane, 1,54-dibromo-	0.16	60.00
Cyclotetradecane, 1,7,11-trimet...	0.10	60.00
Octadecane, 3-methyl-	0.20	59.00
Heptadecane	0.18	83.00
1,2-Tetradecanediol	0.15	64.00
Eicosane, 9-cyclohexyl-	0.02	74.00
Cyclotetradecane, 1,7,11-trimet...	0.12	87.00
Cyclotetradecane, 1,7,11-trimet...	0.07	91.00
Cyclotetradecane, 1,7,11-trimet...	0.21	87.00
Cyclohexadecane, 1,2-diethyl-	0.10	45.00
Cyclotetradecane, 1,7,11-trimet...	0.03	83.00
Cyclotetradecane, 1,7,11-trimet...	0.11	70.00
Octadecane, 1-chloro-	0.10	93.00
Eicosane	0.48	98.00
Octadecane	0.09	55.00
Cyclotetradecane, 1,7,11-trimet...	0.09	95.00
17-Pentatriacontene	0.10	81.00
Cyclotetradecane, 1,7,11-trimet...	0.05	70.00
9-Eicosene, (E)-	0.12	43.00
Cyclopentane, (2-hexyloctyl)-	0.15	83.00
Decane, 5,9-bis (2,2-dimethylpro...	0.03	70.00
Cyclohexadecane, 1,2-diethyl-	0.01	86.00
Octadecane, 1-chloro-	0.05	59.00
Cyclotetradecane, 1,7,11-trimet...	0.12	64.00
Eicosane	0.18	64.00
Heptadecane, 2,6,10,14-tetramet...	0.08	83.00
Tetrapentacontane, 1,54-dibromo-	0.10	64.00
Octadecanoic acid, 17-oxo-, met...	0.18	93.00
Octadecane	0.10	70.00
2-Dodecen-1-yl(-)succinic anhyd...	0.04	50.00
Eicosane, 2-methyl-	0.13	95.00
E11, 13-Dimethyl-12-tetradecen...	0.07	78.00
Nonadecane	0.12	89.00
Eicosane, 9-cyclohexyl-	0.16	90.00
Cyclotetradecane, 1,7,11-trimet...	0.05	87.00
1,11-Dibromoundecane	0.02	60.00
Cyclopentane, (2-hexyloctyl)-	0.15	64.00

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Diesel (b)
Lab No: 801240-03
Job No: 13091-00005181

ASTM D-6733 Modified

Tentatively Identified Compounds	Approximate Quantifcation %	Match Quality
Trispiro [4,2,4,2,4,2] heneicosane	0.01	51.00
2,3-Dioxabicyclo [2.2.2] oct-7-en...	0.06	56.00
E11, 13-Dimethyl-12-tetradecen...	0.03	58.00
Nonadecane	0.41	91.00
Cyclotetradecane, 1,7,11-trimet...	0.06	89.00
2-Butanone, 4-(2,6,6-trimethyl...	0.05	51.00
Octadecanoic acid, 17-oxo-, met...	0.09	93.00
Octadecane, 1-chloro-	0.05	46.00
9-methyl-Z-10-tetradecen-1-ol a...	0.06	49.00
1H-Indene, 5-buytl-6-hexyloctah...	0.08	53.00
2-Dodecen-1-yl (-) succinic anhyd...	0.02	40.00
Nonadecane	0.05	64.00
Cyclotetradecane, 1,7,11-trimet...	0.04	80.00
Octadecane, 1-chloro-	0.03	62.00
Cyclotetradecane, 1,7,11-trimet...	0.12	83.00
Cyclotetradecane, 1,7,11-trimet...	0.05	78.00
Cyclotetradecane, 1,7,11-trimet...	0.08	83.00
Decane, 1-iodo-	0.08	70.00
Cyclohexane, (1-octylnonyl)-	0.09	78.00
Nonadecane	0.10	89.00
erythro-7, 8--Bromochlorodisparlure	0.04	70.00
3-methylheneicosane	0.07	90.00
Cyclohexadecane, 1,2-diethyl-	0.06	83.00
Octadecane, 1-chloro-	0.01	91.00
Cyclohexane, (1-decylundecyl)-	0.08	74.00
Spiro [4.5] decan-7-one, 1,8-dime...	0.03	64.00
Phosphonic acid, 7-Octenyl-, di...	0.04	46.00
Octadecane, 1-chloro-	0.03	90.00
1-Hentetracontanol	0.04	52.00
Cyclotetradecane, 1,7,11-trimet...	0.02	84.00
Docosane	0.20	99.00
Dodecane, 1,2-dibromo-	0.03	45.00
E-11, 13-Dimethyl-12-tetradecen...	0.02	89.00
Cyclotetradecane, 1,7,11-trimet...	0.05	87.00
Nonadecane	0.02	60.00
1-Docosene	0.06	78.00
1-Hentetracontanol	0.02	62.00
2,5-Furandione, 3-(Dodecenyl)di...	0.02	86.00
Hexadecane, 1-chloro-	0.02	44.00
2-Dodecen-1-yl (-) succinic anhyd...	0.05	70.00
1-Hentetracontanol	0.01	46.00
Heptadecane, 8-methyl-	0.12	78.00
1-Octadecene	0.02	60.00
Tricosane	0.04	86.00
Tricosane	0.05	86.00
Docosane	0.05	64.00
Eicosane	0.05	80.00

Diesel (b)
Lab No: 801240-03
Job No: 13091-00005181

ASTM D-6733 Modified

Tentatively Identified Compounds	Approximate Quantifcation %	Match Quality
Cyclohexane, 1-(1,5-dimethylhex...	0.01	53.00
Cyclohexane, 1-(1,5-dimethylhex...	0.03	60.00
Eicosane	0.04	86.00
1-Docosene	0.03	78.00
5-Methyl-Z-5-docosene	0.02	62.00
Undecane, 5-cyclohexyl-	0.04	64.00
Cyclopentane, 1-methyl-3-(2-met...	0.01	51.00
2-Dodecen-1-yl(-)succinic anhyd...	0.01	60.00
2-Dodecen-1-yl(-)succinic anhyd...	0.01	68.00
1-Bromo-11-iodoundecane	0.01	50.00
Spiro[4.5] decane-7-one, 1,8-dime...	0.02	64.00
Tricosane	0.11	98.00
1-Docsene	0.01	42.00
Spiro[4.5] decane-7-one, 1,8-dime...	0.02	46.00
Cyclohexane, 1,2,4,5-tetraethyl...	0.01	30.00
Octadecane, 1-chloro-	0.01	74.00
1,3-Dioxolane, 4-ethyl-5-octyl...	0.02	49.00
Cyclopentane, (4-octyldodecyl)-	0.04	68.00
1-Hentetracontanol	0.01	49.00
2-Dodecen-1-yl(-)succinic anhyd...	0.03	53.00
E-11, 13-Dimethyl-12-tetradecen...	0.03	64.00
Eicosane	0.02	80.00
Cyclopentane, 1-methyl-3-(2-met...	0.01	44.00
Eicosane	0.01	81.00
Pentatriacontane, 13-docosenyli...	0.01	25.00
2,3-Dioxabicyclo[2.2.2] oct-7-en...	0.02	51.00
Hexadecane, 1-(ethenyloxy)-	0.02	91.00
1H-Indene, 5-butyl-6-hexyloctah...	0.01	46.00
Cyclohexane, (1-hexyltetradecyl)-	0.02	43.00
Tricosane	0.03	95.00
1H-Indene, 5-butyl-6-hexyloctah...	0.01	78.00
1H-Indene, 5-butyl-6-hexyloctah...	0.01	43.00
Spiro[4.5] decane-7-one, 1,8-dime...	0.01	64.00
17-Pentatriacontene	0.02	58.00
9-Methyl-Z-10-Tetradecen-1-ol a...	0.02	53.00
Bicyclo [3.1.1] heptan-3-one, 6, 6...	0.01	27.00
1H-Indene, 5-butyl-6-hexyloctah...	0.02	55.00
1,3-Dioxolane, 4-ethyl-5-octyl...	0.01	43.00
Tetracosane	0.06	97.00
E-9-Methyl-8-tridecen-2-ol, ace...	0.01	46.00
9-Methyl-Z-10-Tetradecen-1-ol a...	0.02	70.00
Cyclopentane, 1,1-3-(2-cyclop...	0.01	38.00
1H-Indene, 5-butyl-6-hexyloctah...	0.01	47.00
1H-Indene, 5-butyl-6-hexyloctah...	0.01	49.00
Cyclopentane, 1-(2-decyldodecyl...	0.01	43.00
E-8-Methyl-9-tetradecen-1-ol ac...	0.01	47.00

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Diesel (b)
Lab No: 801240-03
Job No: 13091-00005181

ASTM D-6733 Modified

Tentatively identified Compounds	**Approximate Quantifcation %**	**Match Quality**
Eicosane	0.01	93.00
Ethyl 2-acetamido-3,3,3-trifluo...	0.01	23.00
Hexahydropyridine, 1-methyl-4 [...	0.01	27.00
4-Hydroxy-beta-ionone	0.01	35.00
Cyclohexane, 1,1-(2-propyl-1,3...	0.01	23.00
trans-2,3-Methylenedioxy-b-meth...	0.01	35.00
Eicosane	0.02	98.00
Eicosane	0.01	92.00
1,3-Bis(Trimethylsilyl)benzene	0.01	59.00
Cyclotrisiloxane, hexamethyl-	0.01	58.00
1,3-Bis(trimethylsilyl)benzene	0.01	59.00
Unidentified low level compounds	0.30	-
Total	100.00	

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Certificate of Analysis

ATMOSPHERIC ANALYSIS & CONSULTING INC.
MARCUS HUEPPE
1534 EASTMAN AVENUE
VENTURA, CA 93003

Date Sampled: 7/16/2008
Product: Jet A
Location: Ventura, CA
Sample ID: Sample #080457-33844
Vessel:

Report Date: 9/30/2008
Job No: 13091-00005181
Sample Number: 801240-04
Client Ref: AAC Project #080457

Test	Method	Result	Units
Compostion Breakdown by GC/MS			
Composition Breakdown by GC/MS	GC/MS	See Attached	
Detailed Capillary Analysis			
Detailed Hydrocarbon Analysis	ASTM D-6733M	See Attached	

*Analysis results are submitted by a third party laboratory. Saybolt was not present whilst the analysis was carried out, and has signed for receipt only with no liability accepted.

Approved By: Francine Hanby
Francine Hanby
Laboratory Manager

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Jet A
Lab No: 801240-04
Job No: 13091-00005181

Composition Breakdown, Gas Chromatography/Mass Spectrometer

The sample was analyzed on a gas chromatograph/mass spectrometer. A library search was performed on the collected data using the Wiley 138 Library and the NIST 98 Library. Together the libraries contain approximately 200,000 compounds.

We preformed a composition breakdown on the hydrocarbon material as received. These results are normalized only to the chemicals found. If heavier compounds, high molecular weight additives or polymers are present these were not seen on the gas chromatograph/mass spectrometer.

The material was found to be a kerosene fuel range product. The carbon distribution ranges from a trace of C_4 to a trace of C_{17}, with the apex at C_{12}. The library found some small levels of chemical identified as aldehydes, acids and ketones.

We saw the following organic compounds types in the headspace material. The following is the tentative composition>

Tentatively identified Compounds **Types Found**	**Approximate Quantification** **Weight Percent**
Paraffins	11.0
Isoparaffins	27.1
Cyclic paraffins (naphthenics)	27.4
Mono-aromatics	15.6
Di-aromatics	14.2
Indenes	3.1
Amines	0.3
Aldehydes	1.2
Esters	0.1
Total	100.00

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Jet A
Lab No: 801240-04
Job No: 13091-00005181

Composition Breakdown, Gas Chromatography/Mass Spectrometer, ASTM D-6733 Modified

The sample was analyzed on a gas chromatograph/mass spectrometer. A library search was performed on the collected data using the Wiley 138 Library and the NIST 98 Library. Together the libraries contain approximately 200,000 compounds.

The organic materials are consistent with kerosene fuel range hydrocarbons. The chemicals range from approximately C_4 to C_{17} with an apex around C_{12}.

The following is a list of the individual compounds identified by our libraries and their match qualities. The chemicals found have been reported in retention time order as analyzed. Please note, these are names from the libraries and may or may not be the actual name of the compound, but would be representative of the chemical type based on the spectra. Some duplication of names does occur.

The results are listed on the following pages.

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Jet A
Lab No: 801240-04
Job No: 13091-00005181

ASTM D-6733 Modified

Tentatively Identified Compounds	**Approximate Quantifcation %**	**Match Quality**
Pentane, 2-methyl	0.01	91.00
Hexane	0.01	87.00
Cyclopentane, methyl-	0.01	91.00
Cyclohexane	0.01	87.00
Hexane, 2-methyl-	0.01	94.00
Pentane, 2,3-dimethyl-	0.01	94.00
Hexane, 3-methyl-	0.02	91.00
Cyclopentane, 1,2-dimethyl-, cis	0.01	90.00
CYCLOBUTANE, ISOPROPYL-	0.01	87.00
Cyclopentane, 1,2-dimethyl-, tr...	0.02	91.00
Heptane	0.04	94.00
Cyclohexane, methyl-	0.09	90.00
Hexane, 2,5-dimethyl-	0.01	87.00
Hexane, 2,4-dimethyl-	0.01	87.00
Cyclopentane, ethyl-	0.02	91.00
1,2,4-TRIMETHYL-CYCLOPENTANE	0.02	90.00
CYCLOPENTANE, 1,2,3-TRIMETHYL-,...	0.02	87.00
Hexane, 2,3-dimethyl-	0.01	87.00
Pentane, 3-ethyl-2-methyl-	0.01	87.00
Cyclopentane, 1,1,2-trimethyl-	0.01	83.00
Heptane, 2-methyl-	0.05	90.00
Benzene, methyl-	0.05	95.00
Hexane, 3,4-dimethyl-	0.01	72.00
Heptane, 3-methyl-	0.06	91.00
Cyclohexane, 1,3-dimethyl-, cis-	0.09	94.00
Cyclohexane, 1,4-dimethyl-, trans-	0.04	94.00
Cyclohexane, 1,1-dimethyl-	0.01	87.00
Cyclopentane, 1-ethyl-3-methyl-...	0.02	90.00
Cyclopentane, 1-ethyl-3-methyl-...	0.02	94.00
CYCLOPENTANE, 1-ETHYL-2-METHYL-	0.02	90.00
Cyclohexane, 1,3-dimethyl-, trans-	0.05	93.00
Octane	0.11	83.00
Cyclopentane, 1,2,3-trimethyl-,...	0.01	93.00
Cyclohexane, 1,4-dimethyl-	0.06	96.00
Cyclooctane, methyl-	0.01	50.00
Cyclopentane, (1-methylethyl)-	0.01	86.00
Cyclopentane, 1,2,3-trimethyl-	0.01	47.00
Heptane, 2,2-dimethyl-	0.01	64.00
Cyclopentane, 1-ethyl-2-methyl-...	0.01	96.00
Heptane, 2,4-dimethyl-	0.02	91.00
1-Octene, 6-methyl-	0.02	52.00
Heptane, 2,6-dimethyl-	0.08	90.00
Cyclohexane, 1,3,5-trimethyl-	0.04	91.00
Cyclopentane, propyl-	0.02	96.00
Cyclohexane, ethyl-	0.10	91.00

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Jet A
Lab No: 801240-04
Job No: 13091-00005181

ASTM D-6733 Modified

Tentatively Identified Compounds	**Approximate Quantifcation %**	**Match Quality**
Cyclohexane, 1,1,3-trimethyl-	0.18	95.00
Cyclohexane, 1,1,3-trimethyl-	0.04	87.00
Cyclohexane, 1,3-dimethyl-, trans-	0.02	53.00
Cyclohexane, 1,3-dimethyl-, trans-	0.03	47.00
Cyclohexane, 1,3-dimethyl-, cis-	0.03	49.00
1-Nonene	0.02	52.00
2-Nonene (E)-	0.04	62.00
Cyclohexane, 1,3,5-trimethyl-,...	0.16	87.00
Cyclohexane, 1,3,5-trimethyl-,...	0.03	95.00
Heptane, 2,3-dimethyl-	0.06	87.00
Heptane, 3,4-dimethyl-	0.01	53.00
Heptane, 3,4-dimethyl-	0.01	72.00
Benzene, ethyl-	0.06	95.00
Cyclopentane, 1-methyl-3-(1-met...	0.02	94.00
Hexane, 3-ethyl-	0.10	90.00
Octane, 2-methyl	0.12	90.00
Benzene, 1-4-dimethyl-	0.17	97.00
Nonanal	0.05	47.00
Octane, 3-methyl-	0.17	83.00
Cyclohexane, 1,2,3-trimethyl-,...	0.06	80.00
Cyclohexane, 1,2,4-trimethyl-	0.08	90.00
Cyclohexane, 1,2,3-trimethyl-,...	0.06	90.00
Cyclohexane, 1,2,4-trimethyl-	0.08	94.00
Cyclopentane, 1-methyl-2-propyl-	0.13	81.00
Cyclohexane, 1-ethyl-4-methyl-,...	0.26	86.00
Cyclohexane, 1-ethyl-4-methyl-,...	0.12	91.00
Benzene, 1,4-dimethyl-	0.12	95.00
Cyclopentane, 1,2-dimethyl-3-(1...	0.02	64.00
Cyclohexane, 1,4-dimethyl-,cis-	0.03	78.00
2-Octene, 3,7-dimethyl-, (Z)-	0.01	50.00
trans-2, 4-Dimethylthiane, S,S-d...	0.02	47.00
Nonane	0.50	91.00
Cyclohexane, 1,2,3-trimethyl-,...	0.05	91.00
1-METHYL-3-PROPYL-CYCLOOCTANE	0.07	90.00
Cyclohexane, 1-ethyl-4-methyl-,...	0.17	91.00
Cyclohexane, 1-ethyl-4-methyl-,...	0.07	91.00
Cyclohexane, 1,1,3-trimethyl-	0.02	49.00
Decane, 2,5,6-trimethyl-	0.03	59.00
Cyclohexane, 1,2-dimethyl-	0.07	43.00
1H-Indene, octahydro-, cis-	0.20	92.00
Cyclohexane, 1,1-dimethyl-	0.04	58.00
3-Octene, 4-ethyl-	0.05	38.00
Benzene, (1-methylethyl)-	0.04	86.00
Octane, 2,3-dimethyl-	0.17	49.00
Cyclopentane, 1,2-dimethyl-3-(1...	0.02	90.00
trans-1,3-Diethylcyclopentane	0.08	53.00

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Jet A
Lab No: 801240-04
Job No: 13091-00005181

ASTM D-6733 Modified

Tentatively Identified Compounds	Approximate Quantifcation %	Match Quality
Cyclohexane, propyl-	0.25	87.00
Nonane, 3-methyl-	0.04	62.00
1-Decene	0.03	52.00
Cyclopentane, butyl-	0.07	90.00
Octane, 2,6-dimethyl-	0.33	94.00
Cyclopentane, 1-methyl-1-(2-met...	0.05	60.00
CYCLOHEXANE, 1,2-DIETHYL-	0.26	87.00
2-Decene, 5-methyl-, (Z)-	0.26	47.00
Cyclopentane, (2-methylbutyl)-	0.08	49.00
Cyclopentane, 1-methyl-3-(2-met...	0.08	64.00
Cyclohexane, 1,2,4-trimethyl-	0.11	52.00
2-Hexene, 4-ethyl-2,3-dimethyl-	0.14	52.00
Cyclohexane, 1,2,3-trimethyl-	0.02	49.00
Benzene, propyl-	0.08	87.00
1H-Indene, octahydro-, trans-	0.06	91.00
1,1,2,3-TETRAMETHYLCYCLOHEXANE A	0.20	94.00
Octane, 4-ethyl-	0.07	95.00
CYCLOHEXANE, 1,2-DIETHYL-	0.08	91.00
2-(2-THIENYL) PROPANAL	0.10	83.00
Benzene, 1-ethyl-3-methyl-	0.44	86.00
Nonane, 4-methyl-	0.38	55.00
Nonane, 2-methyl-	0.31	95.00
Silane, difluorodimethyl-	0.03	64.00
Benzene, 1,3,5-trimethyl-	0.24	95.00
Cyclohexane, 3-butyl-	0.08	49.00
Nonane, 3-methyl-	0.32	87.00
Cyclohexane, 1-methyl-4-(1-meth...	0.23	43.00
Cyclohexane, diethyl-	0.09	58.00
1-Methyl-4-(1-methylethyl)-cycl...	0.18	81.00
Benzene, 1-ethyl-2-methyl-	0.24	92.00
Cyclohexane, diethyl-	0.07	52.00
Cyclohexane, 1-methyl-3-propyl	0.30	91.00
m-Menthane (1S, 3R)-(+)-	0.45	64.00
Cyclodecane	0.28	43.00
Cyclopentane, 1-methyl-3-(2-met...	0.16	72.00
Benzene, 1,3,5-trimethyl-	0.52	97.00
2-HEXENE, 4-ETHYL-2,3- DIMETHYL-	0.13	87.00
Cyclohexane, 1-methyl-2-propyl-	0.09	87.00
Cycloheptane, methyl-	0.08	41.00
Cyclopentane, (2-methylbutyl)-	0.09	62.00
Decane	1.10	93.00
Cyclohexane, 1-ethyl-	0.05	62.00
1-Methyl-4-(1-methylethyl)-cycl...	0.17	60.00
endo-2-Methylbicyclo[3.3.1] nonane	0.06	74.00
Cyclopentane, 1,2-dimethyl-3-me...	0.09	49.00
Naphthalene, decahydro-	0.10	89.00

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Jet A
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ASTM D-6733 Modified

Tentatively Identified Compounds	Approximate Quantifcation %	Match Quality
(2-Methylbutyl) cyclohexane	0.14	38.00
Cyclohexane, 4-methyl-1-(1-meth...	0.17	70.00
Cyclohexanol, 2,3-dimethyl-	0.14	46.00
2-Cyclopenten-1-one, 2,3,4,5-te...	0.20	55.00
Hexane, 2,4-dimethyl-	0.12	38.00
Dodecane, 3-methyl-	0.09	43.00
Benzene, 1,3,5-trimethyl-	0.53	93.00
Decane, 4-methyl-	0.84	93.00
1,3-Dimethyl-1-cyclohexene	0.11	55.00
7-Octenal, 3,7-dimethyl-	0.08	49.00
Octadecane, 1-chloro-	0.21	50.00
Bicyclo [3.1.1] heptane, 2,6,6-tr...	0.15	70.00
6-Octenal, 3,7-dimethyl-	0.08	49.00
Cyclohexanone, 2,3-dimethyl-	0.33	83.00
1H-Indene, 2,3-dihydro-	0.33	91.00
Pentadecane	0.28	50.00
Cyclohexane, 1-ethyl-2-methyl...	0.19	64.00
Decane, 3-Methyl-	0.45	68.00
Cyclodecanol	0.25	49.00
1-ETHYL-2,2,6-TRIMETHYLCYCLOHEXANE	0.23	96.00
2-METHYLDECALIN (PROBABLY CIS)	0.10	83.00
Triallylsilane	0.31	64.00
Benzene, 1,3-diethyl-	0.24	92.00
Benzene, 1-methyl-3-propyl-	0.28	95.00
Cyclopentane, 1,2-dipropyl-	0.32	60.00
Naphthalene, decahydro-, trans-	0.69	98.00
Cyclohexane, 1,1,3-trimethyl-	0.21	35.00
Benzene, 1-ethyl-2,3-dimethyl-	0.54	93.00
Decane, 4-methyl-	0.38	93.00
Cyclodecene, 1-methyl-	0.09	62.00
6-Octenal, 3,7-dimethyl-	0.22	43.00
Decane, 2-methyl-	0.51	81.00
Benzene, 1-methyl-2-propyl-	0.15	93.00
5-t-Butyl-hexa-3, 5-dien-2-one	0.16	43.00
Bicyclo [3.1.1] heptan-3-one, 2,6...	0.20	58.00
Decane, 3-methyl-	0.48	92.00
7-Octenal, 3,7-dimethyl-	0.30	53.00
Benzene, 4-ethyl-1, 2-dimethyl-	0.42	91.00
Benzene, 1-ethyl-2, 4-dimethyl-	0.35	94.00
trans-Decalin, 2-methyl-	0.15	49.00
Benzene, 4-ethenyl-1, 2-dimethyl-	0.21	84.00
Cyclohexanol, 5-methyl-2- (1-met...	0.14	46.00
4-Butyl-cyclohexanone	0.06	58.00
Benzene, 1-Methyl-3-(1-methylet...	0.80	92.00
Cyclohexane, 1,4-dimethyl-, cis-	0.37	43.00
Bicyclo [3.1.1] heptan-3-one, 2,6...	0.51	52.00

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Tentatively Identified Compounds	Approximate Quantifcation %	Match Quality
Cyclododecanemethanol	0.06	38.00
1-Dodecene	0.15	38.00
trans, cis-3-Ethylbicyclo[4.4.0...	0.25	35.00
Cyclohexane, 1-methyl-2-pentyl-	0.18	64.00
Bicyclo[4.1.0] heptane, 3-methyl-	0.40	43.00
Undecane	1.97	91.00
Benzene, 1-methyl-2-(1-methylet...	0.34	90.00
Benzene, 2-ethyl-1, 3-dimethyl-	0.46	66.00
1-Undecene, 4-methyl-	0.19	53.00
Naphthalene, decahydro-2-methyl-	1.21	98.00
Bicyclo[3.1.1] heptane, 2,6,6-tr...	0.14	50.00
Adamantane, 1,3-dimethyl-	0.38	50.00
Benzene, 1-methyl-4-(1-methylet...	0.27	90.00
1-Hexanol, 2-ethyl-	0.31	47.00
2,6-Dimethyldecane	0.27	76.00
Benzene, 1,2,3,5-tetramethyl-	0.59	95.00
3,6-Dimethyldecane	0.05	86.00
Tetradecane, 1-bromo-	0.25	30.00
TRANS-ANTI-1-METHYL-DECAHYDRONA	1.33	92.00
3-Octyne, 6-methyl-	0.29	43.00
5-Eicosene, (E)-	0.21	25.00
Cyclohexane, (1-methylbutyl)-	0.68	60.00
Benzene, 1-methyl-4-(1-methylpr...	0.19	60.00
Benzene, 2-ethenyl-1, 4-dimethyl-	0.32	90.00
Cyclohexane, 1,2,3-trimethyl-	0.23	49.00
1-Azabicyclo[2.2.2]octane, 2,6-...	0.32	43.00
Benzene, 1,4-diethyl-2-methyl-	0.39	64.00
1H-1,5-Benzodiazepine, 2,3,4,5-...	0.51	59.00
1H-Indene, 2,3-dihydro-4-methyl-	0.85	93.00
Undecanal	0.08	35.00
Benzene, 1-methyl-4-(Methylet...	0.78	91.00
Undecane, 6-methyl-	0.52	50.00
Undecane, 5-methyl-	0.52	46.00
Naphthalene, 1,2,3,4-tetrahydro-	1.16	84.00
Benzene, diethylmethyl-	0.17	95.00
Undecane, 2-methyl-	0.70	46.00
Naphthalene, decahydro-2,3-dime...	0.87	83.00
Benzene, diethylmethyl-	0.17	90.00
Naphthalene, decahydro-2, 6-dime...	0.11	92.00
Undecane, 3-methyl-	0.50	72.00
Cyclohexanone, 2-methyl-5-(1-me...	0.25	55.00
Benzene, 1-methyl-4-(1-methylpr...	0.31	64.00
5-t-Butyl-cycloheptene	0.23	46.00
Cyclopentane, 1-methyl-3-(2-met...	0.12	44.00
Naphthalene, decahydro-2, 6-dime...	0.72	93.00

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Tentatively Identified Compounds	Approximate Quantifcation %	Match Quality
trans, cis-3-Ethylbicyclo[4.4.0...	0.69	46.00
1H-Indene, 2,3-dihydro-1, 6-dime...	1.06	86.00
1H-Indene, 2,3-dihydro-1, 2-dime...	0.36	95.00
Naphthalene, decahydro-2, 6-dime...	0.51	91.00
Benzene, (1,1-dimethylpropyl)-	0.24	38.00
Benzene, (2-methyl-1-butenyl)-	0.43	91.00
1H-Indene, 2,3-dihydro-1 3-dime...	1.00	91.00
Dodecane	2.01	93.00
1H-Indene, 2,3-dihydro-1,1,5-tr...	0.17	56.00
TRANS-10-METHYL-4-KETOPERHYDROA...	0.40	83.00
Stibine, trimethyl-	0.39	90.00
Benzene, ethyl-1,2,4-trimethyl-	0.57	90.00
(3R-6R)-(+)-3-Isopropenyl-6-met...	0.36	49.00
Undecane, 2,6-dimethyl-	1.51	91.00
3,5-Decadiene, 2,2-dimethyl-, (...	0.18	62.00
Benzene, pentamethyl-	0.17	55.00
1,1,6,6-Tetramethylspiro[4.4]no...	0.44	46.00
Cyclohexane, 2-butyl-1,1,3-trim...	1.20	97.00
cis, cis-3-Ethylbicyclo[4.4.0]d...	0.49	95.00
Bicyclo[3.1.1]heptam-2-one,6,6...	0.37	41.00
Cyclohexane, (2-ethyl-1-methylb...	0.44	53.00
2-Ethyl-2,3-dihydro-1H-indene	0.42	35.00
Benzene, 1,3,5-triethyl-	0.46	42.00
Cyclohexane, (2-methylpropyl)-	0.65	50.00
Cyclododecane	0.52	91.00
1-Methyl-3-ethyladamantane	0.57	25.00
1,1,6,6-Tetramethylspiro[4.4]no...	0.26	46.00
1H-Indene, 2,3-dihydro-4,6-dime...	0.62	95.00
Dodecane, 6-methyl-	0.62	60.00
Dodecane, 5-methyl-	0.36	38.00
Bicyclo[4.1.0]heptane, 2-methyl...	0.25	55.00
Dodecane, 4-methyl-	0.55	42.00
Bicyclo[2.2.1] heptane-2,3-dione...	0.44	30.00
Undecane, 2,10-dimethyl-	0.60	46.00
Naphthalene, 1,2,3,4-tetrahydro...	1.01	96.00
2,6.beta-Dimethyl-delta-1-bic...	0.11	90.00
Undecane, 2,9-dimethyl-	0.50	64.00
Tridecane, 7-methyl-	0.94	83.00
Naphthalene, 1,2,3,4-tetrahydro...	0.30	42.00
Disiloxane, 1,1,3,3-tetramethyl-	0.37	38.00
6-Tridecene, 7-methyl-	0.57	59.00
1H-Indene, 2,3-dihydro-4, 7-dime...	0.52	70.00
Cyclopentane, 2-isopropyl-,1 3-d...	0.13	30.00
(Z)-2-(1'PROPENYL) MESITYLENE	0.28	86.00
Cyclopentane, 2-isopropyl-,1 3-d...	0.43	52.00
Benzene, 1(1-methylethenyl)-3...	0.17	64.00

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Tentatively Identified Compounds	**Approximate Quantifcation %**	**Match Quality**
Naphthalene, 1,2,3,4-tetrahydro...	0.87	90.00
1H-Inden-1-one, 2,3-dihydro-3,3...	0.39	60.00
Tridecane	1.60	97.00
Benzene, 1,3,5-trimethyl-2-(1-m...	0.62	59.00
3-methyl-2-(2-oxypropyl)furan	0.21	55.00
2-Butanone, 4-(2,6,6-trimethyl...	0.12	46.00
Naphthalene, 1-methyl-	0.38	81.00
1-Naphthalenemethanol, 1,2,3,4-...	0.09	66.00
3,8-Nonadien-2-one, (E)	0.19	15.00
3-methyl-2-(2-oxypropyl)furan	0.23	42.00
Tridecane, 6-methyl-	0.37	72.00
Naphthalene, 1,2,3,4-tetrahydro...	0.48	94.00
1-Naphthalenemethanol, 1,2,3,4-...	0.23	80.00
1H-Indene, 2,3-dihydro-1, 1,6-tr...	0.34	89.00
Cyclohexane, 1,2,4,5-tetraethyl-	0.21	30.00
1H-Indene, 2,3-dihydro-1, 1,4-tr...	0.25	93.00
1H-Indene, 2,3-dihydro-1, 1,4-tr...	0.24	91.00
Naphthalene, 2-ethyl-1,2,3,4-te...	0.22	93.00
Cyclopentane, 1-methyl-3-(2-met...	0.12	53.00
17-Pentatriacontene	0.24	25.00
Borane, 2,3-dimethyl-2-butyl-(...	0.15	41.00
Bicyclo[3.1.0]hexane-2-one, 4-me...	0.18	41.00
Heptylcyclohexane	0.63	50.00
Naphthalene, 1,2,3,4-tetrahydro...	0.39	89.00
Benzene, 4-(2-butenyl)-1,2-dime...	0.11	60.00
Tridecane, 6-methyl-	0.26	64.00
Tridecane, 5-methyl-	0.42	49.00
Tridecane, 4-methyl	0.41	83.00
Naphthalene, 6-ethyl-1,2,3,4-te...	0.33	97.00
Tridecane, 2-methyl-	0.30	95.00
2,3-Epoxycarane, (E)-	0.29	25.00
Methyl (1s*,2s*,5R*)-15-dimeth...	0.12	35.00
Tridecane, 3-methyl-	0.35	90.00
1-Hentetracontanol	0.12	58.00
Cyclohexane, (2,2-dimethylcyclo...	0.11	41.00
Dodecane, 2,6,11-trimethyl-	0.85	72.00
Naphthalene, 1,2,3,4-tetrahydro...	0.32	64.00
Benzene, 2-(2-butenyl)-1,3,5-tr...	0.14	45.00
Cyclopentane, 1-butyl-2-pentyl-	0.16	53.00
Cyclohexane, 1,1,3-trimethyl-2-...	0.27	95.00
Cyclodecane, ethyl-	0.20	90.00
Cyclohexane, 1-(Cyclohexymethyl...	0.11	50.00
1H-Indene, 2,3-dihydro-,1,3-tr...	0.26	95.00
Naphthalene, 1,2,3,4-tetrahydro...	0.23	90.00
Tetradecane	1.19	96.00
Tridecane, 4,8-dimethyl-	0.30	93.00

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Tentatively Identified Compounds	Approximate Quantifcation %	Match Quality
Naphthalene, 2,6-dimethyl-	0.14	97.00
Naphthalene, 2,6-dimethyl-	0.12	97.00
Undecane	0.13	46.00
2-Butanone, 4-(2,6,6-trimethyl...	0.25	25.00
Octadecane, 1-chloro-	0.25	38.00
1,12-Tridecadiene	0.20	25.00
Naphthalene, 1,4-dimethyl-	0.36	96.00
Naphthalene, 2,6-dimethyl-	0.47	97.00
Naphthalene, 1,2,3,4-tetrahydro...	0.18	64.00
Naphthalene, 1,2,3,4-tetrahydro...	0.27	83.00
2H-Inden-2-one, 1,3-dihydro-1,1...	0.18	38.00
Bicyclo[3.1.1] heptan-3-one, 6,6...	0.16	35.00
Naphthalene, 1,3-dimethyl-	0.14	95.00
Naphthalene, 1,2,3,4-tetrahydro...	0.12	93.00
Benzene, 1-(1-formylethyl)-4-(1...	0.26	68.00
9,9-dimethoxybicyclo[3.3.1]nona...	0.28	70.00
Tetradecane, 5-methyl-	0.16	81.00
Naphthalene, 1,2,3,4-tetrahydro...	0.10	55.00
Benzene, (1-cyclohexylethyl)-	0.09	25.00
Tetradecane, 4-methyl-	0.27	50.00
Dodecane, 2-methyl-8-propyl-	0.52	81.00
1-(3-methylbutyl)-2,3,6-trimeth...	0.12	46.00
1,3,7,7-Tetramethyl-9-oxo-2-oxa...	0.17	41.00
Dodecane, 3-methyl-	0.17	59.00
Methyl 4-methyl-2-isopropenyl-4...	0.08	47.00
Benzenemethanamine, alpha-met...	0.11	25.00
Benzene, 2-(2-butenyl)-1,3,5-tr...	0.07	64.00
Z-8-Hexadecene	0.19	62.00
Nonane, 3,7-dimethyl-	0.17	55.00
(Z)-2-(1'-BUTENYL) MESITYLENE	0.10	83.00
6-N-BUTYL-1,2,3,4-TETRAHYDRONAP...	0.11	95.00
Ethyl 3-thiopheneacetate	0.13	10.00
9-Oxabicyclo[6.1.0]nonane, 1-me...	0.05	38.00
Disiloxane, 1-ethenyl-1,1,3,3-t...	0.11	35.00
Cyclopentadecane	0.12	59.00
Cyclohexane, 1-(cyclohexymethy...	0.09	35.00
Pentadecane	0.72	97.00
Naphthalene, 1,2,3,4-tetrahydro...	0.18	59.00
9,9-Dimethyl-1,4-dihydro-1, 4-me...	0.21	93.00
5-t-Butyl-6-methylhept-3-yne-2...	0.08	10.00
Dodecane, 1-fluoro-	0.07	64.00
Cyclopropane, 1-chloro-1-ethyl-...	0.12	20.00
3-buten-2-one, 4-(5,5-dimethyl-...	0.05	25.00
Azulene, 1,2,3,4,5,6,7,8-Octahy...	0.03	25.00
Naphthalene, 1,4,6-trimethyl-	0.07	35.00
Spiro[4.5]decan-7-one, 1,8-dime...	0.07	60.00

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Tentatively Identified Compounds	**Approximate Quantifcation %**	**Match Quality**
Methyl (1s*,2s*,5R*)-1, 5-dimeth...	0.04	35.00
1,3-Cyclohexadiene, 2,6,6-trime...	0.17	89.00
Naphthalene, 1,6,7-trimethyl-	0.09	97.00
Methyl (1s*,2s*,5R*)-1, 5-dimeth...	0.09	10.00
Naphthalene, 2,3,6-trimethyl-	0.14	97.00
2H-Inden-2-one, 1,3-dihydro-1,1...	0.06	35.00
Ledene oxide-(II)	0.08	22.00
Naphthalene, 1,2,3,4,4a,5,6,8a-...	0.05	53.00
Decane, 5-propyl-	0.09	78.00
Dodecane, 4,9-dipropyl-	0.09	64.00
Undecane, 4-cyclohexyl-	0.28	89.00
Pentadecane, 4-methyl-	0.08	96.00
Tricyclo[5.4.0.02.8]undec-9-ene...	0.04	25.00
Naphthalene, 6-butyl-1,2,3,4-te...	0.04	38.00
Docosane, 7-hexyl-	0.10	87.00
Decane, 3,8-dimethyl-	0.11	55.00
Tetradecane, 6,9-dimethyl-	0.13	46.00
Naphthalene, 2,3,6-trimethyl-	0.08	90.00
1H-Inden-5-ol, 2,3-dihydro-	0.09	15.00
Cyclohexaneethanol, 4-methyl-b...	0.02	14.00
Z-8-Dodecen-1-ol	0.02	35.00
Bicyclo[3.1.1]hept-2-en-6-ol, 2...	0.03	35.00
2,3-Dioxabicyclo[2.2.2]oct-7-en...	0.02	25.00
Isoquinolonium, 2-[(aminocarbon...	0.07	90.00
Furfuryl glycidyl ether	0.01	11.00
Nonahexacontanoic acid	0.14	38.00
4-n-Hexylthiane, S,S-dioxide	0.01	70.00
Naphthalene, 2,3,6-trimethyl-	0.05	95.00
Hexadecane	0.34	95.00
2,3-Dioxabicyclo[2.2.2]oct-7-en...	0.04	56.00
Cyclohexane, 1,2,4,5-tetraethyl-	0.10	30.00
Boric acid (H3BO3), tributyl ester	0.07	11.00
Cyclohexane, 1,2-dimethyl-3-pen...	0.04	42.00
3a,7a-Epoxy-1H-Inden-4(5H)-one...	0.06	18.00
3H,6H-Thieno[3.4-c]isoxazole, 3...	0.03	43.00
3-n-Pentylithiolane, S,S-dioxide	0.03	25.00
Naphthalene 1,2,3,4-tetramethyl-	0.03	35.00
Cyclopentane, 1-methyl-3-(2-met...	0.03	53.00
2-Octenal, 2-butyl-	0.06	30.00
Naphthalene, 1,2,3,4-tetramethyl-	0.02	56.00
4-Hexenoic acid, 2-acetyl-2,5-d...	0.02	14.00
7,8-Epoxy-alpha-ionone	0.01	20.00
Tetrapentacontane, 1,54-dibromo-	0.04	30.00
2,3-Dioxabicyclo[2.2.2]oct-7-en...	0.02	25.00
3-Pyridinecarbonitrile, 1,4-dih...	0.03	18.00
Hexatriacontane	0.05	62.00

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Tentatively Identified Compounds	**Approximate Quantifcation %**	**Match Quality**
PENTADECANE, 2,6,10-TRIMETHYL	0.11	93.00
Nonane	0.04	41.00
Tridecane, 7-cyclohexyl-	0.02	53.00
Tridecane	0.07	81.00
2-Pentenal, 2-ethyl-, semicarba...	0.01	30.00
Hexadecane, 2-methyl-	0.06	86.00
Cyclopentane, 1,1,3-trimethyl-	0.02	25.00
Falcarinol (Z)-(-)-1,9-heptadec...	0.01	25.00
Pentadecane	0.03	87.00
Cyclohexane, 1,2,4,5-tetraethyl-	0.02	81.00
Cyclopentane, 1-pentyl-2-propyl-	0.04	83.00
Naphthalene, 1,2,3,4-tetramethyl-	0.02	83.00
3-Cyclohexylthiolane, S, S-dioxide	0.04	58.00
3-Methyl-2-(2-oxypropyl)furan	0.02	42.00
Cyclohexadecane	0.02	25.00
Undecane, 5-cyclohexyl-	0.01	35.00
Cyclopentane, 1,1,3-trimethyl-	0.02	41.00
Naphthalene, 1,2,3,4-tetramethyl-	0.01	42.00
Heptadecane	0.11	96.00
Pentadecane, 2,6,10,14-tetramet...	0.08	98.00
Cyclododecane, ethyl-	0.02	38.00
4-Heptafluorobutyroxytetradecane	0.01	43.00
3-Buten-2-one, 4-(4-chlorophenyl)-	0.05	27.00
Cyclopentane, 1-methyl-3-(2-met...	0.01	25.00
6-Nitroundec-5-ene	0.01	25.00
1,2-Cyclobutanedicarboxylic aci...	0.02	9.00
4(1H)-Pyrimidinone, 2-(propylth...	0.02	10.00
1,2-Cyclobutanedicarboxylic aci...	0.01	32.00
5-Octadecene, (E)-	0.01	42.00
4(1H)-Pyrimidinone, 2-(butylthio)-	0.01	9.00
Tetradecane	0.01	52.00
Octadecane, 1-chloro-	0.02	46.00
Tetradecane, 2-methyl-	0.01	27.00
Tetradecane, 1-chloro-	0.03	30.00
Tetradecane	0.01	89.00
Piperidine, 1-nitro-	0.01	7.00
Pentadecane	0.01	56.00
Cyclopentanol, 2-(aminomethyl)...	0.01	9.00
Tetradecane, 1-chloro-	0.01	60.00
Nona-2,3-dienoic acid, ethyl ester	0.01	12.00
Sulfuric acid, diethyl ester	0.01	9.00
Nona-2,3-dienoic acid, ethyl ester	0.01	9.00
Urea, (2-ethylhexyl)-	0.01	9.00
1,2-Cyclobutanedicarboxylic aci...	0.01	17.00
Octadecane	0.04	97.00
Acetic acid, 2-(2-buten-1-yl)-2...	0.01	9.00

Saybolt
A CORE LABORATORIES COMPANY

21730 S. Wilmington Avenue Suite 201
Carson, CA 90810
310-518-4400 Telephone
310-518-4455 Facsimile

Saybolt LP

Jet A
Lab No: 801240-04
Job No: 13091-00005181

ASTM D-6733 Modified

Tentatively identified Compounds	**Approximate Quantifcation %**	**Match Quality**
Tetratetracontane	0.02	90.00
Ethane, 1,2-dibromo-1,1,2,2-tet...	0.01	9.00
Propanedioic acid, (ethoxymethy...	0.01	9.00
Furo[3,4-b]furan-2,6(3H, 4H)-dio...	0.01	9.00
Nonadecane	0.01	96.00
Eicosane	0.01	96.00
Decane, 2-methyl-	0.01	90.00
Decane, 2-methyl-	0.01	90.00
Unidentified low level compounds	0.34	-
Total	100.00	

Headspace Analysis for VOC's and Hydrocarbons

EPA TO-15/TO-12 PAMS Hardcopy Report

Atmospheric Analysis & Consulting, Inc.

Laboratory Analysis Report

CLIENT : Jacob's Consultancy
PROJECT NO : 080457
MATRIX : AIR
UNITS : PPB (v/v)

DATE RECEIVED : 07/16/2008
DATE REPORTED : 08/25/2008
SITE NAME LAX
STATION NAME Liquid_Fuel

HEADSPACE ANALYSIS (VOLATILE ORGANIC COMPOUNDS BY EPA TO-15)

Client ID	Gasoline (Const/Maint Yard)			Diesel (Const/Maint Yard)		
AAC ID	080457-33841			080457-33842		
Date Sampled	07/16/2008			07/16/2008		
Date Analyzed	07/28/2008			07/28/2008		
QC Batch	MS03_072908			MS03_072908		
Can Dilution Factor	1.00			1.00		
	Result	Qualifier	Dil. Fac.	Result	Qualifier	Dil. Fac.
Chlorodifluoromethane	ND	U	100000	ND	U	1000
Propylene	258000		100000	ND	U	1000
Dichlorodifluoromethane	ND	U	100000	ND	U	1000
Chloromethane	ND	U	100000	ND	U	1000
1,2-Dichloro-1,1,2,2-Tetrafluoroethane	ND	U	100000	ND	U	1000
Vinyl Chloride	ND	U	100000	ND	U	1000
Methanol	ND	U	100000	6810		1000
1,3-Butadiene	ND	U	100000	ND	U	1000
Bromomethane	ND	U	100000	ND	U	1000
Chloroethane	ND	U	100000	ND	U	1000
Dichlorofluoromethane	ND	U	100000	ND	U	1000
Ethanol	48300000		1000000	902000	E	10000
Vinyl Bromide	ND	U	100000	ND	U	1000
Acetone	ND	U	100000	3130		1000
Trichlorofluoromethane	ND	U	100000	ND	U	1000
Isopropyl Alcohol	ND	U	100000	ND	U	1000
Acrylonitrile	ND	U	100000	ND	U	1000
1,1-Dichloroethylene	ND	U	100000	ND	U	1000
Methylene Chloride	ND	U	100000	4210		1000
Allyl Chloride (Chloroprene)	ND	U	100000	ND	U	1000
Carbon Disulfide	ND	U	100000	ND	U	1000
1,1,2-Trichloro-1,2,2-Trifluoroethane	ND	U	100000	ND	U	1000
t-1,2-Dichloroethylene	ND	U	100000	ND	U	1000
1,1-Dichloroethane	ND	U	100000	ND	U	1000
MTBE	ND	U	100000	ND	U	1000
Vinyl Acetate	ND	U	100000	ND	U	1000
2-Butanone (MEK)	ND	U	100000	ND	U	1000
cis-1,2- Dichloroethene	ND	U	100000	ND	U	1000
Hexane	4650000		100000	41000		1000
Chloroform	ND	U	100000	ND	U	1000
Ethyl Acetate	ND	U	100000	ND	U	1000
Tetrahydrofuran	ND	U	100000	ND	U	1000
1,2-Dichloroethane	ND	U	100000	ND	U	1000
1,1,1-Trichloroethane	ND	U	100000	ND	U	1000

Atmospheric Analysis & Consulting, Inc.

Laboratory Analysis Report

CLIENT	: Jacob's Consultancy	**DATE RECEIVED**	: 07/16/2008
PROJECT NO	: 080457	**DATE REPORTED**	: 08/25/2008
MATRIX	: AIR	**SITE NAME**	LAX
UNITS	: PPB (v/v)	**STATION NAME**	Liquid_Fuel

HEADSPACE ANALYSIS (VOLATILE ORGANIC COMPOUNDS BY EPA TO-15)

Client ID	Gasoline (Const/Maint Yard)			Diesel (Const/Maint Yard)		
AAC ID	080457-33841			080457-33842		
Date Sampled	07/16/2008			07/16/2008		
Date Analyzed	07/28/2008			07/28/2008		
QC Batch	MS03 072908			MS03 072908		
Can Dilution Factor	1.00			1.00		
	Result	**Qualifier**	**Dil. Fac.**	**Result**	**Qualifier**	**Dil. Fac.**
Benzene	1210000		100000	8290		1000
Carbon Tetrachloride	ND	U	100000	ND	U	1000
Cyclohexane	948000		100000	28800		1000
1,2-Dichloropropane	ND	U	100000	ND	U	1000
Bromodichloromethane	ND	U	100000	ND	U	1000
1,4-Dioxane	ND	U	100000	ND	U	1000
Trichloroethene	ND	U	100000	ND	U	1000
2,2,4-Trimethylpentane	3400000		100000	17900		1000
Heptane	670000		100000	19700		1000
cis-1,3-Dichloropropene	ND	U	100000	ND	U	1000
4-Methyl-2-Pentanone (MiBK)	ND	U	100000	ND	U	1000
t-1,3-Dichloropropene	ND	U	100000	ND	U	1000
1,1,2-Trichloroethane	ND	U	100000	ND	U	1000
Toluene	2050000		100000	28900		1000
2-Hexanone	ND	U	100000	ND	U	1000
Dibromochloromethane	ND	U	100000	ND	U	1000
1,2-Dibromoethane	ND	U	100000	ND	U	1000
Tetrachloroethylene	ND	U	100000	ND	U	1000
Chlorobenzene	ND	U	100000	ND	U	1000
Ethylbenzene	148000		100000	5660		1000
m- & p-Xylenes	530000		100000	19300		1000
Bromoform	ND	U	100000	ND	U	1000
Styrene	ND	U	100000	ND	U	1000
1,1,2,2-Tetrachloroethane	ND	U	100000	ND	U	1000
o-Xylene	170000		100000	7750		1000
4-Ethyltoluene	ND	U	100000	1440		1000
1,3,5-Trimethylbenzene	ND	U	100000	2010		1000
1,2,4-Trimethylbenzene	ND	U	100000	6110		1000
Benzyl Chloride	ND	U	100000	ND	U	1000
1,3-Dichlorobenzene	ND	U	100000	ND	U	1000
1,4-Dichlorobenzene	ND	U	100000	ND	U	1000
1,2-Dichlorobenzene	ND	U	100000	ND	U	1000
1,2,4-Trichlorobenzene	ND	U	100000	ND	U	1000
Hexachlorobutadiene	ND	U	100000	ND	U	1000
BFB-Surrogate Std. % Recovery	98%			103%		

J- Analyte was detected. However the analyte concentration is an estimated value, which is between the Method Detection Limit (MDL) and the Reporting Limit (RL).

U - Compound was analyzed for, but was not detected.

E - Estimated value, result outside linear range of instrument.

Sucha S. Parmar

Sucha S. Parmar, PhD
Technical Director

Atmospheric Analysis & Consulting, Inc.

Laboratory Analysis Report

CLIENT	: Jacob's Consultancy	**DATE RECEIVED**	: 07/16/2008
PROJECT NO	: 080457	**DATE REPORTED**	: 08/25/2008
MATRIX	: AIR	**SITE NAME**	LAX
UNITS	: PPB (v/v)	**STATION NAME**	Liquid_Fuel

HEADSPACE ANALYSIS (VOLATILE ORGANIC COMPOUNDS BY EPA TO-15)

Client ID	Diesel (Aircraft & GSE Maint)			Jet A (Aircraft & GSE Maint)		
AAC ID	080457-33843			080457-33844		
Date Sampled	07/16/2008			07/16/2008		
Date Analyzed	07/28/2008			07/28/2008		
QC Batch	MS03_072908			MS03_072908		
Can Dilution Factor	1.00			1.00		
	Result	Qualifier	Dil. Fac.	Result	Qualifier	Dil. Fac.
Chlorodifluoromethane	ND	U	1000	ND	U	1000
Propylene	32100		1000	ND	U	1000
Dichlorodifluoromethane	ND	U	1000	ND	U	1000
Chloromethane	ND	U	1000	ND	U	1000
1,2-Dichloro-1,1,2,2-Tetrafluoroethane	ND	U	1000	ND	U	1000
Vinyl Chloride	ND	U	1000	ND	U	1000
Methanol	5030		1000	ND	U	1000
1,3-Butadiene	ND	U	1000	ND	U	1000
Bromomethane	ND	U	1000	ND	U	1000
Chloroethane	ND	U	1000	ND	U	1000
Dichlorofluoromethane	ND	U	1000	ND	U	1000
Ethanol	3130000	E	10000	27100		1000
Vinyl Bromide	ND	U	1000	ND	U	1000
Acetone	ND	U	1000	ND	U	1000
Trichlorofluoromethane	ND	U	1000	ND	U	1000
Isopropyl Alcohol	ND	U	1000	ND	U	1000
Acrylonitrile	ND	U	1000	ND	U	1000
1,1-Dichloroethylene	ND	U	1000	ND	U	1000
Methylene Chloride	ND	U	1000	ND	U	1000
Allyl Chloride (Chloroprene)	ND	U	1000	ND	U	1000
Carbon Disulfide	ND	U	1000	ND	U	1000
1,1,2-Trichloro-1,2,2-Trifluoroethane	ND	U	1000	ND	U	1000
t-1,2-Dichloroethylene	ND	U	1000	ND	U	1000
1,1-Dichloroethane	ND	U	1000	ND	U	1000
MTBE	ND	U	1000	ND	U	1000
Vinyl Acetate	ND	U	1000	ND	U	1000
2-Butanone (MEK)	ND	U	1000	ND	U	1000
cis-1,2- Dichloroethene	ND	U	1000	ND	U	1000
Hexane	63300		10000	40000		1000
Chloroform	ND	U	1000	ND	U	1000
Ethyl Acetate	ND	U	1000	ND	U	1000
Tetrahydrofuran	ND	U	1000	ND	U	1000
1,2-Dichloroethane	ND	U	1000	ND	U	1000
1,1,1-Trichloroethane	ND	U	1000	ND	U	1000

Atmospheric Analysis & Consulting, Inc.

Laboratory Analysis Report

CLIENT	: Jacob's Consultancy	**DATE RECEIVED**	: 07/16/2008
PROJECT NO	: 080457	**DATE REPORTED**	: 08/25/2008
MATRIX	: AIR	**SITE NAME**	LAX
UNITS	: PPB (v/v)	**STATION NAME**	Liquid_Fuel

HEADSPACE ANALYSIS (VOLATILE ORGANIC COMPOUNDS BY EPA TO-15)

Client ID	Diesel (Aircraft & GSE Maint)			Jet A (Aircraft & GSE Maint)		
AAC ID	080457-33843			080457-33844		
Date Sampled	07/16/2008			07/16/2008		
Date Analyzed	07/28/2008			07/28/2008		
QC Batch	MS03_072908			MS03_072908		
Can Dilution Factor	1.00			1.00		
	Result	Qualifier	Dil. Fac.	Result	Qualifier	Dil. Fac.
Benzene	10900		1000	9050		1000
Carbon Tetrachloride	ND	U	1000	ND	U	1000
Cyclohexane	32400		1000	22300		1000
1,2-Dichloropropane	ND	U	1000	ND	U	1000
Bromodichloromethane	ND	U	1000	ND	U	1000
1,4-Dioxane	ND	U	1000	ND	U	1000
Trichloroethene	ND	U	1000	ND	U	1000
2,2,4-Trimethylpentane	8810		1000	ND	U	1000
Heptane	18300		1000	31600		1000
cis-1,3-Dichloropropene	ND	U	1000	ND	U	1000
4-Methyl-2-Pentanone (MiBK)	ND	U	1000	ND	U	1000
t-1,3-Dichloropropene	ND	U	1000	ND	U	1000
1,1,2-Trichloroethane	ND	U	1000	ND	U	1000
Toluene	28700		1000	33500		1000
2-Hexanone	ND	U	1000	ND	U	1000
Dibromochloromethane	ND	U	1000	ND	U	1000
1,2-Dibromoethane	ND	U	1000	ND	U	1000
Tetrachloroethylene	ND	U	1000	ND	U	1000
Chlorobenzene	ND	U	1000	ND	U	1000
Ethylbenzene	3220		1000	13600		1000
m- & p-Xylenes	11000		1000	37400		1000
Bromoform	ND	U	1000	ND	U	1000
Styrene	ND	U	1000	ND	U	1000
1,1,2,2-Tetrachloroethane	ND	U	1000	ND	U	1000
o-Xylene	3940		1000	18200		1000
4-Ethyltoluene	ND	U	1000	5580		1000
1,3,5-Trimethylbenzene	1000		1000	5420		1000
1,2,4-Trimethylbenzene	2890		1000	15600		1000
Benzyl Chloride	ND	U	1000	ND	U	1000
1,3-Dichlorobenzene	ND	U	1000	ND	U	1000
1,4-Dichlorobenzene	ND	U	1000	ND	U	1000
1,2-Dichlorobenzene	ND	U	1000	ND	U	1000
1,2,4-Trichlorobenzene	ND	U	1000	ND	U	1000
Hexachlorobutadiene	ND	U	1000	ND	U	1000
BFB-Surrogate Std. % Recovery	99%			116%		

J- Analyte was detected. However the analyte concentration is an estimated value, which is between the Method Detection Limit (MDL) and the Reporting Limit (RL).

U - Compound was analyzed for, but was not detected.

E - Estimated value, result outside linear range of instrument.

Sucha S. Parmar, PhD
Technical Director

Atmospheric Analysis & Consulting, Inc.

Laboratory Analysis Report

CLIENT	**: Jacob's Consultancy**	**DATE RECEIVED**	**: 07/16/2008**
PROJECT NO	**: 080457**	**DATE REPORTED**	**: 08/25/2008**
MATRIX	**: AIR**	**SITE NAME**	**LAX**
UNITS	**: ppbC**	**STATION NAME**	**Liquid_Fuel**

HEADSPACE ANALYSIS (HYDROCARBONS (C_2-C_{12}) SPECIATED)

Client ID	**Gasoline (Const/Maint Yard)**			**Diesel (Const/Maint Yard)**		
AAC ID	**080457-33841**			**080457-33842**		
Date Sampled	**07/16/2008**			**07/16/2008**		
Date Analyzed	**07/28/2008**			**07/28/2008**		
QC Batch	**MS02_072808**			**MS02_072808**		
Can Dilution Factor	**1.00**			**1.00**		
	Result	**Qualifier**	**Dil. Fac.**	**Result**	**Qualifier**	**Dil. Fac.**
ETHYLENE	370000		100000	4200		2000
ACETYLENE	<PQL	U	100000	<PQL	U	2000
ETHANE	853000		100000	323000		2000
PROPYLENE	547000		100000	6510		2000
PROPANE	1030000		100000	1130000		2000
ISOBUTANE	4750000		100000	643000		2000
1-BUTENE	973000		100000	6520		2000
n-BUTANE	57000000		100000	1110000		2000
trans-2-BUTENE	4960000		100000	16400		2000
cis-2-BUTENE	6370000		100000	20000		2000
ISOPENTANE	321000000		100000	1560000		2000
1-PENTENE	6840000		100000	23200		2000
n-PENTANE	93800000		100000	663000		2000
ISOPRENE	485000		100000	1880		2000
trans-2-PENTENE	16600000		100000	55600		2000
cis-2-PENTENE	9250000		100000	30700		2000
2,2-DIMETHYLBUTANE	4200000		100000	31300		2000
CYCLOPENTANE	10600000		100000	76800		2000
2,3-DMB	34200000		100000	128000		2000
2-METHYLPENTANE	65200000		100000	402000		2000
3-METHYLPENTANE	38000000		100000	267000		2000
1-HEXENE	1120000		100000	4040		2000
n-HEXANE	40300000		100000	357000		2000
MCPENTANE	28500000		100000	292000		2000
2,4-DMP	24000000		100000	101000		2000
BENZENE	9300000		100000	62200		2000
CYCLOHEXANE	7520000		100000	234000		2000
2-METHYLHEXANE	10200000		100000	141000		2000
2,3-DIMETHYLPENTANE	27400000		100000	170000		2000

Atmospheric Analysis & Consulting, Inc.

Laboratory Analysis Report

CLIENT : Jacob's Consultancy
PROJECT NO : 080457
MATRIX : AIR
UNITS : ppbC

DATE RECEIVED : 07/16/2008
DATE REPORTED : 08/25/2008
SITE NAME LAX
STATION NAME Liquid_Fuel

HEADSPACE ANALYSIS (HYDROCARBONS (C_2-C_{12}) SPECIATED)

Client ID	Gasoline (Const/Maint Yard)			Diesel (Const/Maint Yard)		
AAC ID	080457-33841			080457-33842		
Date Sampled	07/16/2008			07/16/2008		
Date Analyzed	07/28/2008			07/28/2008		
QC Batch	MS02_072808			MS02_072808		
Can Dilution Factor	1.00			1.00		
	Result	Qualifier	Dil. Fac.	Result	Qualifier	Dil. Fac.
3-METHYLHEXANE	10500000		100000	186000		2000
2,2,4-TRIMETHYLPENTANE	30100000		100000	172000		2000
n-HEPTANE	6100000		100000	197000		2000
METHYLCYCLOHEXANE	3400000		100000	542000		2000
2,3,4-TRIMETHYLPENTANE	5560000		100000	51000		2000
TOLUENE	21200000		100000	254000		2000
2-MHP	1330000		100000	93000		2000
3-MHP	1290000		100000	59400		2000
n-OCTANE	968000		100000	175000		2000
ETHYLBENZENE	1080000		100000	47600		2000
m/p-XYLENES	3590000		100000	110000		2000
STYRENE	<PQL	U	100000	<PQL	U	2000
o-XYLENE	1180000		100000	76100		2000
NONANE	<PQL	U	100000	50300		2000
ISOPROPYLBENZENE	<PQL	U	100000	<PQL	U	2000
n-PROPYLBENZENE	<PQL	U	100000	14000		2000
m-ETHYLTOLUENE	249000		100000	27500		2000
p-ETHYLTOLUENE	115000		100000	23000		2000
1,3,5-TRIMETHYLBENZENE	109000		100000	28000		2000
o-ETHYLTOLUENE	<PQL	U	100000	6030		2000
1,2,4-TRIMETHYLBENZENE	295000		100000	50000		2000
n-DECANE	<PQL	U	100000	30300		2000
1,2,3-TRIMETHYLBENZENE	<PQL	U	100000	9820		2000
m-DIETHYLBENZENE	<PQL	U	100000	3630		2000
p-DIETHYLBENZENE	<PQL	U	100000	13900		2000
n-UNDECANE	<PQL	U	100000	16200		2000
n-DODECANE	1700000		100000	7750		2000

U - Compound was analyzed for, but was not detected.
PQL = 1.00 ppbC x Dilution Factors

Sucha S. Parmar, PhD
Technical Director

Atmospheric Analysis & Consulting, Inc.

Laboratory Analysis Report

CLIENT : Jacob's Consultancy
PROJECT NO : 080457
MATRIX : AIR
UNITS : ppbC

DATE RECEIVED : 07/16/2008
DATE REPORTED : 08/25/2008
SITE NAME LAX
STATION NAME Liquid_Fuel

HEADSPACE ANALYSIS (HYDROCARBONS (C_2-C_{12}) SPECIATED)

Client ID	Diesel (Aircraft & GSE Maint)			Jet A (Aircraft & GSE Maint)		
AAC ID	080457-33843			080457-33844		
Date Sampled	07/16/2008			07/16/2008		
Date Analyzed	07/28/2008			07/28/2008		
QC Batch	MS02 072808			MS02 072808		
Can Dilution Factor	1.00			1.00		
	Result	Qualifier	Dil. Fac.	Result	Qualifier	Dil. Fac.
ETHYLENE	59800		2000	<PQL	U	2000
ACETYLENE	<PQL	U	2000	<PQL	U	2000
ETHANE	413000		2000	6240		2000
PROPYLENE	71900		2000	<PQL	U	2000
PROPANE	1040000		2000	32200		2000
ISOBUTANE	625000		2000	79200		2000
1-BUTENE	17600		2000	<PQL	U	2000
n-BUTANE	1650000		2000	144000		2000
trans-2-BUTENE	73900		2000	<PQL	U	2000
cis-2-BUTENE	82200		2000	<PQL	U	2000
ISOPENTANE	5350000		2000	203000		2000
1-PENTENE	76300		2000	<PQL	U	2000
n-PENTANE	1620000		2000	189000		2000
ISOPRENE	5040		2000	<PQL	U	2000
trans-2-PENTENE	172000		2000	1470		2000
cis-2-PENTENE	92700		2000	<PQL	U	2000
2,2-DIMETHYLBUTANE	116000		2000	11000		2000
CYCLOPENTANE	115000		2000	38300		2000
2,3-DMB	232000		2000	38400		2000
2-METHYLPENTANE	744000		2000	224000		2000
3-METHYLPENTANE	430000		2000	147000		2000
1-HEXENE	6470		2000	<PQL	U	2000
n-HEXANE	453000		2000	307000		2000
MCPENTANE	398000		2000	293000		2000
2,4-DMP	113000		2000	25400		2000
BENZENE	82800		2000	64700		2000
CYCLOHEXANE	264000		2000	173000		2000
2-METHYLHEXANE	146000		2000	170000		2000
2,3-DIMETHYLPENTANE	140000		2000	102000		2000

Atmospheric Analysis & Consulting, Inc.

Laboratory Analysis Report

CLIENT	: Jacob's Consultancy	DATE RECEIVED	: 07/16/2008
PROJECT NO	: 080457	DATE REPORTED	: 08/25/2008
MATRIX	: AIR	SITE NAME	LAX
UNITS	: ppbC	STATION NAME	Liquid_Fuel

HEADSPACE ANALYSIS (HYDROCARBONS (C_2-C_{12}) SPECIATED)

Client ID	Diesel (Aircraft & GSE Maint)			Jet A (Aircraft & GSE Maint)		
AAC ID	080457-33843			080457-33844		
Date Sampled	07/16/2008			07/16/2008		
Date Analyzed	07/28/2008			07/28/2008		
QC Batch	MS02_072808			MS02_072808		
Can Dilution Factor	1.00			1.00		
	Result	Qualifier	Dil. Fac.	Result	Qualifier	Dil. Fac.
3-METHYLHEXANE	184000		2000	242000		2000
2,2,4-TRIMETHYLPENTANE	78800		2000	196000		2000
n-HEPTANE	190000		2000	369000		2000
METHYLCYCLOHEXANE	549000		2000	736000		2000
2,3,4-TRIMETHYLPENTANE	24800		2000	16400		2000
TOLUENE	258000		2000	224000		2000
2-MHP	88000		2000	211000		2000
3-MHP	53200		2000	141000		2000
n-OCTANE	169000		2000	409000		2000
ETHYLBENZENE	34500		2000	158000		2000
m/p-XYLENES	69300		2000	266000		2000
STYRENE	<PQL	U	2000	<PQL	U	2000
o-XYLENE	52400		2000	170000		2000
NONANE	42500		2000	310000		2000
ISOPROPYLBENZENE	<PQL	U	2000	4470		2000
n-PROPYLBENZENE	9200		2000	111000		2000
m-ETHYLTOLUENE	15100		2000	109000		2000
p-ETHYLTOLUENE	16600		2000	95800		2000
1,3,5-TRIMETHYLBENZENE	18700		2000	109000		2000
o-ETHYLTOLUENE	7660		2000	66900		2000
1,2,4-TRIMETHYLBENZENE	28100		2000	175000		2000
n-DECANE	24100		2000	124000		2000
1,2,3-TRIMETHYLBENZENE	4740		2000	49700		2000
m-DIETHYLBENZENE	3560		2000	17700		2000
p-DIETHYLBENZENE	11600		2000	35700		2000
n-UNDECANE	3860		2000	50000		2000
n-DODECANE	7080		2000	10800		2000

U - Compound was analyzed for, but was not detected.

PQL = 1.00 ppbC x Dilution Factors

Sucha S. Parmar, PhD
Technical Director

ANALYSIS DATE : 07/29/08
ANALYST : JJG
INSTRUMENT ID : GC/MS-03
STD ID : PS060208-01

VOLATILE ORGANIC COMPOUNDS BY EPA METHOD TO-15

Continuing Calibration Verification of the 07/21/08 Calibration

Compounds	*Conc*	*Daily Conc*	*%REC*
4-BFB (surrogate standard)***	10	10.51	105
Chlorodifluoromethane*	10	9.25	93
Propylene*	10	9.93	99
DiClDIFMethane*	10	9.44	94
CHLOROMETHANE*	10	8.98	90
1,2 DiCl-1,1,2,2-TetraFEthane*	10	9.08	91
VINYL CHLORIDE*	10	8.87	89
Methanol*	10	10.05	101
1,3-Butadiene*	10	9.20	92
BROMOMETHANE*	10	8.07	81
CHLOROETHANE*	10	8.64	86
Dichlorofluoromethane*	10	9.24	92
Ethanol*	10	10.73	107
Vinyl Bromide*	10	8.77	88
Acetone*	10	9.96	100
TRICHLOROFLUOROMETHANE*	10	9.51	95
Isopropanol*	10	9.05	91
Acrylonitrile*	10	9.51	95
1,1 DICHLOROETHENE*	10	9.06	91
METHYLENE CHLORIDE*	10	8.87	89
Allyl CHLORIDE*	10	8.84	88
Carbon disulfide*	10	8.39	84
1,1,2-TRICHLORO-1,2,2-TRIFLUO	10	8.80	88
trans-1,2- DICHLOROETHYLENE*	10	9.08	91
1,1- DICHLOROETHANE*	10	8.87	89
MTBE*	10	8.94	89
Vinyl Acetate*	10	9.75	98
MEK*	10	9.72	97
cis-1,2- DICHLOROETHYLENE*	10	8.95	90
Hexane*	10	8.81	88
CHLOROFORM*	10	9.27	93
Ethyl Acetate*	10	9.10	91
Tetrahydrofuran*	10	8.95	90
1,2-DICHLOROETHANE*	10	9.95	100
1,1,1-TRICHLOROETHANE*	10	9.55	96

Atmospheric Analysis & Consulting, Inc.

ANALYSIS DATE : 07/29/08
ANALYST : JJG
INSTRUMENT ID : GC/MS-03
STD ID : PS060208-01

VOLATILE ORGANIC COMPOUNDS BY EPA METHOD TO-15

Continuing Calibration Verification of the 07/21/08 Calibration

Compounds	Conc	Daily Conc	%REC
BENZENE**	10	9.07	91
CARBON TETRACHLORIDE**	10	10.12	101
Cyclohexane**	10	9.05	91
1,2-DICHLOROPROPANE**	10	9.31	93
Bromodichloromethane**	10	9.92	99
1,4-Dioxane**	10	9.13	91
TRICHLOROETHENE**	10	9.46	95
2,2,4-Trimethylpentane**	10	10.13	101
Heptane**	10	9.57	96
cis- 1,3 DICHLOROPROPENE**	10	9.57	96
MiBK**	10	9.38	94
trans 1,3 DICHLOROPROPENE**	10	10.09	101
1,1,2-TRICHLOROETHANE**	10	9.41	94
TOLUENE**	10	9.34	93
2-Hexanone**	10	9.66	97
Dibromochloromethane**	10	9.94	99
1,2 DIBROMOETHANE**	10	9.75	98
TETRACHLOROETHYLENE**	10	9.56	96
CHLOROBENZENE***	10	9.31	93
ETHYLBENZENE***	10	9.44	94
m-, & p- XYLENES***	20	19.12	96
Bromoform***	10	9.87	99
STYRENE***	10	9.78	98
1,1, 2,2- TETRACHLORETHANE*	10	9.24	92
o- XYLENE***	10	9.58	96
Ethyltoluene***	10	9.87	99
1,3,5- TRIMETHYLBENZENE***	10	9.80	98
1,2,4- TRIMETHYLBENZENE***	10	9.76	98
Benzyl Chloride***	10	10.35	104
1,3- DICHLOROBENZENE***	10	9.99	100
1,4- DICHLOROBENZENE***	10	9.74	97
1,2-DICHLOROBENZENE***	10	9.98	100
1,2,4-TRICHLOROBENZENE***	10	8.83	88
HEXACHLOROBUTADIENE***	10	9.87	99

* Internal std calculation IS1 : Bromochloromethane
** Internal std calculation IS2 : 1,4-Difluorobenzene
*** Internal std calculation IS3 : Chlorobenzene-d5
%REC should be 70-130%

Sucha S Parmar
Sucha S. Parmar, PhD
Technical Director

Atmospheric Analysis & Consulting, Inc.

Quality Control/Quality Assurance Report

CLIENT ID : Laboratory Control Spike
AAC ID : LCS/LCSD
MEDIA : Air
DATE ANALYZED : 07/29/08
DATE REPORTED : 07/29/08
UNITS : ppbv

TO-15 Laboratory Control Spike Recovery

Compound	Sample Conc.	Spike Added	Spike Res	Dup Spike Res	Spike % Rec *	Spike Dup % Rec *	RPD** %
1,1-DICHLOROETHYLENE	0.0	10.00	9.06	9.19	91	92	1.4
METHYLENE CHLORIDE	0.0	10.00	8.87	9.01	89	90	1.6
BENZENE	0.0	10.00	9.07	9.13	91	91	0.7
TRICHLOROETHENE	0.0	10.00	9.46	9.50	95	95	0.4
TOLUENE	0.0	10.00	9.34	9.42	93	94	0.9
TETRACHLOROETHYLENE	0.0	10.00	9.56	9.62	96	96	0.6
CHLOROBENZENE	0.0	10.00	9.31	9.46	93	95	1.6
ETHYLBENZENE	0.0	10.00	9.44	9.54	94	95	1.1
m-, & p- XYLENES	0.0	20.00	19.12	19.18	96	96	0.3
o- XYLENE	0.0	10.00	9.58	9.62	96	96	0.4

* Must be 70-130%

** Must be < 25%

Sucha S. Parmar, PhD
Technical Director

Atmospheric Analysis & Consulting, Inc.

Method Blank Analysis Report

MATRIX : AIR **ANALYSIS DATE** : 07/29/08
UNITS : ppbv **REPORT DATE** : 07/29/08

VOLATILE ORGANIC COMPOUNDS BY EPA TO-15

Client ID	Method Blank	RL
AAC ID	MB 072908	
Chlorodifluoromethane*	<MDL	0.20
Propylene*	<MDL	0.20
DiClDIFMethane*	<MDL	0.20
CHLOROMETHANE*	<MDL	0.20
1,2 DiCl-1,1,2,2-TetraFEthane*	<MDL	0.20
VINYL CHLORIDE*	<MDL	0.20
Methanol*	<MDL	0.50
1,3-Butadiene*	<MDL	0.20
BROMOMETHANE*	<MDL	0.20
CHLOROETHANE*	<MDL	0.20
Dichlorofluoromethane	<MDL	0.20
Ethanol*	<MDL	0.20
Vinyl Bromide*	<MDL	0.20
Acetone*	<MDL	0.20
TRICHLOROFLUOROMETHANE*	<MDL	0.20
Isopropyl Alcohol*	<MDL	0.20
Acrylonitrile*	<MDL	0.20
1,1 DICHLOROETHENE*	<MDL	0.20
METHYLENE CHLORIDE*	<MDL	0.20
Allyl CHLORIDE*	<MDL	0.20
Carbon disulfide*	<MDL	0.20
1,1,2-TRICHLORO-1,2,2-TRIFLUOROETHANE*	<MDL	0.20
trans-1,2- DICHLOROETHYLENE*	<MDL	0.20
1,1- DICHLOROETHANE*	<MDL	0.20
MTBE*	<MDL	0.20
Vinyl Acetate*	<MDL	0.40
MEK*	<MDL	0.20
cis-1,2- DICHLOROETHYLENE*	<MDL	0.20
Hexane*	<MDL	0.20
CHLOROFORM*	<MDL	0.20
Ethyl Acetate*	<MDL	0.20
Tetrahydrofuran*	<MDL	0.20
1,2-DICHLOROETHANE*	<MDL	0.20
1,1,1-TRICHLOROETHANE*	<MDL	0.20
BENZENE**	<MDL	0.20
CARBON TETRACHLORIDE**	<MDL	0.20
Cyclohexane**	<MDL	0.20
1,2-DICHLOROPROPANE**	<MDL	0.20
Bromodichloromethane**	<MDL	0.20
1,4-Dioxane**	<MDL	0.20
TRICHLOROETHENE**	<MDL	0.20
2,2,4-Trimethylpentane**	<MDL	0.20
Heptane**	<MDL	0.20

Atmospheric Analysis & Consulting, Inc.

Method Blank Analysis Report

MATRIX : AIR
UNITS : ppbv
ANALYSIS DATE : 07/29/08
REPORT DATE : 07/29/08

VOLATILE ORGANIC COMPOUNDS BY EPA TO-15

Client ID	Method Blank	RL
AAC ID	MB 072908	
cis- 1,3 DICHLOROPROPENE**	<MDL	0.20
MiBK**	<MDL	0.20
trans 1,3 DICHLOROPROPENE**	<MDL	0.20
1,1,2-TRICHLOROETHANE**	<MDL	0.20
TOLUENE**	<MDL	0.20
2-Hexanone**	<MDL	0.20
Dibromochloromethane**	<MDL	0.20
1,2 DIBROMOETHANE**	<MDL	0.20
TETRACHLOROETHYLENE**	<MDL	0.20
CHLOROBENZENE***	<MDL	0.20
ETHYLBENZENE***	<MDL	0.20
m-, & p- XYLENES***	<MDL	0.40
Bromoform***	<MDL	0.20
STYRENE***	<MDL	0.20
1,1, 2,2- TETRACHLORETHANE***	<MDL	0.20
o- XYLENE***	<MDL	0.20
Ethyltoluene***	<MDL	0.20
1,3,5- TRIMETHYLBENZENE***	<MDL	0.20
1,2,4- TRIMETHYLBENZENE***	<MDL	0.20
Benzyl Chloride***	<MDL	0.20
1,3- DICHLOROBENZENE***	<MDL	0.20
1,4- DICHLOROBENZENE***	<MDL	0.20
1,2-DICHLOROBENZENE***	<MDL	0.20
1,2,4 TRICHLOROBENZENE***	<MDL	0.20
HEXACHLOROBUTADIENE***	<MDL	0.20
System Monitoring Compounds		
BFB-Surrogate Std. % Recovery	99%	--

Sucha S. Parmar, PhD
Technical Director

Atmospheric Analysis & Consulting, Inc.

Quality Control/Quality Assurance Report

AAC ID : 080457-33841
MATRIX : Air
DATE ANALYZED : 07/29/08
DATE REPORTED : 07/29/08
UNITS : ppbv

TO-15 Duplicate Analysis

Compound	Sample Conc	Duplicate Conc	% RPD
Chlorodifluoromethane*	<MDL	<MDL	0.0
Propylene*	<MDL	<MDL	0.0
DiClDIFMethane*	<MDL	<MDL	0.0
CHLOROMETHANE*	<MDL	<MDL	0.0
1,2 DiCl-1,1,2,2-TetraFEthane*	<MDL	<MDL	0.0
VINYL CHLORIDE*	<MDL	<MDL	0.0
Methanol*	<MDL	<MDL	0.0
1,3-Butadiene*	<MDL	<MDL	0.0
BROMOMETHANE*	<MDL	<MDL	0.0
CHLOROETHANE*	<MDL	<MDL	0.0
Dichlorofluoromethane	<MDL	<MDL	0.0
Ethanol*	48300000	48500000	0.4
Vinyl Bromide*	<MDL	<MDL	0.0
Acetone*	<MDL	<MDL	0.0
TRICHLOROFLUOROMETHANE*	<MDL	<MDL	0.0
Isopropyl Alcohol*	<MDL	<MDL	0.0
Acrylonitrile*	<MDL	<MDL	0.0
1,1 DICHLOROETHENE*	<MDL	<MDL	0.0
METHYLENE CHLORIDE*	<MDL	<MDL	0.0
Allyl CHLORIDE*	<MDL	<MDL	0.0
Carbon disulfide*	<MDL	<MDL	0.0
1,1,2-TRICHLORO-1,2,2-TRIFLUOROETHANE*	<MDL	<MDL	0.0
trans-1,2- DICHLOROETHYLENE*	<MDL	<MDL	0.0
1,1- DICHLOROETHANE*	<MDL	<MDL	0.0
MTBE*	<MDL	<MDL	0.0
Vinyl Acetate*	<MDL	<MDL	0.0
MEK*	<MDL	<MDL	0.0
cis-1,2- DICHLOROETHYLENE*	<MDL	<MDL	0.0
Hexane*	5800000	5800000	0.0
CHLOROFORM*	<MDL	<MDL	0.0
Ethyl Acetate*	<MDL	<MDL	0.0
Tetrahydrofuran*	<MDL	<MDL	0.0
1,2-DICHLOROETHANE*	<MDL	<MDL	0.0
1,1,1-TRICHLOROETHANE*	<MDL	<MDL	0.0
BENZENE**	1310000	1300000	0.8
CARBON TETRACHLORIDE**	<MDL	<MDL	0.0

Atmospheric Analysis & Consulting, Inc.

Quality Control/Quality Assurance Report

AAC ID	**: 080457-33841**	**DATE ANALYZED**	**: 07/29/08**
MATRIX	**: Air**	**DATE REPORTED**	**: 07/29/08**
		UNITS	**: ppbv**

TO-15 Duplicate Analysis

Compound	Sample Conc	Duplicate Conc	% RPD
Cyclohexane**	1050000	1020000	2.9
1,2-DICHLOROPROPANE**	<MDL	<MDL	0.0
Bromodichloromethane**	<MDL	<MDL	0.0
1,4-Dioxane**	<MDL	<MDL	0.0
TRICHLOROETHENE**	<MDL	<MDL	0.0
2,2,4-Trimethylpentane**	3280000	3290000	0.3
Heptane**	<MDL	<MDL	0.0
cis- 1,3 DICHLOROPROPENE**	<MDL	<MDL	0.0
MiBK**	<MDL	<MDL	0.0
trans 1,3 DICHLOROPROPENE**	<MDL	<MDL	0.0
1,1,2-TRICHLOROETHANE**	<MDL	<MDL	0.0
TOLUENE**	2230000	2220000	0.4
2-Hexanone**	<MDL	<MDL	0.0
Dibromochloromethane**	<MDL	<MDL	0.0
1,2 DIBROMOETHANE**	<MDL	<MDL	0.0
TETRACHLOROETHYLENE**	<MDL	<MDL	0.0
CHLOROBENZENE***	<MDL	<MDL	0.0
ETHYLBENZENE***	<MDL	<MDL	0.0
m-, & p- XYLENES***	<MDL	<MDL	0.0
Bromoform***	<MDL	<MDL	0.0
STYRENE***	<MDL	<MDL	0.0
1,1,2,2-TETRACHLORETHANE***	<MDL	<MDL	0.0
o- XYLENE***	<MDL	<MDL	0.0
Ethyltoluene***	<MDL	<MDL	0.0
1,3,5- TRIMETHYLBENZENE***	<MDL	<MDL	0.0
1,2,4- TRIMETHYLBENZENE***	<MDL	<MDL	0.0
Benzyl Chloride***	<MDL	<MDL	0.0
1,3- DICHLOROBENZENE***	<MDL	<MDL	0.0
1,4- DICHLOROBENZENE***	<MDL	<MDL	0.0
1,2-DICHLOROBENZENE***	<MDL	<MDL	0.0
1,2,4 TRICHLOROBENZENE***	<MDL	<MDL	0.0
Hexachlorobutadiene***	<MDL	<MDL	0.0
System Monitoring Compounds			
BFB-Surrogate Std. % Recovery	98%	98%	0.1

Sucha S. Parmar, PhD
Technical Director

Atmospheric Analysis & Consulting, Inc.

ANALYSIS DATE : 07/28/08
ANALYST : JJG

INSTRUMENT ID : MS-02
STD ID : SS0234

PAMS AS Propane and Benzene
Continuing Calibration Verification

Compounds	xCF	daily CF	%RPD+
Propane	294	300	1.9
Benzene	251	254	1.3

+ %RPD must be ≤ 10%

Sucha S Parmar

Sucha S. Parmar, PhD
Technical Director

Quality Control/Quality Assurance Report

CLIENT ID : Laboratory Control Spike
AAC ID : LCS/LCSD
MEDIA : Air
DATE ANALYZED : 07/28/08
DATE REPORTED : 07/28/08
UNITS : ppbC

PAMS Laboratory Control Spike Recovery

Compound	Sample Conc.	Spike Added	Spike Res	Dup Spike Res	Spike % Rec *	Spike Dup % Rec *	RPD** %
Propane	0.0	17.40	17.74	17.50	102	101	1.4
Benzene	0.0	35.00	35.32	35.47	101	101	0.4

* Must be 75-125%

** Must be < 25%

Sucha S. Parmar, PhD
Technical Director

AAC

Atmospheric Analysis & Consulting, Inc.

Method Blank Analysis Report

MATRIX : AIR
UNITS : ppbC
ANALYSIS DATE : 07/28/08
REPORT DATE : 07/28/08

PAMS by FID

Client ID	Method Blank	RL
AAC ID	PAMS Blank	
Dilution Factor	1.0	
ETHYLENE	<PQL	1.0
ACETYLENE	<PQL	1.0
ETHANE	<PQL	1.0
PROPYLENE	<PQL	1.0
PROPANE	<PQL	1.0
ISOBUTANE	<PQL	1.0
1-BUTENE	<PQL	1.0
n-BUTANE	<PQL	1.0
trans-2-BUTENE	<PQL	1.0
cis-2-BUTENE	<PQL	1.0
ISOPENTANE	<PQL	1.0
1-PENTENE	<PQL	1.0
n-PENTANE	<PQL	1.0
ISOPRENE	<PQL	1.0
trans-2-PENTENE	<PQL	1.0
cis-2-PENTENE	<PQL	1.0
2,2-DIMETHYLBUTANE	<PQL	1.0
CYCLOPENTANE	<PQL	1.0
2,3-DMB	<PQL	1.0
2-METHYLPENTANE	<PQL	1.0
3-METHYLPENTANE	<PQL	1.0
1-HEXENE	<PQL	1.0
n-HEXANE	<PQL	1.0
METHYLCYCLOPENTANE	<PQL	1.0
2,4-DMP	<PQL	1.0
BENZENE	<PQL	1.0
CYCLOHEXANE	<PQL	1.0
2-METHYLHEXANE	<PQL	1.0
2,3-DIMETHYLPENTANE	<PQL	1.0
3-METHYLHEXANE	<PQL	1.0
2,2,4-TRIMETHYLPENTA	<PQL	1.0
n-HEPTANE	<PQL	1.0
METHYLCYCLOHEXANE	<PQL	1.0
2,3,4-TRIMETHYLPENTANE	<PQL	1.0
TOLUENE	<PQL	1.0
2-METHYLHEPTANE	<PQL	1.0
3-METHYLHEPTANE	<PQL	1.0
n-OCTANE	<PQL	1.0
ETHYLBENZENE	<PQL	1.0
m/p-XYLENES	<PQL	1.0
STYRENE	<PQL	1.0
o-XYLENE	<PQL	1.0
n-NONANE	<PQL	1.0

Atmospheric Analysis & Consulting, Inc.

Method Blank Analysis Report

MATRIX : AIR
UNITS : ppbC

ANALYSIS DATE : 07/28/08
REPORT DATE : 07/28/08

PAMS by FID

Client ID	Method Blank	RL
AAC ID	PAMS Blank	
Dilution Factor	1.0	
ISOPROPYLBENZENE	<PQL	1.0
n-PROPYLBENZENE	<PQL	1.0
m-ETHYLTOLUENE	<PQL	1.0
p-ETHYLTOLUENE	<PQL	1.0
1,3,5-TRIMETHYLBENZE	<PQL	1.0
o-ETHYLTOLUENE	<PQL	1.0
1,2,4-TMB	<PQL	1.0
n-DECANE	<PQL	1.0
1,2,3-TRIMETHYLBENZE	<PQL	1.0
m-DIETHYLBENZENE	<PQL	1.0
p-DIETHYLBENZENE	<PQL	1.0
n-U<PQLECANE	<PQL	1.0
n-DODECANE	<PQL	1.0

Sucha S. Parmar, PhD
Technical Director

Quality Control/Quality Assurance Report

AAC ID : 080457-33841
MATRIX : Air

DATE ANALYZED : 07/28/08
DATE REPORTED : 07/28/08
UNITS : ppbC

PAMS Duplicate Analysis

Compound	Sample Conc	Duplicate Conc	% RPD
ETHYLENE	370000	370000	0.0
ACETYLENE	<PQL	<PQL	0.0
ETHANE	853000	854000	0.1
PROPYLENE	547000	547000	0.0
PROPANE	1030000	1020000	1.0
ISOBUTANE	4750000	4730000	0.4
1-BUTENE	973000	964000	0.9
n-BUTANE	57000000	56500000	0.9
trans-2-BUTENE	4960000	4920000	0.8
cis-2-BUTENE	6370000	6330000	0.6
ISOPENTANE	321000000	324000000	0.9
1-PENTENE	6840000	6830000	0.1
n-PENTANE	93800000	93600000	0.2
ISOPRENE	485000	486000	0.2
trans-2-PENTENE	16600000	16500000	0.6
cis-2-PENTENE	9250000	9150000	1.1
2,2-DIMETHYLBUTANE	4200000	4180000	0.5
CYCLOPENTANE	10600000	10400000	1.9
2,3-DMB	34200000	34000000	0.6
2-METHYLPENTANE	65200000	64800000	0.6
3-METHYLPENTANE	38000000	38300000	0.8
1-HEXENE	1120000	1080000	3.6
n-HEXANE	40300000	40300000	0.0
MCPENTANE	28500000	28500000	0.0
2,4-DMP	24000000	23900000	0.4
BENZENE	9300000	9230000	0.8
CYCLOHEXANE	7520000	7500000	0.3
2-METHYLHEXANE	10200000	10200000	0.0
2,3-DIMETHYLPENTANE	27400000	27300000	0.4
3-METHYLHEXANE	10500000	10500000	0.0
2,2,4-TRIMETHYLPENTANE	30100000	30000000	0.3
n-HEPTANE	6100000	6080000	0.3
METHYLCYCLOHEXANE	3400000	3380000	0.6
2,3,4-TRIMETHYLPENTANE	5560000	5560000	0.0
TOLUENE	21200000	21200000	0.0
2-MHP	1330000	1340000	0.7

Atmospheric Analysis & Consulting, Inc.

Quality Control/Quality Assurance Report

AAC ID : 080457-33841
MATRIX : Air

DATE ANALYZED : 07/28/08
DATE REPORTED : 07/28/08
UNITS : ppbC

PAMS Duplicate Analysis

Compound	Sample Conc	Duplicate Conc	% RPD
3-MHP	1290000	1260000	2.4
n-OCTANE	968000	963000	0.5
ETHYLBENZENE	1080000	1090000	0.9
m/p-XYLENES	3590000	3650000	1.7
STYRENE	<PQL	<PQL	0.0
o-XYLENE	1180000	1200000	1.7
NONANE	<PQL	<PQL	0.0
ISOPROPYLBENZENE	<PQL	<PQL	0.0
n-PROPYLBENZENE	<PQL	<PQL	0.0
m-ETHYLTOLUENE	249000	255000	2.4
p-ETHYLTOLUENE	115000	119000	3.4
1,3,5-TRIMETHYLBENZE	109000	106000	2.8
o-ETHYLTOLUENE	<PQL	<PQL	0.0
1,2,4-TRIMETHYLBENZENE	295000	297000	0.7
n-DECANE	<PQL	<PQL	0.0
1,2,3-TRIMETHYLBENZE	<PQL	<PQL	0.0
m-DIETHYLBENZENE	<PQL	<PQL	0.0
p-DIETHYLBENZENE	<PQL	<PQL	0.0
n-UNDECANE	<PQL	<PQL	0.0
n-DODECANE	1700000	1690000	0.6

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Module F — On-Airport Inventory

Emissions Inventory of Airport Sources within the Airport Boundary (Task 5)

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EXECUTIVE SUMMARY

The purpose of this task was to develop an inventory of emissions sources within the property boundary of Los Angeles International Airport (the Airport or LAX) as part of the Air Quality and Source Apportionment Study (AQSAS) Technology and Methodology Feasibility Demonstration Project ("Demonstration Project"). This emission inventory, together with other data, will facilitate dispersion modeling analysis in the Demonstration Project. This task included:

- Developing an inventory of emissions sources within the Airport boundary.
- Developing an inventory of criteria pollutants emitted by sources on Airport property.
- Spatially locating each of the emission sources on Airport property.
- Temporally locating the criteria pollutant emissions from sources on Airport property.
- Providing an inventory of spatially and temporally allocated emissions for use in the dispersion modeling analysis being performed for the Demonstration Project.

The emission sources inventoried include aircraft, auxiliary power units (APUs), ground support equipment (GSE), Airport-related roadways, Airport-related parking facilities, and stationary sources. The pollutants inventoried include U. S. Environmental Protection Agency (EPA) criteria pollutants and ozone precursors, including: volatile organic compounds (VOC), nitrogen oxides (NO_x), carbon monoxide (CO), sulfur oxides (SO_x), non-methane hydrocarbons (NMHC), total hydrocarbons (THC), particulate matter with an aerodynamic diameter of 10 micrometers or less (PM_{10}), and particulate matter with an aerodynamic diameter of 2.5 micrometers or less ($PM_{2.5}$). The Federal Aviation Administration's (FAA) Emissions and Dispersion Modeling System (EDMS), Version 5.0.2, [FAA, 2007] and its internal databases were used to estimate the level of these pollutants.

This inventory was developed to estimate emissions expected to occur at LAX during the Demonstration Project's monitoring period—June through August, 2008. Since this emission inventory was prepared prior to the monitoring period, it was based on projected activity levels at the Airport, most often represented by activities for the same period in 2007.

Aircraft emissions generally represent the largest portion of emissions from any one source group of on-Airport sources. EDMS inputs for aircraft include a schedule of operations, aircraft fleet mix, aircraft engine type, aircraft runway and gate assignments, and generalized aircraft taxi routings. A schedule of aircraft operations was developed using data from the LAX noise monitoring system. The noise monitoring system includes data on aircraft operations of commercial, cargo, and general aviation operators; and operational details such as airline, aircraft type, operation type (i.e. arrival/departure), date and time of operation, and runway.

Allocating aircraft emissions to the appropriate sources around the airfield was done within the EDMS model. Aircraft ground sources include runways, terminal aprons, and taxiways. For this study, the simulated schedule was used to spatially distribute flight operations among the runways.

APUs are small jet engines that provide limited power to an aircraft while its main engines are shut down. APU emissions are typically generated at terminal aprons as the product of emission factors and operating time. An Airport-wide average time-in-mode was used for all APU emissions.

All ground service operations are accounted for in the GSE source group. A complete GSE inventory survey from October, 2006 was provided by LAWA that included fuel type, model year, horsepower, and manufacturer and was the basis for an EDMS inventory of GSE. Total hours of operation for each piece of GSE were estimated using the default "annual hours of operation" provided by EDMS. The default "annual hours of operation" was then linearly scaled from a 12-month estimate to a 3-month estimate in order to account for the study period of the Demonstration Project.

Three categories of roadways were modeled in this study: (1) Central Terminal Area (CTA) roadways, (2) local roadways, and (3) service roads. The California Air Resources Board emissions model—EMFAC 2007--was used to estimate speed-dependent emission factors for each roadway inside the Airport boundary, in order to best estimate Los Angeles County-specific motor vehicle operating characteristics (e.g. fleet mix, and operating temperatures). CTA roadway volumes were estimated from traffic counters that are permanently positioned in the inbound and outbound connector ramps for the CTA roadways. Local and service roadway volumes were estimated using traffic data from numerous sources including the LAWA Transportation Planning Department, California Department of Transportation, and traffic data collected in June 2008 specifically for this study.

A total of 12 parking facilities were included in the inventory, consisting of seven public LAWA-owned parking garages in the CTA, two public LAWA-owned surface lots, one LAWA-owned employee surface lot, one public off-airport parking surface lot, and one trucking depot lot that is located east of Runway 25R.

The stationary sources that were included in the inventory included 32 stationary internal combustion engines, four portable internal combustion engines, two turbines, and 30 boilers. The turbines and many of the boilers are part of LAX's Central Utility Plant. In addition, the Central Utility Plant's four cooling towers were included in this inventory.

Ultimately an emission inventory of all LAWA-owned sources within the Airport boundary was produced and can be seen in Section 8.2, Table 8. This inventory of sources, pollutants, spatial allocations, and temporal allocations was provided to the Dispersion Modeling Team for use in Task 8 of this Demonstration Project.

SECTION 1

INTRODUCTION

The purpose of this task is to develop an inventory of emissions sources within the property boundary of Los Angeles International Airport (the Airport or LAX) to provide an estimation of emission sources that may materially affect the air quality monitoring undertaken as part of the Air Quality and Source Apportionment Study (AQSAS). This emission inventory, together with other data, will facilitate dispersion modeling analysis in the Demonstration Project.

Emission inventories are quantities of air pollutants emitted over a given time period and provide information about pollutant contributions from various sources. Emissions are estimated by multiplying emission factors by source activity levels. Emission factors are indicators of the emissions from a single source for a unit of time or distance (e.g., a single motor vehicle traveling one mile). The source activity for such a factor would be the number of vehicle miles traveled in a given time period, such as the Demonstration Project study period of June through August, 2008.

This task included:

- Developing an inventory of emissions sources on Airport property.
- Developing an inventory of criteria pollutants emitted by sources on Airport property.
- Spatially locating each of the emission sources on Airport property.
- Temporally locating the criteria pollutant emissions from sources on Airport property.
- Providing an inventory of spatially and temporally allocated emissions for use in the dispersion modeling analysis being performed for the Demonstration Project.

The emission sources inventoried include aircraft, APUs, GSE, Airport-related roadways, Airport-related parking facilities, and stationary sources. The pollutants inventoried include U.S. EPA criteria pollutants and ozone precursors, including: VOC, NO_x, CO, SO_x, NMHC, THC, PM_{10}, and $PM_{2.5}$. The FAA's EDMS, Version 5.0.2, [FAA, 2007] and its internal databases were used to estimate the level of these pollutants.

Emissions for the three month period June through August, 2008 were estimated from all sources of air pollutants at the Airport. This three month period was chosen to coincide with the schedule of the emissions monitoring and sampling task of the Demonstration Project (Task 6).

This report has been structured in a way such that the emissions calculation, spatial allocation, and temporal distribution methodologies and assumptions are discussed for every major source group of Airport-related emissions. These characteristics have been carefully selected because they have the best opportunity to influence the Airport-related pollutant concentrations measured at the Task 6 monitoring sites.

1.1 Emission Calculation Methodology

The emissions inventory described in this report was developed for airport-related sources at LAX using the FAA's EDMS program. EDMS emission factors were used for aircraft, APUs, and GSE. EDMS served as a platform to spatially allocate emissions from mobile sources whose emission factors were determined using EMFAC2007 for on-road motor vehicles. The FAA requires the use of EDMS when assessing aviation emission sources at airports [FAA, 1998a] and is recognized by the U.S. EPA [U.S. EPA, 2005a].

FAA developed EDMS in the mid-1980s in cooperation with the United States Air Force. The model has become increasingly sophisticated over time and provides users with the ability to conduct emission inventories and dispersion analysis for all of the major emission sources in the airport environment. EDMS develops time- and location-varying emissions from aircraft engines, APUs, GSE, ground access vehicles, training fires, and stationary sources such as generators, commercial kitchens, cooling towers, boilers, and bulk liquid storage tanks. EDMS incorporates specific details on types of aircraft and typical aircraft schedules for taxi, take-off, and landing to develop a robust temporal and spatial representation of airport emissions.

Every major source group of Airport-related emissions was inventoried within the EDMS program. EDMS has within it a database of emission factors for pollutant sources found at airports. There are specific factors for all pollutants tracked by the program, including VOC, NO_x, CO, SO_2, PM_{10}, and $PM_{2.5}$. These emission factors are in units of mass per unit of time or distance (e.g., grams/second, or grams/mile). The EDMS database of emission factors is sufficiently thorough to account for the differences in emissions from fuel type, fuel burn, engine power load, manufacture year, and manufacturer, among many other characteristics.

These emission factors are used by EDMS to calculate a total estimated emission inventory for a specified time period, by multiplying the emission factor for the particular source, by the time, distance, or number of events input by the user, resulting in an estimated total emissions for each source group and ultimately total estimated emissions for the study period.

Airport specific information such as latitude and longitude coordinates of the official Airport Reference Point (ARP), and elevation of the ARP above sea-level are provided within the EDMS structure. All other airport-specific information must be estimated and input to the program.

This inventory was developed to estimate emissions expected to occur at LAX during the Demonstration Project's monitoring period—June through August, 2008. Since this emission inventory was prepared prior to the monitoring period, it was based on projected activity levels at LAX, most often represented by activities for the same period in 2007.

1.2 Spatial Allocation

All emission sources were spatially located in order to ensure the accuracy of the dispersion of the emissions plume into the communities identified in the Technical Work Plan (TWP) for the AQSAS. This spatial allocation is also a fundamental aspect of linking the monitoring results to the emission sources. Source locations were determined using a high resolution, geo-referenced, orthorectified aerial photograph of the Airport Property as defined by the TWP. Source locations were generally specified within 10 feet of their location shown in the aerial photograph. Figure 1 shows the Airport boundary that was considered in this analysis[1].

Depending on the source category (e.g., gate, taxiway, or roadway), EDMS constructs a point, area, or volume source for use in dispersion modeling. Point sources are used to model stacks from boilers and fuel storage facilities. Area sources are used to model emissions from gates (i.e., aircraft at startup, GSE operations, and APU activity), aircraft taxiing, aircraft queuing, aircraft accelerating on the runway, and aircraft in climb-out and approach modes. Volume sources are used to model any source that has an area and height element. Volume sources were only used for the Sepulveda Tunnel Sources (see Section 5.2) in the dispersion analysis of Task 8.

---

[1] Figure 1 does not depict the official boundary of Airport property.

Figure 1

AIRPORT BOUNDARY USED FOR ON-AIRPORT INVENTORY

Los Angeles International Airport

1.3 Temporal Allocation

In order to allocate the inventoried pollutants in time (i.e., quarter hourly, daily, monthly, and yearly), temporal variations in airport-related activity were converted into operational profiles understood by EDMS. These profiles (also known as temporal factors) provide EDMS with a method to realistically distribute activity levels throughout the day, week, or month. Operational profiles are used throughout the EDMS program to account for fluctuations in emissions from all sources. Each source group has a temporal distribution methodology that is unique to that source group; these methodologies are described throughout this report.

1.4 Limitations and Potential Improvements

Although great care was taken to represent the most accurate information possible, limitations in time and data required the Study Team to make a number of assumptions to complete the emission inventory. All recommended improvements to the On-Airport inventory (Task 5) for the Long Term Study are stated within this report and will be addressed in the Long Term Study.

Limitations of this inventory include cases where EDMS default parameters were used in lieu of airport- or equipment-specific data. Efforts will be made during the Long Term Study to acquire missing data, but data for tenant-owned equipment is neither under the control of LAWA nor the Study Team.

The pollutants included in the emissions inventory module of EDMS Version 5.0.2 are CO, THC, NMHC, VOC, NO_x, SO_x, PM_{10} and $PM_{2.5}$. Other pollutants such as hazardous air pollutants (HAPs) are not included in EDMS Version 5.0.2. EDMS version 5.1, released in September 2008, does include emission factors for HAPs, and will be used for the emission inventories of the Long Term Study.

SECTION 2

AIRCRAFT OPERATIONS

2.1 Introduction

Aircraft emissions represent the largest portion of emissions from any one source group of on-Airport sources for all pollutants except carbon monoxide (CO). For six of the eight pollutants that are estimated by EDMS, aircraft emissions contribute more than 50% of the total emissions from Airport sources. Therefore, a reliable assessment of the emissions from aircraft operations is essential for this analysis to meet the needs and objectives of the Demonstration Project.

To estimate emissions from aircraft sources, a series of model inputs are needed. These inputs include aircraft fleet mix, aircraft engine type, aircraft runway and gate assignments, and generalized aircraft taxi routings. As mentioned in Section 1, temporal distributions of aircraft operations are also essential input data.

EDMS portrays aircraft operations in six modes of operation; taxi-out, takeoff, climb-out, approach, landing roll, and taxi-in. The modes "taxi-out" and "taxi-in" have identical emission factors, and any time spent idling is calculated using the same emission factors. These modes combined are often referred to as the "taxi/idle" mode. EDMS distributes aircraft emissions along runways, taxiways, gates, and the flight tracks that aircraft follow into and out of the airspace around the airport.

As with all other source groups in this model, all assumptions about aircraft operations during the study period were based on operations from June, July, and August 2007 ("summer 2007").

2.2 Emission Calculation Methodology

Aircraft emissions are calculated using the factors specific to aircraft and engine type combinations, multiplied by the time spent in each of the operation modes. For takeoff, climb-out, approach and landing roll EDMS defaults were used for the time spent in each mode. Arrival taxiing (taxi-in), departure taxiing (taxi-out), and apron/taxiway idling (idle) times-in-mode are simulated by the Delay and Sequence Model within EDMS.

The Delay and Sequence Model simulates each aircraft's ground movements using the operations schedule and the overall capacity of the Airport and estimates the time it takes for each individual aircraft to taxi from terminal aprons to runway endpoints. This Model adds idle time-in-mode to taxi time-in-mode by aggregating all delays along the taxipath, including delay time at gates, on taxiways, and runways. The Delay and Sequence Model also includes a very rudimentary queuing algorithm that assesses departure queuing delays. This algorithm takes as inputs the estimated hourly capacities of an airport's runway system, runway use configurations, weather conditions of interest and the temporal distribution of aircraft operations from the user-specified "flight schedule". The algorithm produces rough estimates of departure delays attributable to each runway departure end. EDMS is currently not able to account for delays that are unrelated to departure queues (e.g., runway crossing delays, taxiing delays, gate-area delays). Further, the Delay and Sequence Model does not enable convenient comparisons against documented delay data, such as FAA's Aviation System Performance Metrics (ASPM) database.

Airport Capacity

As noted above, EDMS takes the capacity of runway use configurations as inputs to the Delay and Sequence Model. In this modeling effort, two runway use configurations and two weather conditions were considered in the development of runway capacities for LAX. LAX typically operates in west flow, with arrivals using Runways 24R and 25L and departures using Runways 24L and 25R. During periods of high offshore winds, which occur rarely, LAX operates in east flow, with arrivals using Runways 6L and 7R and departures using Runway 6R and 7L. Overnight and wind-permitting, LAX operates in a "head-to-head" configuration with arrivals landing to the east and departures taking off to the west. This operation minimizes overflights of residential neighborhoods to the east of LAX during nighttime hours.

One of the many factors that effect runway capacity is weather, particularly visibility and cloud ceiling. Two weather conditions were considered in the Demonstration Project—visual meteorological conditions (VMC) and instrument meteorological conditions (IMC). VMC in this study was deemed to be when the visibility at LAX was at least 3 statute miles and when cloud ceilings were at least 3,000 feet above ground level. IMC was deemed to be when either the visibility or cloud ceilings at LAX were below these levels.

The FAA's Aviation System Performance Metrics (ASPM) database was used to establish the hourly capacity of LAX's runway system in VMC and IMC conditions. The ASPM database provides historical records of the actual and advertised runway throughput rates at major airports across the United States. Table 1 shows the hourly capacity values that were determined from historical ASPM runway throughput data for LAX.

Table 1

AIRFIELD CAPACITY ESTIMATES
AQSAS—Demonstration Project
Los Angeles International Airport

Runway use configuration	Weather condition	Minimum ceiling (feet above ground level)	Minimum visibility (statute miles)	Hourly arrival capacity *(a)*	Hourly departure capacity *(a)*
West flow	Visual approach conditions	3,000	3	84	88
	Instrument approach conditions	0	0	68	75
East flow	Visual approach conditions	3,000	3	68	75
	Instrument approach conditions	0	0	58	70

West flow: Land on Runways 24R and 25L (overflow arrivals to Runways 24L and 25R), depart from Runways 25R and 24L.

East flow: Land on Runways 6L and 7R, depart from Runways 6R and 7L.

(a) Values shown are 75th percentile Arrival Acceptance Rates (AARs) and Departure Acceptance Rates (DARs) reported in the FAA's Aviation System Performance Metrics database for the most frequently used east and west flow configurations. Data used are for calendar year 2007 except for east flow, instrument approach conditions, which due to limited data samples is for the calendar year 2004 through 2007.

Source: Jacobs Consultancy analysis of runway capacity and throughput data obtained from the FAA's Aviation System Performance Metrics database.

Inventory of Aircraft and Engines

As stated in Section 2.1, aircraft and engine type matching is essential to accurately estimating aircraft emissions. The combinations of aircraft/engine types operating at LAX during the study period were developed specifically for this project. Using the 2007/2008 edition of JP Airline-Fleets International (JP Fleets) [Bucher, 2007], the actual mixture of aircraft/engine combinations for each airline that uses LAX was acquired. LAWA's noise monitoring office provided data that included aircraft type and airline for every operation during summer 2007.

Using these two crucial pieces of information, an engine type was assigned to each flight in the schedule using the distribution of engine types for each operator's aircraft fleet (i.e., all operations for a specific airline and aircraft type were assigned engine types based on a distribution of engine types used by that airline for that aircraft).

Table 2 shows the top ten aircraft most commonly operated at LAX during summer 2007.

Table 2

AIRCRAFT OPERATIONS BY AIRCRAFT TYPE (EDMS SCHEDULE)
AQSAS—Demonstration Project
Los Angeles International Airport

Aircraft type	Number of operations	Percent of operations
Boeing 737	39,958	24.2%
Boeing 757	18,445	11.2
Embraer 120	16,464	10.0
Regional Jets	9,555	5.8
Airbus 320	9,116	5.5
Boeing 767	9,003	5.5
Airbus 319	8,450	5.1
Boeing 747	8,165	4.9
Embraer ERJ	7,258	4.4
MD 80	7,054	4.3
Other	31,520	19.1
Total	164,988	

2.3 Spatial Allocation

The EDMS model allocates aircraft emissions to the appropriate ground sources around the airfield using the Delay and Sequence Module. Aircraft ground sources include runways, terminal aprons, and taxiways that were included in the model as described below.

Runways

The locations of runway endpoints—expressed in terms of their latitude and longitude—were taken from the FAA's Airport Master Record database and are depicted on Figure 2 below.

Figure 2

SPATIAL ALLOCATION OF RUNWAY SOURCES

Los Angeles International Airport

LAX684 F-0002

Terminal Aprons

To localize aircraft emissions at and near aircraft parking positions, nineteen different terminal aprons were defined in the Demonstration Project. These were as follows:

- Terminal apron east of Terminal 1 (A1)
- Terminal apron between Terminal 1 and Terminal 2 (A2)
- Terminal apron between Terminal 2 and Terminal 3 (A3)
- Terminal apron between Terminal 3 and the Bradley International Terminal (TBIT) (A4)
- Terminal apron between TBIT and Terminal 4 (A5)
- Terminal apron between Terminal 4 and Terminal 5 (A6)
- Terminal apron between Terminal 5 and Terminal 6 (A7)
- Terminal apron between Terminal 6 and Terminal 7 (A8)
- Terminal apron between Terminal 7 and Terminal 8 (A9)
- Cargo terminal apron in the Imperial Terminal, west of Sepulveda Boulevard (CG1)
- Cargo terminal apron west of Federal Express (CG2)
- Cargo terminal apron affiliated with Federal Express operations (FX)
- General aviation terminal apron in the Imperial Terminal, west of Sepulveda Boulevard (GA1)
- General aviation terminal apron adjacent to Sepulveda Boulevard, on the east and west sides (GA2)

- Imperial Cargo Center terminal apron on the corner of Aviation Boulevard and Imperial Highway (ICC)
- Remote terminal apron for American Airlines west of taxiways Q and S (RMA)
- Remote terminal apron for International Flights west side of Airport Property (RMI)
- UPS terminal apron (UPS)
- US Postal Service terminal apron (USM)

These apron areas are shown on Figure 3.

Figure 3

SPATIAL ALLOCATION OF TERMINAL APRON SOURCES

Los Angeles International Airport

LAX684 F-0003

Flight activities were assigned to the commercial terminal aprons, general aviation aprons, and cargo terminals by the location of an operator's base terminal. Flight activities were assigned to the remote international aprons (RMW) based on a distribution of international flights using the remote west gates. Flight activities were assigned to the remote American Airlines aprons (RMA) based on a distribution of American Airlines flights that utilize the remote American gates.

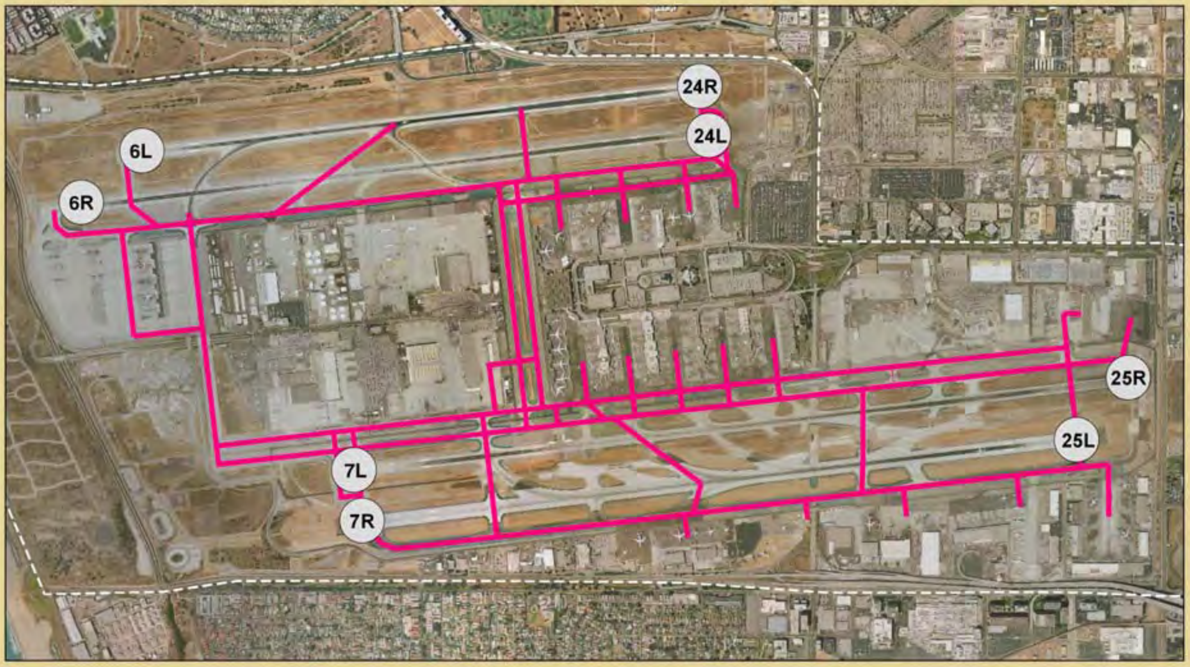
Taxiways

For accuracy in estimating the emissions from taxi and idle modes, and precision in locating the taxi/idle emissions around the airfield, eight major taxiways and 34 feeder taxiways were modeled for this study. Those taxiways are shown in Figure 4 below.

Figure 4

SPATIAL ALLOCATION OF TAXIWAY SOURCES

Los Angeles International Airport



Aircraft taxi speeds assumed in calculating the emissions from taxi mode operations are shown in Table 3.

Table 3

ASSUMED AIRCRAFT TAXIING SPEEDS

AQSAS—Demonstration Project

Los Angeles International Airport

Taxiway type	Taxiing speed (miles per hour)
Angled or high speed exit taxiways	46
90-degree or reverse high-speed exit taxiways	29
Parallel and crossfield taxiways	17
Terminal area taxilanes	12

Source: Jacobs Consultancy, April 2008.

Taxipaths

The route an aircraft takes in taxiing to/from the runway plays a large role in the amount of taxi/idle emissions attributable to that aircraft. These routes, often referred to as taxipaths, are assigned by the Air Traffic Control tower (ATCT). There are logical and common rules and routes that are assigned to aircraft by the ATCT, but these all-purpose taxipaths are circumvented often to accommodate real-time requirements. For the purposes of this study, only one path from each terminal to each runway end, and from each runway exit to each terminal were modeled.

Figures 5 through 8 illustrate the assumptions made on departure taxipaths from the north passenger terminals, the south passenger terminals, cargo and general aviation terminals, and the remote west terminal to each of the eight runway ends, respectively.

Figure 5

NORTH PASSENGER TERMINALS—DEPARTURE TAXIPATH ASSUMPTIONS

Los Angeles International Airport

LAX684 F-0005

Figure 6

SOUTH PASSENGER TERMINALS—DEPARTURE TAXIPATH ASSUMPTIONS

Los Angeles International Airport

LAX684 F-0006

Figure 7

CARGO AND GENERAL AVIATION TERMINALS—DEPARTURE TAXIPATH ASSUMPTIONS

Los Angeles International Airport

LAX684 F-0007

Figure 8

REMOTE WEST TERMINALS—DEPARTURE TAXIPATH ASSUMPTIONS

Los Angeles International Airport

LAX684 F-0008

Figures 9 through12 illustrate the assumed arrival taxipaths from runway exits to the north passenger terminals, the south passenger terminals, cargo and general aviation terminals, and the remote west terminals, respectively.

Figure 9

NORTH PASSENGER TERMINAL—ARRIVAL TAXI PATH ASSUMPTIONS

Los Angeles International Airport

LAX684 F-0009

Figure 10

SOUTH PASSENGER TERMINALS—ARRIVAL TAXIPATH ASSUMPTIONS

Los Angeles International Airport

LAX684 F-0010

Figure 11

CARGO AND GENERAL AVIATION TERMINALS—ARRIVAL TAXIPATH ASSUMPTIONS

Los Angeles International Airport

LAX684 F-0011

Figure 12

REMOTE WEST TERMINALS—ARRIVAL TAXIPATH ASSUMPTIONS

Los Angeles International Airport

LAX684 F-0012

2.4 Temporal Allocation

Aircraft emissions can be temporally allocated in two ways, (1) by way of operational profiles as used for other source groups in the EDMS model, and (2) by way of a simulated schedule of operations for the study period. For this study the simulated schedule option was used in order to better control the distribution of flight operations among the runways. The daily and monthly distribution of operations is shown in Tables 4 and 5, respectively.

Table 4

DAILY DISTRIBUTION OF AIRCRAFT OPERATIONS: SUMMER 2007
AQSAS—Demonstration Project
Los Angeles International Airport

Day of week	Total
Sunday	24,698
Monday	25,369
Tuesday	25,342
Wednesday	25,288
Thursday	25,982
Friday	27,605
Saturday	23,601

Source: FAA Air Traffic Activity Data System, June 2007 through August 2007.

Table 5

MONTHLY DISTRIBUTION OF AIRCRAFT OPERATIONS: SUMMER 2007
AQSAS—Demonstration Project
Los Angeles International Airport

Month	Total
June	55,885
July	60,730
August	61,270

Source: FAA Air Traffic Activity Data System, Calendar Year 2007.

Aircraft Schedule

An EDMS aircraft schedule specifies the aircraft type, engine type, runway, operation type (i.e. arrival/departure), the specific terminal apron where the operation initiated or terminated its ground movement, date, and time[2].

For the Demonstration Project, an aircraft schedule was developed from the data provided by LAWA's Noise Monitoring Office. A data set covering the period June through August, 2007 was obtained from the Noise Monitoring System (NMS) and included aircraft operations of commercial, cargo, and general aviation operators; and includes operation details such as airline, aircraft type, operation type (i.e., arrival/ departure), date and time of operation, and runway. There were 177,885 operations in this data set and these identical operations were used as a proxy for the summer 2008 schedule in EDMS. Determination of engine type and terminal apron are explained in sections 2.2 and 2.3, respectively.

2.5 Limitations and Potential Improvements

Many assumptions have been made in order to assemble the aircraft emissions inventory. This section reviews these assumptions and comments on assumptions that are expected to be refined in the Long Term Study. EDMS has a number of internal modules that are not well documented, leading to assumptions that are difficult to validate. These modules, such as the Sequence and Delay Module and the Performance Module, play important roles in estimating taxi emissions, which in turn play a large role in quantifying the emissions of VOCs and HAPs. Also, given the vast number of contributions to aircraft emissions (every permutation and combination of time in mode, aircraft, source, and idle time for tens of thousands of operations in the study period), it is difficult to audit the accuracy of aircraft emissions, although this can be done in the Long Term Study.

One concern about EDMS is the output of the Sequence and Delay Module. This module performs a simulation-type determination of taxi times, and allocates those emissions along taxipaths where the taxi activities take place. It is difficult to assess the performance of this module since EDMS provides no way to output values for tracking components such as fuel-burn by mode, or delay times per taxiway that are calculated by this module.

EDMS's Performance Module is designed to determine each aircraft's flight path and speed, as well as other characteristics, that assist in the calculation of emissions from approach, landing roll, takeoff, and climb out. This module also determines which exit-path an aircraft can use to exit a runway based on the aircraft's type, weight, and speed.

When the Performance Module was evaluated as part of this study it was apparent that the Module's output did not reflect actual runway exit-path selection at LAX. Detailed evaluation showed that the Module would calculate all aircraft exiting the runway and

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[2] Temporal profiles for aircraft were not used due to the use of the aircraft schedule.

follow the same exit-path regardless of aircraft type or weight. The evaluation also showed that the Module would always select the exit-path option that was farthest from the touchdown end of the runway.

This potential problem could affect the study's inventory and dispersion analysis since small aircraft would in reality exit the runway early and therefore taxi a shorter distance and emit fewer pollutants; while large aircraft would likely need more runway length to land and would not use an exit-path that a smaller aircraft could utilize.

The study team minimized the potential impact of this shortcoming of the Performance Module by modeling the runways at LAX as if they have only one exit-path option. This assumption is expected to be corrected for the Long Term Study.

As stated in Section 1 of this document, the emissions inventory for the Demonstration Project was calculated using EDMS 5.0.2. Currently there is a new version of EDMS (Version 5.1) which may include an updated version of the Performance Module with improved capabilities. It is the intent of the study team to upgrade to the newest version of EDMS, and to test this version for limitations of the exit-path selection process, during the Long Term Study.

In EDMS the Sequence Module estimates the taxi times and delay times for taxi-out emissions. An aircraft that is in taxi-in mode (i.e. is taxiing from the runway to the terminal apron) is assumed to taxi unimpeded to the terminal apron. Therefore no idle emissions are estimated from this segment of an operation. Adding delay to this process to account for airfield and terminal congestion is recommended for the Long Term Study.

Staying within the Demonstration Project's constraints on time and data availability, many streamlining assumptions were made in order to expedite the preparation of the aircraft emission inventory e.g. helicopter operations were not modeled, and EDMS defaults were used for landing and takeoff weight of all aircraft. It is recommended that these assumptions be addressed in the Long Term Study.

SECTION 3

AUXILIARY POWER UNITS

3.1 Introduction

Auxiliary power units (APUs) are on-board generators that power an aircraft while its main engines are shut down. These generators supply the aircraft with power for heating or cooling air, lights, electronics, and restarting the jet engines. If the aircraft is parked at a gate that can provide preconditioned air (PCA) and ground power, then its APU can be turned off while loading and unloading passengers. The APU is, in effect, a small jet engine and the calculations for the emissions generated by it are similar to those of an aircraft engine operating in one power setting only.

3.2 Emission Calculation Methodology

Within EDMS there is a robust list of aircraft/engine/APU combinations. However, it is difficult to obtain accurate information regarding APU equipage directly from the airlines that operate at LAX. Thus, for this study the default APU type was used, as defined by EDMS for each aircraft/engine type.

APU emissions generated per operation are the product of the emission factor and operating time. An average time-in-mode was used for all APU emissions. This average was calculated as follows:

- In accordance with FAA guidance, the recommended APU operating time is 7 minutes per landing and takeoff cycle (LTO) for all aircraft parked at gates that provide PCA and electricity [FAAb, 1998].

- It was assumed that there is PCA and 400 Hz power provided at all permanent passenger gates. Based on this assumption it was estimated that the 86% of all apron operations that took place at permanent passenger gates would utilize the PCA and 400 Hz power provided.[3]

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[3] Since this assumption was made it has come to the attention of the Study Team that there are many Ground Power Units in use at LAX, and therefore it is unlikely that this is thee case in reality. PCA and 400 Hz equipage at terminal gates will be confirmed and corrected for the Long Term Study.

- It was assumed that aircraft parked at gates that cannot provide PCA and electricity would run their APUs an estimated average of 45 minutes per LTO.

- Thus an Airport-wide weighted average APU operating time was calculated as 12.3 minutes (significantly different from the FAA guideline of 7 minutes)

- For the purposes of this Demonstration Study, 6.1 minutes of APU usage for arrivals and 6.1 minutes for departures were assigned to every aircraft and every operation at every terminal in the model.

3.3 Spatial Allocation

EDMS allocates APU emissions to aircraft terminal aprons as defined in Section 2.3 of this report.

3.4 Temporal Allocation

The temporal allocations for APUs are defined within EDMS (i.e. no operational profiles are needed) with the model applying APU emissions for each operation to the time between arrival at a gate and departure from the gate.

3.5 Limitations and Potential Improvements

APUs are engines that burn fuel and emit pollutants. As with aircraft engines and motor vehicle engines, the year, make and model play a significant role in the emissions that are released from each specific engine. In the EDMS model there is no basis for assumptions on which types of APUs are being used at LAX. In the Demonstration Project, EDMS APU-type defaults were assumed for all aircraft operations in the study period. Given that each aircraft-type has a number of possible APU-types and that not all aircraft have APUs, this assumption should be further examined. Improving this assumption will require the cooperation of airlines that use LAX.

Section 3.2 discussed the methodology for calculating the APU run times. While this methodology is satisfactory, it could be enhanced in the following ways:

- Site observations to better estimate if PCA and ground power are being optimally used at LAX.

- Collection of data to estimate the number of aircraft using general aviation and cargo gates that do not have APUs.

- Collection of data that would identify PCA and ground power availability at each aircraft parking position.

- Implementation of a methodology to account for periods during the year when the heating/cooling function of APUs would not be used because of comfortable ambient temperatures (typically aircraft do not need to be heated or cooled when the ambient temperature is between 35 and 55 degrees Fahrenheit).

- With the current assumptions regarding APU usage time, a single average time for all aircraft operations has been applied. This methodology does not provide any variability in spatial distribution of APU emissions between terminal aprons. This methodology is satisfactory; however it can be enhanced in the Long Term Study by discontinuing the average APU usage methodology and assigning specific APU usage times by terminal apron.

- EDMS 5.0.2 does not contain particulate matter (PM) emission factors for aircraft APUs, and therefore PM emissions from APUs are not included in the EDMS results for the Demonstration Project. The latest version of EDMS (Version 5.1) does estimate PM emissions for APUs. It is the intent of the study team to upgrade to the newest version of EDMS, and therefore to inventory PM emissions from APUs during the Long Term Study.

SECTION 4

GROUND SERVICE EQUIPMENT

4.1 Introduction

Ground Support Equipment (GSE) encompasses all equipment that is needed to service aircraft on the ground. Different types of aircraft operations require different services (e.g., passenger airlines require catering trucks, while cargo operations require forklifts). All of these ground support operations are accounted for in the GSE source group.

A complete GSE inventory survey from October, 2006 was provided by LAWA that included fuel type, model year, horsepower, and manufacturer. This list was the basis for an EDMS inventory of GSE, shown in Table 6. For each piece of equipment in the LAX inventory, a proxy in the EDMS system was selected. In that selection process special care was taken to preserve the ratio of fuel-types identified in the LAX inventory. Matching horsepower and manufacturer was given lower priority due to the limitations of the emission factor database in EDMS.

In the 2006 GSE Survey, 10% of the equipment was listed as “other on-road equipment” (other-ORE). It was assumed that the other-ORE category was composed of vehicles used for unscheduled transportation of employees and goods around the airfield that are not closely tied to aircraft operations. These emissions were assumed to have been accounted for as a roadway source and their estimated emissions are described in Section 5 of this report. Consequently, the other-ORE emissions were not estimated as part of the traditional GSE.

4.2 Emission Calculation Methodology

EDMS offers two methods for estimating GSE emissions; the operations-based method, or the population-based method. In the operations-based method EDMS can assign explicit levels of GSE activity to each aircraft specified in the model; therefore providing an emissions estimate based on the number or operations and the type of service each aircraft would likely require. In the population-based method, an inventory of equipment is developed and linked with annual hours of usage to calculate an emissions inventory from hourly emissions factors. For the Demonstration Project, the population-based method was chosen because it most closely corresponded to the information available in the LAX GSE Inventory Survey.

Table 6

EDMS GSE INVENTORY WITH FUEL
AQSAS—Demonstration Project
Los Angeles International Airport

GSE Type	Fuel Type	Number of pieces
Air Conditioner	Diesel	8
Air Start	Diesel	32
Aircraft Tractor	Diesel	157
Aircraft Tractor	Gasoline	3
Baggage Tractor	Diesel	55
Baggage Tractor	Gasoline	79
Baggage Tractor	Propane	173
Belt Loader	Diesel	49
Belt Loader	Gasoline	94
Belt Loader	Propane	34
Bobtail	Diesel	4
Bobtail	Gasoline	26
Cargo Loader	Diesel	156
Cargo Loader	Gasoline	7
Cargo Tractor	Diesel	21
Cargo Tractor	Gasoline	110
Cargo Tractor	Propane	95
Cart	Gasoline	2
Catering Truck	Diesel	41
Catering Truck	Propane	21
Deicer	Gasoline	1
Fork Lift	Diesel	29
Fork Lift	Gasoline	15
Fork Lift	Propane	153
Fuel Truck	Diesel	28
Fuel Truck	Gasoline	6
Fuel Truck	Propane	2
Generator	Diesel	11
Generator	Gasoline	6
Ground Power Unit	Diesel	96
Ground Power Unit	Gasoline	16
Hydrant Truck	Diesel	15
Hydrant Truck	Gasoline	11
Lavatory Truck	Diesel	10
Lavatory Truck	Gasoline	35
Lift	Diesel	32
Lift	Gasoline	46
Lift	Propane	22
Other	Diesel	34
Other	Gasoline	34
Other	Propane	1
Passenger Stand	Diesel	4
Passenger Stand	Gasoline	27
Passenger Stand	Propane	1
Service Truck	Diesel	30
Service Truck	Gasoline	140
Service Truck	Propane	2
Sweeper	Diesel	3
Sweeper	Gasoline	4
Sweeper	Propane	1
Water Service	Gasoline	9

Source: Jacobs Consultancy, August 2008.

After developing the inventory described in section 4.1 for use in the EDMS model, EDMS defaults were used for the following parameters:

- Rated Power (horsepower)
- Load Factor
- Age Distribution

Total hours of operation for each piece of GSE were estimated using the default "annual hours of operation" provided by EDMS. The default "annual hours of operation" was then linearly scaled from a 12-month estimate to a 3-month estimate in order to account for the study period.

4.3 Spatial Allocation

EDMS allocates GSE emissions to aircraft terminal aprons as described in Section 2.3 of this report. The distribution of these emissions among the 19 apron areas in the model was estimated using the following criteria:

- Type of GSE and its prominence at particular aircraft gates
- Percent of total aircraft operations at particular aircraft gates
- Type of aircraft operations (i.e. passenger, cargo, and general aviation) performed at particular gates (e.g. no belt loaders were allocated to cargo terminals, and tanker trucks were not allocated to any gates that have hydrant fueling)

4.4 Temporal Allocation

GSE total emissions estimated during the study period were allocated throughout the hours of the day, days of the week, and months of the study period with the use of operational profiles (see Section 1.4). The use of GSE is coupled closely with aircraft operations and therefore operational profiles for GSE mirror the aircraft schedule.

4.5 Limitations and Potential Improvements

EDMS default emission factors for GSE were used in the Demonstration Project. These emission factors were calculated internally within EDMS using the U.S. EPA's NONROAD2005 model [U.S. EPA 2005b]. However, the California Air Resources Board (CARB) has its own version of this model for use exclusively in California—OFFROAD2007 [CARB, 2007]. Use of the OFFROAD2007 model is expected to provide more accurate emission factors for GSE emissions.

For simplification, in the translation from the LAX-provided inventory to an EDMS-relatable inventory, equipment ages were categorized using the following standards:

- All equipment of model year 1998 or older was categorized as 1998 equipment.
- All equipment of model year 1999 to 2004 was categorized as 2004 equipment.
- All equipment of model year 2004 or newer was categorized using its model year as reported in the LAX GSE Survey.

These categories were chosen to reflect major changes in manufacturing certification standards for GSE engines. An attempt was made to inventory GSE emissions using these age categories as opposed to using the "default age distribution" option in EDMS.

It is the opinion of the study team that the LAX-specific ages reported in the GSE Survey should produce a better representation of LAX-specific GSE emissions.

The GSE inventory results appear to have some shortcomings. FAA has suggested that there may be problems with the emission factors database acquired from EPA. Until these problems are investigated further and/or corrected, the "default age distribution" methodology results may be more representative of the GSE emissions. It should be noted, that even when using the "default age distribution" methodology the performance of this aspect of EDMS has not been rigorously evaluated by FAA and EDMS users.

The LAX GSE Survey used in this estimation of emissions was from 2006, thus there are no 2007 or 2008 model years reflected in the inventory. Also any electric GSE that may have replaced gas or diesel equipment within the last two years would not be reflected resulting in an overestimation of GSE emissions. This can be corrected in the Long Term Study by updating the inventory of GSE being used at LAX.

In order to scale average annual hours of usage to the study period, it was assumed that GSE activity does not vary by month of the year. Also, EDMS defaults were used to estimate usage hours for GSE. These assumptions should be corrected in the Long Term Study by conducting a new GSE Survey.

As stated in Section 4.1, GSE that were listed as "other-ORE" were assumed to have been accounted for in the estimates of roadways (see Section 5). Ten percent of the GSE Inventory was categorized in this manner. This is an unsophisticated assumption, given that it is unknown what "other-ORE" equipment may be. This assumption can be refined with a more detailed current GSE inventory.

The LAX airfield contains a network of roadways used by employees, construction crews, and GSE. Little is documented about the usage and vehicle class distribution of these service roads. A 24-hour vehicle count and classification was completed in June 2008 at one location on an airfield service road in order to inventory vehicle emissions near monitors. This enabled approximately 16% of the airfield roadways to be modeled. Improvements to this emissions inventory could be realized with greater data on the airfield service road usage.

SECTION 5

ROADWAYS

5.1 Introduction

Roadways have been modeled in EDMS as one of three categories; (1) Central Terminal Area (CTA) roadways, (2) local roadways, and (3) service roads.

CTA roadways consist of five roadways in the center of the LAX terminal buildings and the connector ramps that connect West Century Boulevard and South Sepulveda Boulevard to World Way for inbound and outbound traffic. The five roadways in the central terminal are:

- World Way North
- World Way South
- West Way
- East Way
- Center Way

Several local roadways were defined as on-Airport in the Technical Work Plan. These roads include the following:

- La Cienega Boulevard between Century Boulevard and Imperial Highway
- Aviation Boulevard between Century Boulevard and Imperial Highway
- Sepulveda Boulevard between Century Boulevard and Imperial Highway
- Century Boulevard between La Cienega Boulevard and the central terminal roadways
- Imperial Highway between La Cienega Boulevard and Pershing Drive
- World Way West

Service roadways that were modeled consist of two Airport service roads (or portions thereof) that are close to the monitoring locations of the Demonstration Project. These roads include the following:

- Airfield Service Road F – This service road allows transport of GSE and automobile traffic around parts of the south runways. The roadway runs north/south behind the ends of Runways 25R and 25L, and runs east/west just south of terminals 4, 5, 6, 7, and 8.
- South Cargo Complex Access Road – This service road allows transport around the south cargo complex buildings and parking lots, on the landside. This roadway

runs parallel to Aviation Boulevard and Imperial Highway along the east and south perimeters of the South Cargo Complex east of Sepulveda Boulevard

Some roadways defined as "On-Airport" have a significant portion of traffic that is not Airport-related. Therefore these On-Airport and Off-Airport Roadway distinctions do not perform the "apportionment" roadway emissions. Separating the Airport-related traffic from the non-Airport-related traffic will be a significant part of the roadway task of the Long Term Study[4].

5.2 Emission Calculation Methodology

Motor Vehicle Emission Factors

EDMS has a built-in on-road emission factor module, MOBILE 6.2, which contains vehicle emission modeling software provided by the U.S. EPA. However, the CARB model (EMFAC 2007) [CARB, 2006] was used in order to best estimate Los Angeles County-specific motor vehicle operating characteristics (e.g. fleet mix, operating temperatures, etc.). EMFAC was used to estimate speed-dependent emission factors for each roadway inside the Airport boundary.

This model used average speed and vehicle class distribution data to produce emission factors in grams per vehicle-mile for CO, THC, NMHC, VOC, NO_x, SO_x, PM_{10}, and $PM_{2.5}$. These factors were then substituted for the EDMS factors and when combined with traffic volumes and spatial orientation, provided the roadway emission inventory.

The vehicle classifications provided as input to the EMFAC model were collected in two ways. CTA roadway classifications were estimated using the Airport's Automatic Vehicle Identification (AVI) system for commercial vehicles. This system allowed for an estimation of commercial gasoline vehicles (such as taxicabs and limousines), small buses, large buses, and LAX-owned shuttle buses. Commercial gasoline vehicles were assumed to be made up of a default public roadway mix; small buses were classified as single unit trucks due to limitations of EMFAC; large buses were classified as diesel buses; and LAX parking shuttle buses were ignored on this roadway because they are fueled by Liquid Natural Gas (LNG).

Local roadway classifications were estimated using data that was manually collected for a 24-hour period at 11 different locations to classify the following roadway segments:

- Aviation Boulevard
- Sepulveda Boulevard
- Imperial Highway between Sepulveda Boulevard and Aviation Boulevard
- Imperial Highway between Sepulveda Boulevard and LaCienega Boulevard
- Airfield Service Road F
- South Cargo Complex Access Road

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[4] It is also true that roadways in the Off-Airport Inventory have Airport-related traffic included in the Off-Airport Inventory. This also will be addressed in the Long Term Study

Due to a lack of data for some roadways in the on-Airport inventory, the following assumptions were made regarding vehicle class distribution.

- La Cienega Boulevard was assumed to have the same class distribution as Imperial Highway, between Aviation Boulevard and LaCienega Boulevard
- World Way West was assumed to have the same class distribution as Imperial Highway, between Sepulveda and Aviation
- Century Boulevard was assumed to have the same class distribution as the CTA roadways.
- Imperial Highway between Pershing Drive and Sepulveda Boulevard was assumed to have the same class distribution as Sepulveda Boulevard

Traffic Speeds

The assumed traffic speeds on roadway segments listed in Section 5.1 were estimated from observations of each roadway segment [Jacobs Consultancy, 2008] that showed the average speed tended to be about half of the speed limit on the roadway. The estimated average speed used in the model came from these observations.

Table 7 shows the vehicle distributions for local roadways collected in the vehicle counts of summer 2008, and the assumed average speed. Tables 8 shows the percent of traffic on each roadway by EMFAC input categories, and Table 9 shows the fuel classification used for each EMFAC vehicle category.

Traffic Volumes

CTA roadway volumes were estimated using June, July, and August 2007 data from traffic counters (loop detectors) that are permanently positioned in the inbound and outbound connector ramps for the CTA roadways. The loop detectors provided a basis to estimate the total number of vehicles on CTA roadways. The following assumptions were made for traffic using the CTA roadways:

- 70% of all inbound traffic travels the outer loop roadway, passing in front of Tom Bradley International Terminal (TBIT).
- 15% of the traffic cuts through on East Way and 15% on West Way.
- During anytime that inbound traffic exceeded outbound traffic, the difference between the two was assumed to be entering parking facilities and was placed on East Way and West Way
- During any time that outbound traffic exceeded inbound traffic the difference between the two was assumed to be leaving parking facilities and was therefore placed on Center Way.

Local roadway volumes were estimated using traffic data from numerous sources including the LAWA Transportation Planning Department, California Department of Transportation (CalTrans) [CalTrans, 2008], and traffic data collected in June 2008 specifically for this study. These sources provided daily volume and/or weekly volume. Where only daily volumes were available, the weekly totals from other locations were used to scale up the daily volumes into a weekly volume. Once the weekly volume was determined, the volume for the entire study period was estimated as weekly volume multiplied by 13 weeks in the study period.

Table 7

ASSUMED ROADWAY CLASS DISTRIBUTIONS AND SPEEDS
AQSAS—Demonstration Project
Los Angeles International Airport

	Personal vehicles	Single unit truck	Multi unit trucks	LAX buses	All other buses	Motor cycles	Speed
Upper and Lower Level of the Central Terminal Area	81.83%	17.27%	0.00%	0.02%	0.88%	0.00%	15
Aviation Blvd.	84.79%	7.55%	2.59%	2.41%	2.17%	0.49%	20
Century Blvd.	81.83%	17.27%	0.00%	0.02%	0.88%	0.00%	20
Imperial Hwy., between Pershing and Sepulveda	96.55%	1.01%	0.18%	0.71%	1.09%	0.45%	25
Imperial Hwy., between Sepulveda and Aviation	91.12%	5.27%	1.43%	0.15%	1.42%	0.61%	25
Imperial Hwy., between Aviation and LaCienega	84.79%	7.55%	2.59%	2.41%	2.17%	0.49%	25
La Cienega Blvd.	84.79%	7.55%	2.59%	2.41%	2.17%	0.49%	20
Sepulveda Blvd	96.55%	1.01%	0.18%	0.71%	1.09%	0.45%	20
World Way West	91.12%	5.27%	1.43%	0.15%	1.42%	0.61%	20
Airfield Service Road F	44.18%	44.50%	10.31%	0.75%	0.27%	0.00%	10
South Cargo Complex Access Road	71.46%	17.21%	7.25%	2.98%	0.52%	0.58%	10

Source: Jacobs Consultancy from vehicle classification data provided by LAWA, August 2008.

Table 8

EDMS VEHICLE CLASS BY ROADWAY

AQSAS—Demonstration Project
Los Angeles International Airport

Street Name	Light-Duty Autos	Light-Duty Trucks	Medium-Duty Trucks	Light-Heavy Gas Trucks	Light-Heavy Diesel Trucks	Medium-Heavy Gas Trucks	Heavy-Heavy Diesel Trucks	Urban Transit Buses	Motorcycles
Aviation Blvd.	49.4%	6.2%	19.4%	8.5%	3.6%	7.6%	2.6%	2.2%	0.5%
Cargo Service Road	41.7%	5.2%	16.4%	7.2%	4.0%	17.2%	7.2%	0.5%	0.6%
Century Blvd.	47.7%	6.0%	18.8%	8.2%	18.5%	--	--	0.9%	--
Imperial Blvd. (between Sepulveda and Aviation)	53.1%	6.6%	20.9%	9.2%	1.5%	5.3%	1.4%	1.4%	0.6%
Imperial Blvd. (between Aviation and La Cienega)	49.4%	6.2%	19.4%	8.5%	3.6%	7.6%	2.6%	2.2%	0.5%
Imperial Blvd. (between Pershing and Sepulveda)	56.3%	7.0%	22.1%	9.7%	2.1%	1.0%	0.2%	1.1%	0.4%
La Cienega Blvd.	49.4%	6.2%	19.4%	8.5%	3.6%	7.6%	2.6%	2.2%	0.5%
Sepulveda Blvd.	56.3%	7.0%	22.1%	9.7%	2.1%	1.0%	0.2%	1.1%	0.4%
Airfield Service Road	25.8%	3.2%	10.1%	4.4%	1.4%	44.5%	10.3%	0.3%	--
World Way West	53.1%	6.6%	20.9%	9.2%	1.5%	5.3%	1.4%	1.4%	0.6%
CTA Upper and Lower Drives (Passenger Vehicles and Gasoline Commercial Vehicles)	58.3%	7.3%	22.9%	10.1%	1.4%	--	--	--	--
CTA Upper and Lower Drives (Large Buses)	--	--	--	--	--	--	--	100.0%	--
CTA Upper and Lower Drives (Small Buses)	--	--	--	--	100.0%	--	--	--	--
Other CTA Roadways	47.7%	6.0%	18.8%	8.2%	18.5%	--	--	0.9%	--

Source: Jacobs Consultancy from vehicle classification data provided by LAWA, August 2008.

Table 9

LOS ANGELES COUNTY FUEL USAGE By EMFAC VEHICLE CATEGORY

AQSAS—Demonstration Project
Los Angeles International Airport

Vehicle Category	Gasoline	Diesel	Electric
Light-Duty Autos	99.56%	0.30%	0.14%
Light-Duty Trucks	97.23%	2.68%	0.096%
Medium-Duty Trucks	99.83%	0.17%	0.00%
Light-Heavy Gas Trucks	99.66%	0.34%	0.00%
Light-Heavy Diesel Trucks	86.31%	13.69%	0.00%
Medium-Heavy Gas Trucks	59.79%	40.21%	0.00%
Heavy-Heavy Diesel Trucks	9.73%	90.27%	0.00%
Urban Transit Buses	50.18%	49.81%	0.00%
Motorcycles	100.00%	0.00%	0.00%

Sepulveda Tunnel

Sepulveda Boulevard travels in two tunnels under the runways of the south airfield—one three-lane tunnel in each direction (see Figure 13); and therefore was modeled quite differently from all other roadways in this model.

The Sepulveda Boulevard tunnel was modeled separately using EDMS in order to estimate the total emissions that are produced by vehicles inside the tunnel, while ensuring that the roadway emissions were not input into the dispersion model as if it were an area source emitting from ground level. The estimated total emissions from the tunnel were incorporated in the dispersion model as two volume sources, at the north and south openings of the tunnel. The emission factors, traffic speed, and traffic volume input to the tunnel model were equivalent to the assumptions made for the above ground sections of the roadway.

Figure 13

SPATIAL ALLOCATION OF THE SEPULVEDA TUNNEL SOURCES

Los Angeles International Airport

5.3 Spatial Allocation

The roadways listed in Section 5.1 were chosen due to their close proximity to the Demonstration Project monitoring locations. Figure 14 shows all roadways that are classified as on-Airport emissions sources.

Figure 14

SPATIAL ALLOCATION OF ON-AIRPORT ROADWAY SOURCES

Los Angeles International Airport

LAX684 F-0014

5.4 Temporal Allocation

Quarter-hour, day-of-the-week, and monthly profiles for CTA roadways were estimated from permanent loop detector data that continually count vehicles entering and exiting the LAX CTA. This data was provided by LAWA's Transportation Planning Department.

For local roadways, quarter-hour profiles were estimated using quarter-hour data collected at many locations for one 24-hour period, allowing each roadway in the model to have a quarter-hour profile specific to that roadway. Day-of-the-week profiles were estimated using quarter-hour data collected at two locations for seven consecutive days. From the aforementioned seven days of data, day-of-the-week profiles were specific to the roadway for Aviation Boulevard and Imperial Highway, while all other local roadways used the same day-of-the-week profile, developed from an average of the profiles for Aviation Boulevard and Imperial Highway.

Due to a lack of monthly data for local roadways, all monthly profiles for local roadways assumed that the volume of traffic in June, July, and August were equal.

5.5 Limitations and Potential Improvements

Roadways are a significant emissions source group in the on-Airport inventory. However, roadway emissions are difficult to estimate due to the variability in traffic patterns and different types of vehicles utilizing the roadways. Although traffic volumes are recorded on a semi-regular basis in and around the Airport to provide planners insight into the Airport's contribution to traffic flow, very little is documented about vehicle classifications and/or the contribution of roadways that are not main arterials. Particulate Matter from diesel vehicles and gasoline vehicles has not been separated in this Demonstration Project inventory, however, doing so would help to quantify and locate Diesel PM emissions.

Only roadways located within close proximity to the five monitoring sites for the Demonstration Project were included in this model. Due to the locations of the five sites, only roadways on the east, south, and central part of the Airport were included in this inventory. No roadways within the Airport boundary located to the north or to the west of the airfield were included in the study. Additional roads providing complete coverage of the on-Airport area are expected to be included in the Long Term Study.

There are a number of airfield service roads that are used to transport goods around the airfield. Of these service roads only a small section of one road was modeled for the Demonstration Project. This section of service road was selected due to its close proximity to the monitoring sites. A more comprehensive network of airfield service roads is expected to be included in the Long Term Study.

Many variables were estimated in allocating the temporal pattern of the vehicles. Also, vehicle classification data for all roadways was difficult to obtain. Therefore, extensive vehicle volume, speed, classification, and temporal data are expected to be collected for the Long Term Study.

SECTION 6

PARKING FACILITIES

6.1 Introduction

All parking facilities modeled by EDMS were chosen because of their close proximity to the Demonstration Project monitoring locations. Parking facilities modeled by EDMS included seven public LAWA-owned parking garages in the CTA (LAX lots 1-7), two public LAWA-owned surface lots (LAX lots B and C), one LAWA-owned employee surface lot (LAX lot E), one public off-airport parking surface lot east of the CTA, and one trucking depot lot that is located east of Runway 25R.

6.2 Emission Calculation Methodology

Emissions were estimated using similar methodology for all parking facilities except for the trucking depot east of Runway 25R. These two methodologies are described in sections 6.2.1 and 6.2.2, respectively.

6.2.1 Emission Calculation Methodology for All Parking Facilities Excluding the Trucking Depot East of Runway 25R

Motor Vehicle Emissions

Emissions for eleven public parking facilities within the Airport boundary were estimated using EDMS with the embedded MOBILE 6.2 module. These emissions are calculated using emission factors in units of grams per vehicle that take into account vehicle fleet mix, distance traveled, volumes, speed, and idle time.

Vehicle Class Distribution

It was assumed that public parking lots in or near the Airport would have a vehicle class distribution consistent with the default fleet mix option offered in EDMS.

Distance Traveled

Average distance traveled was calculated independently for each facility modeled. Average occupancy and differences in facility characteristics were taken into account in estimating the average distance traveled within each parking facility.

Average occupancy plays a role in average distance traveled; because when a parking facility is full it is difficult to find a parking space and thus patrons drive long distances to find one spot. Other attributes that play a role in distance traveled are where entrances and exits are located, where pedestrian access is located, how many levels a garage has, and how the ramp system within the garage is designed. All of these attributes have been identified from observation, interviews with LAWA staff, and experience of the study team.

Traffic Volumes

The total volume of vehicles entering and exiting each LAWA-owned public parking facility was estimated using June, July and August parking data from 2007 [LAWA, 2008a]. Total traffic volume for the LAWA-owned employee lot (Lot E) was estimated using seven days of automated traffic counts taken in June 2008[LAWA, 2008c]. Traffic volumes in the public off-airport parking lot located on Century Boulevard directly east of the CTA was estimated using volumes from a LAWA-owned long-term surface lot (Lot C) that were scaled by surface area to reflect the number of parking spaces available in the lot.

Traffic Speeds

Average speeds in all parking facilities were assumed to be five miles per hour.

Idle Time

Average idle times in all parking facilities were assumed to be the EDMS default of 1.5 minutes.

6.2.2 Emission Calculation Methodology for the Trucking Depot East of Runway 25R

Motor Vehicle Emission Factors

Emission factors for the trucking depot east of Runway 25R were estimated using EMFAC2007 much like roadways (see Section 5). Vehicle fleet mix and speed were input into EMFAC to produce emission factors that were used as inputs to EDMS along with traffic volumes. Vehicle class distribution and traffic volumes were estimated from manual traffic counts taken in June 2008. Average speed was assumed to be five miles per hour.

6.3 Spatial Allocation

The parking facilities listed in Section 6.1 were chosen due to their close proximity to monitoring locations for the Demonstration Project. Each surface parking lot was modeled as an area emissions source. Each parking garage was modeled as one area source per garage level, that are stacked to simulate a parking garage, accounting for the number of levels in each garage, and the average separation between levels. Figure 15 shows all parking facilities that are classified as on-Airport emissions sources.

Figure 15

SPATIAL ALLOCATION OF ON-AIRPORT PARKING FACILITIES

Los Angeles International Airport

6.4 Temporal Allocation

In order to represent actual motor vehicle emissions from parking facilities at the Airport, quarter-hour and month-of-year operational profiles were developed from temporal data provided by LAWA's Parking Operations Department. The information provided was not presented in a way that would allow day-of-week profiles to be developed. Therefore, day-of week profiles from CTA roadways were used as a proxy for this information.

6.5 Limitations and Potential Improvements

All LAWA-owned parking facilities and select non-LAWA-owned parking facilities were accounted for in the analysis. Parking facilities that are not included but could potentially improve the accuracy of this inventory include off-Airport parking operators that are located nearby and are serviced by shuttles, rental car company lots that are nearby and serviced by shuttles, and the taxicab hold lot. All of these parking facilities are Airport-related and should be included in the Long Term Study.

The parking facility inventory could be made more accurate by utilizing a better methodology for "average distance driven". However this input to the EDMS model is difficult to assess. Improved methodology for this parameter may be further investigated in the Long Term Study.

The built-in emission factor module in EDMS for computing emissions factors from motor vehicles is the U.S. EPA's MOBILE6.2 module. However, CARB's emission factor model (EMFAC 2007) will be used in the Long Term Study to best estimate Los Angeles County-specific motor vehicle operating characteristics (e.g. fleet mix and operating temperatures). Particulate Matter from diesel vehicles and gasoline vehicles has not been separated in this Demonstration Project inventory, however, doing so would help to quantify and locate Diesel PM emissions.

The large cargo facility on the corner of Aviation Boulevard and Imperial Highway has a substantial amount of diesel truck traffic. The many different buildings that make up the Imperial Cargo Complex are each surrounded by parking lots and tractor trailer truck loading positions. The only estimation of motor vehicle emissions in this complex are from the cargo service road modeled in the roadways section (see Section 5). A new methodology that can account for the emissions from cold starts, idling, and travel around these building should be established for the Long Term Study.

SECTION 7

STATIONARY SOURCES

7.1 Introduction

Emissions inventories of LAWA-owned on-Airport stationary sources were developed based on data from a number of resources. Emissions from tenant-owned on-Airport stationary sources were developed in connection with off-Airport sources in Task 3 [Aspen, 2008].

The sources that were included in the inventory included 32 stationary internal combustion engines, 4 portable internal combustion engines, 2 turbines, and 30 boilers. The turbines and many of the boilers are part of LAX's Central Utility Plant. In addition, the four cooling towers for the Central Utility Plant were included in the inventories. Not specifically included in this inventory are emissions from aircraft parts painting/degreasing facilities, dry cleaning facilities, food kitchens, and terminal-based food concessions but these types of emissions would be included in the aggregate area sources of the CHAPIS database.

Training fires were not included in this analysis as no training fires were scheduled to occur during the study period.

7.2 Emission Calculation Methodology

The annual emissions for all on-Airport stationary sources owned by LAWA were calculated based on the product of the actual fuel usage for the period of July 2006 through June 2007 for every source (every piece of equipment) and the corresponding fuel based emission factors from EPA's AP-42 reference document [EPA, 1995]. The actual annual fuel usage for each of the stationary sources was obtained from the "Combustion Fuel Usage Inventory" listed in the "2006 – 07 Air Toxics Inventory Report for the Los Angeles International Airport" (SCAQMD ID #SO0335) submitted to South Coast Air Quality Management District in January 2008. The fuel based emission factors were chosen based on the following parameters: stationary source type (engine, turbine, boiler etc.), combustion fuel type (diesel, natural gas, etc.), rated capacity (hp, heated capacity, etc.), and air-fuel ratio (lean-burn or rich-burn).

7.3 Spatial Allocation

Spatial allocation of each of the LAWA-owned on-Airport sources was accomplished based on street addresses and/or UTM coordinates provided by LAWA's environmental staff [LAWA, 2008b].

7.4 Temporal Allocation

No temporal allocation of the LAWA-owned stationary source emissions was possible. No hourly, weekly, monthly or seasonal data was available to allocate the emissions over time. Therefore, a constant emission rate was assumed for each hour of the modeling period based on the annual average data.

7.5 Limitations and Potential Improvements

There are limitations and/or inconsistencies in the data collected for the Demonstration Project. There are also certain areas in the emissions estimates that may be able to be improved with additional work in the Long Term Study.

Among the limitations in the data are:

- The spatial allocation of many of the sources used in this assessment has not been field verified. A review of the source locations suggests that some coordinates need to be revisited.
- There was no temporal allocation data available for many of the sources assessed. These times would make the modeling analysis much more representative of actual conditions being modeled. This is especially relevant for the emergency/backup engines which would typically be operated only for selected periods of time.
- Emissions from fuel storage facilities at the Airport (i.e., fuel storage tanks for JET A, aviation gasoline, motor gasoline, and motor diesel fuels) were not included in the analysis. These data are expected to be included in the emissions inventory for the Long Term Study.
- Stack parameters provided appear to be based on global assumptions for each unit type. Individual unit information should be collected for the Long Term Study.

SECTION 8

CONCLUSIONS

8.1 Observations of the Task Team

Phases 1 and 2 of the AQSAS is a short-term Technology and Methodology Feasibility Demonstration Project ("Demonstration Project") that was conducted to collect source emissions inventory data for use in the dispersion modeling task. The Demonstration Project looked at emissions from mobile sources (e.g. aircraft, GSE, and on- and off-road vehicles), and stationary sources (e.g. combustion equipment) using appropriate emission models, databases, and available emission measurements.

The objectives of this task were to:

- Develop an inventory of emissions sources on Airport property.
- Develop an inventory of criteria pollutants emitted by sources on Airport property.
- Spatially locate each of the emission sources on Airport property.
- Temporally locate the criteria pollutant emissions from sources on Airport property.
- Provide an inventory of spatially and temporally allocated emissions for use in the dispersion modeling analysis being performed for the Demonstration Project.

Given the complexity of the sources and the extensive amount of data needed to categorize those sources, the overall data collection and inventorying effort adequately fulfilled the stated goals and purposes of the Demonstration Project. Specifically:

- The study inventoried emissions from all on-Airport sources required in the study objectives. Data for other sources and for sources which had insufficient data can be rectified in the Long Term Study.
- Performing the tasks associated with this effort identified a number of methodological concerns, most of which can be remedied in the Long Term Study.
- Technological issues, mostly associated with EDMS, will be investigated further and some may be resolved with use of the newer versions of EDMS.
- Based on the preliminary dispersion modeling results, acceptable emissions inventories were compiled, despite shortcomings identified with EDMS and the available data. More complete data for a wider variety of on-Airport sources will make the inventories more accurate.

8.2 Inventory Summary

The FAA's EDMS emissions model, in conjunction with other emission inventory models, was used to prepare the three-month Demonstration Project emission inventories of CO, THC, NMHC, VOC, NOx, SOx, PM10, and PM2.5 for aircraft, GSE, APU, parking facilities, and On-Airport roadways. As can be seen in Table 10, on-Airport emissions of CO for the 3-month period were just over 1,151 tons, VOC emissions were just over 238 tons, NOx emissions totaled just under 1,086 tons, SOx emissions were just over 80 tons, PM10 emissions totaled just over 28 tons, and PM2.5 emissions were just over 27 tons. (Note that this version of EDMS does not calculate PM emissions from APUs.)

As would be expected at LAX, aircraft contribute the largest amounts to these totals with 38 percent of the CO emissions, 79 percent of the VOC emissions, 68 percent of the NO_x emissions, 83 percent of the SO_x emissions, 53 percent of the PM_{10} emissions and 55 percent of the $PM_{2.5}$ emissions.

Table 10

ON-AIRPORT INVENTORY OF EMISSIONS
AQSAS—Demonstration Project
Los Angeles International Airport

	CO	THC	NMHC	VOC	NOx	SOx	PM10	PM2.5
Aircraft	435.723	199.360	199.360	188.455	737.338	66.235	15.071	15.071
GSE	501.248	30.555	28.763	30.989	222.402	8.932	8.495	8.259
APU	38.010	2.896	2.896	2.896	30.020	4.455	--	--
Parking Facilities	28.434	4.521	4.306	4.361	6.279	0.015	0.091	0.070
Roadways (on-airport)	138.888	11.275	9.393	11.430	58.842	0.297	3.981	3.107
Stationary Sources (on-airport, LAX owned)	8.707	--	--	0.269	30.794	0.322	0.711	0.711
Total	**1,151.010**	**248.607**	**244.718**	**238.400**	**1,085.675**	**80.256**	**28.349**	**27.218**

Source: Jacobs Consultancy, August 2008.

8.3 Recommendations for the Long Term Study

- EDMS default parameters that were used in lieu of airport- or equipment-specific data should be further investigated during the Long Term Study. Efforts will be made to acquire such data, but it should be noted that data for tenant-owned equipment is neither under the control of LAWA nor the study team.

- Hazardous air pollutants (HAPs) and PM emissions for APUs had not yet been included in the EDMS program used in preparing this inventory. EDMS Version 5.1, released in September 2008, does include emission factors for up to 44 HAPs and

PM emissions from APUs. The Study Team recommends use of EDMS 5.1 in the Long Term Study.

- Tests of the EDMS Performance and Sequence Modules should be performed in EDMS Version 5.1 to determine if module algorithms have been upgraded or altered in any way. If limitations still exist the Study Team recommends developing strategies that circumvent those limitations and provide a more detailed emission inventory.
- The Study Team recommends modeling helicopter operations in the Long Term Study.
- The Study Team recommends investigating options for APU model selection other than EDMS defaults.
- APU usage time has been assumed uniform for all aircraft operations. It is recommended that this methodology be improved to add spatial distribution of APU emissions among terminal aprons.
- EDMS default emission factors for GSE were used in the Demonstration Project. These emission factors were based on the U. S. EPA's NONROAD2005 model for computing emission factors for these vehicle types. CARB has its own version of this model, OFFROAD2007. It is recommended that the OFFROAD2007 model to be used in the Long Term Study.
- There are data gaps in vehicle classifications and/or the contribution to the emissions of roadways that are not main arterials. The Study Team sees this as an area for potential improvements in the Long Term Study.
- Only roadways on the east, south, and central part of the Airport were included in this inventory because of the location of the Demonstration Project monitors. Roadways located to the north or to the west of the Airport should be included in the Long Term Study.
- Particulate Matter from diesel vehicles and gasoline vehicles should be tracked separately where possible, in order to quantify and locate Diesel PM.
- Only one section of an airfield service road was modeled for the Demonstration Project. Additional service roads providing greater coverage of the on-airfield area should be included in the Long Term Study.
- Parking facilities that are not included but could potentially improve the accuracy of this inventory include off-Airport parking operators that are located nearby and are serviced by shuttles, rental car company lots that are nearby and serviced by shuttles, and the taxicab queue hold lot.

- The only estimation of motor vehicle emissions in the South Cargo Complex are from the cargo service road modeled with roadway sources. A new methodology that can account for the emissions from cold starts, idling, and travel around these building should be established for the Long Term Study.
- There was no temporal allocation data available for many of the stationary sources assessed. These times would make the modeling analysis much more representative of actual conditions being modeled.
- A large number of emergency/back up sources were included in the study. However, these sources are not run continuously and use of an annual average value for these emissions is incorrect. Actual run time data should be used. Stack parameters should be verified.

SECTION 9

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Module G

Monitoring and Sampling Report

(Task 6)

Overview

This report serves as documentation of the procedures and general conclusions of the gas chromatograph / mass spectrometer (GC/MS) feasibility test performed at and around the Los Angeles International Airport (LAX) southern-most runway that occurred during the LAX Source Apportionment Study Demonstration Project. The following sections describe the details from the GC/MS operator's field notes and the onsite analysis / observations.

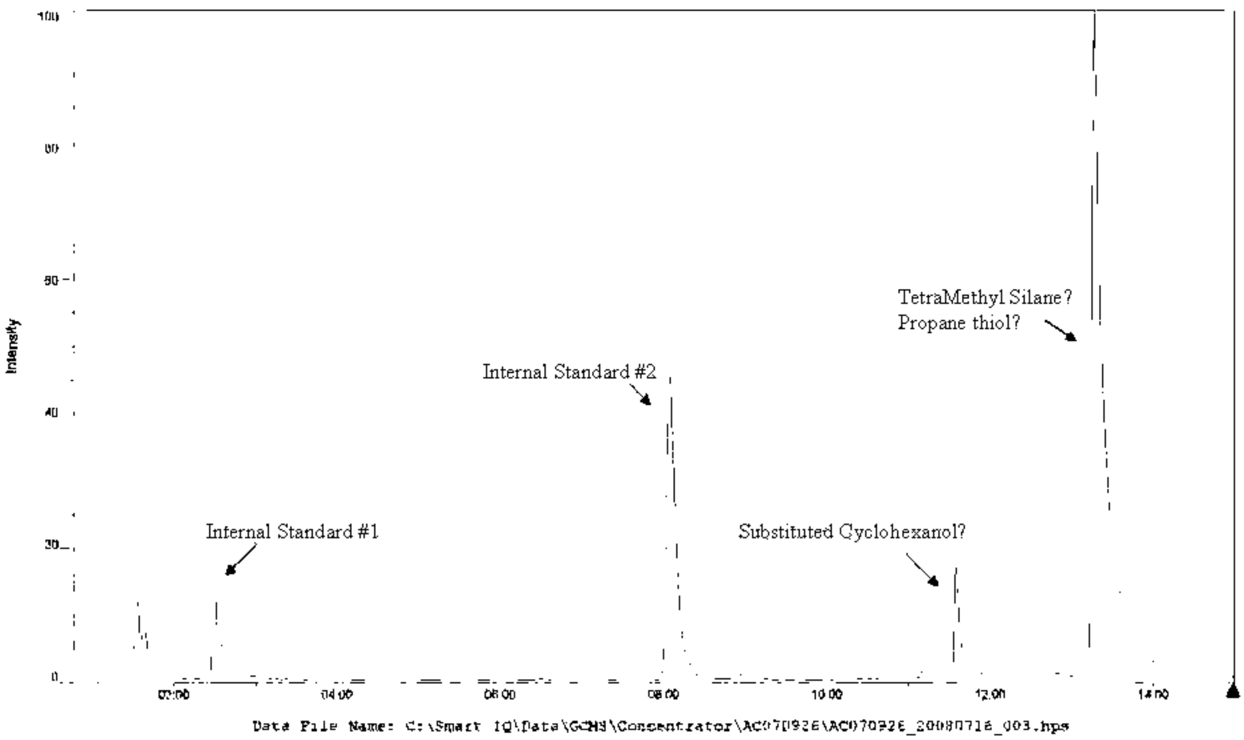
Purpose

Weston was tasked with operating the Inficon™ portable GC/MS to acquire data near the south runway blast fence and outlying locations. The data collected was to determine the feasibility of using the Inficon device to measure ambient air pollutants that may be useful in tracing aircraft-related emissions and determine whether the Inficon GC/MS had sufficient sensitivity to detect and measure volatile organic compounds (VOCs) in ambient air. This would in turn help determine whether any fingerprint or indicator compounds could be identified to differentiate aircraft exhaust from other combustion sources, such as auto and diesel exhaust. This study evaluated instrument performance. Identification of specific aircraft signature compounds was beyond the scope of this study. Collecting comprehensive time-series data for use in the Demonstration Study was also beyond the scope of this study.

Chronology and Example Results

This feasibility study was performed 14 July through 26 July 2008. Monday and Tuesday, 14 and 15 July, were used for training and familiarization with the equipment at the AQMD facility in Diamond Bar, CA. Brad Parrack of AQMD facilitated the Weston GC/MS operator's orientation and equipment loan checkout. Wednesday, 16 July, was spent completing the LAX security badge process and transferring the equipment to the Jacobs project office on Avion Boulevard. Weston performed several ambient air blanks offsite at the hotel room and had limited success with these blanks, as some compounds were present in significant quantities, shown in the example figure below. It was difficult to determine whether the compounds detected were actually present in ambient air, artifacts of the GC/MS system, artifacts of the charcoal tubes used as pre-filters, or some other unknown factors.

Ambient Air Blank – At Motel Window Rosecrans & Aviation



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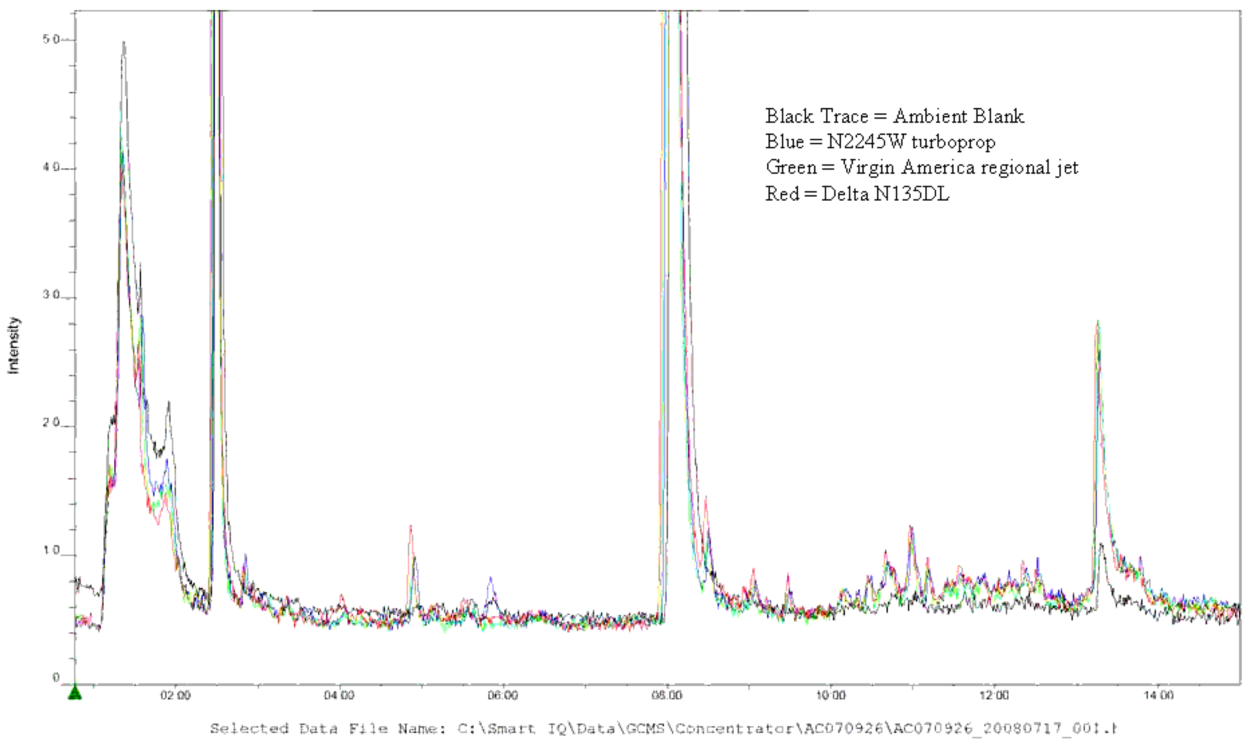
On Thursday, 17 July, Weston acquired data for nine take-offs using the "AC070926" program AQMD provided. The program was renamed as LAXPROJ to make the source of data files obvious, but did not change any parameters in this program at this time. The one minute concentration signals were barely discernable from background noise, and temperature programs were not sufficiently hot or of sufficient duration to prevent carry-over from run to run. A few small peaks could be identified with rather low match probabilities. However, data could not be differentiated between aircraft exhaust or ambient air at the project office versus the blast fence during take-off. (see comparison figure below)

Ambient Blank and 3 Take-offs Overlaid

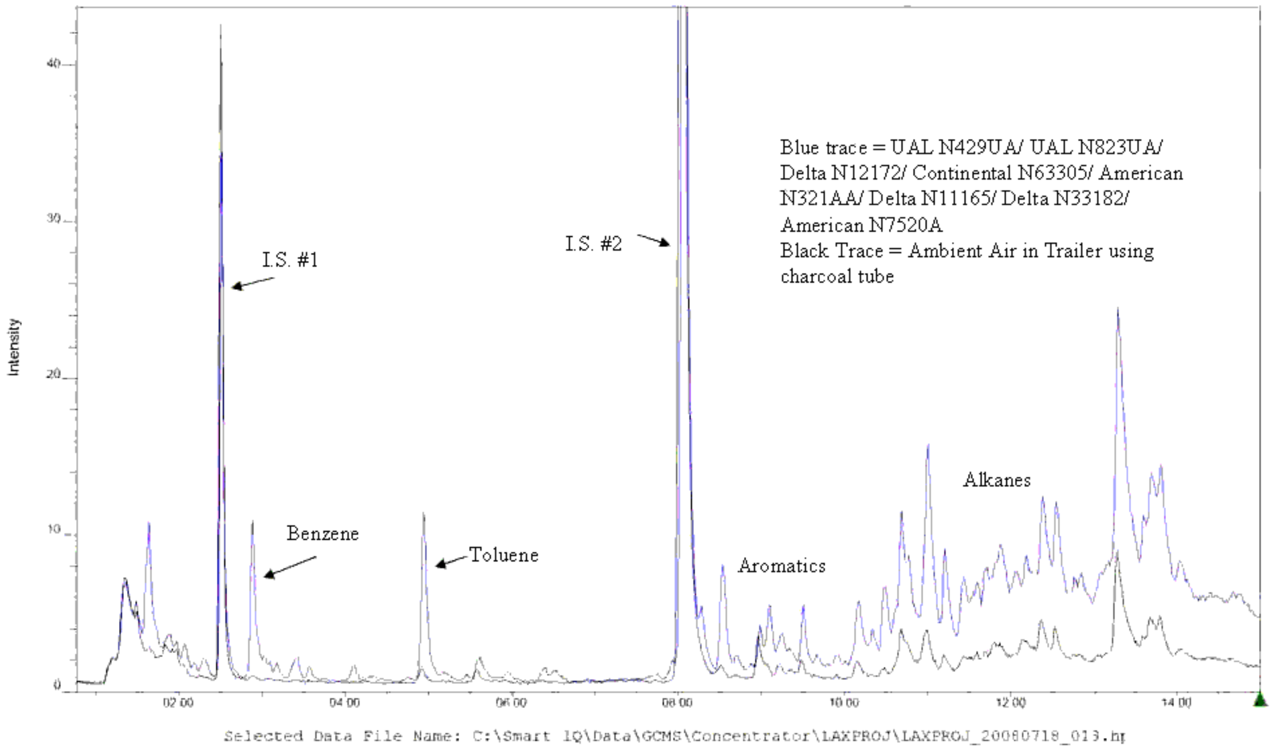


The initial take-off results shown above yielded similar chromatograms (colored traces), that all have features distinct from the blank (black trace). However, signals are so small that spectral identifications were not possible, even with averaging across peaks and baseline spectra subtraction. Scale and peak size were relative to internal standards.

The next figure illustrates six additional take-off samples, compared with two ambient blank samples. Again, features for take-off exhaust are similar for all aircraft.

Friday morning, 18 July, after performing an ambient air blank, the line purge flow rate was determined using a BIOS Drycal and found to be 170 mL/min. Assuming five feet of quarter-inch Teflon sample line from probe to Inficon unit, transfer line void time was determined to be about 15 seconds. The line purge time was changed from one minute to fifteen seconds in the GC/MS program to allow easier timing and “capture” of the aircraft take-off events. After capturing a three take-off event that morning, Weston modified the program for a 30-second concentrator fill. Three additional take-offs were captured using 15-second line purge and 30-second concentrator fill. Sensitivity was not sufficient enough with these parameters, so at mid-morning the concentrator fill time was increased to ten minutes. This was done to determine whether the increased sensitivity expected from the ten-fold longer concentration period provided more useful data. After acquiring data for four take-off and eight take-off sets ending at about 11:03 am, there were still issues with significant levels of detected VOC's in blanks. The following figure shows the eight take-off set compared with a blank using a charcoal tube pre-filter.

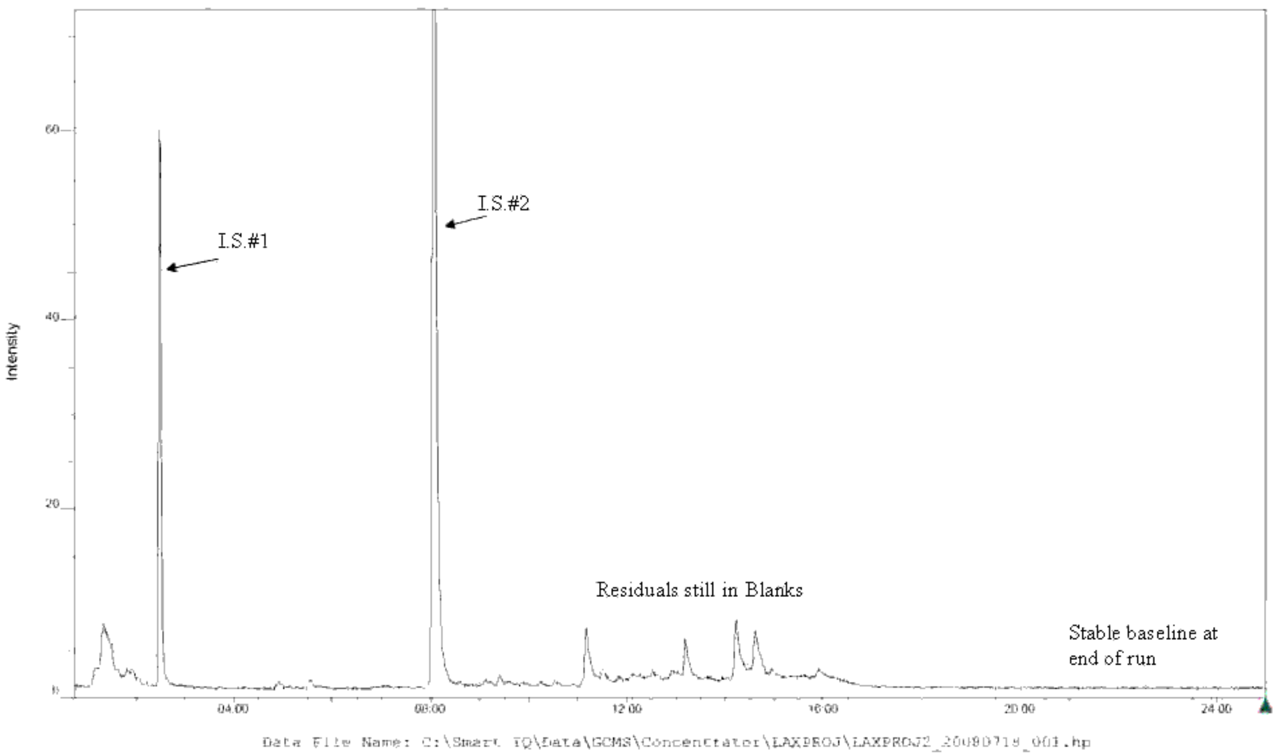
Eight Take-offs During 10 Minute Concentrator Fill - Overlaid With Ambient Blank Using Charcoal Tube "Filter"



The sensitivity did improve using ten-minute concentrator fill, as expected. Individual compounds gave better mass spectra ID's with the use of a ten minute concentrator fill. However, there was carry-over to the blank, and baseline did not return to a starting point due to the oven ramp not being hot enough for the large alkanes in the samples.

The unit was baked out and the final temperature in the GC program was changed to 200° C. At this point, the oven ramp program was changed to a single ramp at 15° C per minute to 200° C with a hold for 8:40 to give 25 minutes total time. The method file was renamed LAXPROJ2 at this point. Also, MS dwell time was decreased to 300 microseconds and the mass range was increased to 300 AMU. After bake-outs and blanks, the oven initial start temp to 50° C was decreased and the hold time decreased to eight minutes to maintain a 25 minute total run time. Weston also increased the probe transfer line temperature, and injection valve temperature, to 80° C and 90° C respectively.

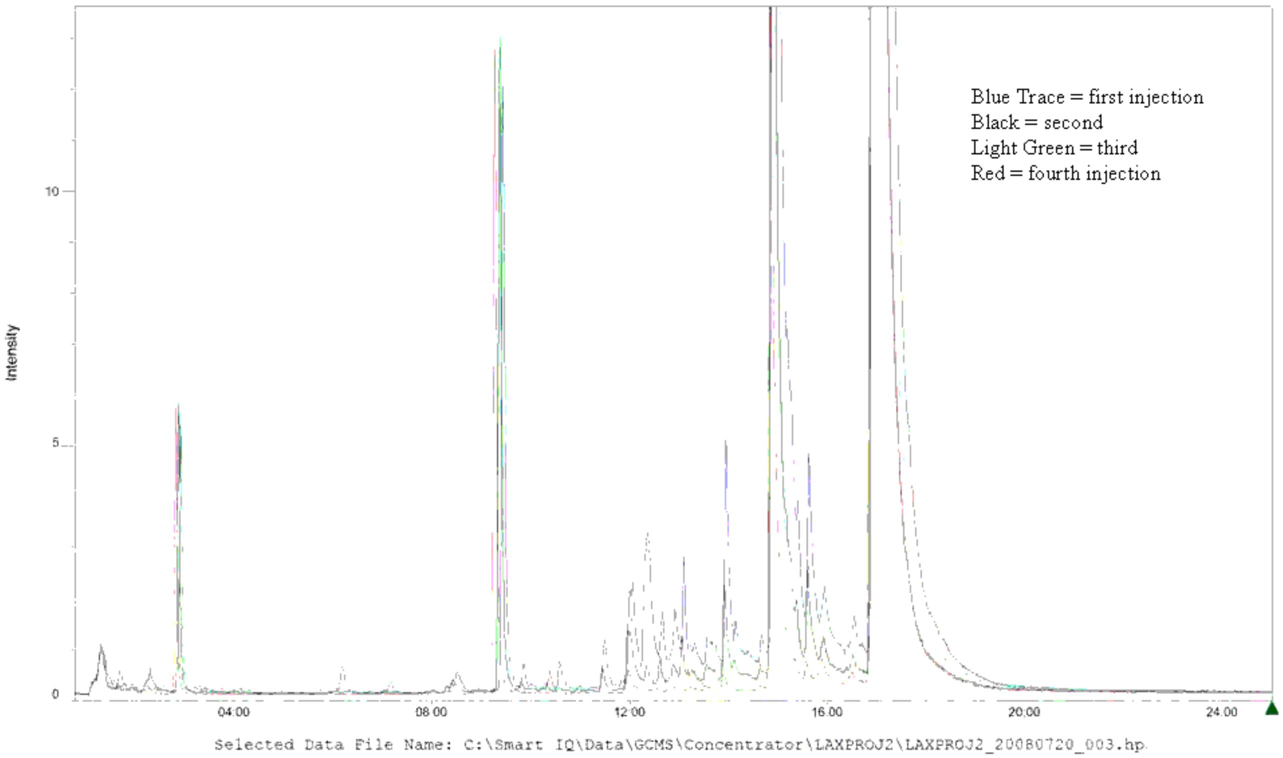
Ambient Air Blank through Charcoal tube "Filter" – Note baseline return after alkanes elute and compound still present from 9 to 16 minutes This is new LAXPROJ2 program used for remainder of study



Saturday, 19 July, Weston was still experimenting with blank issues and finalizing GC program details. A new concentrator trap was installed. The probe line was purged for 60 minutes and more blanks were performed with charcoal tube at probe tip. The Runways were being serviced on Saturday and Sunday, and the south runway was closed to take-offs, so we could not acquired on those days.

Sunday, 20 July, GC parameter adjustments continued and more blanks were performed. The valve oven was changed to 85° C, probe transfer line to 75° C, line purge time to 20 seconds and concentrator fill time to 5 minutes. The probe line was purged for 30 minutes. However, there continued to be background problems with blanks. At this point, the south runway was closed again for maintenance and/or repair and Weston could not test take-offs.

Five Ambient Air Blanks with Charcoal Tube “Filters”

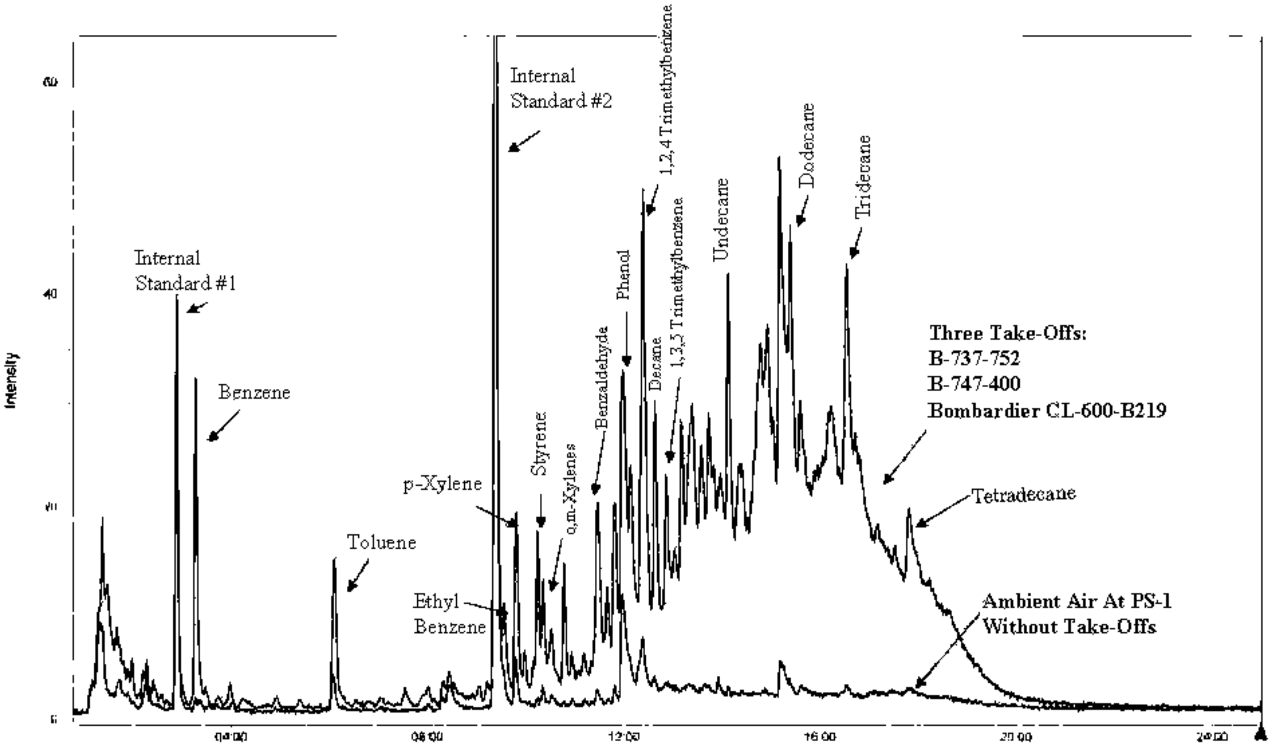


The blanks were still posing difficulties. There were residual hydrocarbons and the same two system artifacts seen previously. The scale and amount of material in blanks were determined to be relative to aircraft exhaust data. It was suspected that some extended probe transfer line purging and heated zone temperature increases liberated compounds from past use.

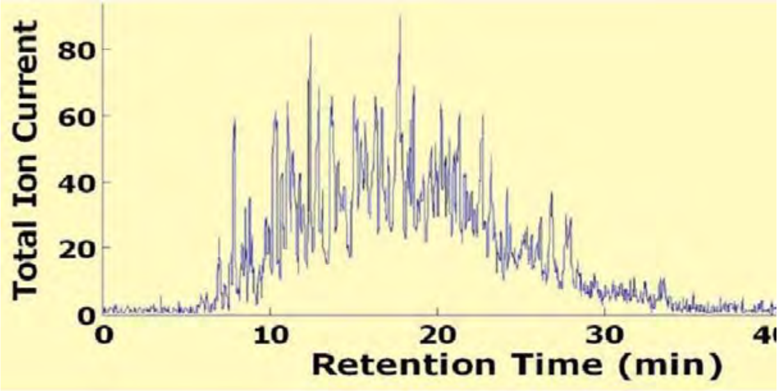
Monday, 21 July, the oven maximum temperature was changed to 190° C and the hold time to 8:40 to maintain a 20 minute run. The heated zones were adjusted down slightly to reduce power consumption and speed cool-down cycle after each run. Ambient data was collected at blast fence during periods of time with no take-offs.

There were five take-off events collected, with two or three take-offs during each concentrator fill. Ambient air during jet blast was clearly discernable from air at fence without any takeoffs, as shown in the figure below.

Comparison of Aircraft Exhaust vs Ambient Air at Blast Fence

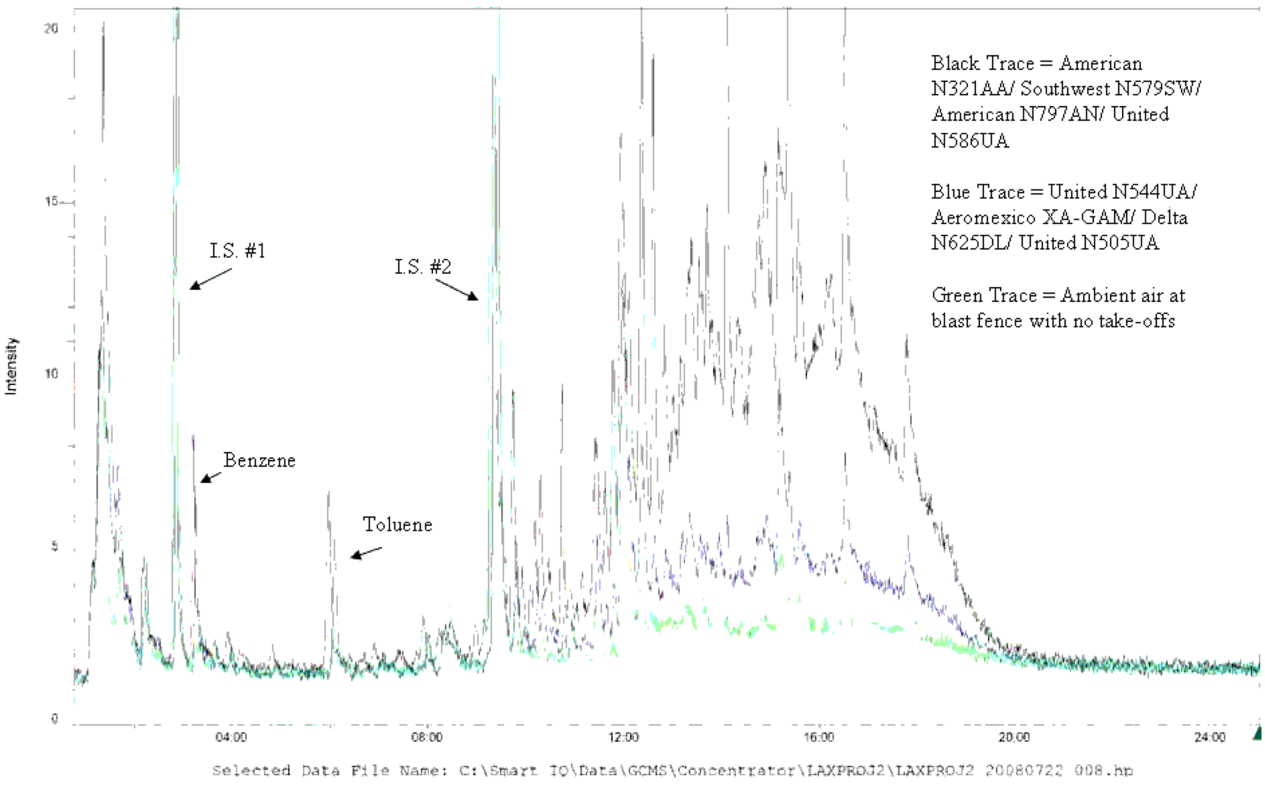


Mass spectral ID's are of sufficient quality to identify the majority of VOC's present. Profile and compounds agree with literature references. Compare with this reference TIC for JP-5 shown below.



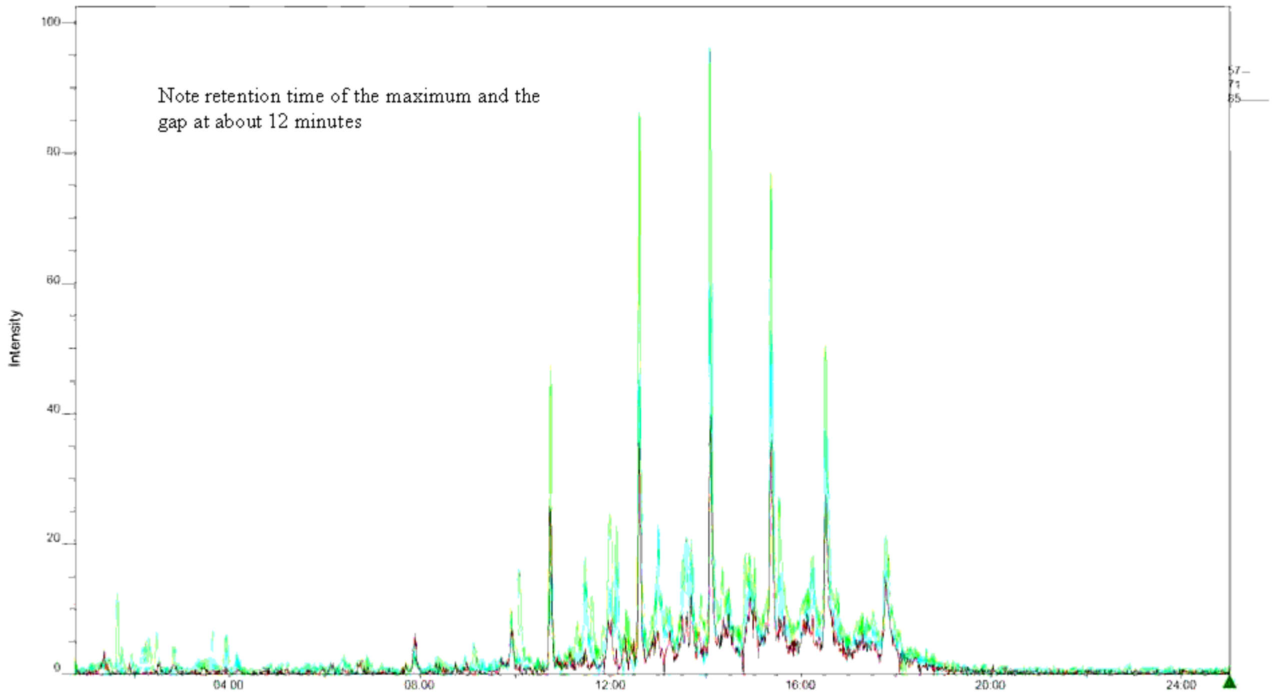
Tuesday, 22 July, Weston performed blanks and bake-out. There were still unresolved blank issues. Blanks with charcoal tube on probe tip sometimes are not as clean as ambient air blanks without any VOC scrubber. Weston suspects possible causes to include pump oils, plasticizers back-streaming due to flow restriction of the charcoal tube, or artifacts from the charcoal tube itself. Despite blank issues, Weston collected two good sets of take-off data with four take-offs occurring during each concentrator fill. Compounds identified using spectral searches are similar and reproducible. Also, two ambient air samples were collected at blast fence without any take-offs.

Two Runs With 4 Take-offs Each and Ambient Air Run at Blast Fence Without Take-offs



The Extracted Ion Chromatogram below (RIC on the Inficon Software) for masses 57, 71, and 85, (corresponding to butyl, pentyl and hexyl (C_4-C_6) straight chain fragments) clearly illustrates the boiling fraction nature of the black trace fingerprint above.

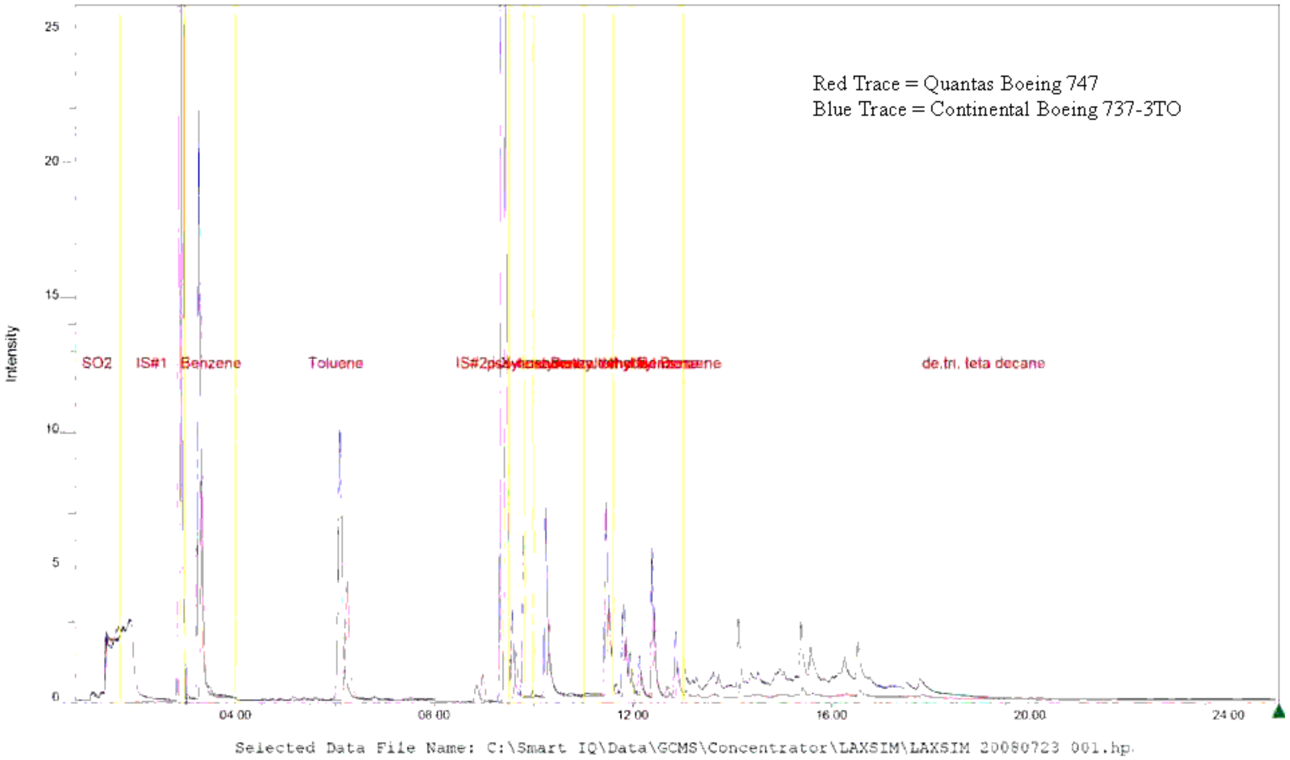
Extracted Ion Chromatogram for C_4, C_5, and C_6 n- alkane fragments in Black Trace Chromatogram Above – (For N321AA/N579SW/N797AN/N586UA Take-offs)



Data File Name: C:\Smart IQ\Data\GCMS\Concentrator\LAXPROJ2\LAXPROJ2_20080722_008.

Wednesday, 23 July, focused on preparing a selected ion monitoring (SIM) program method. SIM mode MS detection can be one thousand times more sensitive than scan mode. Using a tentative list of compounds in aircraft exhaust, the retention times and primary ions were used to develop a SIM table looking only for those specific compounds with much greater sensitivity. Concentrator fill time was cut to thirty seconds (from five minutes) to take advantage of SIM's much improved sensitivity. Other GC and MS parameters, such as oven ramp and transfer line temperature, were unchanged. This configuration was an attempt to obtain information about a specific aircraft's exhaust profile. This new method was named LAXSIM. Note scale on total ion chromatogram and that these are single take-off events with 30-second concentrator fill.

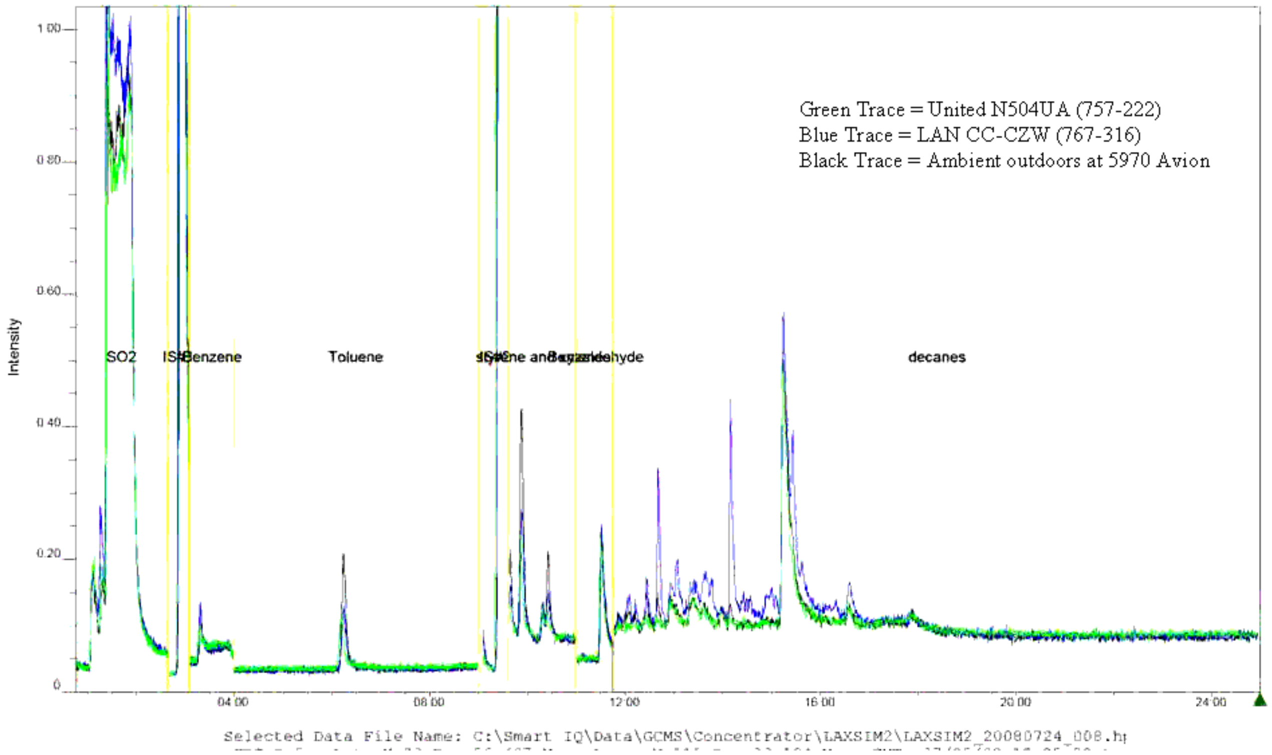
First SIM Mode data – Two Take-off Events With Single Take-offs Captured During 30 Second Concentrator Fill



After acquiring these two takeoffs in the morning, Inficon sampling was suspended to assist the project team in relocating the main Demonstration Project sampling trailer to the PS2 location in the terminal parking area. After the trailer move, the Inficon began malfunctioning with hardware errors and had to be restarted several times. After several different errors and spontaneous re-boots by the Inficon system computer, testing was abandoned and the instrument was returned to Jacobs' project office. Heat on the flight line may have led to the hardware errors and possibly a corrupted method file.

Thursday, 24 July, Weston rebuilt the SIM method program (naming it LAXSIM2) and continued the test with hardware fault problems. Weston worked through hardware and software faults and began to acquire SIM mode data after noon. Four good take-off events were acquired in SIM mode acquisition. The SIM mode, with 30-second concentrator fill, allows data acquisition from single take-offs. It is not possible to separate the effects of aircraft distance from the blast fence and aircraft size, but there appear to be differences in SIM mode VOC profile with aircraft type.

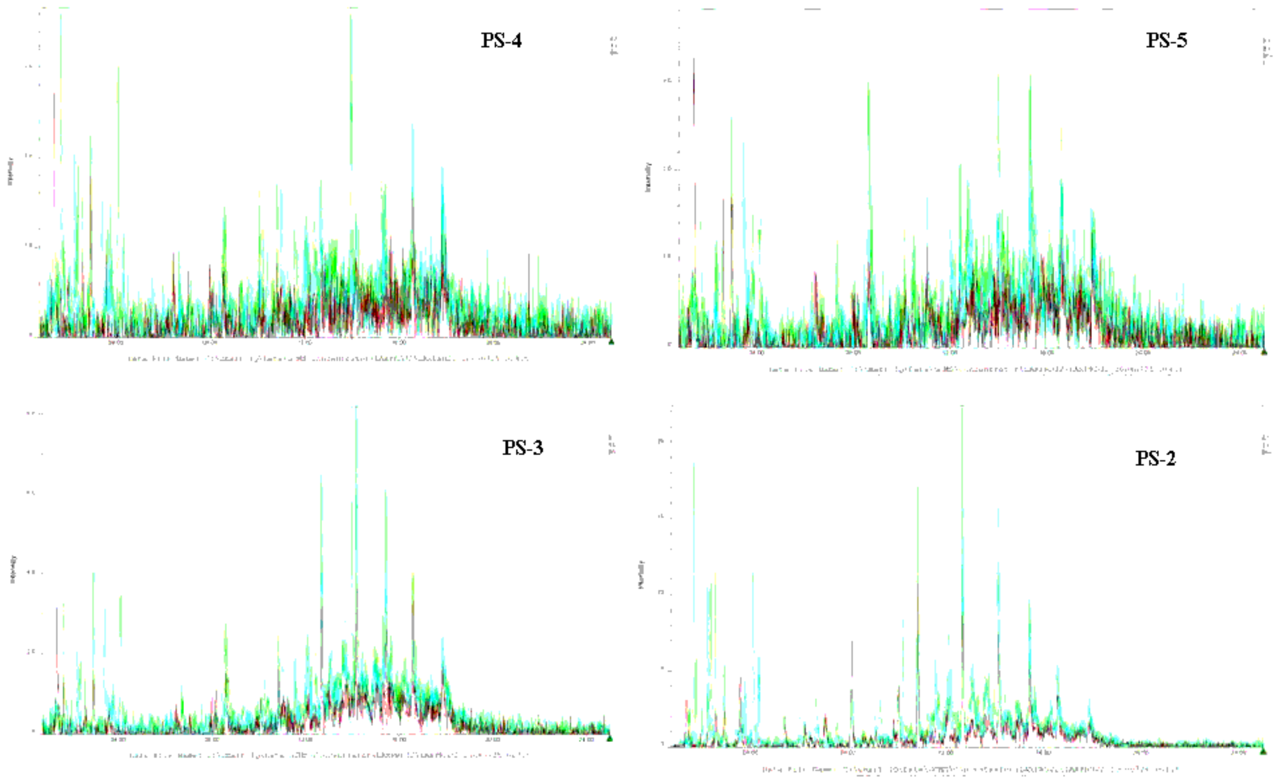
Two take-offs verses Ambient at Jacobs Avion Office Friday Afternoon
Selected Ion Monitoring (SIM) Mode Total Ion Chromatogram (TIC)



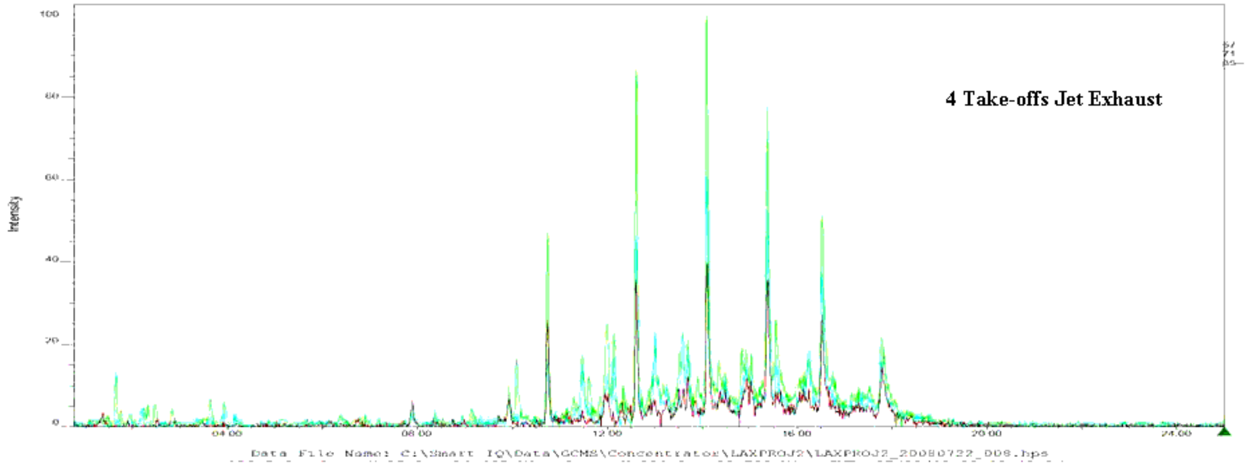
Friday, 25 July, Weston began acquiring both scan and SIM mode data for the PS4 and PS5 locations in the approach field east of Aviation Boulevard. Instrument rebooted during first scan run at PS4. Weston acquired two good scan and two good SIM runs at each location. Basic features of TICs at each location were reproducible. The test was then moved to the PS3 location in the southeast cargo complex by Japan Airlines Cargo, where one scan mode sample run and one SIM mode sample run were acquired in the early evening.

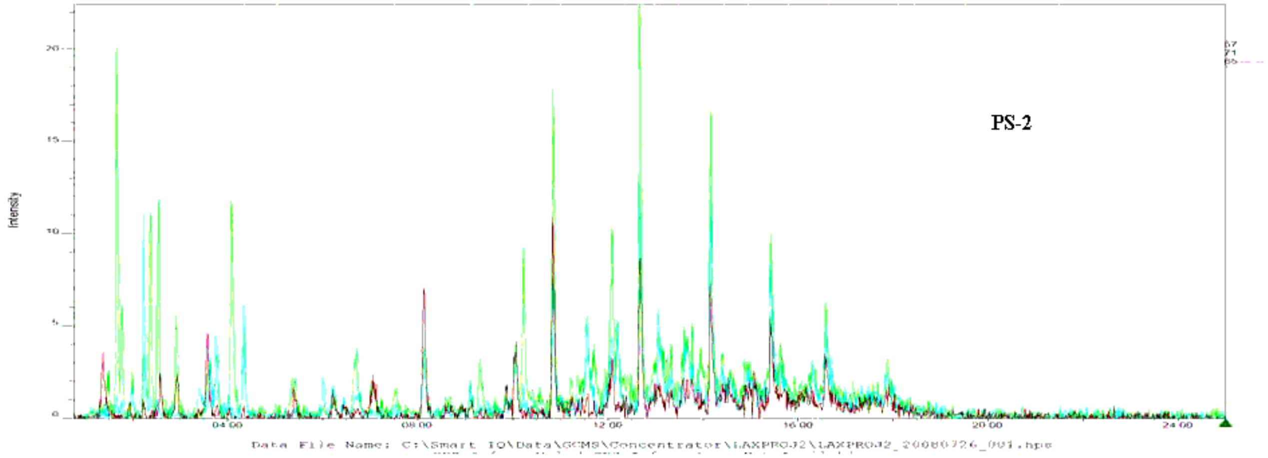
Saturday, 26 July, Weston acquired two scan mode TICs and two SIM mode chromatograms at the PS2 terminal parking location. Interestingly, the extracted ion chromatogram of C_4 through C_6 alkane fragments at the PS2 site produced a different “fingerprint” from the PS4 & PS5 locations. The extracted ion chromatogram from PS3 is similar to PS4 & PS5. A comparison of runs at the sites is shown below.

Extracted Ion Chromatograms From Scan Runs at Remote Locations



Notice the similarities in locations PS4 and PS5. Note the retention time of maxima at about 14 minutes and spacing between peaks. Notice the shift in maxima in the PS2 location indicating a lighter boiling fraction cut of gasoline versus kerosene. Notice the difference in ion abundance in the peak at about 8.2 minutes in the PS2 sample versus PS3. Compare PS2 RIC with the RIC for the “Black Trace” from Wednesday the 22nd below.





Finally, Weston returned the Inficon instrument and accessories to the AQMD office in Diamond Bar, CA at approximately noon on Saturday.

Conclusions

The Inficon portable GC/MS can be used to detect VOC’s from unburned fuel at ambient concentration levels with sufficient sample concentration time, especially in SIM mode. Using SIM mode, the Inficon can probably detect aromatic VOCs at low part-per-trillion (ppt) levels using a 30-second concentration step. Since gasoline, jet fuel, and diesel fuel are distinct petroleum distillate fractions, a fingerprint is apparently discernable reflecting the unburned portion of each fuel source. Analyzing this potential fingerprint observed in the Inficon data was beyond the scope of this study.

Some additional method development is needed to optimize retention windows and masses scanned in each window for SIM mode data acquisition. Retention time shifts due to heat buildup, and the effect of running a scan immediately after the previous run finished without enough cool-down and equilibrium time made setting retention time windows difficult.

To move towards acquiring more robust semi-quantitative data in either mode, a system must be developed to analyze true zero-air blanks and possibly provide for compound by compound calibration. Tedlar bags and charcoal tubes do not provide acceptable blanks, since each apparently produces artifact peaks larger than the fuel constituent compounds of interest. Calibration gases are readily available for a wide variety of fuel components in TO-14 and TO-15 calibration gas mixes, or alkane “C” range mixes, but these are usually available in the low parts per million (ppm) to high parts per billion (ppb) ranges, not parts per trillion. Performing accurate dilutions without introducing artifacts to achieve sub-ppb calibration levels will be a challenge.

Comparative relative “fingerprint” or “signature” data may prove valuable even without absolutely accurate compound-by-compound calibration. A multivariate statistical analysis package for chromatography using principal component regression or analysis might be beneficial to extract information from TIC “signatures”. These methods are commonly used in near-infrared spectroscopy applications for process control. Given a reference set of chromatograms that are representative primarily of gasoline combustion, jet exhaust, and diesel exhaust separately or even using known mixtures, these numerical methods might be able to predict the contribution of each fuel type in an unknown field sample.

Module H

Quality Assurance Audits

(Tasks 4, 6 and 7)

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EXECUTIVE SUMMARY

ENSR and Weston Solutions, Inc installed and operated ambient air monitoring equipment as part of the Los Angeles Air Quality Source Apportionment Study Demonstration Project (Demonstration Project) which is the second phase of a three phased monitoring and source apportionment effort to collect, analyze and model preliminary ambient air quality and meteorological data. Results from this effort will help determine strategic siting locations of key monitoring equipment for the phase 3 monitoring effort.

As part of the monitoring effort, a number of external audits were conducted by T&B Systems. T&B Systems is completely independent of all monitoring activities, and could thus provide an unbiased assessment of the activities. The audits consisted of a performance evaluation to review the measurements made and assess the accuracy of the data collected. A system audit was performed to assess the consistency of measurements with the applicable Standard Operating Procedures (SOPs) and program Data Quality Objectives (DQOs). The sites audited for this effort included: South Runway (SR) (all parameters), Southeast Cargo Area (PS3) (SO_2, SUMA canisters), LAX-Hastings (gaseous and PM_{10}) and LAX-PAMS (upper-air and surface meteorology). The latter two sites are operated by the South Coast AQMD, but because of their close proximity to the study area, collected data will be used for analyses. The primary measurements at the sites consisted of a suite of air quality parameters including NO_2, SO_2, CO, CO_2, O_3 an array of particle samplers, nephelometer, VOC, surface and upper air meteorological instrumentation. Audits at the LAX-Hastings and LAX-PAMS sites were conducted on May 13, 2008, South Runway on July 10-11, 2008 and PS3 and surface meteorology on August 6, 2008.

The overall audit results showed that with a few exceptions, the operations and procedures followed were appropriate to collect the desired data. From a systems aspect, recommendations were made during the audit process to improve the on-site documentation as well as the record keeping as it related to the time synchronization of the data logging clocks. Operationally, with the exception of the radar wind profiler reported winds, the accuracy of all instrumentation audited met the program objectives. While there were some instrument specific issues, those were corrected at the time of the audit and/or the data could be recalibrated during the validation as needed. With respect to the radar wind profiler reported winds, the reason for the observed discrepancies was investigated by the SCAQMD and problems were identified with the antenna switches. At the time of this report writing, work was continuing on the repair of the radar system. Wind data collected by the radar system during the Demonstration Project should be considered suspect and any use of the data would need careful validation by a trained meteorologist to assure the data are valid.

SECTION 1

INTRODUCTION

ENSR and Weston Solutions, Inc installed and operated ambient air monitoring equipment as part of the LAWA Demonstration Project which is the second phase of a three phased monitoring and source apportionment effort to collect, analyze and model preliminary ambient air quality and meteorological data. Results from this effort will help determine strategic siting locations of key monitoring equipment for the third phase monitoring effort and provide insight into the needed measurements during the Long-Term Study monitoring program.

As part of the monitoring effort, a number of external audits of the effort were conducted by T&B Systems. T&B Systems is completely independent of all monitoring activities, and could thus provide an unbiased assessment of the activities. The audits consisted of a performance evaluation to review the measurements made and assess the accuracy of the data collected. A system audit was performed to assess the consistency of measurements with the applicable Standard Operating Procedures (SOPs) and program Data Quality Objectives (DQOs). Performance audits were conducted of all primary study measurements, which consisted of a suite of air quality parameters including NO_2, SO_2, CO, CO_2, and O_3; an array of particle samplers; a nephelometer; VOC and carbonyl samplers; and surface and upper air meteorological instrumentation. The audits of study-specific measurements were conducted at South Runway and PS3. In addition, audits were conducted at two sites operated by the SCAQMD: LAX-Hasting and LAX-PAMS. The LAX-Hastings air quality site measures a complement of air quality variables relevant to this study, and provides good background information during typical onshore flow conditions. The Photochemical Assessment Monitoring Station (PAMS) surface and upper air meteorological site is located on the west end of the airport and provides detailed vertical temperature and wind profiles that will be very useful in understanding and modeling the flows in the region. The LAX-Hastings and LAX-PAMS sites were conducted on May 13, 2008, South Runway on July 10-11, 2008 and PS3 and surface meteorology on August 6, 2008.

This report presents the findings of the audit. Section 1 is this introduction. Section 2 presents the system and performance audit methods. The audit results are presented in Section 3. Section 4 provides results of additional audit activities, and Section 5 lists references cited in the report. The audit records for the air quality analyzers and 10-m tower are provided in Appendix A.

SECTION 2

AUDIT METHODS

The auditing methods employed in the Demonstration Project were based on the most recent USEPA guidance provided in Meteorological Monitoring Guidance for Regulatory Modeling Applications (EPA, 2000), Quality Assurance Handbook for Air Pollution Measurement Systems Volume II (EPA 1998) and Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV (EPA, 1995, 2008), and were enhanced to include additional checks based on the experience of the auditing team. A description of the audit equipment, system audit procedures and the performance audit procedures is provided below.

2.1 DESCRIPTION OF AUDIT EQUIPMENT

AIR QUALITY

Environics 100 Dilution Calibrator And Ozone Transfer Standard

A Environics model 100 mass flow controlled dilution calibrator (S/N 1287) was used to dilute known concentrations of audit gas with zero air and create known audit concentrations. Dilution flow rates were certified on-site at the time of the audit using a Gilian Gilibrator 2 NIST-traceable bubble flow meter. Ozone concentrations were generated by a stable ozone generator and verified by a certified transfer standard (a Dasibi 1008-PC S/N 5951). Our transfer standards are routinely certified against a primary laboratory standard, which is maintained as a primary ozone standard in accordance with the EPA technical assistance document for ozone standards (EPA, 1979). Zero air was provided using a zero air system with activated charcoal and PuraFil scrubbers and certified zero air cylinders provided by Scott Marrin Inc., Riverside, California.

Audit Cylinders

Sulfur dioxide (SO_2), nitric oxide (NO), carbon monoxide (CO), methane (CH_4), and carbon dioxide (CO_2) concentrations were generated using a National Institute of Standards and Testing (NIST) traceable EPA Protocol cylinder and gas dilution. The cylinder was provided by Scott Marrin Inc., Riverside, California.

Particulate Samplers

A Gilian Gilibrator 2 NIST-traceable bubble flow meter and a Kimmon SK-25 dry test meter were used to measure flow rates of the project particulate samplers.

METEOROLOGY

Viz-9000 Rawinsonde System

A VIZ-9000 rawinsonde system was used to collect upper-air wind, temperature and relative humidity data for comparison to the radar wind profiler, RASS and sodar data sets. Three launches were conducted during the audit. The sondes used GPS wind finding techniques.

Acoustic Pulse Transponder (APT)

The APT was used to simulate acoustic echoes corresponding to known wind speeds and directions in the atmosphere. The APT is a microcomputer-based system that is programmable for the number of pulses, pulse duration, pulse frequency, and timing delays. The system detects the transmit pulse from the sodar antenna and retransmits a preprogrammed pulse sequence. The pulse sequence consists of one or more sequential frequencies at specific timed intervals that represent known frequency offsets from the sodar system. The frequency offsets and timing of the pulses simulate wind speeds along each of the sodar component axes. A description of the development of the APT system can be found in Baxter (1994).

Garmin 12-Channel Global Positioning System (GPS)

A Garmin Etrex 12-channel GPS was used to verify the sodar and radar antenna alignment and the wind direction sensor orientation. The measurements were made by pacing off the alignment directions multiple times to achieve repeatable bearings. A description of the method is provided in Baxter (2001). In addition, the integrated GPS pressure sensor was used to conduct the audit of the barometric pressure sensor. T&B Systems conducts routine comparisons of the GPS pressure sensor to our laboratory mercury in glass barometer.

Pro Smartlevel

A 24-inch Pro SmartLevel was used to check the level of the sodar array radar antenna and RASS sources. The SmartLevel is a digital level with a direct readout, in degrees, of the tilt angle of the surface it is placed on. The resolution of the level is 0.1° with an accuracy of about ±0.2°.

Integrating Sound Level Meter

A Realistic model 33-2055 digital integrating sound level meter was used to measure the noise environment at and around the sodar antenna array and the power output from the RASS sources. The sound level meter has both A and C weighted scales. The ambient noise measurements are intended to give a general indication of the noise environment in which the sodar is operating. Sound level measurements are made on the A weighting scale. This sound level meter meets ANSI S1.4 Type III specifications.

Digital Voice Recorder

The noise environment and sodar transmit frequency were recorded using a Sony digital voice recorder model #ICD-MS1. The recorded noise samples were analyzed using the software programs Cool Edit 95 and Spectrogram to identify any ambient audio frequency transmissions that may create erroneous wind data and to determine the sodar transmit frequency.

Licor Silicon Pyranometer

A LiCor LI-200 Silicon Pyranometer (S/N PY10938) was used to audit the site radiometer at the ENSR operated meteorological site. The data were recorded on a Campbell Scientific CR10 data logger. The audit pyranometer is certified annually against a reference pyranometer.

Kipp and Zonen (Accuflux) Pyranometer

A Kipp and Zonen Pyranometer (S/N 015290) was used to audit the site radiometer at the SCAQMD PAMS site. Multiple instantaneous millivolt readings were noted on a digital voltmeter and converted to engineering units based on the radiometer calibration. The audit pyranometer is certified annually against a reference pyranometer.

Digital Thermometer

A Radio Shack model 63-1009A digital thermometer (S/N RSN3) was bundled with the site temperature probes for immersion in the different calibration water baths. The digital thermometer was certified against a mercury-in-glass thermometer.

R.M. Young Selectable Speed Anemometer Drive

To audit the wind speed sensor, various known rates of rotation were obtained using an RM Young Model 18801 anemometer drive. The rate of rotation was digitally controlled and the calibration verified using either a frequency counter or phototachometer.

R.M. Young Torque Disc

An RM Young model 18310 torque disc was mounted on the senor shaft and calibrated screws were placed at known distances from the shaft center to determine the starting torque of the sensor.

2.2 SYSTEM AUDIT PROCEDURES

The purpose of the system audit is to assess consistency of measurements with the applicable Standard Operating Procedures (SOPs) and program Data Quality Objectives (DQOs). A system audit form/checklist is used to ensure that the pertinent items of the audit are covered and to report the audit findings. The audit procedures employed are consistent with *Meteorological Monitoring Guidance for Regulatory Modeling Applications* (EPA-454/R-99-005), EPA, 2000 and the EPA *Quality Assurance Handbook for Air Pollution Measurement Systems, Volumes I, II and IV* (EPA, 1994, 1998, 1995, 2008). We recognize that an update to the EPA QA Handbook Volume IV was just released and, as there are still some technical issues with the current version, we have implemented pertinent sections as appropriate.

The subjects that are addressed by the system audits include:

- Network design and siting
    - Network size and design
    - Sensor exposure
    - Review of station

- Resources and facilities
    - Instruments and methods
    - Staff and facilities
    - Standards and traceability

- Quality assurance and quality control
    - Status of quality assurance program

- Audit participation
- Precision and accuracy checks

Additionally, once the system audits of all sites in a network are complete, the auditor checks for possible differences in operation among the various sites. This will be important, as data collected by the LAWA project contractors will be under different guidelines and objectives than data collected by the SCAQMD and others.

GASEOUS AIR QUALITY AND PARTICULATE MEASUREMENTS

The system audit of air quality monitoring systems consists of (1) an inspection to determine if the sampling and data acquisition system (DAS) equipment are operational, (2) verification that sample lines are clean and secure, and (3) a review of the station check logs and onsite forms to determine if the documentation conforms to the specifications of the plan. The system audit of particulate samplers consists of (1) an inspection to determine if the samplers are operational and clean, (2) verification that the spatial distribution of the samplers at each site conforms to the siting criteria, and (3) flow records and QC checks appear reasonable. Specifically designed system audit forms are used to document the system audit results and maintain consistency in the checks. The findings of the checks are included in this report.

An evaluation of the quality assurance/quality control plan procedures including preventive maintenance is performed. Reviews of calibration records and maintenance logs are checked for consistency, frequency and accuracy. Equipment settings including flow rates and zero/span settings are evaluated to determine if ranges are acceptable. Additionally, once the system audits of all sites in a network are complete, the auditor checks for possible differences in operation among the various sites.

SURFACE METEOROLOGICAL MEASUREMENTS

The system audit of the surface meteorological sensing systems consist of an inspection of the site to assess proper siting of the instrument sensors, a review of the station check logs and other site documentation, as well as an interview with the site operator concerning his or her knowledge of the project's Quality Assurance Program Plan (QAPP) and applicable SOP sections. Sensor siting criteria for meteorological sensors are specified in the EPA *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV* (EPA, 1995) and *Meteorological Monitoring Guidance for Regulatory Modeling Applications* (EPA, 2000). On-site forms and site logs are reviewed to check that the documentation conforms to the specifications of the plan.

UPPER-AIR MEASUREMENTS

For the Demonstration Study there were no upper-air measurements made by the project team. However, SCAQMD operates an upper air station as part of their monitoring network on the airport property. The monitoring station is located at the west end of the airport, beyond the end of World Way. This station consists of a miniSODAR, radar wind profiler and a Radio Acoustic Sounding System (RASS).

The sodar, radar wind profiler and RASS system audit is divided into several tasks. A description of each task is provided below:

The antenna and controller interface cables are inspected for proper connections. Antennas and enclosures or clutter fences are inspected for structural integrity. The orientations of the antennas are checked using either the solar siting or GPS "walk-off" methods. Both of these methods are described in detail in Baxter (2001). The levels of the antennas are measured using a Pro SMARTLEVEL. Measurements are made in at least two directions on the bottom of the antenna array's support structure. For the multiple antenna systems the inclination angle is also measured and compared to the software setting. The results of the measurements are compared to the audit criteria of ±2° for orientation and ±0.5° for level.

A vista table is prepared that documents the surroundings of the site. The table identifies potential reflective sources for the radar or sodar signal, as well as potential active sources that could generate interference. The table also provides a description of the view in 30-degree increments around the antenna, including the elevation angle and estimated distance to potential sources. Pictures are taken in 45° increments looking from the antenna to further document the vista.

An evaluation of the site characteristics is performed. Passive and active noise sources are identified and noted to evaluate their impact on the sodar's or radar's ability to separate the return pulses from the background noise. Passive sources are objects that may reflect the pulse and contaminate the return spectra with what appears to be near-zero wind speeds. These sources include buildings, trees, nearby towers, road traffic, birds, etc. Active sources generate their own noise such as air conditioners, fans and industrial complexes for sodars and radio transmitters for radars. Low-level active white noise sources are not generally a problem except to reduce the maximum altitude. Active noise sources in the frequency spectrum of the sodar or radar operations may affect the operations. For the sodar, general sound levels are measured using an integrating sound level meter to measure levels. A spectral analysis of the background noise is also performed to determine if there are significant sources within the operating range of the sodar.

In addition to the evaluation of the noise spectrum above, a system check is performed with the system "listening only," i.e., without transmitting a pulse. The results of this check should produce no measured winds, or winds with very low reliability. If winds are reported at any level, then there is probably an active noise source in the area that is generating frequencies in the operational region of the sodar or radar.

Finally, the system computers are checked for the proper calendar and clock timing and the ability of the software to appropriately handle the current date and time formats. The network consistency of time zones is included in this check. All clocks are checked and compared to the PAMS specified ±2 minute criteria for the upper air monitoring site.

LABORATORY

A system audit of the Atmospheric Analysis and Consulting, Inc. (AAC) laboratory was conducted through an on-site visit and review of the operations. The system audits began with the review of the QAPP and SOPs and continued with a detailed inspection of the laboratory facilities along with an evaluation of the following project components, in accordance with the QAPP and applicable SOPs:

- Sample logging
- Storage and identification methods
- Calibration procedures
- Preparation and storage of standards
- Quality control checks (such as blanks and duplicates)
- Chain-of-custody protocols
- Data reduction, validation and reporting methods
- Documentation of all pertinent actions

Also included in the system audits were interviews of all laboratory staff working on the study. The interviews focused on the staff’s familiarity with the job(s) performed for the study, how they track samples and assurance of data quality, and to whom they report problems when a parameter or system is outside of the control limits. A laboratory system audit checklist was used to assist the auditor in conducting the audit.

2.3 PERFORMANCE AUDIT PROCEDURES

AIR QUALITY AUDIT PROCEDURES

NO/NO_x/NO_2, SO_2, CO, O_3, CO_2

The entire sample train of the analyzer is connected to a certified Environics Series 100 dilution system output port via a glass manifold. Care is taken to introduce the audit span gas through as much of the normal sampling train (i.e., filters, and scrubbers) as possible. The analyzers are challenged with specific concentrations of span gas as indicated below. Some ranges were modified in the field to more closely bracket the observed ambient concentrations.

Audit Points	Concentration Range (ppm)
	$NO/NO_x/NO_2$, SO_2, O_3
1	0.000
2	.03 to .08
3	.15 to .20
4	.35 to .45
	CO
1	0.0
2	3 to 8
3	15 to 20
4	35 to 45
	CO_2
1	0
2	250 to 350
3	750 to 850
4	2100 to 2200
	THC
1	0.0
2	1.2 to 3.2
3	6.0 to 8.0
4	14.0 to 18.0

Nitric oxide (NO), sulfur dioxide (SO_2), carbon monoxide (CO) and carbon dioxide (CO_2) concentrations are generated using National Institute of Standards and Testing (NIST) traceable EPA Protocol No. 2 cylinders and gas dilution. Ozone concentrations were generated by the Environics 100 ozone generator and verified by a certified transfer standard. Zero air is used to dilute the concentrations of cylinder gas. The zero air is provided by Scott Marrin Inc., Riverside, California, or by a zero air generator. Zero air for the CO_2 dilution is provided by a cylinder of CO_2 free air.

Nitrogen dioxide concentrations are introduced into a $NO/NO_2/NO_x$ analyzer by gas-phase titration (GPT) of NO with O_3. Nitric oxide reacts completely with ozone to produce nitrogen dioxide and oxygen.

The NO_2 input concentration is determined by:

$$[NO_2\ \text{input}] = \frac{[NO\ \text{initial}] - [NO\ \text{final}]}{NO\ \text{slope}}$$

[NO initial] = analyzer's NO channel response to the NO span prior to the addition of O_3
[NO final] = analyzer's NO response after the addition of O_3
NO slope = slope of the curve generated by linear regression of the NO concentrations versus the analyzer's response during the audit of the NO channel, where the NO input is the abscissa and the response is the ordinate

The final stage of the $NO/NO_2/NO_x$ analyzer audit is to determine the converter efficiency from the following relationships:

$$[NO_2\ \text{converted}] = [NO_2\ \text{input}] - \frac{[NO_x\ \text{initial}] - [NO_x\ \text{final}]}{NO_x\ \text{slope}}$$

[NO_x initial] = analyzer's NO_x channel response before the addition of O_3
[NO_x final] = analyzer's NO_x response after the input sample of NO is titrated with O_3
NO_x slope = slope obtained from the audit of the NO_x channel

The analyzer converter efficiency is defined as the slope of the linear regression using the NO_2 source versus the NO_2 converted x 100. The converter efficiency must be greater than or equal to 96 percent to pass the audit.

Canister sampling

The canister sampling is qualitatively audited by measuring the flow rate with the audit flow meter in the sampler inlet and verifying the approximate rate is appropriate to fill the canister in a linear manner over the 12-hour sample period. The canister flow rate is controlled by a critical orifice.

Carbonyls

The Carbonyl samplers are audited by measuring the flow rate with the audit flow meter in the sampler inlet and comparing it to the sampler set point. As the key component is the total flow through the sampling media, the audit will just compare the sampler set point flow to the measured audit flow.

Light Scattering (Nephelometer)

The nephelometer zero is audited using particle free air generated by scrubbing the inlet with a HEPA filter. The response of the instrument is then verified by flooding the chamber with Freon 134a gas, also known as SUVA. The upscale response is then compared to the calculated response for the gas at the station altitude.

PARTICULATE MATTER AIR QUALITY MEASUREMENTS

Minivols

Minivol samplers are turned on and allowed to warm up and the flows are allowed to stabilize with the sample filter in place. The rain cap is removed and an adapter is used to connect the audit flow meter to the sample inlet. The readings from the flow meter are used as-is because the flow is provided at actual conditions. The measured audit flow rate is compared to the operator provided sampler flow rate as well as the manufacturer specified 5 liters per minute (lpm) flow rate.

Beta Attenuation Monitors (BAMs)

PM_{10} and $PM_{2.5}$ BAM sampler flow rates are audited at the sample inlet by removing the sample head and using an adaptor to the audit flow meter at the sampler cyclone. Readings obtained from the flow meter are used as-is because the flow is provided at actual conditions. The measured audit flow rate is compared to the operator provided sampler flow rate as well as the manufacturer specified 16.67 lpm flow rate.

PM Speciation Samplers

PM Speciation samplers are audited by first performing a leak check in accordance with the manufacturers' procedures. An audit filter cassette is then loaded into the sampler with the calibration/leak check adapter placed on the sampler inlet. The audit dry test meter is then connected to the sample inlet, via an adapter, and the sampler is started and allowed to stabilize. Timing of the sampler total flow is then initiated and the audit flow rate is calculated from the audit dry test meter registered total flow and elapsed time. The measured audit flow is compared to the operator provided sampler flow as well as the manufacturer specified 16.67 lpm flow rate. The ambient temperature probe is audited by comparison to a collocated NIST-traceable digital thermometer. The audit probe is placed within the ambient temperature radiation shield. When both the audit and sampler temperature probe readings stabilize, a one-point comparison is made. A one-point comparison of the sampler barometric sensor is conducted by comparing average audit standard and sampler readings based on three separate readings performed at 10-minute intervals.

Ultrafine Particles

The sampler flow rate is checked using an audit flow meter. In addition, a HEPA filter is placed on the inlet to verify reduction in particle count, particularly for the larger particles.

Aethalometer

As there are no practical field methods to audit the precision or accuracy of the aethalometer measurements, the only audit performed is of the flow rate. This flow rate is specific to the cut point of the sample inlet. The flow rate was audited using an audit flow meter and the measured flow compared to both the sampler set point and specified flow to achieve the proper sampler cut point. In addition, a HEPA filter is placed on the inlet to produce near-zero concentrations.

SURFACE METEOROLOGICAL MEASUREMENTS

Wind Speed

The wind speed audit begins with the inspection of the wind speed cups or propeller(s) to ensure that they are intact. The cups are then removed to produce a zero point. Next, the R.M. Young selectable speed anemometer drive is connected to the sensor shaft to simulate wind speeds of approximately 5, 15 and 35 m/s. Actual values depend on the sensor model and are determined by multiplying the motor speed by a cup or propeller transfer coefficient supplied by the manufacturer. The data logger responses are compared to the calculated actual values.

The sensor bearings are then checked for excessive wear by manually turning the sensor shaft to determine whether there is any bearing drag. Next, the sensor is removed from the crossarm and the R.M. Young torque disk is mounted on the sensor shaft. The starting torque is determined using the manufacturer-recommended procedures.

Wind Direction

The wind sensor crossarm alignment relative to true north is checked using a GPS unit or a tripod mounted Brunton surveyor compass. The angle of declination is taken into account when performing this check. This angle is verified using a solar siting. The wind direction vane is then pointed toward at least the four cardinal directions and the responses of the data logger and chart recorder are noted and differences calculated. The sensor bearings are then checked for excessive wear, first by manually turning the sensor shaft to determine whether bearing drag is present and then by using an R.M. Young vane bearing torque gauge according to the manufacturer-recommended procedures.

Ambient Temperature

The temperature-sensing system is audited by immersing the system sensor and a calibrated precision digital thermometer, which is certified against a NIST-traceable mercury-in-glass thermometer, in the same water bath. The thermometer readings are compared with the data logger and chart recorder outputs at approximately zero, 20° and 40° C.

Solar Radiation

A certified LiCor or Kipp and Zonen (Accuflux) pyranometer is collocated with the station solar radiation sensor and at least five simultaneous readings over the course of the audit are collected and the differences compared with the audit criteria. Similarly, the audit pyranometer may be hooked up to an audit data logger, and the audit readings can be averaged into periods comparable to those collected by the station.

Barometric Pressure

Simultaneous readings of the data logger and chart recorder for barometric pressure and the audit barometer are made at the beginning and the end of each audit visit. The audit barometer is certified against a NIST-traceable mercury-in-glass barometer maintained by T&B Systems.

UPPER AIR METEOROLOGICAL MEASUREMENTS

Sodar

The performance audit of the sodar consists of two elements: first by comparison with simulated winds from an Acoustic Pulse Transponder (APT), and second, by comparison to independent wind measurements. The latter comparison to the independent wind measurements is needed if the sodars are of the phased array variety. This comparison verifies the beam steering is appropriate by assessing the reasonableness of the data.

Unlike conventional sensors where known wind speeds and directions can be input directly to the sensor through various rotational methods, the acoustic system relies on the measurement of time and frequency shift of the backscattered acoustic pulse. The only means of truly providing a known input is through the introduction of fixed audio frequencies at known times. The frequency shift will correspond to a Doppler shift introduced by winds to or from an antenna. The timing of the simulated return will represent a known altitude based on the speed of sound. These simulations of the Doppler shifted signal are performed using the APT.

A comparison of the sodar response is made against independently measured winds. For this monitoring effort, a rawinsonde system was used with several releases over the course of the day. This system was also used to audit the station radar wind profiler and RASS.

All wind speed data are evaluated based on components along the sodar antenna axes. Where multiple comparisons are made, the systematic and RMS differences are calculated and compared to criteria of ±1 m/s and 2 m/s, respectively. In addition, comparisons are made to the sodar resultant vector values, but only for qualitative evaluation purposes. This is consistent with the newest EPA guidance and will help identify component related problems that may be missed by looking at the resultant data alone.

As a final check of the sodar data, data collected during several days prior to the audit are reviewed to establish the internal consistency of the values. As this is a qualitative check, there are no fixed evaluation criteria. The goal is to evaluate the following:

- Data reliability or quality codes for consistency
- Measured vertical intensity values for detection of potential fixed echoes
- Vertical profile of the individual wind components for detection of potential fixed echoes and consistency
- Vertical profile of the calculated vector winds for internal consistency
- Methods used to create hourly values from subhourly intervals

Radar Wind Profiler

The EPA guidance for QA on radar profilers defines a series of system checks inherent to the profiler electronics. Unlike the sodar where instrumentation exists for simulation of winds by introduction of "Doppler shifted frequencies", no such instrumentation exists for the profiler or RASS systems. Thus, to audit the data gathered by profilers, the data are compared to measurements from multiple rawinsonde balloon launches or other upper air data sources. At least three launches are performed over the course of a day to collect data under a variety of meteorological conditions. The collected meteorological data are then reduced into components along the radar wind profiler axes and the speeds compared with the radar data using the same systematic and RMS difference criteria as the sodar. This method is consistent with the newest EPA guidance. T&B Systems uses a suite of software programs that create compatible data files from the audit system and radar wind profiler, and perform statistical analysis of systematic differences and operational comparability between the systems.

As a final part of the audit, data from several days prior to the audit are reviewed for internal consistency. This type of review will check indicated flags for data reliability or quality codes for consistency, individual component intensity values to identify potential reflections, and the vertical profiles of the components and resultant values for internal consistency both in space and time.

Radio Acoustic Sounding System (RASS)

Audits of the RASS measurements are performed using at least three temperature and humidity soundings from the rawinsonde system over the course of the day. Sonde measurements are used to calculate the virtual temperature profiles (Tv) for comparison to the RASS-derived Tv values. The data collected from each launch is volume averaged to match the averaging intervals of the RASS. The results of the audit comparisons are evaluated against the criteria of ±1.0°C and 1.5°C for systematic and RMS differences, respectively.

As in the wind profiles, data from several days prior to the audit is reviewed. The review focuses on the internal consistency of the data in both space and time and evaluating the reasonableness of the Tv profiles.

2.4 PERFORMANCE AUDIT CRITERIA

The criteria used to evaluate the audit results are summarized in **Table 2-1**.

Table 2-1

SUMMARY OF INDEPENDENT AUDIT CRITERIA AND PROCEDURES

Measurement Variable	Audit Criteria	Procedure Reference	General Procedure
Time	±5 seconds	Audit clock synchronized to either WWV or to the satellite GPS network	Comparison check to the data logging clocks.
Horizontal Wind Speed	Accuracy ±(0.2 m/s + 5% of observed) Equivalent wind speed starting torque to meet the wind speed starting thresholds for the respective sensors.	EPA-454/R-99-005 EPA/600/R-94-038d	Three wind speeds within the expected range of operation. If any points are outside of criteria then corrective action is necessary.
Horizontal Wind Direction	Accuracy ±3 degrees for linearity, ±2 degrees for alignment to known direction, ±5 degrees total error. Equivalent wind speed starting torque to meet the wind speed starting thresholds for the respective sensors.	EPA-454/R-99-005 EPA/600/R-94-038d	Depending on the mechanical sensor type from 4 to 36 points equally spaced around the compass are compared. If any points are outside of criteria then corrective action is necessary. Torque measurements are made to determine the mechanical sensor starting threshold. Sensor alignment is verified using solar or GPS methods.
Temperature	±0.5°C (monitoring criteria)	EPA-454/R-99-005 EPA/600/R-94-038d	Three temperatures within the expected range of temperatures (0 to 40°C). If any points are outside of criteria then corrective action is necessary.
Solar Radiation	± 5% of observed	EPA-454/R-99-005 EPA/600/R-94-038d	Five measurements within the range of operations on a given audit day are made. If any points are outside of criteria then corrective action is necessary.
Relative Humidity	±7% RH	EPA-454/R-99-005 EPA/600/R-94-038d	Three comparisons are made of the station sensor to an aspirated psychrometer. If any points are outside of criteria then corrective action is necessary. The preferred method uses a self-contained RH/Temperature data logging system, which is collocated with a site sensor, recording data over the audit period. These data are compared to several observed station readings. If any points are outside of criteria then corrective action is necessary.
Remote Sensing Horizontal Wind Speed and Direction (sodar and radar wind profiler)	Antenna alignment to true -- ±2° Antenna level and/or zenith -- ±0.5° Sodar transponder response -- ±0.2 m/s for component Comparison systematic difference – Beam component, ±1.0 m/s Comparison RMS difference – Beam component, ±2.0 m/s	EPA-454/R-99-005	Anticipated comparison instruments to be used include a rawinsonde. Three to four soundings will be conducted. For sodars that are amenable to a transponder audit, that may be used in place of the comparison.
RASS Virtual Temperature	RASS element level -- ±1° Comparison systematic difference – ±1.0°C Comparison RMS difference – ±1.5°C	EPA-454/R-99-005	Anticipated comparison instruments to be used include a rawinsonde. Three to four soundings will be conducted.

Table 2-1

SUMMARY OF INDEPENDENT AUDIT CRITERIA AND PROCEDURES

Measurement Variable	Audit Criteria	Procedure Reference	General Procedure
Gaseous Air Quality Response	Slope – 1.00 ±0.15 Intercept -- ±3% (full-scale) NO_2 GPT Efficiency -- ≥96%	EPA-600/R-94-038b	Dilution of known traceable concentrations of gas. Zero air to be provided by CO_2 free air for the CO_2 analyzer and by a zero air system for the remaining pollutants.
Particulate Matter Minivol	PM_{10} Filter -- ±10% (5 lpm)	EPA-600/R-94-038b and experience. No audit criteria exists specifically for the minivol. Methods also developed during the 2000 CRPAQS program.	Measurement of inlet flow using a certified Gilibrator flow device
Particulate Matter BAM $PM_{2.5}$ and PM_{10}	±5% of 16.67 lpm		Measurement of the inlet flow using a certified flow device
Ultrafine particle number and sizer	±10%		Measurement of the inlet flow using a certified Gilibrator flow device
Light Scattering (Nephelometer)	±10% response to SUVA ±1°C temperature ±5% RH ±3 mb pressure	CRPAQS Audit Methods	HEPA filter to zero the instrument and SUVA for the span check. Audit by comparison of the internal pressure, temperature and relative humidity sensors.
Black Carbon (Aethalometer)	±5% of audit flow ±5% flow difference from design flow		Measurement of the inlet flow using a certified Gilibrator flow device. Check of zero using a HEPA filter
PM2.5 mass and speciation	±4% of audit flow ±5% flow difference from design flow ±2°C temperature ±10mm Hg pressure	EPA/600/R-94/038b	Measurement of the inlet flow using a certified dry test meter. Comparison of the available temperature sensors to the audit standard. Comparison of the internal pressure measurement to the audit standard.
Carbonyls	±5% of audit flow		Measurement of the inlet flow using a certified Gilibrator flow device

SECTION 3

AUDIT RESULTS

Results of the audits are summarized below. Detailed audit records are included in **Appendix A**.

3.1 LAWA – SOUTH RUNWAY, PS3 AND SURFACE METEOROLOGY

KEY AIR QUALITY PERFORMANCE AUDIT FINDINGS

The audit of the South Runway site was conducted on July 10 and July 11, 2008. Equipment audited included gaseous analyzers and particulate samplers. The audit of PS3 and the revised location for the meteorological station was conducted on August 6, 2008. Equipment audited included the SO_2 analyzers, SUMA canisters and meteorological sensors. **Table 3-1** presents the audit results. The individual audit summary sheets can be found in Appendix A. The following are key performance audit findings noted at the time of the audits:

1. Per Vince Sheetz of ENSR, the original location for the meteorological monitoring equipment at the SR site was not audited, as the conditions at this location made the readings unrepresentative and unusable. After viewing the sensors and the siting, the auditors agreed. A meteorological tower was later installed east of the South Runway site (east of Aviation Blvd) by ENSR and an audit was subsequently conducted. Results of the audit are summarized in **Table 3-2**.
2. The CO_2 response was about 20% low. This was consistent with an auto zero/span check conducted immediately after the audit. Thus, the audit showed agreement between the audit and the site standards. The low response should be further investigated.
3. EPA guidelines recommend that sample inlets be positioned at least 1 meter from supporting walls. The AQ inlet is currently located about 0.8 meters from the wall.
4. SO_2 was included in the QAPP, but not monitored at the SR site. As a result, the start of SO_2 monitoring was initiated after this audit was conducted and was audited at Site PS3. No problems were noted during the audit of the SO_2 analyzer at PS3.
5. During the audit of the PS3 site it was noted that the calibration cylinder indicated "non-EPA protocol, in-house only, do not use in field". While the audit results for SO_2 showed good agreement thus verifying the accuracy of the

calibration cylinder, it is highly recommended that a cylinder certified to the recommended EPA protocol be used for the annual monitoring program.

6. During the audit of the PS3 site, the various instruments and data loggers had time accuracies outside of the project objective of ± 5 seconds. Only the CR3000 was accurate. It was indicated that this data logger clock is synchronized to the time server daily. It was recommended that a time check be conducted during each of the site visits.
7. Checks of the Minivol flows were initially being conducted with filters removed from the cassettes. The recommendation was made to make the flow checks with filters installed in order to identify any changes in flow rate that might occur from filter loading.
8. The flow rate for channel 2 of sequential sampler no. 2 was greater than 10% lower than indicated. The channel should be calibrated.
9. The PM_{10} BAM leak check was somewhat higher than normal, and the flow was slightly lower than indicated. While the sampler met the audit criteria, the combination indicates a possible leak.
10. Initially, the TSI sample flowrate was about 17% higher than the indicated 8.0 lpm. Subsequent to the audit it was indicated the reading was not taken properly from the front panel flow. The indicated flow was actually 10.0 lpm. Thus, no problems were noted.
11. Some questions arose about the length of the sample inlet of the TSI FMPS and the potential effects of the bends in the sample inlet. The manufacturer (TSI) was contacted by the auditor and information provided that indicated the length of the inlet and the indicated bends will have a minimal effect on the fine particle counts of interest. The inlet materials used were appropriate and at the 10 lpm flow rate will help prevent any diffusion losses. The primary issue indicated by TSI would be condensation losses on the walls of the inlet if the temperature in the shelter was significantly lower than the outside temperature and the humidity was high.
12. Tenax, carbonyl and SUMMA canister sampling were not initially audited, as sampling with this media had not yet begun. However, a comparison made with the flow standard to be used for the Tenax and carbonyl flows showed good agreement between the audit and the site. The SUMMA canister operation was later audited at PS3 where a qualitative assessment of the procedure and flow rate indicated that no problems were present.

13. Trip/field blanks are to be collected for the filter and cartridge samplers. However, no sampling blanks are currently being collected (subjected to loading and unloading procedures). Given potentially high PM loading, sampling blanks are suggested.
14. The following summarizes the data logger clock checks: AQ data logger - 17 seconds slow (in addition, the hour was set 2 hours fast relative to PST, which was corrected at the time of the audit); Nephelometer data logger - 30 seconds slow; PAS, BAM data logger - within 1 second; Aethalometer - 3 seconds fast; TSI particle sizer - 15 seconds slow. The need to check the clocks and maintain the project objective of ±5 seconds was reiterated.
15. At the PS3 site it was noted that the particulate samplers on the west side of the trailer should be moved further out to meet the recommended spacing of 1 meter from the side of buildings.
16. The barometric pressure sensor (meteorological tower) audit results do not meet the recommended audit criteria. At the time of the audit the sensor had not yet been calibrated. The sensor was to be calibrated following the audit.
17. The audit of the wind direction sensor had two audit points that did not meet the maximum allowable recommended audit criteria. This was apparently due to the "as-found" orientation of the sensor. The data can be corrected by applying the appropriate offset.

Table 3-1.

SUMMARY OF SOUTH RUNWAY/PS3 AIR QUALITY PERFORMANCE AUDIT RESULTS

AMBIENT AIR QUALITY MONITORS

Audit Date	Parameter	DAS Slope	DAS Intercept	DAS Correlation
7/10/2008	**Ozone**	0.934	0.005	1.0000
7/10/2008	**Nitric Oxide**	0.953	0.001	1.0000
7/10/2008	**Nitrogen Oxides**	0.948	0.002	1.0000
7/10/2008	**Nitrogen Dioxide**	0.951	0.002	1.0000
8/6/2008	**Sulfur Dioxide**	0.956	-0.001	1.0000
7/10/2008	**Carbon Monoxide**	0.928	-0.240	1.0000
7/10/2008	**Carbon Dioxide**	0.769	-110.479	0.9999
7/10/2008	**Total Hydrocarbons**	0.967	0.004	1.0000

Audit Criteria: Slope 1.000 ± 0.15: Intercept 0 ± 0.015 ppm (CO 0 ± 1.5 ppm; THC 0 ± 0.9 ppm; CO Correlation > 0.9950

SAMPLERS

Audit Date	Sampler	Audit	Site	% Diff.	Audit Criteria
7/10/2008	**Aethalometer**	**slpm**	**slmp**	**slpm**	
		5.13	4.90	-4.5%	± 5%
7/10/2008	**PAH Sampler**	**lpm**	**lpm**	**lpm**	
		2.18	2.01	-7.8%	± 10%
7/10/2008	**Particle Size**	**lpm**	**lpm**	**lpm**	
		9.66	10.0	3.5%	± 10%
7/10/2008	**BAM PM2.5**	**lpm**	**lpm**	**lpm**	
		16.76	16.70	-0.4%	± 5%
7/10/2008	**BAM PM10**	**lpm**	**lpm**	**lpm**	
		16.36	16.70	2.1%	± 5%
7/10/2008	**MiniVols**	**lpm**	**lpm**	**lpm**	
		5.09	4.99	-2.0%	± 10%
		5.13	5.11	-0.4%	
		4.94	4.90	-0.8%	
7/10/2008	**PM2.5 Speciation**	**lpm**	**lpm**	**lpm**	
	Unit 1 - Channel 1	10.08	10.00	-0.8%	± 5%
	Unit 1 - Channel 2	10.24	10.00	-2.3%	
	Unit 2 - Channel 1	10.22	10.00	-2.2%	
	Unit 2 - Channel 2	8.77	10.00	14.0%	
7/10/2008	**Carbonyl Sampler**	**lpm**	**lpm**	**lpm**	
	Unit 1 - Channel 1	0.693	0.708	2.2%	± 5%
	Unit 2 - Channel 2	0.520	0.526	1.2%	
7/10/2008	**Nephelometer**			**Diff**	
	Zero	57	71	14	
	Span	133	133	0	

Table 3-2

SUMMARY OF LAWA SURFACE METEOROLOGICAL TOWER PERFORMANCE AUDIT RESULTS.

LAWA METEOROLOGICAL SENSORS				
Audit Date	**Sensor**	**Audit Input**	**DAS Diff.**	**Audit Criteria**
8/6/2008	**Wind Speed (10 meters)**	**m/s**	**m/s**	± (0.2 + 5%) m/s
		0.00	0.00	
		2.56	0.00	
		5.12	0.00	
		7.68	0.00	
		12.8	0.00	
		17.92	0.00	
8/6/2008	**Wind Direction (10 Meters)**	**Degrees**	**Degrees**	± 5 degrees
		42.9	5.6	
		87.9	5.7	
		132.9	4.5	
		177.9	3.0	
		222.9	2.7	
		267.9	2.0	
		312.9	3.0	
8/6/2008	**Temperature (2 Meters)**	**Deg C**	**Deg C**	± 0.5 degree Celsius
		0.6	-0.2	
		28.5	-0.1	
		41.4	0.1	
8/6/2008	**Solar Radiation (2 Meters)**	**W/m2**	**W/m2**	± 5% of observed
		867	9	
		882	8	
8/6/2008	**Pressure (1.5 meters)**	**mm Hg**	**mm Hg**	± 2.3 mm Hg
		758.5	-36.1	

3.2 LAX-HASTINGS MONITORING STATION (SCAQMD)

KEY AIR QUALITY AUDIT FINDINGS

No problems were identified during the performance audit conducted on May 13, 2008. Parameters audited include: O_3, CO, SO_2, NO_X and PM10. **Table 3-3** presents the performance audit results. The individual audit summary sheets can be found in Appendix A.

Table 3-3

LAX-HASTINGS AUDIT RESULTS

Site: LAX-Hastings
Project: LAWA
Operator: SCAQMD

AMBIENT AIR QUALITY MONITORS

Audit Date	Parameter	DAS Slope	DAS Intercept	DAS Correlation
5/13/2008	**Ozone**	0.999	0.001	1.0000
5/13/2008	**Nitric Oxide**	0.962	0.003	1.0000
5/13/2008	**Nitrogen Oxides**	0.966	0.003	1.0000
5/13/2008	**Nitrogen Dioxide**	0.953	0.002	0.9999
5/13/2008	**Sulfur Dioxide**	0.963	-0.002	0.9999

Audit Criteria: Slope 1.000 ± 0.15: Intercept 0 ± 0.015 ppm (CO 0 ± 1.5 ppm; THC 0 ± 0.9 ppm); Correlation > 0.9950

PARTICULATE SAMPLERS

Audit Date	Sampler	Audit (ACFM)	Site (ACFM)	% Diff.	Audit Criteria
5/13/2008	**PM10 Hi-Vol**	38.4	40.0	4.1%	± 7%

SITE CHARACTERISTICS

The site is located approximately one mile north of LAX and is operated by the SCAQMD. The station is located north of Westchester Parkway in an open field. Residences and a neighborhood school border the site property. The monitoring site has good exposure in all directions.

3.3 LAX PAMS (SCAQMD) SURFACE AND UPPER AIR MONITORING SITE

KEY UPPER AIR SYSTEM AUDIT FINDINGS

- White noise was noted from RASS transmit antennas. Spectral analysis showed that the magnitude of the noise dropped off in the frequency spectrum above 4000 hertz, thus it should not be a problem with the sodar operating in the approximate 5000 Hz range.
- The acoustic foam lining in the enclosure sodar should be replaced or repaired as it is deteriorating.
- The front of sodar trailer was low by 0.5°. It was leveled to within 0.1° during the audit.
- The sodar antenna was showing a fault, indicating one or more faulty elements. ASC, the sodar manufacturer, was at the site shortly before the audit, so it is

likely just one element was bad. The accuracy of the data is unaffected by the fault.
- The RASS enclosures were all level to within 1° except the NE enclosure, which was 1.6°. This was corrected during the audit.
- The RASS sound level was 112 – 114 dBA, as measured just over the cuff enclosure that surrounds the acoustic source transmit antenna. This acoustic level appeared low compared to other RASS systems that have been previously audited. The amplifier was turned up slightly by the operator.

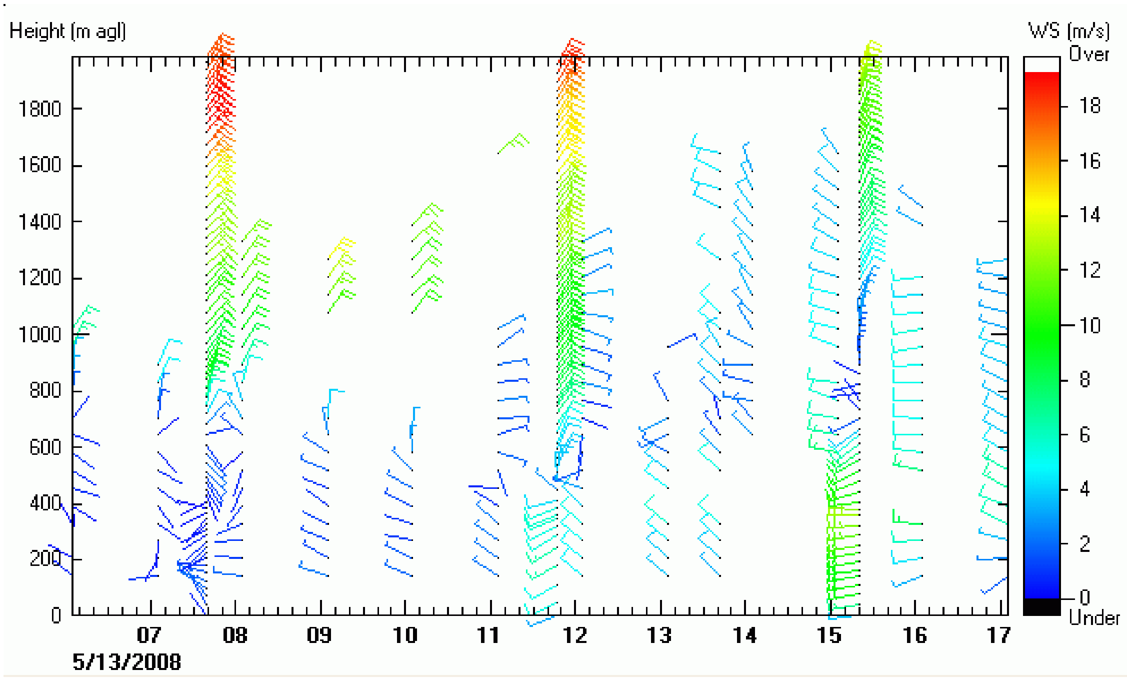
KEY RADAR PROFILER PERFORMANCE AUDIT FINDINGS

The performance audit for winds used several rawinsonde soundings to evaluate the radar wind profiler performance. The rawinsonde launch times were 0739, 1147, and 1520 PST. These times were selected to cover the early morning relatively calm conditions, mid-morning transition, and the afternoon unstable periods. **Figure 3-1** shows the data collected in both the low and high modes of operation. The comparison data uses both the high and low mode winds from the 0.5 validation level. The first sounding shows good agreement, but the 2nd and 3rd have significant issues. The upper level Santa Ana winds blowing this day were not reflected in the radar data. A suggestion was made to look at the operational parameters to see if there was something in the setup that may explain the discrepancies. A summary of the results of the statistical analysis is presented in **Table 3-4**. As can be seen, the results fail to meet the EPA recommended audit criteria. Subsequent servicing of the system found faulty components with the antenna switches that would likely explain the noted discrepancies. Thus, the wind data produced by the radar should be considered suspect and any use will need careful validation by a trained meteorologist.

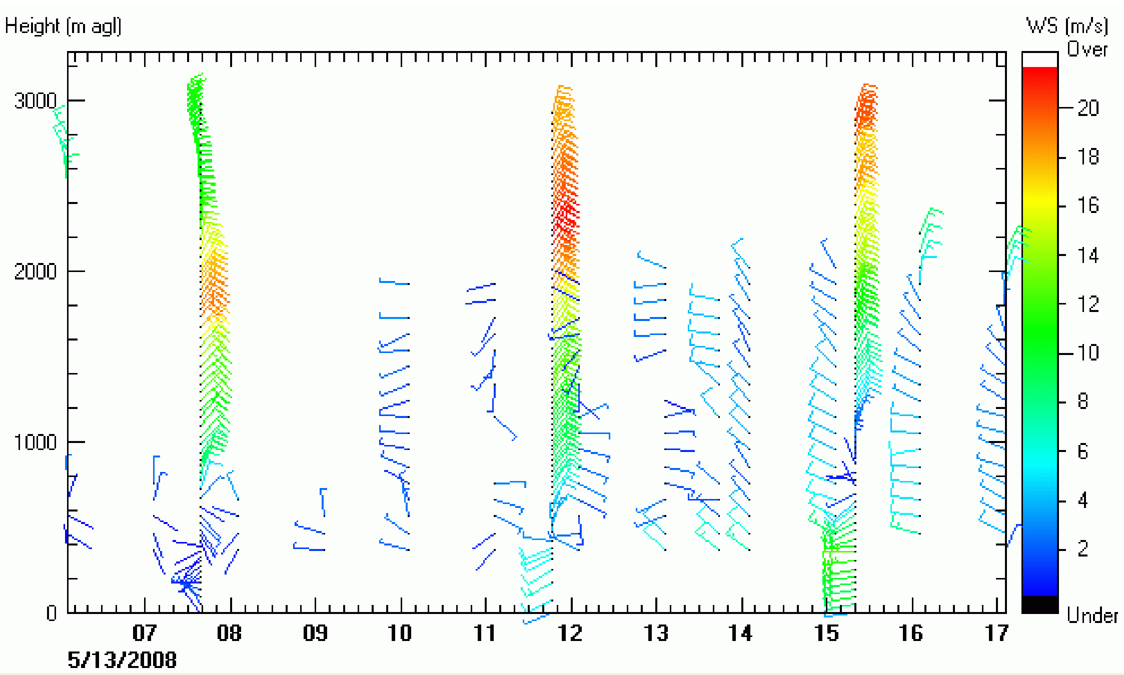
KEY RASS PERFORMANCE AUDIT FINDINGS

The three rawinsondes launched during the 0700, 1100 and 1500 PST hours provided virtual temperature profiles for comparison to the RASS data. **Figure 3-2** shows the comparison profiles for the 0700, 1200 and 1500 soundings for the non-vertical velocity corrected RASS data (Tv). One clearly invalid point can be seen at the bottom of the 1500 sounding.

Comparisons were made to both the non-vertical velocity corrected RASS data (Tv) and the vertical velocity corrected RASS data (Tc), with a summary of the results presented in **Table 3-5**. The invalid point noted above was removed prior to the comparison. Results of the comparisons were good, meeting the audit criteria. Interestingly, comparisons using the vertical velocity data (Tc) were noticeably poorer than those for Tv.



Radar Low Mode



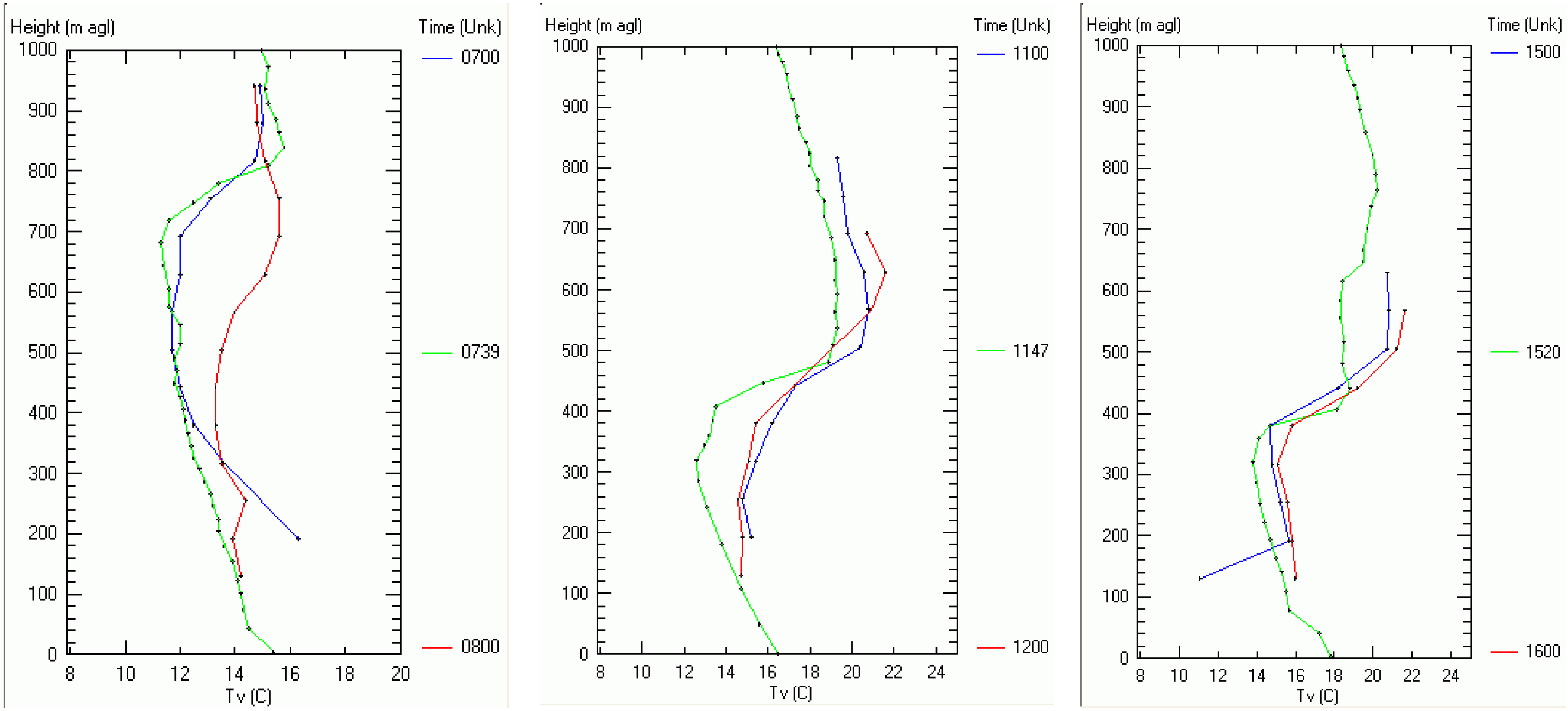
Radar High Mode

Figure 3-1. Audit and radar wind data. The audit data are shown by the greater number of values in the vertical resolution and the soundings not on the hour.

Table 3-4

SUMMARY OF RAWINSONDE TO RADAR WIND PROFILER STATISTICS

Difference (m/s)	Radar Operational Mode			
	Low		High	
	Comp 1	Comp 2	Comp 1	Comp 2
Systematic	2.3	0.1	6.5	-3.3
RMS	3.4	5.3	7.9	6.4
Min	0.0	-0.2	0.5	-0.1
Max	7.0	13.9	13.4	-12.0
Number	46		35	



0700 PST

1100 PST

1500 PST

Figure 3-2. Comparison plots showing the rawinsonde sounding profile and corresponding non-vertical velocity corrected RASS data. The green profile is the rawinsonde while the blue is the RASS. The profile for the hour immediately following the sounding is in red.

Table 3-5

SUMMARY OF RAWINSONDE TO RASS VIRTUAL TEMPERATURE STATISTICS

Difference (°C)	Signal Processing Method							
	Non-vertical velocity corrected (Tv)				Vertical velocity corrected (Tc)			
	0700	1100	1500	All	0700	1100	1500	All
Systematic	-0.3	-0.1	-0.3	-0.5	-0.4	-1.6	-1.1	-1.0
RMS	0.7	0.7	1.6	1.0	1.0	1.8	1.5	1.4
Min	0.1	0.1	-0.2	0.1	-0.1	-0.9	0.0	0.0
Max	-1.4	-1.2	2.7	2.7	-2.8	-2.9	-2.5	-2.9
Number	14	10	8	32	12	10	8	30

KEY SODAR PERFORMANCE AUDIT FINDINGS

A wind simulation was performed during the 1212 to 1215 PDT period using the Acoustic Pulse Transponder by introducing return echoes that were shifted in frequency from the measured transmit frequency. The sodar transmit frequency was measured at 4981 Hz. The APT return frequencies were 4971 Hz for the vertical beam and 4951 Hz for the horizontal beams. Using the sodar programmed Antenna Rotation Angle of 0°, the audit calculated winds should be 3.79 m/s at 315° with a vertical velocity of 0.34 m/s. Additionally, using an APT simulation pulse length of 600 ms for both the horizontal and vertical pulses, an assumed speed of sound of 340 m/s, and a zenith angle of 15° resulted in a transition altitude (the altitude where the simulation ends) of 99 meters for the horizontal winds and 102 meters for the vertical. The results of the simulations are presented in **Table 3-6**. All results met the audit criteria

Table 3-6

SUMMARY OF THE ACOUSTIC PULSE TRANSPONDER AUDIT RESULTS

Audit Input						Transition Altitude	
Time	Speed	Direction	W	U	V	Horiz.	Vert.
(PST)	(m/s)	(°)	(m/s)	(m/s)	(m/s)	(m)	(m)
All	3.79	315	0.34	2.68	2.68	99	102
Sodar Measured						Transition Altitude	
Time	Speed	Direction	W	U	V	Horiz.	Vert.
(PST)	(m/s)	(°)	(m/s)	(m/s)	(m/s)	(m)	(m)
1454-1455	3.87	314	0.30	2.71	2.77	100	105
1455-1456	3.72	314	0.34	2.61	2.65	100	105
1456-1457	3.90	314	0.30	2.73	2.81	100	105
1457-1458	3.79	313	0.32	2.62	2.73	100	105
1458-1459	3.82	314	0.32	2.67	2.73	100	105
1459-1500	3.86	314	0.31	2.66	2.79	100	105
1500-1501	4.05	314	0.27	2.80	2.93	100	105
1501-1502	3.87	313	0.30	2.67	2.80	100	105
Difference (Sodar - Audit)						Transition Altitude	
Time	Speed	Direction	W	U	V	Horiz.	Vert.
(PST)	(m/s)	(°)	(m/s)	(m/s)	(m/s)	(m)	(m)
1454-1455	0.08	-1	-0.04	0.03	0.09	1	3
1455-1456	-0.07	-1	0.00	-0.07	-0.03	1	3
1456-1457	0.11	-1	-0.04	0.05	0.13	1	3
1457-1458	0.00	-2	-0.02	-0.06	0.05	1	3
1458-1459	0.03	-1	-0.02	-0.01	0.05	1	3
1459-1500	0.07	-1	-0.03	-0.02	0.11	1	3
1500-1501	0.26	-1	-0.07	0.12	0.25	1	3
1501-1502	0.08	-2	-0.04	-0.01	0.12	1	3

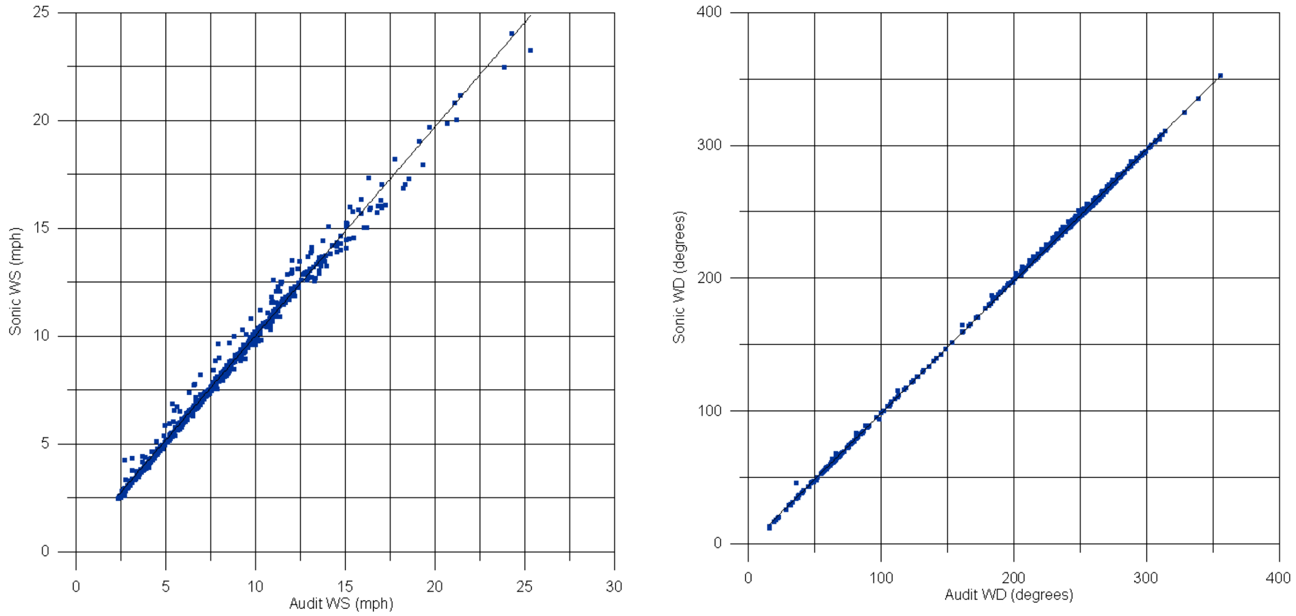
SURFACE METEOROLOGY PERFORMANCE AUDIT RESULTS

The performance audit had several types of comparisons performed. For those sensors amenable to auditing with an artificial environment such as the RM Young wind speed/wind direction sensor and the Met One 083D temperature probe, a multipoint comparison was made with the results presented in the audit reports at the end of this report. Other sensor comparisons were performed using collocated sensors and data collected during the audit. To evaluate the performance of the Met One sonic anemometer, hourly data from a one-month period were compared for reasonableness to data from the station's RM Young Wind Monitor. **Table 3-7** presents the results from the collocation audits. Plots of the comparisons of the station Met One sonic anemometer to the station RM Young Wind Monitor are shown in **Figure 3-3**.

Table 3-7

SUMMARY OF COLLOCATED AUDIT RESULTS

		Differences (site-audit)		
Sensor Audited	**Audit Criteria**	**Avg**	**Max**	**STD**
Scalar Wind Speed	SD < .44 mph with WS >2.3 mph	0.090304	-2.08	0.377646
Unit Vector Wind Direction	Avg diff < 5 and SD < 2 with WS > 2.3 mph	-2.40467	9.67	1.366123



Sonic vs. RM Young Scalar Wind Speed

Sonic vs. RM Young Unit Wind Direction

Figure 3-3. Plots showing the audit results from the Sonic to RM Young comparisons.

Table 3-8 summarizes the results of the audits of the meteorological sensors. Results represent post-maintenance conditions following corrective maintenance conducted during the audit. Key results are summarized below:

- The mounting of the temperature and relative humidity (RH) sensor in the aspirator blocked the airflow through the sensor. This caused the initial failure of the RH audit. The temperature audit was unaffected because the sensor was removed for the audit. RH and temperature data prior to the audit should be flagged as suspect or invalid. The mounting was corrected following the audit.
- The UV radiation comparisons did not meet the recommended audit criteria when initially audited. The station sensor response was lower than the audit sensor response. The sensor was re-audited after cleaning the sensor head, with results meeting criteria. Data prior to the audit should be reviewed and invalidated or flagged as necessary.
- The time on the data logger was fast by 7 seconds.

Table 3-8

SUMMARY OF METEOROLOGICAL SENSOR AUDIT RESULTS

Audit Date	Sensor	Audit Input	DAS Diff.	Audit Criteria
5/13/2008	**Wind Speed (10 meters)**	**MPH**	**MPH**	
		0.0	0.0	±.56 + 5% MPH
		5.7	0.0	
		17.2	0.0	
		28.6	0.0	
		40.1	0.0	
		51.5	0.0	
5/13/2008	**Wind Direction (10 Meters)**	**Degrees**	**Degrees**	
		-1	1.6	± 5 degrees
		44	0.2	
		89	0.1	
		134	-0.7	
		179	-1.2	
		224	-2.1	
		269	0.7	
		314	0.6	
5/13/2008	**Relative Humidity (2.5 Meters)**	**%**	**%**	
		67.7	2.0	± 7% RH
		69.2	1.1	
		67.2	0.2	
		68.2	0.6	
		0	0	
5/13/2008	**Temperature (2.5 Meters)**	**Deg C**	**Deg C**	
		2.2	0.3	± 0.5^{o}C
		19.0	0.2	
		41.4	0.0	
5/13/2008	**Solar Rad**	**W/m^2**	**W/m^2**	
		658	-5	± 5% of observed
		687	5	
		771	6	
		940	24	
5/13/2008	**UV Rad**	**W/m^2**	**W/m^2**	
		31.7	-1.3	± 5% of observed
		36.5	-1.4	
		47.3	-0.1	
5/13/2008	**Pressure**	**mb**	**mb**	
		1009.0	0.0	± 3 mb

SITE CHARACTERISTICS

The site is located on the western side of the Los Angeles International Airport (LAX) with good exposure in all directions. Adjacent to the radar wind profiler and RASS system and Sodar is a 10-meter meteorological tower. Pictures of the site are shown in **Figure 3-4**. The pictures are from a prior audit of the station in 2004. The site characteristics have not changed since that audit.

POTENTIAL ACTIVE NOISE SOURCES

An RF scan from 910 to 920 MHz was performed while the radar was turned off and some carriers were noted near the radar operating frequency at approximately 914 MHz. This is not unexpected as there are numerous potential sources of RF associated with the aircraft operations.

As the site is at the end of an airport runway, the audible noise is significant with passing aircraft. At the time of the audit the ambient noise levels with no aircraft flying overhead were approximately 52 dBA. These levels increased to greater than 80 dBA during aircraft fly-overs. That fact that the sodar is operating at a high frequency (~5000 Hz) helps to minimize this influence. However, during periods when aircraft pass directly overhead, the noise levels will most likely obscure any atmospheric returns.

POTENTIAL PASSIVE NOISE SOURCES

The sodar's Y-beam direction was aimed at the fence surrounding the profiler antenna and monitoring trailers and was producing a noticeable reflection heard from the buildings. Changing the beam angles toward the ocean and away from the buildings to minimize any reflection is recommended.

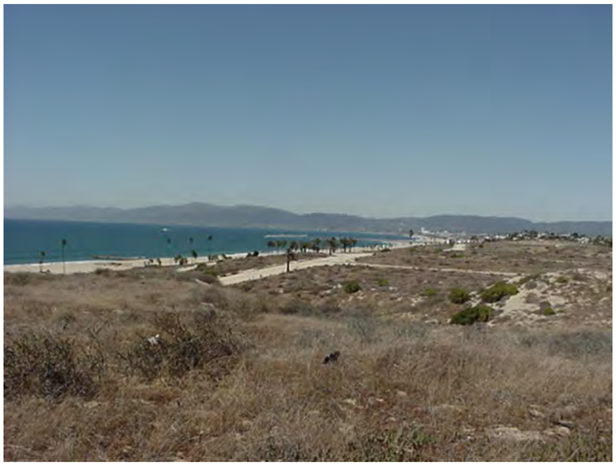
Figure 3-4. Site pictures with views looking from the sodar antenna.

000° (north) 045° (northeast)

090° (east) 135° (southeast)

180° (south) 225° (southwest)

270° (west)



315° (northwest)

Sodar, radar antenna array and RASS

RADAR PROFILER DATA INTERNAL CONSISTENCY

Approximately five days of data prior to the audit were reviewed to evaluate the internal consistency and reasonableness of the radar wind profiler wind data. **Figures 3-5 and 3-6** show the time-height cross-sections for the low and high operational modes, respectively. The reported values look reasonable. Additionally, the archived images on the FTP server were reviewed as well and the prior data did look reasonable.

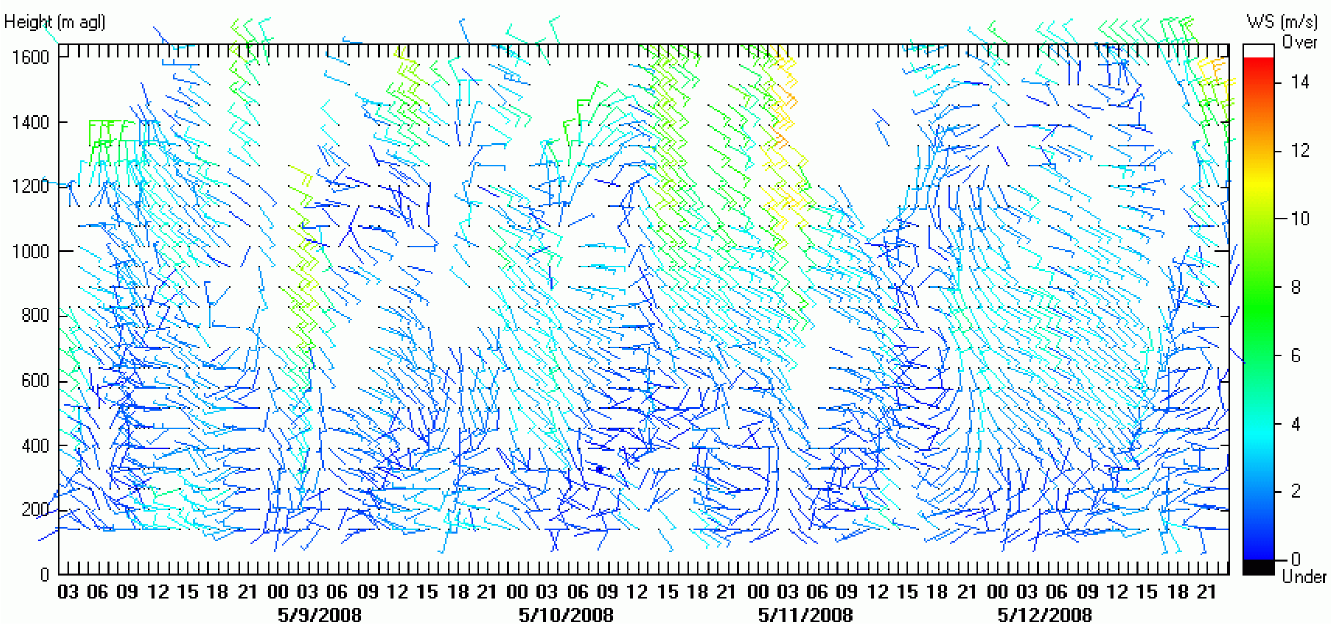


Figure 3-5. Low mode radar wind data prior to the audit.

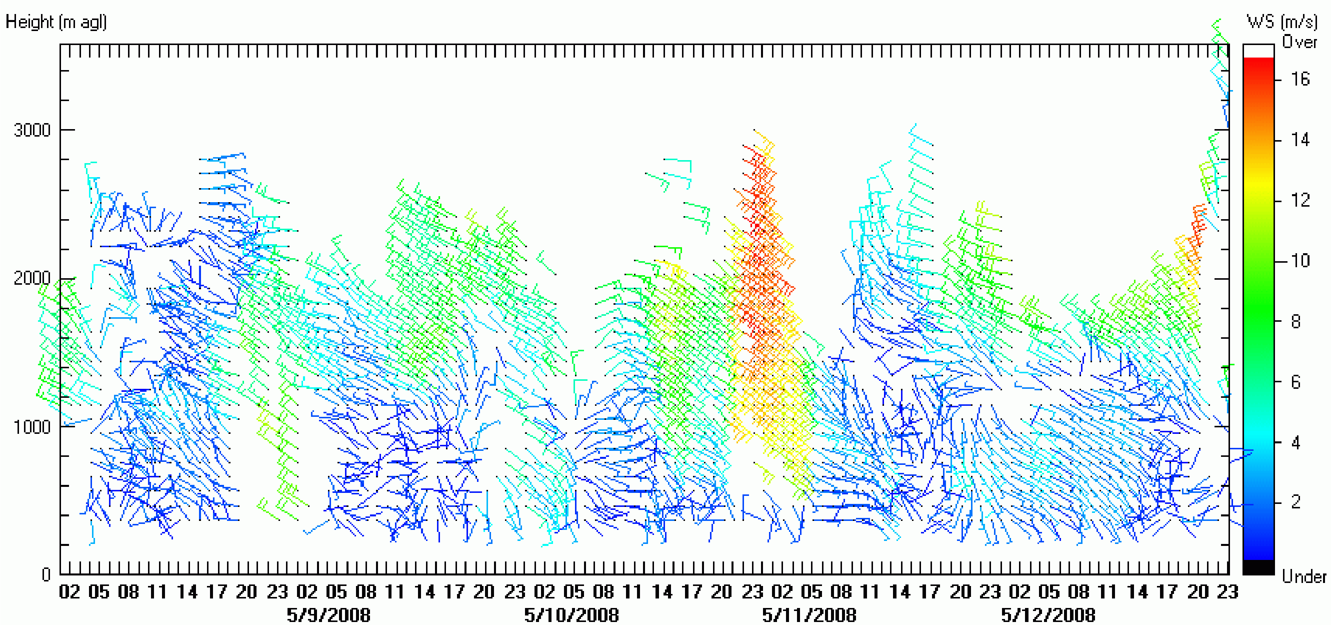


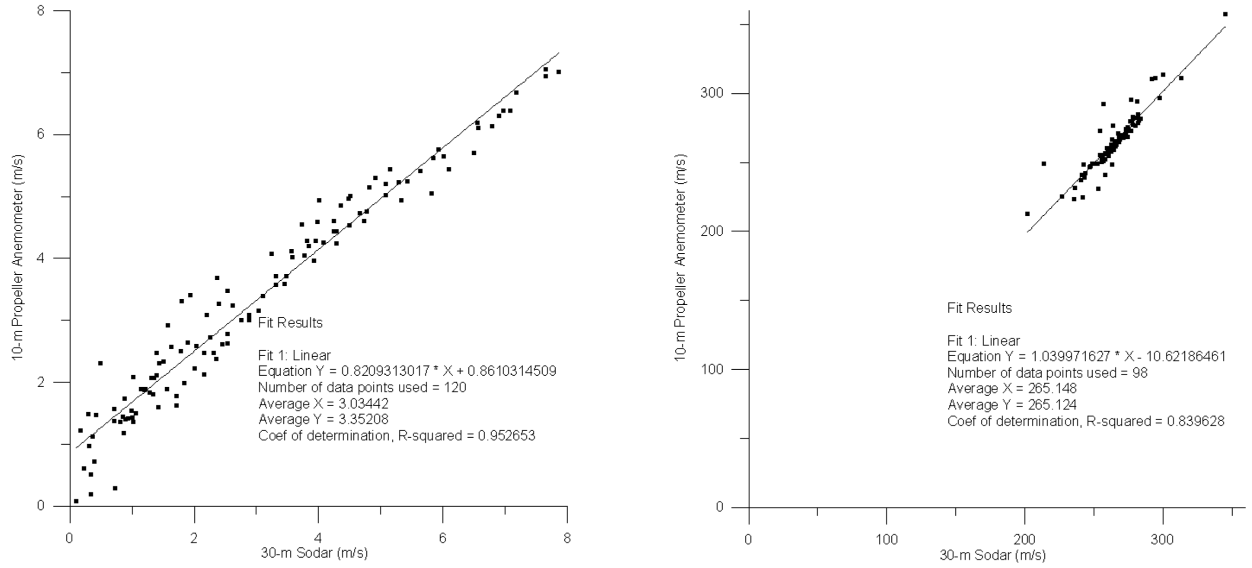
Figure 3-6. High mode radar wind data prior to the audit.

RASS DATA INTERNAL CONSISTENCY

Approximately five days of data prior to the audit were reviewed to evaluate the internal consistency and reasonableness of the RASS data. The RASS data looked reasonable. Inversion heights were consistent with levels where wind sheer occurred, and days with higher wind speeds and no wind sheer showed adiabatic lapse rates consistent with a well mixed air mass.

SODAR DATA INTERNAL CONSISTENCY

Approximately five days of data prior to the audit were reviewed to evaluate the internal consistency and reasonableness of the sodar data. No problems were noted. As part of the review, the 30-meter level sodar data (the first consistently reliable level) was compared with the 10-meter surface data reported by the meteorological tower. **Figure 3-7** presents plots of the comparison. Note that hourly averages were used for the comparison, and for the wind direction comparison only points when the surface wind speed was greater than 1 m/s (2.2 MPH) were used. There is good agreement between the two methods, particularly given the difference in altitude, indicating that the sodar data is reasonable.



Sodar vs. RM Young Scalar Wind Speed

Sonic vs. RM Young Unit Wind Direction

Figure 3-7. Plots comparing Sodar winds with RM Young anemometer winds.

SODAR VISTA, ORIENTATION AND LEVEL RECORD

No problems were noted with the system orientation and level. The values measured are included in the Vista, Orientation and Level audit record in **Table 3-9**.

Table 3-9

VISTA, ORIENTATION AND LEVEL RECORD

T&B SYSTEMS
VISTA, ORIENTATION AND LEVEL

Site Name:	LAX	Instrument:	Radian LAP 3000 AV Sodar
Date:	May 13, 2008	Radar Orientation:	39°/129°
		Measured Orientation:	39°/129°
		Difference:	0°
Measurements group:	SCAQMD		
Key contact:	Kevin Durkee/Kevin Smith	Radar array level:	≤ 0.2°
Audited by:	B. Baxter/D. Yoho	RASS level:	Northeast 1.6°
Site longitude:	118° 26.188’ W	Sodar Orientation:	90°
Site latitude:	33° 56.430’ N	Measured Orientation:	90°
Site elevation:	NA	Difference:	-0°
		Sodar Level	0.5°

True Az. Angle (deg)	Terrain El. Angle (deg)	Features and Distances
0	1	Phone and Power poles at 200
30	6	Power poles and airport ramp at 500 m
60	8	Power poles and airport ramp at 500 m
90	10	Shelter at 42 m and tower at 64 m; fence and RASS at 24 m
120	3	Small trees at 10 – 20 m
150	2	Palm trees at 500 m and ocean
180	0	Field with palm trees and ocean
210	-1	Ocean
240	1	Palm trees and ocean
270	-3	Road to ocean
300	-1	Palm trees at ~ 800 m
330	0	Open to houses at 1 – 1.5 km

Comments: Exposure is good for the radar, sodar and surface meteorology. The RASS source on the northeast was re-leveled, as was the sodar trailer. The measured vista angles were from the 2004 audit.

SECTION 4

ADDITIONAL AUDIT ACTIVITIES

4.1 FUEL SAMPLING QUALITY ASSURANCE

As part of the sampling and analysis program for the fuel farm, The Source Group, a LAWA on-call contractor, was responsible for collecting ambient VOC samples in the fuel farm area as well as one grab sample in the headspace of a representative Jet A storage tank. The extent of the QA of this process included a review of the procedures, as provided by the sampling team. Prior to the sampling, the auditor contacted Sean Nathan (with The Source Group) requesting a copy of sampling procedures. As the data collected appeared that it would also be used for the Air Toxics Inventory Report (ATIR) update, PCR, a second LAWA contractor, reviewed the procedures and indicated that they were reasonable for the sampling of the headspace in the tank. The sampling procedures were also reviewed by the auditor and the methods appeared appropriate for a simple extraction of a shallow headspace volume. For simplicity, and to maintain a clear chain of custody, the samples were collected by Marcus Hoeppe of AAC and physically transported to the laboratory by him. This also took advantage of the expertise of the analysis laboratory in the collection of the sample. The limitations in understanding the sample-to-sample and seasonal variations in using a single sample collected of the headspace for the analysis was recognized by all parties involved. This limitation may be addressed during the Long Term Study when it is hoped that the budget will allow for more samples to be collected.

4.2 LABORATORY QUALITY ASSURANCE

A system audit of laboratory operations was conducted on August 18, 2008 at Atmospheric Analysis and Consulting Inc. (AAC). The audit consisted of interviews with key laboratory personnel, including the following:

- Marcus Hueppe – Laboratory manager
- Thien Tran – Sample tracking and custody
- Jerry Grevel – VOC analyses
- Krista Parker – Filter analyses

While AAC performed a number of analyses for the Demonstration Project, the review concentrated on TO-12 and TO-15 VOC analyses, as these provided a good overview of general laboratory procedures.

The audit revealed no issues. AAC is a professional, EPA certified laboratory with a well-established and documented quality assurance program, with written SOPs for all analyses and processes. Tracking of samples is accomplished using Lab Track software and networked computers. QC data, including GC calibrations, blanks, and spikes, were reviewed in detail, revealing that data quality objectives were being met. At the time of the audit, AAC was still awaiting final approval of the Electronic Data Deliverable (EDD) from Weston, so routine submission of the laboratory data had not yet commenced and therefore was not reviewed. Similarly, data from the University of Wisconsin and Research Triangle Institute (RTI) had not yet been received, so the management of data from external labs could not be reviewed completely. However, procedures appeared to be in place for these activities.

The only issue noted during the audit was related to the field sampling effort rather than the laboratory procedures. Some inconsistencies were noted in the reporting canister start and end pressures and the field forms. This brought up a general comment by laboratory personnel that a better mechanism for providing feedback between the laboratory and field personnel regarding sampling issues would be useful. This could include an orientation session at the laboratory for field personnel in order to emphasize sample custody and integrity concerns.

4.3 DATABASE MANAGEMENT QUALITY ASSURANCE

An audit of the study database was conducted after receipt of the finalized dataset, which was submitted with the draft report. The audit consisted of two primary efforts. First, data in the submitted files were compared against the original data sources to verify the data integrity. Second, a review of data quality using available sources of information was conducted. Key elements of the audit effort included the following:

- Reviewed sample data, tracking data entry from field entry forms, through chain-of-custody forms, and ending with laboratory reports. Approximately 10% of the samples were reviewed.
- Performed cursory review of sample data for reasonableness.
- Reviewed laboratory QC data.
- Plotted continuous air quality data and reviewed for consistency and reasonableness.
- Reviewed automatic zero/span data for the gaseous parameters.
- Compared finalized continuous data with the original data logger files.

The following summarized the audit findings, along with associated recommendations.

- No problems were identified in the processing and reporting of the sample data.
- Several of the finalized monitoring data files have the Excel Time value truncated to just two decimal places, which results in a lack of resolution to the nearest minute. These files should be re-created. The affected files were:

  - SR_MAIN_01.CSV
  - SR_UFP_01.CSV
  - P2_PORT_01.CSV
  - P3_PORT_01.CSV
  - P4_PORT_01.CSV
- In the existing data files, nitrate values for the P3 and P5 sites have been truncated to the nearest whole number, whereas data for the other sites are reported to two decimal places. The reporting precision should be standardized.
- Zeros are used in the MAIN files when gaseous data are missing (i.e. analyzers are not installed or are turned off). While it is readily apparent when these zeros refer to a concentration of zero and when they refer to "no data", it is recommended that the "no data" zeros be replaced with a flagging number, such as the –999 that is used when data are invalidated during normal operations.
- While extensive QC data for the laboratory were included in the final report, virtually no QC data was submitted for the gaseous data. While daily automatic zero/span data were available on demand for the audit, it is recommended that at least a summary of the daily zero/span data be submitted to allow data users to evaluate the data quality relative to desired data quality objective. In general, future reports would benefit from a section summarizing QC findings for all measurements.
- With one exception (see below), all QC data for both the air samples and the gaseous air quality data were good. However, based on the data files submitted for the audit for the NMHC sampler, there appeared to be no daily span checks after July 12, 2008.
- Original Campbell Scientific raw data logger files were requested for the audit comparison conducted on the gaseous air quality data. However, the raw files available appear to have already been altered from their original form. This included editing of the time for a know logger set time issue early in the study and conversion of the Campbell error codes to –999. If not already the practice, it is recommended that unaltered data logger files be archived and available for review if needed.
- Between July 10 and July 16, 2008, the daily automatic span checks showed a CO_2 analyzer response that was around 15% low, which was consistent with audit results from July 10 that were a little over 20% low. The shift in response is visible in the hourly averages. The initial shift in response appears to start during the audit, though a reason for the shift was never determined. The analyzer appears to have been adjusted on the 16th. Afterward, span checks and the data in general appear normal. Since the data quality objective for accuracy stated in the QAPP is ±10%, and since both the audit and the daily span checks show a response at least 15% low, it is recommended that the CO_2 be adjusted using the daily zero/span data.
- Data collected on hours 8 through 11 on July 10, 2008 should be invalidated. The audit mentioned above was being conducted during this period.

SECTION 5

REFERENCES

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APPENDIX A

PERFORMANCE AUDIT RECORDS

A.1 LAWA OPERATED (SOUTH RUNWAY, PS3 AND METEOROLOGY)

T&B SYSTEMS
OZONE

Date:	07/10/08	Site Name:	LAX / S Runway
Start:	08:00 PST	Operator:	Weston/ENSR
Finish:	13:00 PST	Project:	LAWA
Audited by:	David Yoho		
Witness:	Mark Jorn		

Analyzer make:	Thermo Electron	Model:	49C
Serial No.:	49203	Filter:	06/20/08
Sample flow:	0.7 lpm	Sample freq:	96443
Auto span:	1.050	Control freq:	1132870
Range:	0.500 PPM	Last cal.:	06/20/08

Operator provided correction factors:
Corrected data = (IND. * A) + B

	Chart	DAS
Factors= A:	1.000	1.000
B:	-0.025	0.000

O3 Audit Point	PPM Input (X)	PPM Chart (Y)	PPM DAS (Y)
1	0.000	#N/A	0.004
2	0.076	#N/A	0.076
3	0.181	#N/A	0.174
4	0.459	#N/A	0.433

Linear Regression: (Y=PPM Corrected, X=PPM Input)

	Chart	DAS
Slope:	#N/A	0.934
Intercept:	#N/A	0.005
Correlation:	#N/A	1.0000

Comments: No problems noted.

Audit Equipment	Make	Model	ID	Last Calibration
Dilution System:	Environics	100	1287	7/9/08
Ozone Transfer Std:	Dasibi	1008-PC	5951	06/03/08
Zero Air System:	AV	DB100	NA	NA

Ozone Transfer Standard			
Sample Freq: 43.01	Cell Temperature: 35	C
Control Freq: 50.000	Ambient Pressure: 29.73	"Hg
Span Setting: 51.5	T/P Correction?: No	

T&B SYSTEMS
NITRIC OXIDE

Date:	07/10/08	Site Name:	LAX / S Runway
Start:	08:00 PST	Operator:	Weston/ENSR
Finish:	15:00 PST	Project:	LAWA
Audited by:	David Yoho		
Witness:	Mark Jorn		

Analyzer make:	Thermo Electron Corp.	Model:	42C
Serial No.:	436610044	Filter:	06/20/08
Sample flow:	0.6 lpm	Span setting:	1.512
Zero setting:	9.1	Vacuum:	NA
Range:	0.500 PPM	Mode:	NA
		Last cal.:	06/20/08

Operator provided correction factors:
Corrected data = (IND. * A) + B

	Chart	DAS
Factors= A:	1.000	1.000
B:	-0.025	0.000

NO Audit Point	PPM Input (X)	PPM Chart (Y)	PPM DAS (Y)
1	0.000	#N/A	0.001
2	0.080	#N/A	0.078
3	0.174	#N/A	0.166
4	0.434	#N/A	0.415

Linear Regression: (Y=PPM Corrected, X=PPM Input)

	Chart	DAS
Slope:	#N/A	0.953
Intercept:	#N/A	0.001
Correlation:	#N/A	1.0000

Comments: None.

Audit Equipment	Make	Model	ID	Last Calibration
Dilution System:	Environics	100	1287	7/9/08
Zero Air System:	AV	DB100		NA
Calibration Gas:	SMI	Multi	JJ8545	05/01/08

T&B SYSTEMS
OXIDES OF NITROGEN

Date:	07/10/08		
Start:	08:00 PST	Site Name:	LAX / S Runway
Finish:	15:00 PST	Organization:	Weston/ENSR
Audited by:	David Yoho	Project:	LAWA
Witness:	Mark Jorn		
Analyzer make:	Thermo Electron Corp.	Model:	42C
Serial No.:	436610044	Filter:	06/20/08
Sample flow:	0.6 lpm	Span setting:	0.992
Zero setting:	10.1	Vacuum:	NA
Range:	0.500 PPM	Last cal.:	06/20/08

Operator provided correction factors:
Corrected data = (IND. * A) + B

	Chart	DAS
Factors= A:	1.000	1.000
B:	-0.025	0.000

NOx Audit Point	PPM Input (X)	PPM Chart (Y)	PPM DAS (Y)
1	0.000	#N/A	0.001
2	0.080	#N/A	0.078
3	0.174	#N/A	0.167
4	0.434	#N/A	0.413

Linear Regression: (Y=PPM Corrected, X=PPM Input)

	Chart	DAS
Slope:	#N/A	0.948
Intercept:	#N/A	0.002
Correlation:	#N/A	1.0000

Comments: None.

Audit Equipment	Make	Model	ID	Last Calibration
Dilution System:	Environics	100	1287	7/9/08
Zero Air System:	AV	DB100	NA	NA
Calibration Gas:	SMI	Multi	JJ8545	05/01/08

T&B SYSTEMS
NITROGEN DIOXIDE

Date:	07/10/08	Site Name:	LAX / S Runway
Start:	08:00 PST	Organization:	Weston/ENSR
Finish:	15:00 PST	Project:	LAWA
Audited by:	David Yoho		
Witness:	Mark Jorn		

Analyzer make:	Thermo Electron Corp.	Model:	42C
Serial No.:	436610044	Converter T.:	323 Deg C
Ozone flow:	0.999	Last cal.:	06/20/08
Range:	0.500 PPM		

Operator provided correction factors:
Corrected data = (IND. * A) + B

	Chart	DAS
Factors= A:	1.000	1.000
B:	-0.025	0.000

NO2 Audit Point	PPM Input (X)	PPM Chart (Y)	PPM DAS (Y)
1	0.000	#N/A	0.001
2	0.076	#N/A	0.075
3	0.170	#N/A	0.163
4	0.439	#N/A	0.419

Linear Regression: (Y=PPM Corrected, X=PPM Input)

	Chart	DAS
Slope:	#N/A	0.951
Intercept:	#N/A	0.002
Correlation:	#N/A	1.0000

Converter Efficiency
98.5%

Comments: None.

Audit Equipment	Make	Model	ID	Last Calibration
Dilution System:	Environics	100	1287	7/9/08
Zero Air System:	AV	DB100	NA	NA
Calibration Gas:	SMI	Multi	JJ8545	05/01/08

T&B SYSTEMS
TOTAL HYDROCARBONS

Date:	07/10/08	Site name:	LAX / S Runway
Start:	08:00 PST	Operator:	Weston/ENSR
Finish:	15:00 PST	Project:	LAWA
Audited by:	David Yoho		
Witness:	Mark Jorn		

Analyzer make:	Thermo Electron	Model:	55C
Serial No.:	55C74897378	Filter:	06/20/08
Sample flow:	0.5 lpm	Span setting:	26.05
Zero setting:	NA	H2 Flow:	NA
Range:	20 PPM	Air Flow:	NA
		Last cal.:	06/20/08

Operator provided correction factors:
Corrected data = (IND. * A) + B

	Chart	DAS
Factors= A:	1.000	1.000
B:	-1.500	0.000

THC Audit Point	PPM Input (X)	PPM Chart (Y)	PPM DAS (Y)
1	0.00	#N/A	0.01
2	1.64	#N/A	1.58
3	3.57	#N/A	3.46
4	8.87	#N/A	8.58

Linear Regression: (Y=PPM Corrected, X=PPM Input)

	Chart	DAS
Slope:	#N/A	0.967
Intercept:	#N/A	0.00
Correlation:	#N/A	1.0000

Comments: None.

Audit Equipment	Make	Model	ID	Last Calibration
Dilution System:	Environics	100	1287	7/9/08
Zero Air System:	UP Air	SMI	NA	NA
Calibration Gas:	SMI	Multi	JJ8545	05/01/08

T&B SYSTEMS

Carbon Monoxide

Date:	07/10/08	Site name:	LAX / S Runway
Start:	08:00 PST	Operator:	Weston/ENSR
Finish:	15:00 PST	Project:	LAWA
Audited by:	David Yoho		
Witness:	Mark Jorn		

Analyzer make:	Thermo Electron	Model:	48
Serial No.:	NA	Filter:	06/20/08
Sample flow:		Span setting:	939
Zero setting:	332	Last cal.:	06/20/08
Range:	50 PPM		

Operator provided correction factors:
Corrected data = (IND. * A) + B

	Chart	DAS
Factors= A:	1.000	1.000
B:	-1.500	0.000

THC Audit Point	PPM Input (X)	PPM Chart (Y)	PPM DAS (Y)
1	0.00	#N/A	-0.34
2	8.20	#N/A	7.40
3	17.80	#N/A	16.40
4	44.25	#N/A	40.76

Linear Regression: (Y=PPM Corrected, X=PPM Input)

	Chart	DAS
Slope:	#N/A	0.928
Intercept:	#N/A	-0.24
Correlation:	#N/A	1.0000

Comments: None.

Audit Equipment	Make	Model	ID	Last Calibration
Dilution System:	Environics	100	1287	7/9/08
Zero Air System:	UP Air	SMI	NA	NA
Calibration Gas:	SMI	Multi	JJ8545	05/01/08

T&B SYSTEMS

Carbon Dioxide

Date:	07/10/08	Site name:	LAX / S Runway
Start:	08:00 PST	Operator:	Weston/ENSR
Finish:	15:00 PST	Project:	LAWA
Audited by:	David Yoho		
Witness:	Mark Jorn		

Analyzer make:	Thermo Electron	Model:	410i
Serial No.:	816830651	Filter:	06/20/08
Sample flow:	1.1 lpm	Span setting:	0.92
Zero setting:	90.6	Last cal.:	06/20/08
Range:	10000 PPM		

Operator provided correction factors:
Corrected data = (IND. * A) + B

	Chart	DAS
Factors= A:	1.000	1.000
B:	-1.500	0.000

THC Audit Point	PPM Input (X)	PPM Chart (Y)	PPM DAS (Y)
1	0.00	#N/A	-99.00
2	326.24	#N/A	135.00
3	804.59	#N/A	498.00
4	2194.62	#N/A	1583.00

Linear Regression: (Y=PPM Corrected, X=PPM Input)

	Chart	DAS
Slope:	#N/A	0.769
Intercept:	#N/A	-110.48
Correlation:	#N/A	0.9999

Comments: None.

Audit Equipment	Make	Model	ID	Last Calibration
Dilution System:	Environics	100	1287	7/9/08
Zero Air System:	UP Air	SMI	NA	NA
Calibration Gas:	SMI	Multi	JJ389	06/04/08

TECHNICAL & BUSINESS SYSTEMS, INC.

NEPHELOMETER

Date: 07/10/08
Start: 10:30 PDT
Finish: 13:00 PDT
Audited By: David Bush
Witness: Dayna Pelc

Site name: LAX / S Runwa
Operator: Weston/ENSR
Project: LAWA

Sampler:
S/N:

Make: Optec
Model: NGN-2
Last cal.: NA

	Auditor		Nephelometer	
Amb. Press:	#N/A	in. Hg		
	#N/A	mb	#N/A	mb
Amb. Temp.:	#N/A	deg. C		
	#N/A	K	#N/A	K
Amb. RH:	#N/A	%	#N/A	%

	Audit	Site
Response to zero air:	57	71
Response to Suva gas:	133	133
Net response:	76	62

Audit Criteria: ±10%

Comments: Audited using instrument cal sequence using different SUVA canister and substituting zero air for filtered air. Audit zero was lower, indicating that instrument filtered zero air may not be actually zero.

Check insturment time and date.	30 s slow
Check downloading procedures.	OK
Is the sample fan operational?	NA
Is fan filter clean?	NA
Are all display settings correct?	Yes
Overall condition of nephelometer.	Good

TECHNICAL & BUSINESS SYSTEMS, INC.
PARTICULATE SAMPLERS

Date: 07/10/08
Start: 15:00 PDT
Finish: 16:00 PDT
Audited By: David Yoho / David Bush
Witness: Dayna Pelc

Site name: LAX / S Runway
Operator: Weston/ENSR
Project: LAWA

Sampler: PAH
Sampler ID: NA

Make: Ecochem
Model: PAH 2000
Last cal.: NA

Amb. Press: in. Hg
Amb. Temp.: deg. C

Flowmeters:

Model	S/N
Gilibrator 2	003457-H

Serial Number	Audit Flow	Site Flow	% Diff.
SN 10466	2.18 lpm	2.01 lpm	-7.8

Audit Criteria: ±10%

Comments: No problems noted.

T&B SYSTEMS
PARTICULATE SAMPLERS

Date: 07/10/08
Start: 15:00 PDT
Finish: 16:00 PDT
Audited By: David Bush, David Yoho
Witness: Dayna Pelc

Site name: LAX / S Runway
Operator: Weston/ENSR
Project: LAWA

Sampler: Elemental Carbon
Sampler ID: SN 872-0803

Make: Magee Scientific
Model: Aethalometer
Last cal.: NA

Amb. Press: NA in. Hg
Amb. Temp.: NA deg. C

Flowmeters:

Model	S/N
Gilibrator 2	009603-H

Audit Flow (slpm)	Site Flow (slpm)	% Diff.
5.13	4.90	-4.5

Audit Criteria ± 10%

Comments: Leak check using HEPA filter at inlet: ~100 ug/m^3 vs ambient reading of 5000 ug/m^3.

T&B SYSTEMS
PARTICULATE SAMPLERS

Date: 07/10/08
Start: 15:00 PDT
Finish: 16:00 PDT
Audited By: David Yoho / David Bush
Witness: Dayna Pelc

Site name: LAX / S Runway
Operator: Weston/ENSR
Project: LAWA

Sampler: PM2.5
Sampler ID: SN D6088

Make: MetOne
Model: BAM
Last cal.: NA

Amb. Press: 759.00 mm Hg
Amb. Temp.: 23.7 deg. C

Flowmeters:

Model	S/N
Gilibrator 2	009603-H

Audit Flow (slpm)	Site Flow (slpm)	% Diff.
16.76	16.70	-0.4

Audit Criteria ± 10%

Comments: Leak check - 2.1 lpm

T&B SYSTEMS
PARTICULATE SAMPLERS

Date: 07/10/08
Start: 15:00 PDT
Finish: 16:00 PDT
Audited By: David Yoho / David Bush
Witness: Dayna Pelc

Site name: LAX / S Runway
Operator: Weston/ENSR
Project: LAWA

Sampler: PM10
Sampler ID: SN D6087

Make: MetOne
Model: BAM
Last cal.: NA

Amb. Press: 757.00 mm Hg
Amb. Temp.: 24.4 deg. C

Flowmeters:

Model	S/N
Gilibrator 2	009603-H

Audit Flow (slpm)	Site Flow (slpm)	% Diff.
16.36	16.70	2.1

Audit Criteria ± 10%

Comments: Leak check - 5.8 lpm

TECHNICAL & BUSINESS SYSTEMS, INC.
PARTICULATE SAMPLERS

Date: 07/10/08
Start: 15:00 PDT
Finish: 16:00 PDT
Audited By: David Yoho / David Bush
Witness: Dayna Pelc

Site name: LAX / S Runway
Operator: Weston/ENSR
Project: LAWA

Sampler: APS
Sampler ID: NA

Make: TSI
Model:
Last cal.: NA

Amb. Press: in. Hg
Amb. Temp.: deg. C

Flowmeters:

Model	S/N
Gilibrator 2	003457-H

Serial Number	Audit Flow	Site Flow	% Diff.
SN 10466	9.66 lpm	10.00 lpm	3.5

Audit Criteria: ±10%

Comments: Revised results, initial indicated flow rate was incorrect. No problems noted.

TECHNICAL & BUSINESS SYSTEMS, INC.
PARTICULATE SAMPLERS

Date: 07/10/08
Start: 15:00 PDT
Finish: 16:00 PDT
Audited By: David Yoho / David Bush
Witness: Dayna Pelc

Site name: LAX / S Runway
Operator: Weston/ENSR
Project: LAWA

Sampler: PM2.5
Sampler ID: See below

Make: Airmetrics
Model: MiniVol
Last cal.: NA

Amb. Press: NA in. Hg
Amb. Temp.: NA deg. C

Flowmeters:

Model	S/N
Gilibrator 2	003457-H

Serial Number	Audit Flow	Site Flow	% Diff.
SN 4206	5.09 lpm	4.99 lpm	-2.0
SN 4336	5.13 lpm	5.11 lpm	-0.4
SN 4240	4.94 lpm	4.90 lpm	-0.8

Audit Criteria: ±10%

Comments: No problems noted.

TECHNICAL & BUSINESS SYSTEMS, INC.
PARTICULATE SAMPLERS

Date: 07/10/08
Start: 15:00 PDT
Finish: 16:00 PDT
Audited By: David Yoho / David Bush
Witness: Dayna Pelc

Site name: LAX / S Runway
Operator: Weston/ENSR
Project: LAWA

Sampler: PM2.5 Speciation
Sampler ID: Unit 1

Make: URG
Model:
Last cal.: NA

Amb. Press: NA in. Hg
Amb. Temp.: NA deg. C

Flowmeters:

Model	S/N
Gilibrator 2	003457-H

Serial Number	Audit Flow	Site Flow	% Diff.
Channel 1	10.08 lpm	10.00 lpm	-0.8
Channel 2	10.24 lpm	10.00 lpm	-2.3

Audit Criteria: ±10%

Comments: No problems noted.
Temperature sensor check: Site - 21.3 deg C, Audit - 21.4 deg C.

TECHNICAL & BUSINESS SYSTEMS, INC.
PARTICULATE SAMPLERS

Date: 07/10/08
Start: 15:00 PDT
Finish: 16:00 PDT
Audited By: David Yoho / David Bush
Witness: Dayna Pelc

Site name: LAX / S Runway
Operator: Weston/ENSR
Project: LAWA

Sampler: PM2.5 Speciation
Sampler ID: Unit 2

Make: URG
Model:
Last cal.: NA

Amb. Press: NA in. Hg
Amb. Temp.: NA deg. C

Flowmeters:

Model	S/N
Gilibrator 2	003457-H

Serial Number	Audit Flow	Site Flow	% Diff.
Channel 1	10.22 lpm	10.00 lpm	-2.2
Channel 2	8.77 lpm	10.00 lpm	14.0

Audit Criteria: ±10%

Comments: Channel 2 flow low.
Temperature sensor check: Site - 25 deg C, Audit - 22 deg C.
Site temperature reading 3 deg C high.

TECHNICAL & BUSINESS SYSTEMS, INC.
CARBONYL SAMPLERS

Date:	07/10/08	Site name:	LAX / S Runway
Start:	15:00 PDT	Operator:	Weston/ENSR
Finish:	16:00 PDT	Project:	LAWA
Audited By:	David Yoho / David Bush		
Witness:	Dayna Pelc		
Sampler:	Carbonyl Samplers	Make:	SKC
Sampler ID:		Model:	
		Last cal.:	NA

Amb. Press: NA in. Hg
Amb. Temp.: NA deg. C

Flowmeters:

Model	S/N
Gilibrator 2	003457-H

Serial Number	Audit Flow	Site Flow	% Diff.
S/N RFW09938	0.693 lpm	0.708 lpm	2.2
S/N RFW09937	0.520 lpm	0.526 lpm	1.2

Audit Criteria: ±10%

Comments: No problems noted.

T&B SYSTEMS
SULFUR DIOXIDE

Date:	08/06/08	Site name:	LAX (PS3)
Start:	6:55 PST	Operator:	ENSR
Finish:	7:40 PST	Project:	LAWA
Audited by:	David Yoho		
Witness:	NA		

Analyzer make:	Thermo Electron	Model:	43C
Serial No.:	000044309	Filter:	NA
Sample flow:	0.497 lpm	Span setting:	0.867
Zero setting:	8.4	Vacuum:	NA
Range:	0.500 PPM	Last cal.:	NA

Operator provided correction factors:
Corrected data = (IND. * A) + B

	Chart	DAS
Factors= A:	1.000	1.000
B:	-0.025	0.000

SO2 Audit Point	PPM Input (X)	PPM Chart (Y)	PPM DAS (Y)
1	0.000	#VALUE!	0.000
2	0.079	#VALUE!	0.075
3	0.172	#VALUE!	0.161
4	0.429	#VALUE!	0.410

Linear Regression: (Y=PPM Corrected, X=PPM Input)

	Chart	DAS
Slope:	#VALUE!	0.956
Intercept:	#VALUE!	-0.001
Correlation:	#VALUE!	1.0000

Comments: Analyzer has not been calibrated.

Audit Equipment	Make	Model	ID	Last Calibration
Dilution System:	Environics	100	1287	5/12/08
Zero Air System:	AV	DB100	NA	NA
Calibration Gas:	SMI	Multi	JJ8545	05/01/08

T&B SYSTEMS
HORIZONTAL WIND SPEED

Date:	08/06/08	Site Name:	LAWA-Met
Start:	9:30 MST	Operator:	ENSR
Finish:	11:45 MST	Project:	LAWA
Audited By:	David Yoho		

Manufacturer:	RM Young		Model:	05305	
Serial No.:	64589		Sensor Ht.:	10 meters	
K factor:	3.8		Starting torque:	0.2	gm cm
Range:	0-40	m/s	Starting threshold:	0.23	m/s

		Chart	DAS
	Slope:	1.000	1.000
Last calibration date: NA	Int.:	0.000	0.000

WS Audit Point	m/s Input	m/s Chart	m/s Diff. Chart	m/s DAS	m/s Diff. DAS
1	0.00	#N/A	#N/A	0.00	0.00
2	2.56	#N/A	#N/A	2.56	0.00
3	5.12	#N/A	#N/A	5.12	0.00
4	7.68	#N/A	#N/A	7.68	0.00
5	12.80	#N/A	#N/A	12.80	0.00
6	17.92	#N/A	#N/A	17.92	0.00

Audit Criteria: ± (0.2 + 5%) m/s

Comments: No problems noted.

T&B SYSTEMS
HORIZONTAL WIND DIRECTION

Date:	08/06/08	Site name:	LAWA-Met
Start:	9:30 MST	Project:	LAWA
Finish:	11:45 MST	Operator:	ENSR
Auditor:	David Yoho		

Sensor Mfg:	RM Young	Model:	05305	
Serial No.:	64589	Sensor Ht.:	10 m	
K Factor:	37	Starting torque:	8.0	gm-cm
Range:	0 - 355°	Starting threshold:	0.5	m/s

Last calibration date: NA

Crossarm: 179 deg true

Cal. Factors	DAS
Slope:	1.000
Int.:	0.000

WD Audit Point	Degrees Reference	Corrected Degrees Reference			Degrees DAS	Linearity	Total Diff DAS Deg.
Orientation	179.0				182.0		3.0
1	45	42.9			48.5	1.8	5.6
2	90	87.9			93.6	1.9	5.7
3	135	132.9			137.4	0.7	4.5
4	180	177.9			181.0	-0.7	3.0
5	225	222.9			225.6	-1.1	2.7
6	270	267.9			269.9	-1.8	2.0
7	315	312.9			315.9	-0.8	3.0

Avg difference:		3.8
Maximum difference:	1.9	5.7

Criteria: Orientation:		± 2 degrees
Linearity:		± 3 degrees
Maximum Difference:		± 5 degrees

Comments: Two points exceeded the maximum difference of ± 5 degrees.

T&B SYSTEMS
SOLAR RADIATION

Date:	08/06/08	Site name:	LAWA-Met
Start:	9:30 MST	Project:	LAWA
Finish:	11:45 MST	Operator:	ENSR
Auditor:	David Yoho		
Sensor Mfg:	Eppley	Model:	8-48
Serial No.:	34060	Sensor Ht.:	2 m
Range:	0-1500 W/m2		

	Cal. Factors DAS
Slope:	1.000
Int.:	0.000

Last calibration date: NA

Solar Rad Audit Point	W/m2 Input		W/m2 DAS	W/m2 Diff. DAS	Criteria (W/m2) ±
10:17 LST	867		876	9	53
10:24 LST	882		890	8	54

Criteria: ± 5% of observed + 10 W/m2

Comments: No problems noted.

T&B SYSTEMS
AMBIENT TEMPERATURE

Date: 08/06/08
Start: 9:30 MST
Finish: 11:45 MST
Audited By: David Yoho

Site Name: LAWA-Met
Operator: ENSR
Project: LAWA

Manufacturer: RM Young
Serial No.: 7939
Lower Range: -50 Deg C
Upper Range: 50 Deg C

Model: 41406
Sensor Ht.: 2 m

Last calibration date: NA

	Chart	DAS
Slope:	1.000	1.000
Int.:	0.000	0.000

Temperature Audit Point	Deg C Input	Deg C Chart	Deg C Diff. Chart	Deg C DAS	Deg C Diff. DAS
1	0.6	#N/A	#N/A	0.4	-0.2
2	28.5	#N/A	#N/A	28.4	-0.1
3	41.4	#N/A	#N/A	41.5	0.1

Audit Criteria: ± 1.0 degree Celsius

Comments: None

T&B SYSTEMS
AMBIENT PRESSURE

Date:	8/6/08	Site name:	LAWA-Met
Start:	9:30 MST	Project:	LAWA
Finish:	11:45 MST	Operator:	ENSR
Auditor:	David Yoho		

Sensor Mfg:	Setra	Model:	276
Serial No.:	96	Sensor Ht.:	2 m
Range:	660 - 813 mm Hg	Calibrated:	NA

	Cal. Factors
	DAS
Slope:	1.000
Int.:	0.000

Audit Point	Audit (mm Hg)	Site (mm Hg)	Diff. (mm Hg)
1	758.5	722.4	-36.10

Criteria: ± 2.3 mm Hg

Comments: Within the range audited the sensor response was outside audit criteria. Correction is required.

A.2 LAX - HASTINGS

T&B SYSTEMS

OZONE

Date:	05/13/08	Site Name:	LAX-Hastings
Start:	9:50 PST	Operator:	SCAQMD
Finish:	10:50 PST	Project:	LAWA
Audited by:	David Yoho		
Witness:	NA		

Analyzer make:	API		Model:	400E
Serial No.:	524		Filter:	NA
Sample flow:	.84 lpm		Sample freq:	3097
Auto span:	1.030		Control freq:	3099
Range:	0.500	PPM	Last cal.:	12/20/07

Operator provided correction factors:
Corrected data = (IND. * A) + B

	Chart	DAS
Factors= A:	1.000	1.000
B:	-0.025	0.000

O3 Audit Point	PPM Input (X)	PPM Chart (Y)	PPM DAS (Y)
1	0.000	#VALUE!	0.003
2	0.069	#VALUE!	0.068
3	0.186	#VALUE!	0.185
4	0.450	#VALUE!	0.451

Linear Regression: (Y=PPM Corrected, X=PPM Input)

	Chart	DAS
Slope:	#VALUE!	0.999
Intercept:	#VALUE!	0.001
Correlation:	#VALUE!	1.0000

Comments: No problems noted.

Audit Equipment	Make	Model	ID	Last Calibration
Dilution System:	Environics	100	1287	5/12/08
Ozone Transfer Std:	Dasibi	1003-PC	24	04/07/08
Zero Air System:	AV	DB100	NA	NA

T&B SYSTEMS
NITRIC OXIDE

Date:	05/13/08	Site Name:	LAX-Hastings
Start:	07:40 PST	Operator:	SCAQMD
Finish:	09:30 PST	Project:	LAWA
Audited by:	David Yoho		
Witness:	NA		

Analyzer make:	API	Model:	200E
Serial No.:	241	Filter:	NA
Sample flow:	0.6 lpm	Span setting:	1.107
Zero setting:	-0.8	Vacuum:	NA
Range:	0.500 PPM	Mode:	NA
		Last cal.:	11/07/07

Operator provided correction factors:
Corrected data = (IND. * A) + B

	Chart	DAS
Factors= A:	1.000	1.000
B:	-0.025	0.000

NO Audit Point	PPM Input (X)	PPM Chart (Y)	PPM DAS (Y)
1	0.000	#VALUE!	0.003
2	0.077	#VALUE!	0.077
3	0.169	#VALUE!	0.165
4	0.421	#VALUE!	0.408

Linear Regression: (Y=PPM Corrected, X=PPM Input)

	Chart	DAS
Slope:	#VALUE!	0.962
Intercept:	#VALUE!	0.003
Correlation:	#VALUE!	1.0000

Comments: None.

Audit Equipment	Make	Model	ID	Last Calibration
Dilution System:	Environics	100	1287	5/12/08
Zero Air System:	AV	DB100		NA
Calibration Gas:	SMI	Multi	JJ8545	05/01/08

T&B SYSTEMS

OXIDES OF NITROGEN

Date:	05/13/08		
Start:	07:40 PST	Site Name:	LAX-Hastings
Finish:	09:30 PST	Organization:	SCAQMD
Audited by:	David Yoho	Project:	LAWA
Witness:	NA		
Analyzer make:	API	Model:	200E
Serial No.:	241	Filter:	NA
Sample flow:	0.6 lpm	Span setting:	1.105
Zero setting:	1.8	Vacuum:	NA
Range:	0.500 PPM	Last cal.:	11/07/07

Operator provided correction factors:
Corrected data = (IND. * A) + B

	Chart	DAS
Factors= A:	1.000	1.000
B:	-0.025	0.000

NOx Audit Point	PPM Input (X)	PPM Chart (Y)	PPM DAS (Y)
1	0.000	#VALUE!	0.003
2	0.077	#VALUE!	0.078
3	0.169	#VALUE!	0.166
4	0.421	#VALUE!	0.410

Linear Regression: (Y=PPM Corrected, X=PPM Input)

	Chart	DAS
Slope:	#VALUE!	0.966
Intercept:	#VALUE!	0.003
Correlation:	#VALUE!	1.0000

Comments: None.

Audit Equipment	Make	Model	ID	Last Calibration
Dilution System:	Environics	100	1287	5/12/08
Zero Air System:	AV	DB100	NA	NA
Calibration Gas:	SMI	Multi	JJ8545	05/01/08

T&B SYSTEMS

NITROGEN DIOXIDE

Date: 05/13/08
Start: 07:40 PST
Finish: 09:30 PST
Audited by: David Yoho
Witness: NA

Site Name: LAX-Hastings
Organization: SCAQMD
Project: LAWA

Analyzer make: API
Serial No.: 241
Ozone flow: 0.999
Range: 0.500 PPM

Model: 200E
Converter T.: 323 Deg C
Last cal.: 11/07/07

Operator provided correction factors:
Corrected data = (IND. * A) + B

	Chart	DAS
Factors= A:	1.000	1.000
B:	-0.025	0.000

NO2 Audit Point	PPM Input (X)	PPM Chart (Y)	PPM DAS (Y)
1	0.000	0.000	0.000
2	0.071	0.070	0.070
3	0.192	0.187	0.187
4	0.436	0.416	0.416

Linear Regression: (Y=PPM Corrected, X=PPM Input)

	Chart	DAS
Slope:	0.953	0.953
Intercept:	0.002	0.002
Correlation:	0.9999	0.9999

Converter Efficiency
99.3%

Comments: None.

Audit Equipment	Make	Model	ID	Last Calibration
Dilution System:	Environics	100	1287	5/12/08
Zero Air System:	AV	DB100	NA	NA
Calibration Gas:	SMI	Multi	JJ8545	05/01/08

T&B SYSTEMS
SULFUR DIOXIDE

Date:	05/13/08	Site name:	LAX-Hastings
Start:	07:40 PST	Operator:	SCAQMD
Finish:	09:30 PST	Project:	LAWA
Audited by:	David Yoho		
Witness:	NA		

Analyzer make:	Thermo Electron	Model:	43i
Serial No.:	527612597	Filter:	NA
Sample flow:	0.5 lpm	Span setting:	NA
Zero setting:	NA	Vacuum:	NA
Range:	0.500 PPM	Last cal.:	12/19/07

Operator provided correction factors:
Corrected data = (IND. * A) + B

	Chart	DAS
Factors= A:	1.000	1.000
B:	-0.025	0.000

SO2 Audit Point	PPM Input (X)	PPM Chart (Y)	PPM DAS (Y)
1	0.000	#VALUE!	0.001
2	0.076	#VALUE!	0.070
3	0.167	#VALUE!	0.155
4	0.416	#VALUE!	0.400

Linear Regression: (Y=PPM Corrected, X=PPM Input)

	Chart	DAS
Slope:	#VALUE!	0.963
Intercept:	#VALUE!	-0.002
Correlation:	#VALUE!	0.9999

Comments: None.

Audit Equipment	Make	Model	ID	Last Calibration
Dilution System:	Environics	100	1287	5/12/08
Zero Air System:	AV	DB100	NA	NA
Calibration Gas:	SMI	Multi	JJ8545	05/01/08

T&B SYSTEMS
CARBON MONOXIDE

Date:	05/13/08	Site name:	LAX-Hastings
Start:	09:30 PST	Operator:	SCAQMD
Finish:	09:50 PST	Project:	LAWA
Audited by:	David Yoho		
Witness:	NA		
Analyzer make:	Horiba	Model:	APMA-360CE
Serial No.:	576876074	Filter:	NA
Sample flow:	NA	Span setting:	1.9663
Zero setting:	52	Vacuum:	N/A
Range:	50 PPM	Last cal.:	12/20/07

Operator provided correction factors:
Corrected data = (IND. * A) + B

	Chart	DAS
Factors= A:	1.000	1.000
B:	0.000	0.000

CO Audit Point	PPM Input (X)	PPM Chart (Y)	PPM DAS (Y)
1	0.0	#N/A	0.2
2	7.9	#N/A	7.9
3	17.2	#N/A	17.0
4	43.0	#N/A	42.3

Linear Regression: (Y=PPM Corrected, X=PPM Input)

	Chart	DAS
Slope:	#N/A	0.979
Intercept:	#N/A	0.2
Correlation:	#N/A	1.0000

Criteria: Slope: 1.00 ± 0.15; Intercept: ±3% (full scale); Correlation: ≥ .9950

Comments: None.

Audit Equipment	Make	Model	ID	Last Calibration
Dilution System:	Environics	100	1287	5/12/08
Zero Air System:	UP Air	SMI	NA	NA
Calibration Gas:	SMI	Multi	JJ8545	05/01/08

T&B Systems, Inc PM_{10} Sampler Audit Data Sheet

Date:	5/13/2008	Site name:	LAX
Start:	11:20 PST	Project:	SCAQMD PM10 QA
Finish:	11:30 PST	Operator:	SCAQMD
Auditor:	David Yoho		
Witness:	None		

Sensor Mfg:	Andersen	Model:	IP 10
Serial No.:	50470	Sensor Ht.:	3 m
Last inlet cleaning:	11/15/2007	40 CFM Set Point:	38
Last calibration date:	5/5/2008		

Orifice id.:	1259		Orifice Qstd slope:	1.9968
Amb. Press:	29.88	in. Hg	Orifice Qstd Intcpt:	-0.02449
Amb. Temp.:	19.2	deg. C	Orifice Qact slope:	1.25035
			Orifice Qact Intcpt:	-0.01543
Orifice Certified:	09/18/07			

Sampler flow in ACFM:	40.0
Chart flow (Dickson) in ACFM:	41
Orifice delta in. H2O:	4.70
Audit flow in SCFM:	
Audit flow in m3/min:	1.088
Audit flow in ACFM:	38.4

Audit Flow (ACFM) Diff.:	1.560
Audit Flow (ACFM) % Diff.:	4.1%

CARB Audit Criteria Design Flow: ±10% (36-44 ACFM); ±7% from audit flow
EPA Audit Criteria: Design Flow: ±10% (36-44 ACFM); ±10% from audit flow

Comments: No problems noted.

A.3 UPPER AIR METEOROLOGY – LAX PAMS

Overall upper air performance audit wind results using rawinsondes.

Three audit soundings with rawinsondes were performed on May 13, 2008 at 0739, 1147, and 1520 PST. The results below show data from both the low and high modes of operation. Results from the audit were very good, meeting all audit criteria. Under "NUMBER OF DATA PAIRS", the values listed under "Vector Wind Threshold (m/s)" represent the number of comparison data pairs with wind speeds greater than or equal to the indicated audit threshold speed. The same applies under "STATISTICAL EVALUATION OF DIFFERENCES" to evaluate how well the vector data compares with increasing wind speeds. The evaluation criteria used was based on the component comparisons and was ±1 m/s for the systematic differences and ±2 m/s for the RMS differences. This is consistent with the most recently released EPA guidance entitled *Meteorological Monitoring Guidance for Regulatory Modeling Applications* (EPA-454/R-99-005), February 2000. Vector data are used only as a secondary evaluation.

Composite statistical data for the 0739, 1147 and 1520 PST rawinsonde audit soundings compared to the low mode radar data.

```
Statistical Analysis Report of Audit Data
Produced using STATCOMP v1.0
This file name: RWPLOALL.DAT
File list used: RWPLOALL.TXT
Operational mode: LOW
Run Date: 09-09-2008
Run Time: 22:36:23

FILES PROCESSED IN LIST FILE
----------------------------
                                 Rotation
File Name    Month   Day  Year  Ax 1  Ax 2  Site          Data Type    Mode
---------    -----   ---  ----  ----  ----  ----          ---------    ----
rwind1lo.da4     0   0       0    39   129  LAX          Winds        Low
rwind2lo.da4     0   0       0    39   129  LAX          Winds        Low
rwind3lo.da4     0   0       0    39   129  LAX          Winds        Low
--------------------------------------------------------------------------


NUMBER OF DATA PAIRS
--------------------
         |       |         |           Vector Wind
         | Compo-| Virtual |         Threshold (m/s)
   Date  |  nent |   Temp  |  0  |  1  |  2  |  3  |  4  |  5
---------------------------------------------------------------
  0  0  0     13        0     13     8     4     4     3     3
  0  0  0     16        0     16    16    16    16    14    11
  0  0  0     17        0     17    15    13    11    10     9

---------------------------------------------------------------
    Total     46        0     46    39    33    31    27    23


STATISTICAL EVALUATION OF DIFFERENCES
-------------------------------------
          |                     |                      Vector Wind Threshold (m/s)
          |                     |    -0-     |     -1-     |     -2-     |     -3-     |     -4-     |     -5-
Difference| Comp 1 Comp 2  Tvirt|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD
--------------------------------------------------------------------------------------------------------
Systematic|    2.3    0.1 -999.0   -2.0  -10   -2.6   -3   -3.2   -1   -3.6    5   -3.9    6   -4.1    4
RMS       |    3.4    5.3 -999.0    3.7   63    3.9   64    4.1   68    4.2   66    4.4   61    4.6   59
Minimum   |    0.0   -0.2 -999.0    0.0    0   -0.3    0   -0.3    0   -0.3    0   -0.3    0   -0.3    0
Maximum   |    7.0   13.9 -999.0   -7.2  151   -7.2  151   -7.2  151   -7.2  151   -7.2  -99   -7.2  -95
--------------------------------------------------------------------------------------------------------
```

Composite statistical data for the 0739, 1147, and 1520 PST rawinsonde audit soundings compared to the high mode radar data.

```
Statistical Analysis Report of Audit Data
Produced using STATCOMP v1.0
This file name: RWPHIALL.DAT
File list used: RWPHIALL.TXT
Operational mode: HIGH
Run Date: 09-09-2008
Run Time: 22:36:23

FILES PROCESSED IN LIST FILE
----------------------------
                                 Rotation
File Name    Month   Day  Year  Ax 1  Ax 2  Site         Data Type    Mode
---------    -----   ---  ----  ----  ----  ----         ---------    ----
rwind1hi.da4     0     0     0   129    39  LAX          Winds        High
rwind2hi.da4     0     0     0   129    39  LAX          Winds        High
rwind3hi.da4     0     0     0   129    39  LAX          Winds        High
--------------------------------------------------------------------------


NUMBER OF DATA PAIRS
--------------------
         |       |         |           Vector Wind
         | Compo-| Virtual |         Threshold (m/s)
   Date  |  nent |   Temp  |  0  |  1  |  2  |  3  |  4  |  5
---------------------------------------------------------------
  0  0  0      5        0      5     4     1     1     1     1
  0  0  0     13        0     13    13    13    13    12    11
  0  0  0     17        0     17    15    14    13    12    11

---------------------------------------------------------------
    Total     35        0     35    32    28    27    25    23


STATISTICAL EVALUATION OF DIFFERENCES
-------------------------------------
          |                     |                      Vector Wind Threshold (m/s)
          |                     |    -0-     |    -1-     |    -2-     |    -3-     |    -4-     |    -5-
Difference| Comp 1 Comp 2  Tvirt|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD
---------------------------------------------------------------------------------------------------------
Systematic|    6.5   -3.3 -999.0   -4.8  -23   -5.6  -21   -6.4  -21   -6.7  -19   -7.1  -13   -7.8  -21
RMS       |    7.9    6.4 -999.0    7.5   92    7.7   95    8.3  101    8.4  102    8.7  102    9.1  103
Minimum   |    0.5   -0.1 -999.0    0.1    0    0.1  -13    0.9  -13    0.9  -13   -0.9  -13   -0.9  -13
Maximum   |   13.4  -12.0 -999.0  -17.2 -176  -17.2 -176  -17.2 -176  -17.2 -176  -17.2 -176  -17.2 -176
---------------------------------------------------------------------------------------------------------
```

Statistical data for the 0739 PST rawinsonde audit sounding to low mode data set.

```
Statistical Analysis Report of Audit Data
Produced using STATCOMP v1.0
This file name: RWP1LO.DAT
File list used: RWP1LO.TXT
Operational mode: LOW
Run Date: 09-09-2008
Run Time: 22:36:23

FILES PROCESSED IN LIST FILE
----------------------------
                                 Rotation
File Name    Month   Day  Year  Ax 1  Ax 2  Site         Data Type    Mode
---------    -----   ---  ----  ----  ----  ----         ---------    ----
rwind1lo.da4     0     0     0    39   129  LAX          Winds        Low
--------------------------------------------------------------------------


NUMBER OF DATA PAIRS
--------------------
         |       |         |           Vector Wind
         | Compo-| Virtual |          Threshold (m/s)
   Date  |  nent |   Temp  |  0  |  1  |  2  |  3  |  4  |  5
---------------------------------------------------------------
  0  0  0     13        0     13     8     4     4     3     3

---------------------------------------------------------------
    Total     13        0     13     8     4     4     3     3

STATISTICAL EVALUATION OF DIFFERENCES
-------------------------------------
          |                     |                      Vector Wind Threshold (m/s)
          |                     |    -0-    |    -1-    |    -2-    |    -3-    |    -4-    |    -5-
Difference| Comp 1 Comp 2  Tvirt|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD
--------------------------------------------------------------------------------------------------------
Systematic|    0.6   -1.0 -999.0   -1.4  -32   -2.3  -13   -3.7   -7   -3.7   -7   -4.2   -3   -4.2   -3
RMS       |    1.7    2.0 -999.0    2.2   46    2.8   17    3.8   10    3.8   10    4.2    5    4.2    5
Minimum   |    0.0   -0.2 -999.0    0.0    0   -0.7    0   -2.3    0   -2.3    0   -3.9    0   -3.9    0
Maximum   |    3.6   -4.7 -999.0   -4.6 -104   -4.6  -28   -4.6  -19   -4.6  -19   -4.6   -8   -4.6   -8
--------------------------------------------------------------------------------------------------------
```

Statistical data for the 0739 PST rawinsonde audit sounding to high mode data set.

```
Statistical Analysis Report of Audit Data
Produced using STATCOMP v1.0
This file name: RWP1HI.DAT
File list used: RWP1HI.TXT
Operational mode: HIGH
Run Date: 09-09-2008
Run Time: 22:36:23

FILES PROCESSED IN LIST FILE
----------------------------
                                 Rotation
File Name    Month   Day  Year  Ax 1  Ax 2  Site         Data Type    Mode
---------    -----   ---  ----  ----  ----  ----         ---------    ----
rwind1hi.da4     0     0     0   129    39  LAX          Winds        High
--------------------------------------------------------------------------


NUMBER OF DATA PAIRS
--------------------
         |       |         |            Vector Wind
         | Compo-| Virtual |          Threshold (m/s)
   Date  |  nent |   Temp  |  0  |  1  |  2  |  3  |  4  |  5
---------------------------------------------------------------
  0  0  0      5        0      5     4     1     1     1     1

---------------------------------------------------------------
    Total      5        0      5     4     1     1     1     1


STATISTICAL EVALUATION OF DIFFERENCES
-------------------------------------
          |                     |                      Vector Wind Threshold (m/s)
          |                     |    -0-    |    -1-    |    -2-    |    -3-    |    -4-    |    -5-
Difference| Comp 1 Comp 2  Tvirt|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD
--------------------------------------------------------------------------------------------------------
Systematic|    0.9   -1.6 -999.0   -1.0  -23   -1.3  -10   -3.6  -13   -3.6  -13   -3.6  -13   -3.6  -13
RMS       |    3.4    2.6 -999.0    1.8   38    2.0   19    3.6   13    3.6   13    3.6   13    3.6   13
Minimum   |   -0.6    0.2 -999.0    0.1  -13    0.1  -13   -3.6  -13   -3.6  -13   -3.6  -13   -3.6  -13
Maximum   |    7.0   -4.7 -999.0   -3.6  -76   -3.6  -28   -3.6  -13   -3.6  -13   -3.6  -13   -3.6  -13
--------------------------------------------------------------------------------------------------------
```

Statistical data for the 1147 PST rawinsonde audit sounding to low mode data set.

```
Statistical Analysis Report of Audit Data
Produced using STATCOMP v1.0
This file name: RWP2LO.DAT
File list used: RWP2LO.TXT
Operational mode: LOW
Run Date: 09-09-2008
Run Time: 22:36:23

FILES PROCESSED IN LIST FILE
----------------------------
                                 Rotation
File Name    Month   Day  Year  Ax 1  Ax 2  Site         Data Type    Mode
---------    -----   ---  ----  ----  ----  ----         ---------    ----
rwind2lo.da4     0    0      0    39   129  LAX          Winds        Low
--------------------------------------------------------------------------


NUMBER OF DATA PAIRS
--------------------
         |       |         |            Vector Wind
         | Compo-| Virtual |          Threshold (m/s)
   Date  |  nent |   Temp  |  0  |  1  |  2  |  3  |  4  |  5
---------------------------------------------------------------
  0  0  0     16        0     16    16    16    16    14    11

---------------------------------------------------------------
    Total     16        0     16    16    16    16    14    11

STATISTICAL EVALUATION OF DIFFERENCES
-------------------------------------
          |                     |                      Vector Wind Threshold (m/s)
          |                     |    -0-    |    -1-    |    -2-    |    -3-    |    -4-    |    -5-
Difference| Comp 1 Comp 2  Tvirt|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD
--------------------------------------------------------------------------------------------------------
Systematic|    1.7   -1.6 -999.0   -4.4   50   -4.4   50   -4.4   50   -4.4   50   -4.6   51   -5.0   48
RMS       |    3.0    6.9 -999.0    4.7   65    4.7   65    4.7   65    4.7   65    4.9   55    5.3   52
Minimum   |   -0.3    1.3 -999.0   -2.1   15   -2.1   15   -2.1   15   -2.1   15   -2.1   15   -3.0   15
Maximum   |    4.5  -11.5 -999.0   -7.2  151   -7.2  151   -7.2  151   -7.2  151   -7.2   82   -7.2   72
--------------------------------------------------------------------------------------------------------
```

Statistical data for the 1147 PST rawinsonde audit sounding to high mode data set.

```
Statistical Analysis Report of Audit Data
Produced using STATCOMP v1.0
This file name: RWP2HI.DAT
File list used: RWP2HI.TXT
Operational mode: HIGH
Run Date: 09-09-2008
Run Time: 22:36:23

FILES PROCESSED IN LIST FILE
----------------------------
                                 Rotation
File Name    Month   Day  Year  Ax 1  Ax 2  Site         Data Type    Mode
---------    -----   ---  ----  ----  ----  ----         ---------    ----
rwind2hi.da4     0     0     0   129    39  LAX          Winds        High
--------------------------------------------------------------------------


NUMBER OF DATA PAIRS
--------------------
         |       |         |           Vector Wind
         | Compo-| Virtual |          Threshold (m/s)
   Date  |  nent |   Temp  |  0  |  1  |  2  |  3  |  4  |  5
---------------------------------------------------------------
  0  0  0     13        0     13    13    13    13    12    11

---------------------------------------------------------------
    Total     13        0     13    13    13    13    12    11

STATISTICAL EVALUATION OF DIFFERENCES
-------------------------------------
          |                     |                      Vector Wind Threshold (m/s)
          |                     |    -0-    |    -1-    |    -2-    |    -3-    |    -4-    |    -5-
Difference| Comp 1 Comp 2  Tvirt|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD
--------------------------------------------------------------------------------------------------------
Systematic|    6.4   -6.1 -999.0   -8.9    4   -8.9    4   -8.9    4   -8.9    4   -9.5   14  -10.2    7
RMS       |    7.8    7.8 -999.0   10.3  128   10.3  128   10.3  128   10.3  128   10.7  129   11.2  132
Minimum   |    0.5    0.9 -999.0   -1.3  -28   -1.3  -28   -1.3  -28   -1.3  -28   -1.3  -28   -2.8  -28
Maximum   |   13.4  -12.0 -999.0  -17.2 -176  -17.2 -176  -17.2 -176  -17.2 -176  -17.2 -176  -17.2 -176
--------------------------------------------------------------------------------------------------------
```

Statistical data for the 1520 PST rawinsonde audit sounding to low mode data set.

```
Statistical Analysis Report of Audit Data
Produced using STATCOMP v1.0
This file name: RWP3LO.DAT
File list used: RWP3LO.TXT
Operational mode: LOW
Run Date: 09-09-2008
Run Time: 22:36:23

FILES PROCESSED IN LIST FILE
----------------------------
                                 Rotation
File Name    Month   Day  Year  Ax 1  Ax 2  Site          Data Type    Mode
---------    -----   ---  ----  ----  ----  ----          ---------    ----
rwind3lo.da4     0     0     0    39   129  LAX           Winds        Low
--------------------------------------------------------------------------


NUMBER OF DATA PAIRS
--------------------
         |       |         |           Vector Wind
         | Compo-| Virtual |          Threshold (m/s)
   Date  |  nent |   Temp  |  0  |  1  |  2  |  3  |  4  |  5
---------------------------------------------------------------
  0  0  0     17        0     17    15    13    11    10     9

---------------------------------------------------------------
    Total     17        0     17    15    13    11    10     9

STATISTICAL EVALUATION OF DIFFERENCES
-------------------------------------
          |                     |                      Vector Wind Threshold (m/s)
          |                     |    -0-    |    -1-    |    -2-    |    -3-    |    -4-    |    -5-
Difference| Comp 1 Comp 2  Tvirt|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD
--------------------------------------------------------------------------------------------------------
Systematic|    4.1    2.7 -999.0   -0.2  -50   -0.9  -56   -1.7  -62   -2.4  -57   -2.8  -54   -3.0  -49
RMS       |    4.5    5.3 -999.0    3.7   72    3.5   77    3.4   80    3.6   78    3.7   77    3.9   74
Minimum   |    0.3    0.3 -999.0   -0.3   12   -0.3   37   -0.3   49   -0.3   49   -0.3   49   -0.3   49
Maximum   |    7.0   13.9 -999.0   -6.7 -101   -6.7 -101   -6.7 -101   -6.7  -99   -6.7  -99   -6.7  -95
--------------------------------------------------------------------------------------------------------
```

Statistical data for the 1520 PST rawinsonde audit sounding to high mode data set.

```
Statistical Analysis Report of Audit Data
Produced using STATCOMP v1.0
This file name: RWP3HI.DAT
File list used: RWP3HI.TXT
Operational mode: HIGH
Run Date: 09-09-2008
Run Time: 22:36:23

FILES PROCESSED IN LIST FILE
----------------------------
                                 Rotation
File Name    Month   Day  Year  Ax 1  Ax 2  Site         Data Type    Mode
---------    -----   ---  ----  ----  ----  ----         ---------    ----
rwind3hi.da4     0     0     0   129    39  LAX          Winds        High
--------------------------------------------------------------------------


NUMBER OF DATA PAIRS
--------------------
         |       |         |           Vector Wind
         | Compo-| Virtual |          Threshold (m/s)
   Date  |  nent |   Temp  |  0  |  1  |  2  |  3  |  4  |  5
---------------------------------------------------------------
  0  0  0     17         0     17    15    14    13    12    11

---------------------------------------------------------------
    Total     17         0     17    15    14    13    12    11

STATISTICAL EVALUATION OF DIFFERENCES
-------------------------------------
          |                     |                      Vector Wind Threshold (m/s)
          |                     |    -0-    |    -1-    |    -2-    |    -3-    |    -4-    |    -5-
Difference| Comp 1 Comp 2  Tvirt|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD
--------------------------------------------------------------------------------------------------------
Systematic|    8.3   -1.7 -999.0   -2.9  -43   -3.8  -46   -4.2  -45   -4.6  -43   -5.1  -39   -5.7  -48
RMS       |    8.9    5.9 -999.0    5.7   67    5.9   71    6.1   71    6.3   71    6.5   70    6.8   70
Minimum   |    3.1   -0.1 -999.0    0.9    0    0.9   51    0.9   51    0.9   51   -0.9   51   -0.9   51
Maximum   |   13.4   11.3 -999.0  -12.2  -89  -12.2  -89  -12.2  -89  -12.2  -89  -12.2  -88  -12.2  -88
--------------------------------------------------------------------------------------------------------
```

OVERALL UPPER AIR PERFORMANCE AUDIT VIRTUAL TEMPERATURE RESULTS USING RAWINSONDES.

Three audit soundings with rawinsondes were performed on May 13, 2008 at 0739, 1147, and 1520 PST. The comparison criteria used was ±1°C for the systematic differences and ±1.5°C for the RMS differences. This is consistent with the most recently released EPA guidance entitled *Meteorological Monitoring Guidance for Regulatory Modeling Applications* (EPA-454/R-99-005), February 2000. Composite statistical data for the 0739, 1147, and 1520 PST rawinsonde audit soundings for the non-vertical velocity corrected RASS data.

```
Statistical Analysis Report of Audit Data
Produced using STATCOMP v1.0
This file name: RTEMPALL.DAT
File list used: RTEMPALL.TXT
Operational mode: LOW
Run Date: 09-09-2008
Run Time: 14:17:09

FILES PROCESSED IN LIST FILE
----------------------------
                                 Rotation
File Name    Month   Day  Year  Ax 1  Ax 2  Site         Data Type    Mode
---------    -----   ---  ----  ----  ----  ----         ---------    ----
rtemp1.da4       5    13     8   346   256  LAX          Temperature  NA
rtemp2.da4       5    13     8   346   256  LAX          Temperature  NA
rtemp3.da4       5    13     8   346   256  LAX          Temperature  NA
--------------------------------------------------------------------------


NUMBER OF DATA PAIRS
--------------------
         |       |         |            Vector Wind
         | Compo-| Virtual |          Threshold (m/s)
   Date  |  nent |   Temp  |  0  |  1  |  2  |  3  |  4  |  5
---------------------------------------------------------------
  5 13   8      0       14      0     0     0     0     0     0
  5 13   8      0       10      0     0     0     0     0     0
  5 13   8      0        9      0     0     0     0     0     0

---------------------------------------------------------------
    Total       0       33      0     0     0     0     0     0

STATISTICAL EVALUATION OF DIFFERENCES
-------------------------------------
          |                     |                      Vector Wind Threshold (m/s)
          |                     |    -0-    |    -1-    |    -2-    |    -3-    |    -4-    |    -5-
Difference| Comp 1 Comp 2  Tvirt|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD
--------------------------------------------------------------------------------------------------------
Systematic| -999.0 -999.0   -0.3 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
RMS       | -999.0 -999.0    1.2 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
Minimum   | -999.0 -999.0    0.1 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
Maximum   | -999.0 -999.0    4.4 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
--------------------------------------------------------------------------------------------------------
```

Statistical data for the 0739 PST rawinsonde audit sounding for the non-vertical velocity corrected RASS data.

```
Statistical Analysis Report of Audit Data
Produced using STATCOMP v1.0
This file name: RTEMP1.DAT
File list used: RTEMP1.TXT
Operational mode: LOW
Run Date: 09-09-2008
Run Time: 14:17:09

FILES PROCESSED IN LIST FILE
----------------------------
                                 Rotation
File Name    Month   Day  Year  Ax 1  Ax 2  Site         Data Type    Mode
---------    -----   ---  ----  ----  ----  ----         ---------    ----
rtemp1.da4       5    13     8   346   256  LAX          Temperature  NA
--------------------------------------------------------------------------


NUMBER OF DATA PAIRS
--------------------
         |       |         |           Vector Wind
         | Compo-| Virtual |         Threshold (m/s)
   Date  |  nent |   Temp  |  0  |  1  |  2  |  3  |  4  |  5
---------------------------------------------------------------
  5 13  8      0       14      0     0     0     0     0     0

---------------------------------------------------------------
    Total      0       14      0     0     0     0     0     0

STATISTICAL EVALUATION OF DIFFERENCES
-------------------------------------
          |                     |                      Vector Wind Threshold (m/s)
          |                     |    -0-    |    -1-    |    -2-    |    -3-    |    -4-    |    -5-
Difference| Comp 1 Comp 2  Tvirt|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD
--------------------------------------------------------------------------------------------------------
Systematic| -999.0 -999.0   -0.3 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
RMS       | -999.0 -999.0    0.7 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
Minimum   | -999.0 -999.0    0.1 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
Maximum   | -999.0 -999.0   -1.4 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
--------------------------------------------------------------------------------------------------------
```

Statistical data for the 1147 PST rawinsonde audit sounding for the non-vertical velocity corrected RASS data.

```
Statistical Analysis Report of Audit Data
Produced using STATCOMP v1.0
This file name: RTEMP2.DAT
File list used: RTEMP2.TXT
Operational mode: LOW
Run Date: 09-09-2008
Run Time: 14:17:09

FILES PROCESSED IN LIST FILE
----------------------------
                                 Rotation
File Name    Month   Day  Year  Ax 1  Ax 2  Site          Data Type    Mode
---------    -----   ---  ----  ----  ----  ----          ---------    ----
rtemp2.da4       5    13     8   346   256  LAX           Temperature  NA
--------------------------------------------------------------------------


NUMBER OF DATA PAIRS
--------------------
         |       |         |           Vector Wind
         | Compo-| Virtual |          Threshold (m/s)
   Date  |  nent |   Temp  |  0  |  1  |  2  |  3  |  4  |  5
---------------------------------------------------------------
  5 13  8      0       10      0     0     0     0     0     0

---------------------------------------------------------------
    Total      0       10      0     0     0     0     0     0

STATISTICAL EVALUATION OF DIFFERENCES
-------------------------------------
          |                     |                      Vector Wind Threshold (m/s)
          |                     |    -0-    |    -1-    |    -2-    |    -3-    |    -4-    |    -5-
Difference| Comp 1 Comp 2  Tvirt|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD
--------------------------------------------------------------------------------------------------------
Systematic| -999.0 -999.0   -0.1 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
RMS       | -999.0 -999.0    0.7 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
Minimum   | -999.0 -999.0    0.1 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
Maximum   | -999.0 -999.0   -1.2 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
--------------------------------------------------------------------------------------------------------
```

Statistical data for the 1520 PST rawinsonde audit sounding for the non-vertical velocity corrected RASS data.

```
Statistical Analysis Report of Audit Data
Produced using STATCOMP v1.0
This file name: RTEMP3.DAT
File list used: RTEMP3.TXT
Operational mode: LOW
Run Date: 09-09-2008
Run Time: 14:17:09

FILES PROCESSED IN LIST FILE
----------------------------
                                 Rotation
File Name    Month   Day  Year  Ax 1  Ax 2  Site          Data Type    Mode
---------    -----   ---  ----  ----  ----  ----          ---------    ----
rtemp3.da4       5    13     8   346   256  LAX          Temperature  NA
--------------------------------------------------------------------------


NUMBER OF DATA PAIRS
--------------------
         |       |         |           Vector Wind
         | Compo-| Virtual |          Threshold (m/s)
   Date  |  nent |   Temp  |  0  |  1  |  2  |  3  |  4  |  5
---------------------------------------------------------------
  5 13  8      0        9      0     0     0     0     0     0

---------------------------------------------------------------
    Total      0        9      0     0     0     0     0     0

STATISTICAL EVALUATION OF DIFFERENCES
------------------------------------
          |                     |                      Vector Wind Threshold (m/s)
          |                     |    -0-    |    -1-    |    -2-    |    -3-    |    -4-    |    -5-
Difference| Comp 1 Comp 2  Tvirt|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD
--------------------------------------------------------------------------------------------------------
Systematic| -999.0 -999.0   -0.6 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
RMS       | -999.0 -999.0    2.1 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
Minimum   | -999.0 -999.0   -0.2 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
Maximum   | -999.0 -999.0    4.4 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
--------------------------------------------------------------------------------------------------------
```

Composite statistical data for the 0739, 1147, and 1520 PST rawinsonde audit soundings for the vertical velocity corrected RASS data.

```
Statistical Analysis Report of Audit Data
Produced using STATCOMP v1.0
This file name: RTEMPALL.DAT
File list used: RTEMPALL.TXT
Operational mode: LOW
Run Date: 09-09-2008
Run Time: 14:13:27

FILES PROCESSED IN LIST FILE
----------------------------
                                 Rotation
File Name    Month   Day  Year  Ax 1  Ax 2  Site         Data Type    Mode
---------    -----   ---  ----  ----  ----  ----         ---------    ----
rtemp1.da4       5    13     8   346   256  LAX          Temperature  NA
rtemp2.da4       5    13     8   346   256  LAX          Temperature  NA
rtemp3.da4       5    13     8   346   256  LAX          Temperature  NA
--------------------------------------------------------------------------


NUMBER OF DATA PAIRS
--------------------
         |       |         |           Vector Wind
         | Compo-| Virtual |          Threshold (m/s)
   Date  |  nent |   Temp  |  0  |  1  |  2  |  3  |  4  |  5
---------------------------------------------------------------
  5 13  8      0       12      0     0     0     0     0     0
  5 13  8      0       10      0     0     0     0     0     0
  5 13  8      0        9      0     0     0     0     0     0

---------------------------------------------------------------
    Total      0       31      0     0     0     0     0     0


STATISTICAL EVALUATION OF DIFFERENCES
-------------------------------------
          |                     |                      Vector Wind Threshold (m/s)
          |                     |    -0-    |    -1-    |    -2-    |    -3-    |    -4-    |    -5-
Difference| Comp 1 Comp 2  Tvirt|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD
--------------------------------------------------------------------------------------------------------
Systematic| -999.0 -999.0   -0.8 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
RMS       | -999.0 -999.0    1.6 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
Minimum   | -999.0 -999.0    0.0 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
Maximum   | -999.0 -999.0    4.3 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
--------------------------------------------------------------------------------------------------------
```

Statistical data for the 0739 PST rawinsonde audit sounding for the vertical velocity corrected RASS data.

```
Statistical Analysis Report of Audit Data
Produced using STATCOMP v1.0
This file name: RTEMP1.DAT
File list used: RTEMP1.TXT
Operational mode: LOW
Run Date: 09-09-2008
Run Time: 14:13:27

FILES PROCESSED IN LIST FILE
----------------------------
                                 Rotation
File Name    Month   Day  Year  Ax 1  Ax 2  Site         Data Type    Mode
---------    -----   ---  ----  ----  ----  ----         ---------    ----
rtemp1.da4       5    13     8   346   256  LAX          Temperature  NA
--------------------------------------------------------------------------


NUMBER OF DATA PAIRS
--------------------
         |       |         |           Vector Wind
         | Compo-| Virtual |          Threshold (m/s)
   Date  |  nent |   Temp  |  0  |  1  |  2  |  3  |  4  |  5
---------------------------------------------------------------
  5 13  8      0       12      0     0     0     0     0     0

---------------------------------------------------------------
    Total      0       12      0     0     0     0     0     0

STATISTICAL EVALUATION OF DIFFERENCES
-------------------------------------
          |                     |                      Vector Wind Threshold (m/s)
          |                     |    -0-    |    -1-    |    -2-    |    -3-    |    -4-    |    -5-
Difference| Comp 1 Comp 2  Tvirt|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD
--------------------------------------------------------------------------------------------------------
Systematic| -999.0 -999.0   -0.4 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
RMS       | -999.0 -999.0    1.0 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
Minimum   | -999.0 -999.0   -0.1 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
Maximum   | -999.0 -999.0   -2.8 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
--------------------------------------------------------------------------------------------------------
```

Statistical data for the 1147 PST rawinsonde audit sounding for the vertical velocity corrected RASS data.

```
Statistical Analysis Report of Audit Data
Produced using STATCOMP v1.0
This file name: RTEMP2.DAT
File list used: RTEMP2.TXT
Operational mode: LOW
Run Date: 09-09-2008
Run Time: 14:13:27

FILES PROCESSED IN LIST FILE
----------------------------
                                 Rotation
File Name    Month   Day  Year  Ax 1  Ax 2  Site         Data Type    Mode
---------    -----   ---  ----  ----  ----  ----         ---------    ----
rtemp2.da4       5    13     8   346   256  LAX          Temperature  NA
--------------------------------------------------------------------------


NUMBER OF DATA PAIRS
--------------------
         |       |         |            Vector Wind
         | Compo-| Virtual |          Threshold (m/s)
   Date  |  nent |   Temp  |  0  |  1  |  2  |  3  |  4  |  5
---------------------------------------------------------------
  5 13  8      0       10      0     0     0     0     0     0

---------------------------------------------------------------
    Total      0       10      0     0     0     0     0     0

STATISTICAL EVALUATION OF DIFFERENCES
-------------------------------------
          |                     |                      Vector Wind Threshold (m/s)
          |                     |    -0-    |    -1-    |    -2-    |    -3-    |    -4-    |    -5-
Difference| Comp 1 Comp 2  Tvirt|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD
--------------------------------------------------------------------------------------------------------
Systematic| -999.0 -999.0   -1.6 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
RMS       | -999.0 -999.0    1.8 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
Minimum   | -999.0 -999.0   -0.9 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
Maximum   | -999.0 -999.0   -2.9 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
--------------------------------------------------------------------------------------------------------
```

Statistical data for the 1520 PST rawinsonde audit sounding for the vertical velocity corrected RASS data.

```
Statistical Analysis Report of Audit Data
Produced using STATCOMP v1.0
This file name: RTEMP3.DAT
File list used: RTEMP3.TXT
Operational mode: LOW
Run Date: 09-09-2008
Run Time: 14:13:27

FILES PROCESSED IN LIST FILE
----------------------------
                                 Rotation
File Name    Month   Day  Year  Ax 1  Ax 2  Site         Data Type    Mode
---------    -----   ---  ----  ----  ----  ----         ---------    ----
rtemp3.da4       5    13     8   346   256  LAX          Temperature  NA
--------------------------------------------------------------------------


NUMBER OF DATA PAIRS
--------------------
         |       |         |           Vector Wind
         | Compo-| Virtual |          Threshold (m/s)
   Date  |  nent |   Temp  |  0  |  1  |  2  |  3  |  4  |  5
---------------------------------------------------------------
  5 13  8      0        9      0     0     0     0     0     0

---------------------------------------------------------------
    Total      0        9      0     0     0     0     0     0


STATISTICAL EVALUATION OF DIFFERENCES
-------------------------------------
          |                     |                      Vector Wind Threshold (m/s)
          |                     |    -0-    |    -1-    |    -2-    |    -3-    |    -4-    |    -5-
Difference| Comp 1 Comp 2  Tvirt|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD|    WS   WD
--------------------------------------------------------------------------------------------------------
Systematic| -999.0 -999.0   -0.5 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
RMS       | -999.0 -999.0    2.0 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
Minimum   | -999.0 -999.0    0.0 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
Maximum   | -999.0 -999.0    4.3 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999 -999.0 -999
--------------------------------------------------------------------------------------------------------
```

A.4 SURFACE METEOROLOGY – LAX PAMS

T&B SYSTEMS AUDIT RECORD
HORIZONTAL WIND SPEED

Date:	May 13, 2008	Site name:	LAX PAMS
Start:	12:00 PST	Project:	Audit
Finish:	14:15 PST	Operator:	SCAQMD
Auditor:	Bob Baxter	Site Operator:	Kevin Smith

Sensor Mfg:	RM Young	Model:	05305AQ
Sensor s/n:	80572	Sensor Ht.:	10 m
K factor:	3.8	Starting torque:	0.5 gm-cm
Range:	0 - 90 mph	Starting Threshold:	0.8 m/s
Logger:	CSI CR1000		
Logger s/n:	1920		Cal. Factors
Prop s/n:	62277		DAS
		Slope:	1.000
Last calibration date:	Unknown	Int.:	0.000

WS Audit Point	MPH Input		MPH DAS	Diff. DAS	MPH % Diff. DAS
1	0.0		0.0	0.0	#N/A
2	5.7		5.7	0.0	0.0
3	17.2		17.2	0.0	0.0
4	28.6		28.6	0.0	0.0
5	40.1		40.1	0.0	0.0
6	51.5		51.5	0.0	0.0

Pass/Fail Criteria: ±.56 + 5% MPH
Starting Threshold: 0.5 m/s

Comments: No problems noted, though WD bearings close to not meeting criteria. Sensor was replaced at time of audit.

T&B SYSTEMS AUDIT RECORD
HORIZONTAL WIND SPEED

Date:	May 13, 2008	Site name:	LAX PAMS	
Start:	12:00 PST	Project:	Audit	
Finish:	14:15 PST	Operator:	SCAQMD	
Auditor:	Bob Baxter	Site Operator:	Kevin Smith	
Sensor Mfg:	RM Young	Model:	05305AQ	
Sensor s/n:	80573	Sensor Ht.:	10 m	
K factor:	3.8	Starting torque:	0.3	gm-cm
Range:	0 - 90 mph	Starting Threshold:	0.6	m/s
Logger:	CSI CR1000			
Logger s/n:	1920		Cal. Factors	
Prop s/n:	62277		DAS	
		Slope:	1.000	
Last calibration date:	Unknown	Int.:	0.000	

WS Audit Point	MPH Input		MPH DAS	Diff. DAS	MPH % Diff. DAS
1	0.0		0.0	0.0	#N/A
2	5.7		5.7	0.0	0.0
3	17.2		17.2	0.0	0.0
4	28.6		28.6	0.0	0.0
5	40.1		40.1	0.0	0.0
6	51.5		51.5	0.0	0.0

Pass/Fail Criteria: ±.56 + 5% MPH
Starting Threshold: 0.5 m/s

Comments: No problems noted. Replacement sesor at time of audit

T&B SYSTEMS AUDIT RECORD
HORIZONTAL WIND DIRECTION

Date: May 13, 2008
Start: 12:00 PST
Finish: 14:15 PST
Audited by: Bob Baxter

Site name: LAX PAMS
Project: Audit
Operator: SCAQMD
Site Operator: Kevin Smith

Sensor Mfg: RM Young
Serial No.: 80572
K Factor: 37
Range: 0 - 355°
Logger: CSI CR1000
Logger s/n: 1920

Model: 05305-AQ
Sensor Ht.: 6m
Starting torque: 10.0 gm-cm
Starting threshold: 0.5 m/s

Last calibration date: Unknown

Crossarm: 179 deg true

Cal. Factors
DAS
Slope: 1.000
Int.: 0.000

WD Audit Point	Degrees Reference	Corrected Degrees Reference			Degrees DAS	Linearity	Total Diff DAS Deg.
Orientation	179.0				178.0		-1.0
1	0	-1.0			0.1	0.9	1.1
2	45	44.0			44.1	-0.1	0.1
3	90	89.0			89.1	-0.1	0.1
4	135	134.0			134.6	0.4	0.6
5	180	179.0			178.1	-1.1	-0.9
6	225	224.0			224.1	-0.1	0.1
7	270	269.0			268.6	-0.6	-0.4
8	315	314.0			314.9	0.7	0.9

Avg difference:		0.2
Maximum difference:	-1.1	1.1

Criteria: Orientation: ± 2 degrees
Linearity: ± 3 degrees
Maximum Difference: ± 5 degrees
Starting Threshold: 0.5 m/s

Comments: No problems noted, though WD bearings close to not meeting criteria. Sensor was replaced at time of audit.

T&B SYSTEMS AUDIT RECORD
HORIZONTAL WIND DIRECTION

Date: May 13, 2008
Start: 12:00 PST
Finish: 14:15 PST
Audited by: Bob Baxter

Site name: LAX PAMS
Project: Audit
Operator: SCAQMD
Site Operator: Kevin Smith

Sensor Mfg: RM Young
Serial No.: 80573
K Factor: 37
Range: 0 - 355°
Logger: CSI CR1000
Logger s/n: 1920

Model: 05305-AQ
Sensor Ht.: 6m
Starting torque: 5.0 gm-cm
Starting threshold: 0.4 m/s

Last calibration date: Unknown

Crossarm: 179 deg true

Cal. Factors
DAS
Slope: 1.000
Int.: 0.000

WD Audit Point	Degrees Reference	Corrected Degrees Reference			Degrees DAS	Linearity	Total Diff DAS Deg.
Orientation	179.0				178.0		-1.0
1	0	-1.0			0.6	1.7	1.6
2	45	44.0			44.2	0.3	0.2
3	90	89.0			89.1	0.2	0.1
4	135	134.0			133.3	-0.6	-0.7
5	180	179.0			177.8	-1.1	-1.2
6	225	224.0			221.9	-2.0	-2.1
7	270	269.0			269.7	0.8	0.7
8	315	314.0			314.6	0.7	0.6

Avg difference:		-0.1
Maximum difference:	-2.0	-2.1

Criteria: Orientation: ± 2 degrees
Linearity: ± 3 degrees
Maximum Difference: ± 5 degrees
Starting Threshold: 0.5 m/s

Comments: No problems noted. Replacement sesor at time of audit

T&B SYSTEMS AUDIT RECORD
AMBIENT TEMPERATURE

Date:	May 13, 2008	Site name:	LAX PAMS
Start:	12:00 PST	Project:	Audit
Finish:	14:15 PST	Operator:	SCAQMD
Auditor:	Bob Baxter	Site Operator:	Kevin Smith
Sensor Mfg:	Vaisala HMP 45AC	Model:	083D-1-3
Serial No.:	C1430013	Sensor Ht.:	2.5m
Range:	-30 - 50 Deg C		

Logger: CSI CR1000
Logger s/n: 1920

Last calibration date: NA

	Cal. Factors DAS
Slope:	1.000
Int.:	0.000

Temperature Audit Point	Deg C Input		Deg C DAS	Deg C Diff. DAS
1	2.2		2.5	0.3
2	19.0		19.2	0.2
3	41.4		41.4	0.0

Criteria: ±0.5°C

Comments: Temperature Audit time was 1220 PST with all points in the 1200 hour.

T&B SYSTEMS AUDIT RECORD
RELATIVE HUMIDITY

Date:	May 13, 2008	Site name:	LAX PAMS
Start:	09:00 PST	Project:	Audit
Finish:	12:00 PST	Operator:	SCAQMD
Auditor:	Bob Baxter	Site Operator:	Kevin Smith
Sensor Mfg:	Vaisala HMP 45AC	Model:	083D-1-3
Serial No.:	C1430013	Sensor Ht.:	2.5 m
Range:	0-100%		
Logger:	CSI CR1000		Cal. Factors
Logger s/n:	1920		DAS
		Slope:	1.000
Last calibration date:	NA	Int.:	0.000

RH/DP Audit Point (end time)	%RH Input	T_d Deg C Input		%RH DAS	RH % Diff. DAS
9:36 PST	65.0	26.7		64.0	-1.0
9:46 PST	71.7	24.9		63.0	-8.7
10:03 PST	69.7	24.3		61.4	-8.3
10:11 PST	70.2	23.0		63.0	-7.2
10:52 PST	69.7	23.0		61.4	-8.3

Criteria: ± 7% RH

Ave Diff	-6.7
Max Diff	-8.7

Comments: Realtive humidity using Onset s/n 295872 in a naturally aspirated shield.
Comparison when site RH was improperly mounted.

T&B SYSTEMS AUDIT RECORD
RELATIVE HUMIDITY

Date: May 13, 2008
Start: 09:00 PST
Finish: 12:00 PST
Auditor: Bob Baxter

Site name: LAX PAMS
Project: Audit
Operator: SCAQMD
Site Operator: Kevin Smith

Sensor Mfg: Vaisala HMP 45AC
Serial No.: C1430013
Range: 0-100%

Model: 083D-1-3
Sensor Ht.: 2.5 m

Logger: CSI CR1000
Logger s/n: 1920

Last calibration date: NA

	Cal. Factors DAS
Slope:	1.000
Int.:	0.000

RH/DP Audit Point (end time)	%RH Input	T_d Deg C Input		%RH DAS	RH % Diff. DAS
11:31 PST	67.7	26.7		69.7	2.0
11:43 PST	69.2	24.9		70.3	1.1
11:48 PST	67.2	24.3		67.4	0.2
11:52 PST	68.2	23.0		68.8	0.6

Criteria: ± 7% RH

Ave Diff	1.0
Max Diff	0.6

Comments: Comparison when the site RH was remounted in the proper configuration

T&B SYSTEMS AUDIT RECORD
SOLAR RADIATION

Date: May 13, 2008
Start: 09:00 PST
Finish: 14:00 PST
Auditor: Bob Baxter

Site name: LAX PAMS
Project: Audit
Operator: SCAQMD
Site Operator: Kevin Smith

Sensor Mfg: Kipp&Zonen
Serial No.: 973031
Range: 0-1200 Wm2

Model: CM6B
Sensor Ht.: 3 m

Logger: CSI CR1000
Logger s/n: 1920

Last calibration date: 10/3/2007

Cal. Factors
DAS
Slope: 1.000
Int.: 0.000

Solar Rad Audit Point (end time)	W/m^2 Input		W/m^2 DAS	W/m^2 Diff. DAS	Criteria (W/m^2)
08:11 PST	658		653	-5	± 56
08:20 PST	687		692	5	± 51
08:45 PST	771		777	6	± 44
13:42 PST	940		964	24	± 34

Criteria: ± 5% of observed

Comments: Level of the sensor was ok.

T&B SYSTEMS AUDIT RECORD
UV RADIATION

Date: May 13, 2008
Start: 09:00 PST
Finish: 14:00 PST
Auditor: Bob Baxter

Site name: LAX PAMS
Project: Audit
Operator: SCAQMD
Site Operator: Kevin Smith

Sensor Mfg: Eppley
Serial No.: 31719
Range: 0-70 W/m2

Model: TUVR
Sensor Ht.: 3 m

Logger: CSI CR1000
Logger s/n: 1920

Last calibration date: Unknown

Cal. Factors	DAS
Slope:	1.000
Int.:	0.000

UV Rad Audit Point (end time)	W/m^2 Input		W/m^2 DAS	W/m^2 Diff. DAS	Criteria (W/m^2)
8:11 PST	29.9		22.9	-7.0	±1.5
	31.1		23.5	-7.6	±1.6

Criteria: ± 5% of observed

Comments: Level of sensor was ok. Before UV sensor cleaning.

T&B SYSTEMS AUDIT RECORD
UV RADIATION

Date:	May 13, 2008	Site name:	LAX PAMS
Start:	09:00 PST	Project:	Audit
Finish:	14:00 PST	Operator:	SCAQMD
Auditor:	Bob Baxter	Site Operator:	Kevin Smith
Sensor Mfg:	Eppley	Model:	TUVR
Serial No.:	31719	Sensor Ht.:	3 m
Range:	0-70 W/m2		
Logger:	CSI CR1000		
Logger s/n:	1920		

Cal. Factors

	DAS
Slope:	1.000
Int.:	0.000

Last calibration date: Unknown

UV Rad Audit Point (end time)	W/m^2 Input		W/m^2 DAS	W/m^2 Diff. DAS	Criteria (W/m^2)
8:20 PST	31.7		30.4	-1.3	±1.6
8:45 PST	36.5		35.1	-1.4	±1.8
13:42 PST	47.3		47.2	-0.1	±2.4

Criteria: ± 5% of observed

Comments: The site UV initially failed the criterea. The sensor did not have visible dirt of salt, but was cleaned and reaudited. Following the cleaning the sensor passed. Recommend routine cleaning of both the solar and UV sensors.

TECHNICAL AND BUSINESS SYSTEMS AUDIT RECORD
AMBIENT PRESSURE

Date: May 13, 2008
Start: 08:00 PST
Finish: 08:30 PST
Auditor: Bob Baxter

Site name: LAX PAMS
Project: Audit
Operator: SCAQMD
Site Operator: Kevin Smith

Sensor Mfg: Met One
Serial No.: G5359
Range: 600 - 1060 hPa (mb)

Model: 91
Sensor Ht.: 1 m

Logger: CSI CR1000
Logger s/n: 1920

Last calibration date: Factory

	Cal. Factors DAS
Slope:	1.000
Int.:	0.000

Pressure Audit Point (end time)	Input (mb)		DAS (mb)	DAS Diff. (mb)
8:26 PST	1009.0		1009	0.0

Criteria: ±3 mb

Comments:

Module I

Analysis of Air Quality Emissions Data

(Task 8)

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INTRODUCTION

This report summarizes Jacobs Consultancy's preliminary analysis of air quality emissions data collected within the property boundary of Los Angeles International Airport (the Airport or LAX) as part of the Air Quality and Source Apportionment Study (AQSAS) Technology and Methodology Feasibility Demonstration Project ("Demonstration Project").

The purpose of this preliminary data analysis was to provide an initial qualitative assessment of the monitoring results by:

- Examining the monitoring data for indications that it tracked with or "signaled" aviation activity that occurred over the same period.
- Identifying which monitored pollutants clearly tracked with aviation activity and which did not.
- Identifying data gaps or other data issues that could affect signal-tracking fidelity or quality.
- Identifying preliminary observations relevant to the future Phase 3 of the AQSAS.

The preliminary analysis focused on emissions monitoring results for ultra-fine particulate matter and key gas compounds at four of the five monitoring locations included in the Demonstration Project. The pollutants and associated monitoring sites covered in this analysis are presented in Table 1 and Figure 1 illustrates the location of the monitoring stations.

ANALYSIS APPROACH

The approach used in this analysis was to examine the emissions monitoring data for visual evidence of signal tracking using time-series charts. Key steps involved in this approach are outlined below:

- Raw monitoring data for each pollutant and monitoring site was processed to obtain a normalized time series of results for each sampling day.
- Similar normalized time series for daily aircraft operations at LAX during the study period were developed from data recorded in the Airport's radar-based Noise Monitoring System (NMS).
- An Excel-based tool was developed to generate charts from the time series to compare each day's emissions monitoring results with aviation activity for that day.
- The data was examined with the charting tool for evidence of signal tracking by observing whether pairs of curves comparing monitoring data

and aviation activity data closely matched in overall shape and peaking patterns.

- To capture wind effects that could influence a tracking signal's quality or strength, information on wind direction was incorporated into the charting analysis.

Table 1

MONITORING DATA ANALYZED

Monitored Emission			Monitoring Site			
Category	Symbol/Tag	Description	SR	PS5	PS2	PS3
UFPs	Condensable Particulate Matter	Particulate size less than 29.4 nm	✓	✓	✓	✓
	Carbonaceous Aircraft Particulate Matter	Particulate size greater than 45.3 and less than 107.5 nm	✓	✓	✓	✓
	Non-aircraft Particulate Matter	Particulate size greater than 191.1 and less than 523.3.0 nm	✓	✓	✓	✓
Gas compounds	NOx	Oxides of nitrogen	✓	n/a	n/a	n/a
	NO2	Nitrogen dioxide	✓	n/a	n/a	n/a
	NO	Nitrogen oxide	✓	n/a	n/a	n/a
	NO/NO2	Ratio of nitrogen oxide to nitrogen dioxide	✓	n/a	n/a	n/a
	Co	Carbon monoxide	✓	n/a	n/a	n/a
	O3	Ozone	✓	n/a	n/a	n/a
	CO2	Carbon dioxide	✓	✓	✓	✓
	CO2 adj	Carbon dioxide concentration minus global constant of 360 ppm	✓	✓	✓	✓
	CH4	Methane	✓	n/a	n/a	n/a
	NMHC	Non-methane hydrocarbons	✓	n/a	n/a	n/a
	SO2	Sulfur dioxide	✓	✓	✓	✓
	PAH	Polynuclear aromatic hydrocarbons	✓	✓	✓	✓

Figure 1

DEMONSTRATION PROJECT MONITORING SITES

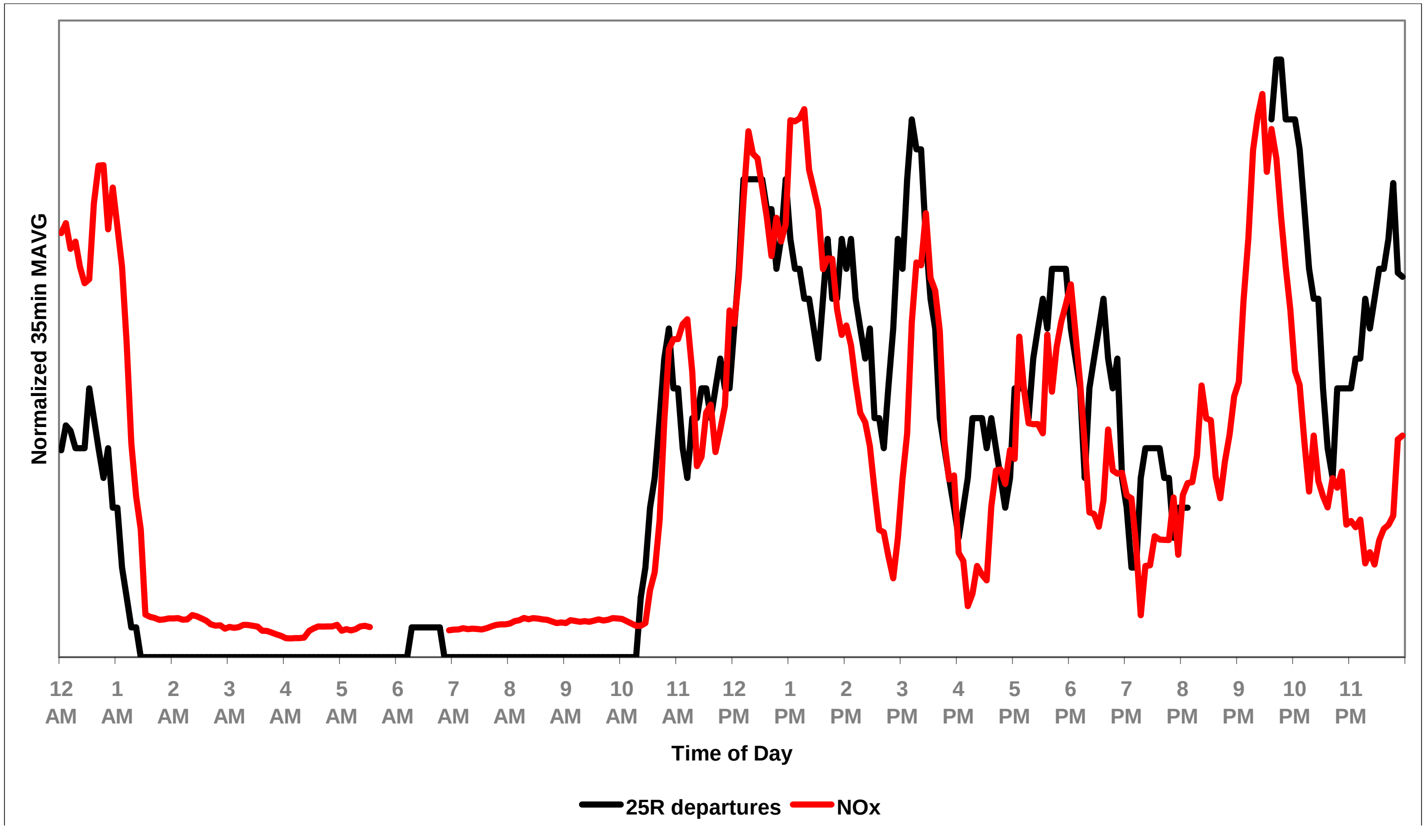
Los Angeles International Airport

Figure 2 is a chart developed with the above-described charting tool using data for Saturday July 19, 2008. The red line plots the detected NOx concentration from monitoring samples taken at 5-minute intervals at the SR site. The black line plots departures from Runway 25R on the same timeline. The raw data for each of these curves was normalized to enable charting on the same y-axis and facilitate visual comparison. To reduce noise in the data and make signal-tracking more apparent, a 35-minute moving average was applied.

As shown on Figure 2, the NOx curve closely tracks the curve for Runway 25R departures. In this example it can be concluded that the monitoring data for NOx exhibited a strong tracking signal with respect to aircraft departures from Runway 25R. In developing this methodology, wind effects and data gaps were identified as two factors that could generate misleading or erroneous charting results. Measures described in following paragraphs were implemented to eliminate or mitigate these effects.

FIGURE 2
Example Time Series Chart

Site	**SR**	
Sample date	**Saturday July 19, 2008**	
Aviation activity	**25R departures**	
Observable		
Description	**NOx**	
Daily peak value	**0.598**	**ppm**



WIND EFFECTS

Wind could significantly affect how well a detection signal tracks with aviation activity. When the monitor is located down-wind from the source a stronger tracking signal should be evident. Conversely, when the monitor is up-wind the tracking signal should be weaker if not entirely absent.

Wind data for the study period was analyzed and incorporated into the charting analysis by plotting wind direction for each 5-minute averaging interval as a colored background on the chart. This information was developed from 1-minute data recorded at the Automated Surface Observing Systems (ASOS) weather station located on the Airport's south airfield. The ASOS data was processed to obtain the vector-averaged wind speed and direction at 5-minute intervals for each day in July and August 2008. In this analysis, a regular daily pattern was observed with westerly, on-shore winds in the range of 8 to 12 knots prevailing during the day. Off-shore flows occurred only at night with wind speed typically in the rage of 3 to 4 knots.

For purposes of this analysis, three wind direction categories were defined which were generally characterized as on-shore, off-shore, and neutral. Figure 3 is a diagram illustrating the compass sectors used to define these wind direction categories. During periods of on-shore wind flow, the SR and P5 monitoring sites would be down-wind of aircraft sources using Runway 25R, and any detection results that track with aviation activity should be reinforced. During periods of off-shore wind flow tracking signals from aviation activity at these sites should be weaker or may not appear at all.

Figure 4 is an example chart illustrating wind effects on detection monitoring for condensable particulate matter at the SR site on Thursday July 10, 2008. The red line, which represents detection results, has peaks that occur virtually simultaneously with the black line, which represents Runway 25R departures. Wind effects are evident in the way the peaks on the red line are exaggerated during on-shore wind and diminished during off-shore wind.

FIGURE 3
Compass Diagram for Wind Direction Categories

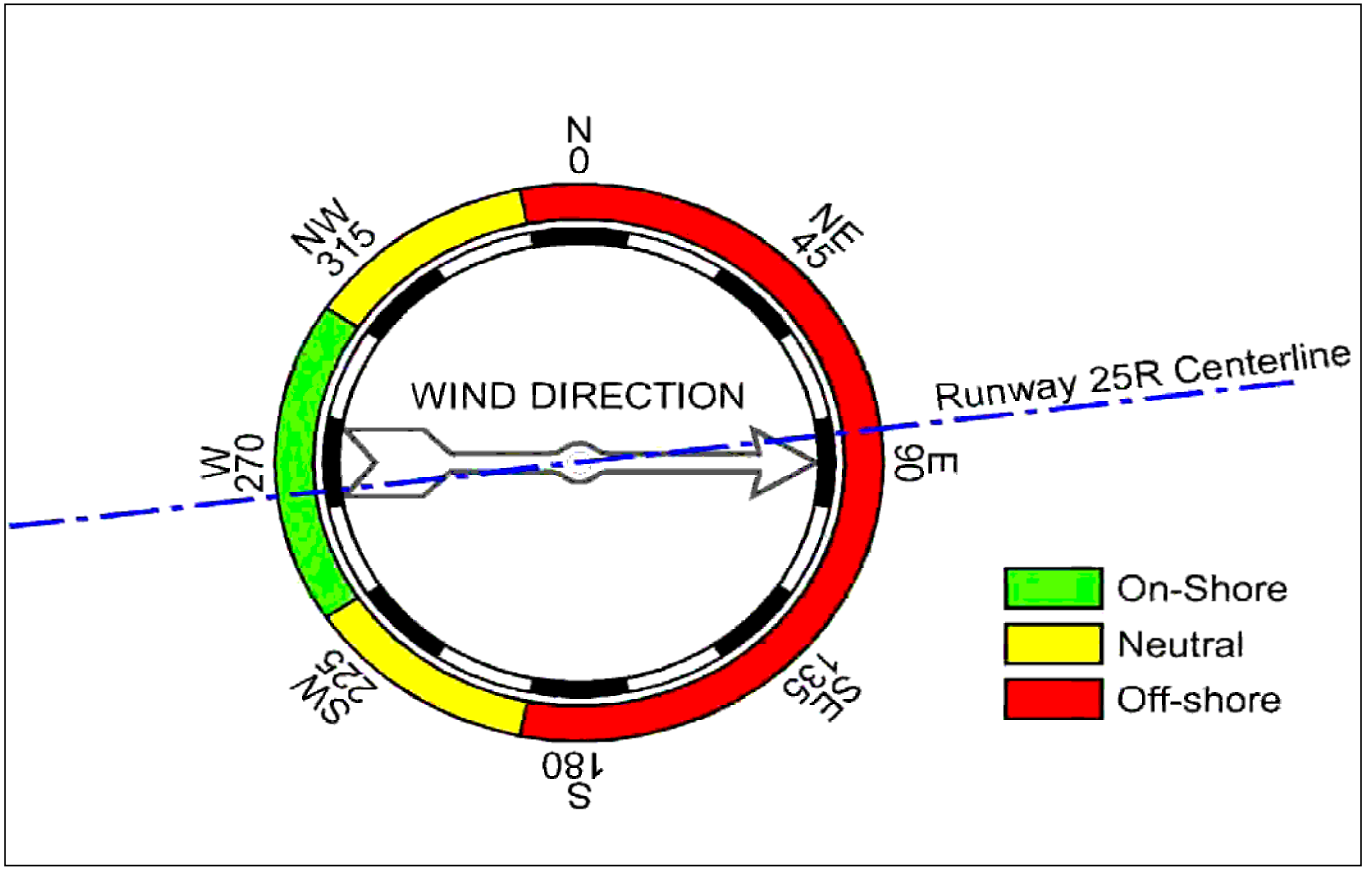
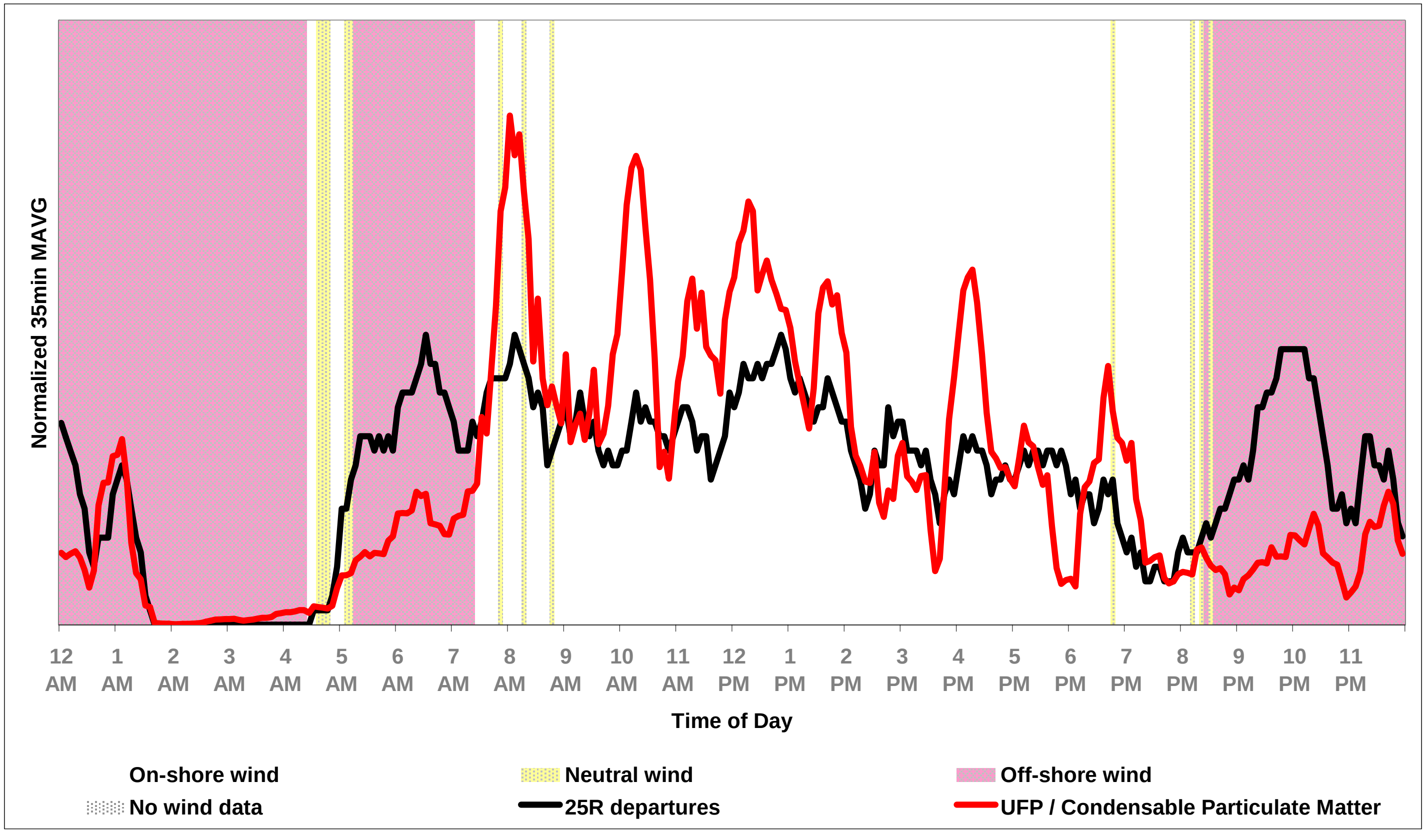


FIGURE 4

Example Time Series Chart with Wind Direction Indicated

Site	**SR**	
Sample date	**Thursday July 10, 2008**	
Aviation activity	**25R departures**	
Observable		
Description	**UFP / Condensable Particulate Matter**	
Daily peak value	**24,614,377.000**	**#/cm3**



DATA GAPS

There were occasional gaps in the raw data used to generate the time series charts. Data gaps inevitably result when monitoring equipment goes offline to allow necessary maintenance to be performed, due to equipment malfunctions, or other reasons. Curve plotting errors would result if these data gaps were handled as zero values, i.e. handled as if the detection monitor or radar system involved was operational but found nothing to report during the averaging interval. This error would be compounded when normalizing and applying moving averages. To eliminate this type of error, the data was processed to ensure that chart lines were discontinuous during gap periods and drop to zero only in periods when monitoring was performed but zero activity was detected. Thus, there may be discontinuities in the chart lines for a given day, as on Figure 1 where the line for Runway 25R departures disappears during the period between 8:00 p.m. and 9:30 p.m.

EXAMPLE RESULTS FOR THE SR SITE

Figures 5 through 19 (provided at the end of this report) comprise a series of charts presenting detection monitoring results for selected days at the SR site. The series includes one chart for each of the 15 monitored emissions covered in this analysis. In each chart monitoring results are compared to Runway 25R departures.

Ultra-fine Particulates

Monitoring results for three size categories of ultra-fine particulate (UFP) matter are shown in Figures 5 through Figure 7. These results are based on data for Sunday July 13, 2008.

Condensable particulate matter. Detection monitoring results for this category of UFP, (which includes particulates less than 29.4 nm in size), are shown on Figure 5. Monitoring results for these particles tracked closely with departures from Runway 25R.

Carbonaceous aircraft particulate matter. Detection monitoring results for this category of UFP, (which includes particles greater than 45.3 nm and less than 107.5 nm in size), are shown on Figure 6. Monitoring results for these particles tracked closely with departures from Runway 25R.

Non-aircraft particulate matter. Results for this category of UFP, which includes particles greater than 191.1 nm and less than 523.3.0 nm in size, are shown on Figure 7. Monitoring results for these particles did not track with departures from runway 25R.

Gas Compounds

Figures 8 through 19 present results for the various gas compounds that were monitored at the SR site. This series is based on data for Friday July 18, 2008.

Observations that apply to each chart in this series are listed in the bullets below. The paragraphs that follow provide observations for each individual chart.

- The black line plotting Runway 25R departures drops to zero from about 1:30 a.m. to about 5:00 a.m. when the runway was closed for maintenance.
- The black line plotting 25R departures discontinues from about 8:00 p.m. to about 9:00 p.m. reflecting a gap that in the NMS data.
- Off-shore winds prevailed from about 2:00 a.m. to about 9:00 a.m. During this period the detection of aircraft emissions evident in many of the charts in the series was noticeably weaker.

Oxides of nitrogen (NOx)—detection monitoring results are shown on Figure 8. These results exhibited relatively strong tracking with respect to aviation activity.

Nitrogen dioxide (NO2)—detection monitoring results are shown on Figure 9. These results exhibited relatively strong tracking with respect to aviation activity.

Nitrogen oxide (NO)—detection monitoring results are shown on Figure 10. These results exhibited relatively strong tracking with respect to aviation activity.

Ratio of nitrogen oxide to nitrogen dioxide (NO/NO2)—detection monitoring results are shown on Figure 11. These results exhibited relatively strong tracking with respect to aviation activity.

Carbon monoxide (CO)—detection monitoring results are shown on Figure 12. These results exhibited relatively strong tracking with respect to aviation activity.

Ozone (O3)—detection monitoring results are shown on Figure 13. These results did not track with aviation activity.

Carbon dioxide (CO2)—detection monitoring results are shown on Figure 14. These results did not appear to track with aviation activity. The results on Figure 14 are based on the detected concentrations as reported in the raw data with no adjustment to deduct a baseline average. (See next item.)

Carbon dioxide - adjusted for global constant (CO2 adj)—detection monitoring results for CO2 after adjusting the data by deducting a baseline representing a global average concentration of 360 ppm are shown on Figure 15. This adjustment allows the incremental amount contributed by aviation activity to be seen more clearly. With this adjustment the data exhibited relatively strong tracking with aviation activity.

Methane (CH4)—detection monitoring results are shown on Figure 16. These results did not track with aviation activity.

Non-methane hydrocarbons (NMHC)—detection monitoring results are shown on Figure 17. The NMHC results exhibited large spikes on several of the days that were monitored and did not track with aviation activity.

Sulfur dioxide (SO2)—detection monitoring results are shown on Figure 18. These results exhibited relatively strong tracking with respect to aviation activity.

Polynuclear aromatic hydrocarbons (PAH)—detection monitoring results are shown on Figure 19. These results exhibited relatively strong tracking with respect to aviation activity.

DATA ISSUES

The following data issues were identified during this analysis. These issues mostly pertain to NMS data used to develop the aircraft activity time series which were key in assessing tracking signal quality and fidelity. Jacobs Consultancy does not believe these issues are serious enough to invalidate the analysis results, however addressing them could improve accuracy may be warranted for the Phase 3 AQSAS. For the long term study, it may be beneficial to augment the NMS data with other data on flight activity such as Performance Data Analysis and Reporting System (PDARS) and Aviation System Performance Metrics (ASPM).

Unidentified gaps in the NMS data. There can be gaps in the NMS data that are not readily apparent in the data itself. The NMS data is event-based, i.e. a record is provided for each aircraft arrival and departure with a time stamp indicating when the flight was first detected by the system. If the radar system temporarily goes offline for any reason the data file provides no indication that this occurred. There are simply no events logged in the data file during this time. A separate analysis of the NMS was required to identify obvious data gaps, however less obvious gaps which could not be not identified may exist.

Time stamps. The precise point on a flight's approach or take-off path that the NMS first detects the flight and records a time stamp can vary.

Intersection departures. Rather than starting their take-off roll at the end of the runway, some aircraft perform intersection departures, i.e, they begin their departure from the next taxiway intersection down from the entrance taxiway. Emissions for these operations likely register a much lower detection value at the SR and P5 sites.

Miscoded NMS data. There appear to be occasional miscoded data items. For example, the NMS data includes a small number of operations on Runway 25R on July 19, 2008 during the period that the runway was reportedly closed for concrete repairs. These could have been miscoded identifiers in the runway data field.

SIGNAL LOSS BETWEEN SR AND P5 MONITORING SITES

The degree to which detected emissions diminish as the distance between source and monitor increases will be an important consideration in (1) setting the detection limits and (2) locating monitoring sites for Phase 3 of the AQSAS. Data for the SR and P5 sites was analyzed to provide a preliminary assessment of the amount of detection signal that was lost as emissions traveled the approximately 1,800 feet of distance separating these locations.

Ideally an assessment of signal loss between two locations would analyze data covering the same time period. However, because each site was monitored in sequence there are no results for SR and P5 that cover the same calendar dates. The following analysis is based on comparing data for two different days that were comparable in terms of aviation activity and wind conditions. For both days the data covers a four-hour period beginning at noon.

The results of the signal loss analysis are presented in Table 2. As shown in Table 2, averages for the detection signal at each site were approximated as the difference between maximum and minimum reported values, i.e., differences between peaks and troughs on a time-series chart covering a comparable 4-hour period. With these signal estimates, an indication of the amount of signal loss between the two sites is given by the ratio of average P5 signal to average SR signal.

Table 2
SR/P5 SIGNAL LOSS ANALYSIS

Detected values between 12:00 PM and 4:00 PM

	Monitored Emission					
	Ultra-fine particulates			Gas compounds		
Description	Condensable Particulate Matter (particles per cm3)	Carbonaceous Aircraft Particulate Matter (particles per cm3)	Non-aircraft Particulate Matter (particles per cm3)	CO2 adjusted (ppm) *(f)*	SO2 (ppm)	PAH (fA PAH PID Current Signal)
SR Site *(a)*						
Peaks (c)						
Maximum	23,906,869	559,044	2,621	279.2	0.090	457.6
Average of 5 highest peaks	19,863,325	466,868	2,118	219.4	0.075	383.2
Average of 10 highest peaks	17,970,725	425,732	1,723	199.4	0.067	323.1
Average of 15 highest peaks	16,854,055	387,696	1,551	189.2	0.063	269.7
Average of 20 highest peaks	15,711,285	362,680	1,438	181.6	0.060	237.3
Troughs (d)						
Minimum	28,754	8,310	246	27.9	-	1.5
Average of 5 lowest troughs	7,136,099	152,993	980	117.6	0.032	87.6
Average of 10 lowest troughs	7,443,867	158,874	989	119.7	0.032	90.9
Average of 15 lowest troughs	7,768,832	165,272	1,001	123.8	0.033	96.6
Average of 20 lowest troughs	8,120,102	176,537	1,013	127.6	0.035	100.6
Signal (e)						
Max - Min	23,878,115	550,734	2,375	251.3	0.090	456.1
5 Highest - 5 Lowest	12,727,226	313,876	1,138	101.8	0.043	295.6
10 Highest - 10 Lowest	10,526,858	266,858	733	79.8	0.035	232.2
15 Highest - 15 Lowest	9,085,222	222,424	550	65.4	0.029	173.1
20 Highest - 20 Lowest	7,591,183	186,142	425	53.9	0.025	136.7
P5 Site *(b)*						
Peaks (c)						
Maximum	1,472,187	56,477	1,805	47.4	0.004	42.9
Average of 5 highest peaks	1,221,043	53,403	1,775	43.5	0.003	34.3
Average of 10 highest peaks	1,112,552	47,410	1,740	41.0	0.003	29.2
Average of 15 highest peaks	1,005,518	44,090	1,650	39.2	0.002	26.4
Average of 20 highest peaks	927,809	41,739	1,589	37.8	0.002	24.7
Troughs (d)						
Minimum	22,460	5,192	506	4.3	--	2.2
Average of 5 lowest troughs	483,797	22,486	1,227	17.9	0.001	11.8
Average of 10 lowest troughs	500,760	22,854	1,234	18.3	0.001	12.5
Average of 15 lowest troughs	515,807	23,533	1,248	18.7	0.001	13.0
Average of 20 lowest troughs	531,916	24,518	1,270	19.3	0.001	13.5
Signal (e)						
Max - Min	1,449,727	51,285	1,299	43.1	0.004	40.7
5 Highest - 5 Lowest	737,246	30,917	548	25.6	0.002	22.5
10 Highest - 10 Lowest	611,792	24,556	506	22.7	0.002	16.7
15 Highest - 15 Lowest	489,712	20,557	402	20.5	0.001	13.4
20 Highest - 20 Lowest	395,892	17,221	319	18.5	0.001	11.2
P5 signal percent of SR signal						
Max - Min	6.1%	9.3%	54.7%	17.2%	4.4%	8.9%
5 Highest - 5 Lowest	5.8%	9.8%	48.2%	25.2%	5.6%	7.6%
10 Highest - 10 Lowest	5.8%	9.2%	69.0%	28.5%	5.2%	7.2%
15 Highest - 15 Lowest	5.4%	9.2%	73.2%	31.3%	5.0%	7.7%
20 Highest - 20 Lowest	5.2%	9.3%	75.1%	34.3%	4.4%	8.2%

(a) Data for SR site sampled on Thursday July 17.
(b) Data for P5 site sampled on Thursday August 28.
(c) Highest values detected in 48 5-minute averaging intervals from 12:00 PM to 4:00 PM.
(d) Lowest values detected in 48 5-minute averaging intervals from 12:00 PM to 4:00 PM.
(e) Average of peaks minus average of troughs.
(f) Detected CO2 concentration minus global average baseline concentration of 360 ppm.

FIGURE 5
Detection Results for Condensable Particulate Matter Compared to Runway 25R Departures

Site	**SR**
Sample date	**Sunday July 13, 2008**
Aviation activity	**25R departures**
Observable	
Description	**UFP / Condensable Particulate Matter**
Daily peak value	**24,475,164.000 #/cm3**

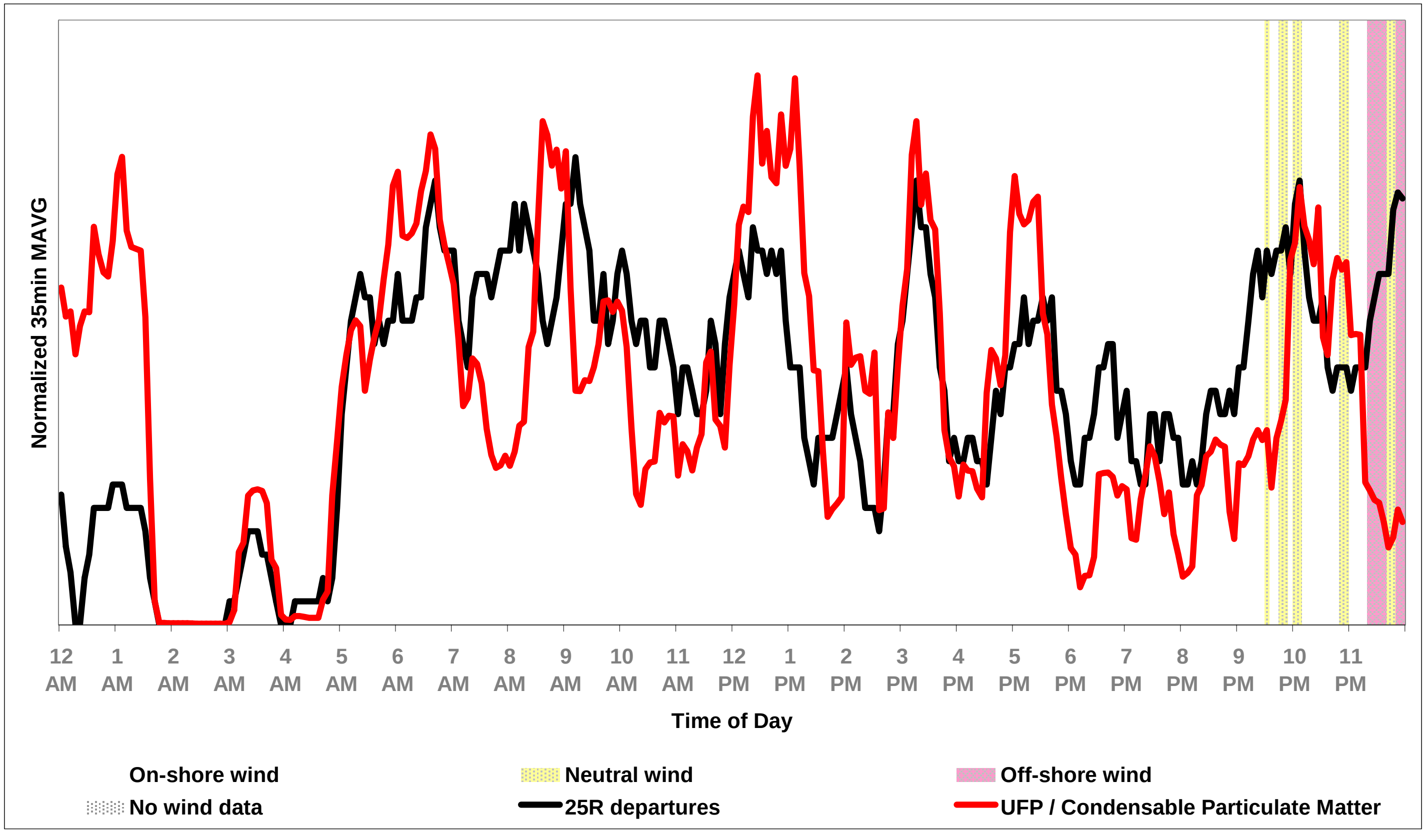


FIGURE 6

Detection Results for Carbonaceous Aircraft Particulate Matter Compared to Runway 25R Departures

Site	**SR**
Sample date	**Sunday July 13, 2008**
Aviation activity	**25R departures**
Observable	
Description	**UFP / Carbonaceous Aircraft Particulate Matter**
Daily peak value	**849,902.000 #/cm3**

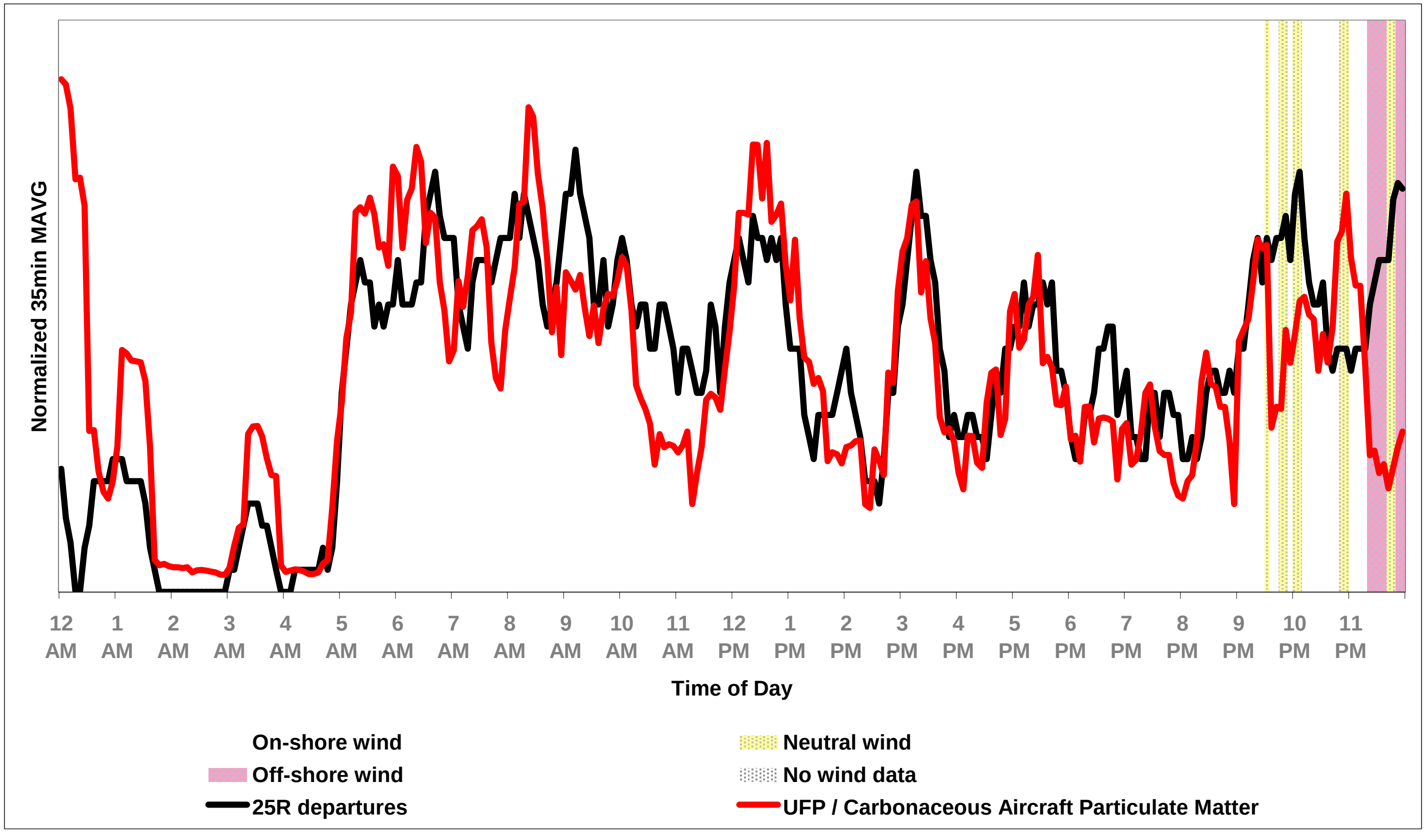


FIGURE 7

Detection Results for Non-aircraft Particulate Matter Compared to Runway 25R Departures

Site	**SR**
Sample date	**Sunday July 13, 2008**
Aviation activity	**25R departures**
Observable	
Description	**UFP / Non-aircraft Particulate Matter**
Daily peak value	**2,087.000 #/cm3**

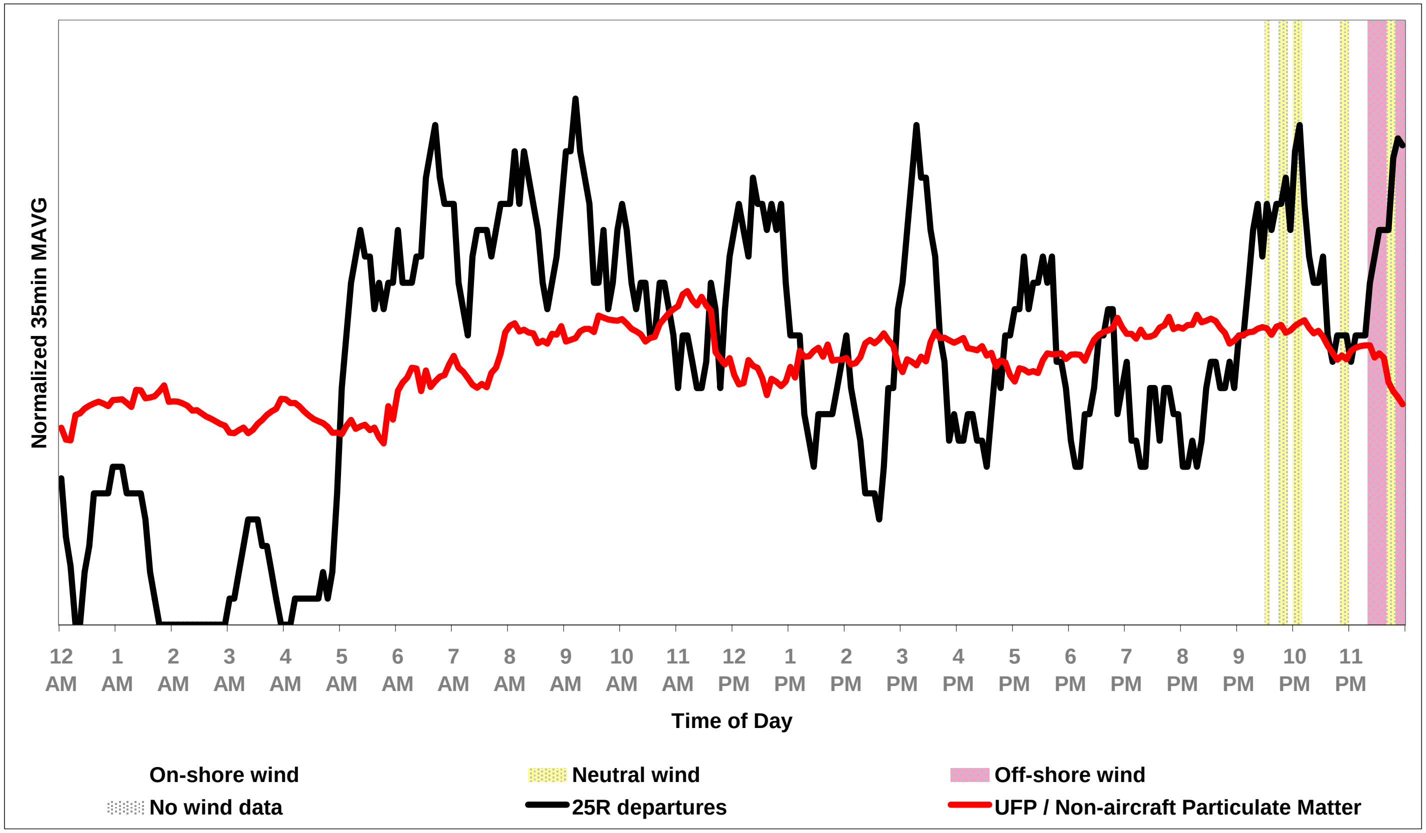


FIGURE 8

Detection Results for Oxides of Nitrogen Compared to Runway 25R Departures

Site	**SR**	
Sample date	**Friday July 18, 2008**	
Aviation activity	**25R departures**	
Observable		
Description	**NOx**	
Daily peak value	**0.692**	**ppm**

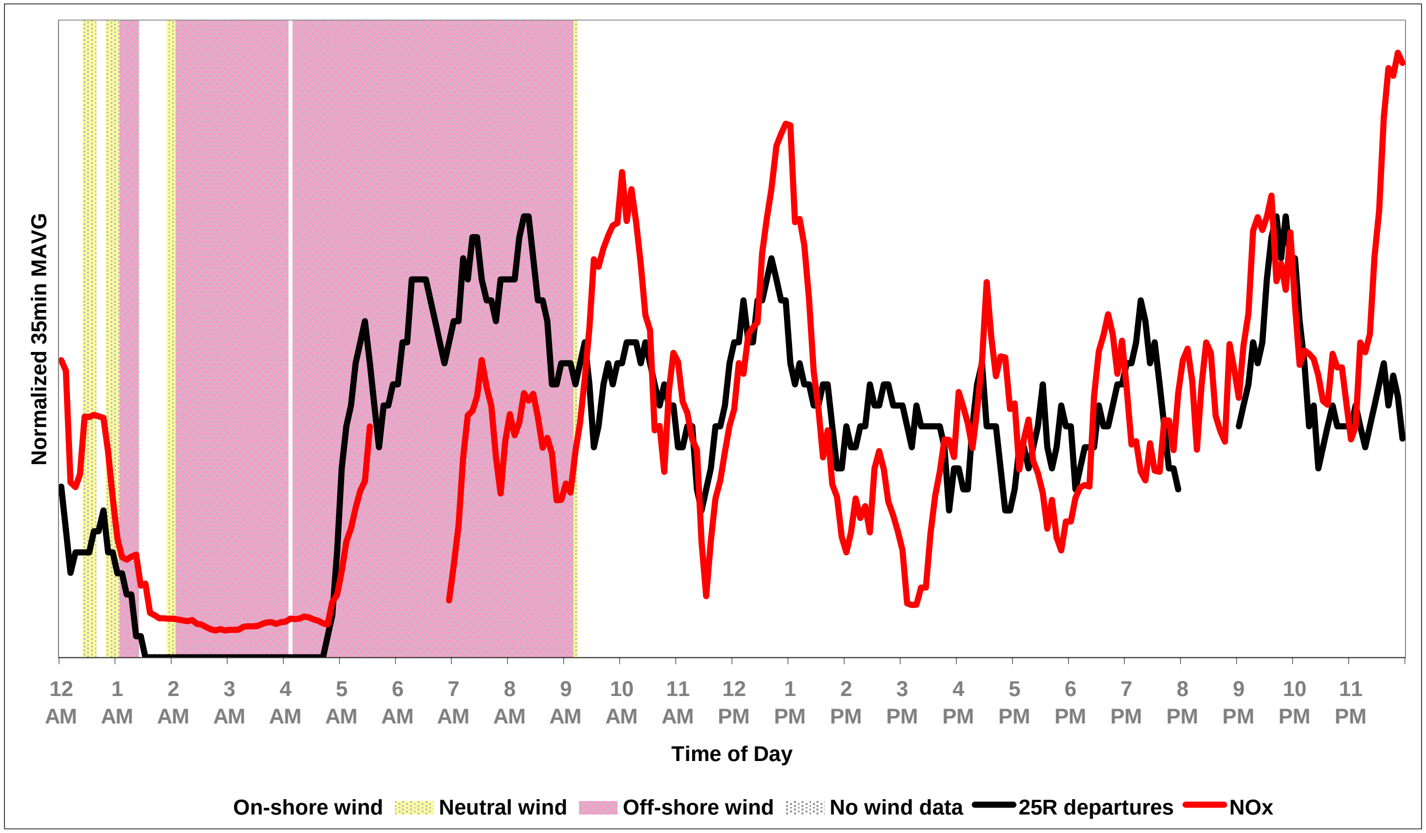


FIGURE 9
Detection Results for Nitrogen Dioxide Compared to Runway 25R Departures

Site SR
Sample date Friday July 18, 2008
Aviation activity 25R departures
Observable
Description NO2
Daily peak value 0.166 ppm

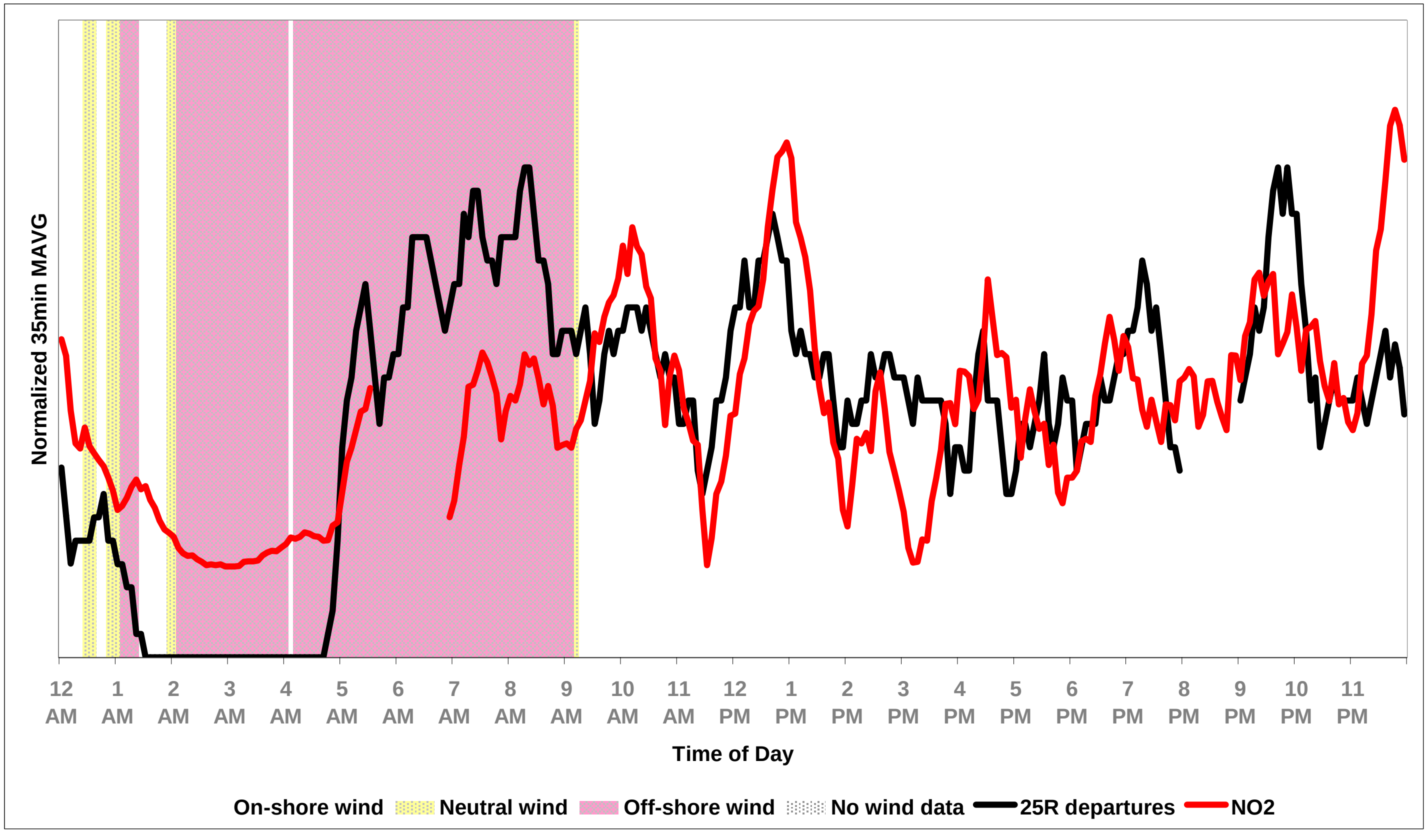


FIGURE 10
Detection Results for Nitrogen Oxide Compared to Runway 25R Departures

Site	**SR**	
Sample date	**Friday July 18, 2008**	
Aviation activity	**25R departures**	
Observable		
Description	**NO**	
Daily peak value	**0.598**	**ppm**

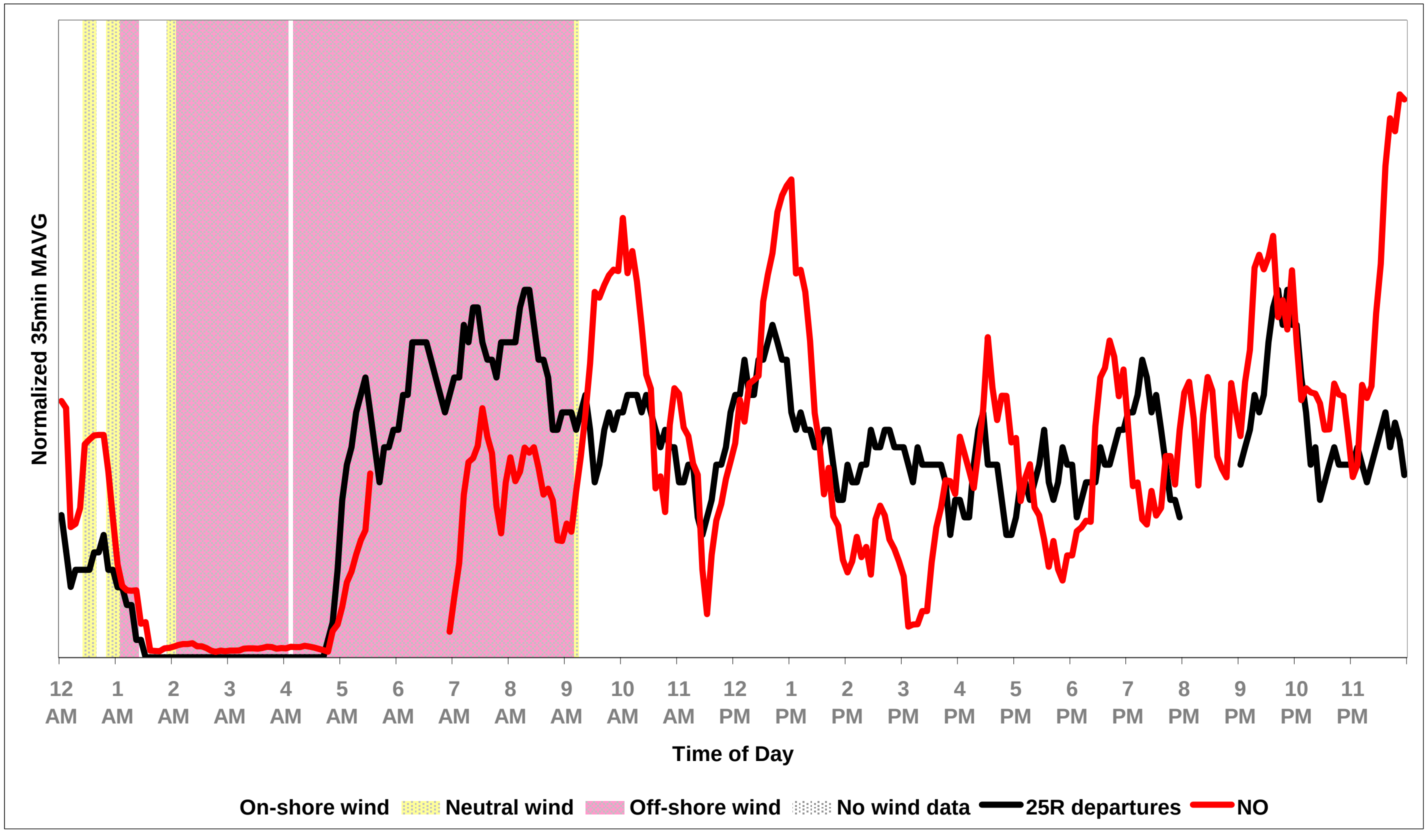


FIGURE 11
Detection Results for Ratio of Nitrogen Oxide to Nitrogen Dioxide Compared to Runway 25R Departures

Site	**SR**	
Sample date	**Friday July 18, 2008**	
Aviation activity	**25R departures**	
Observable		
Description	**NO / NO2**	
Daily peak value	**6.521**	**ppm**

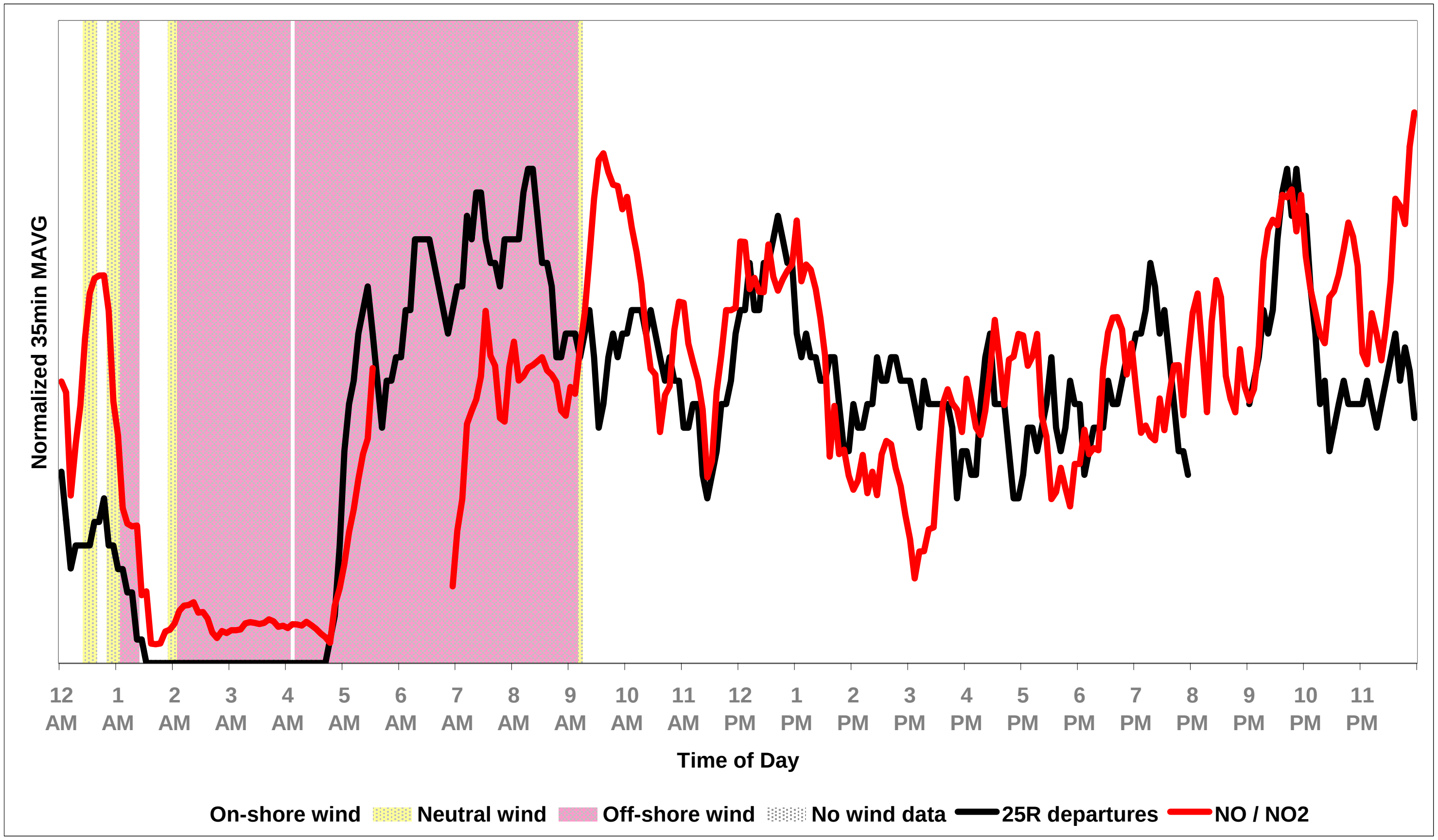


FIGURE 12+E402
Detection Results for Carbon Monoxide Compared to Runway 25R Departures

Site	**SR**	
Sample date	**Friday July 18, 2008**	
Aviation activity	**25R departures**	
Observable		
Description	**Co**	
Daily peak value	**3.318**	**ppm**

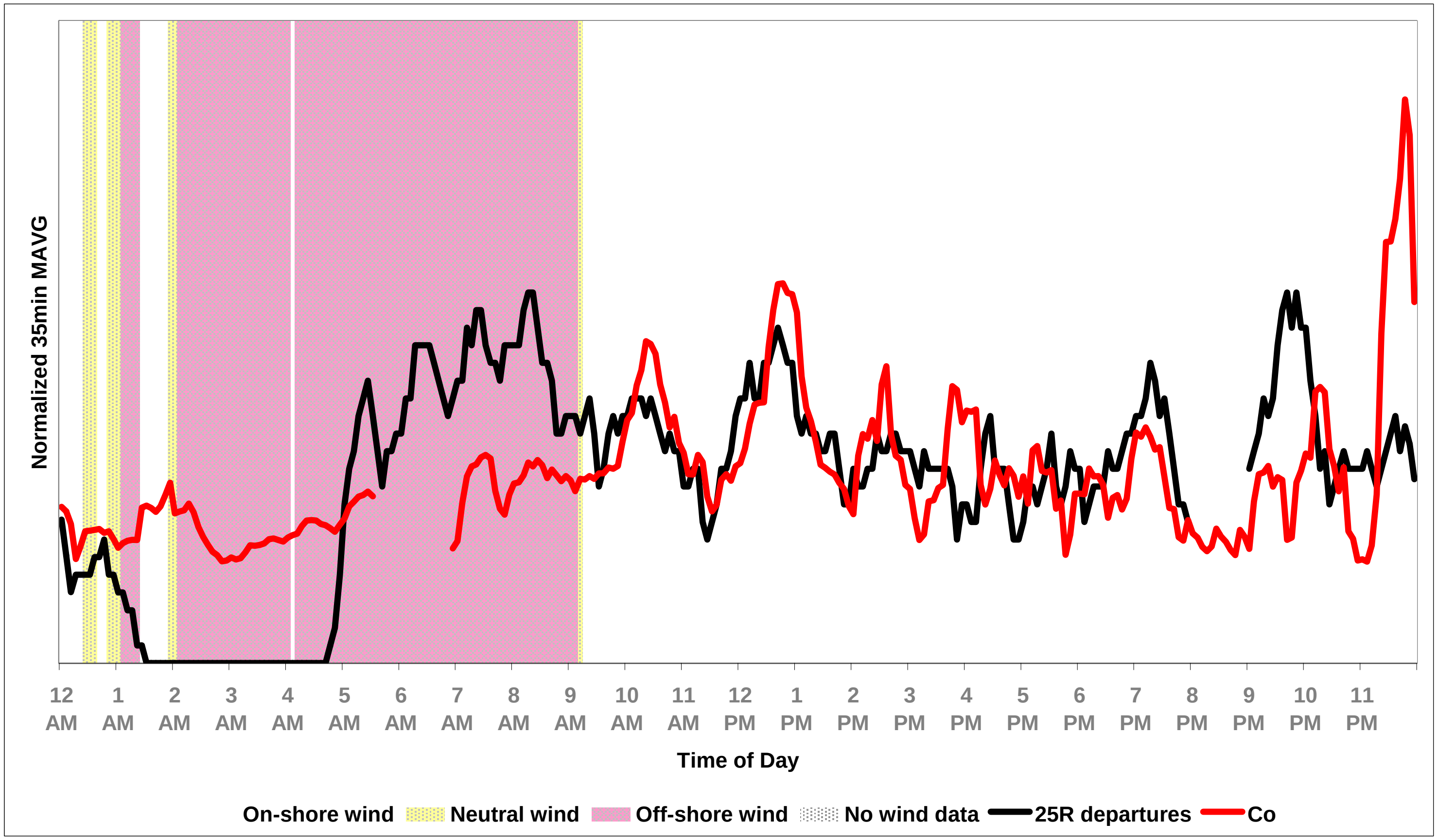


FIGURE 13

Detection Results for Ozone Compared to Runway 25R Departures

Site	**SR**	
Sample date	**Friday July 18, 2008**	
Aviation activity	**25R departures**	
Observable		
Description	**O3**	
Daily peak value	**0.049**	**ppm**

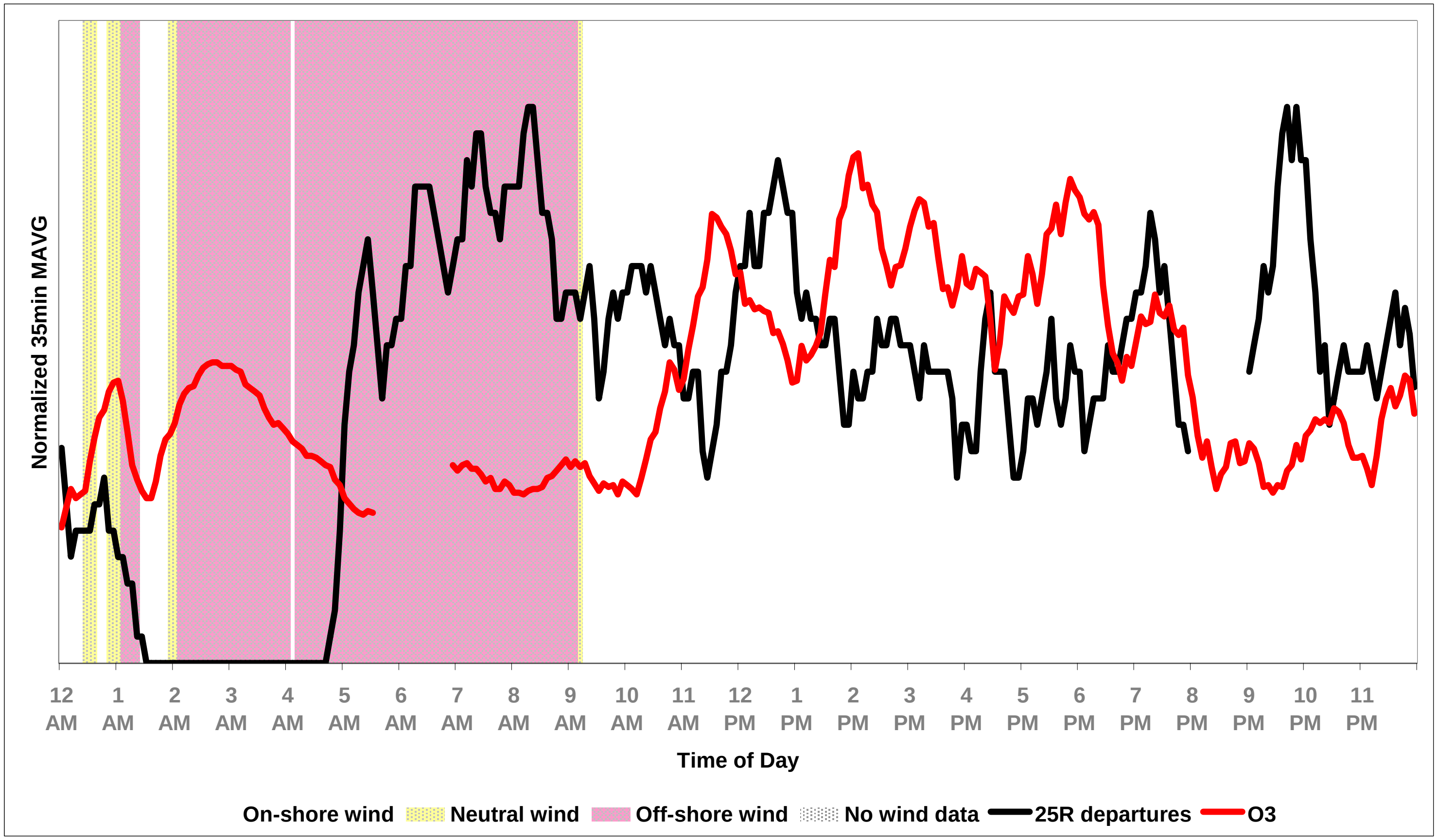
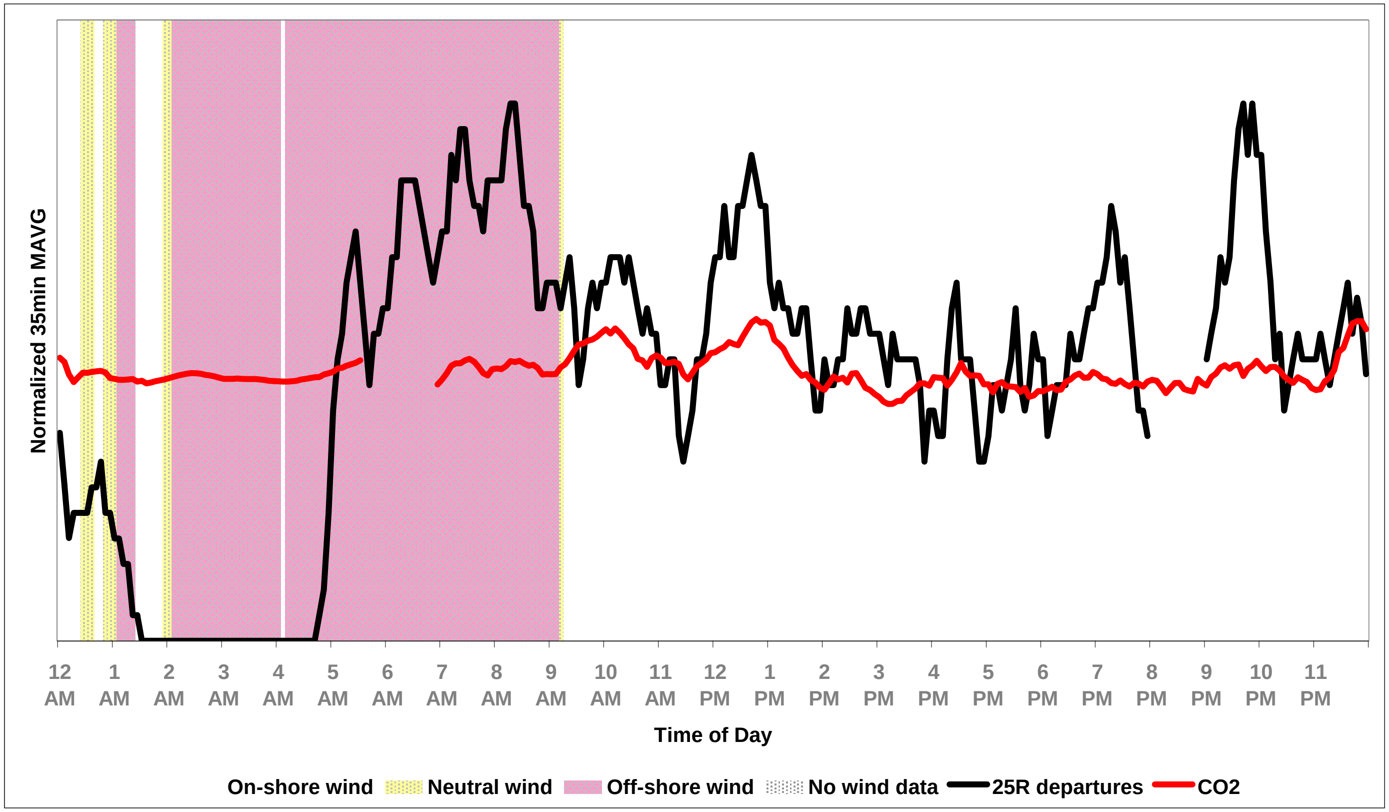


FIGURE 14
Detection Results for Carbon Dioxide (unadjusted)* Compared to Runway 25R Departures

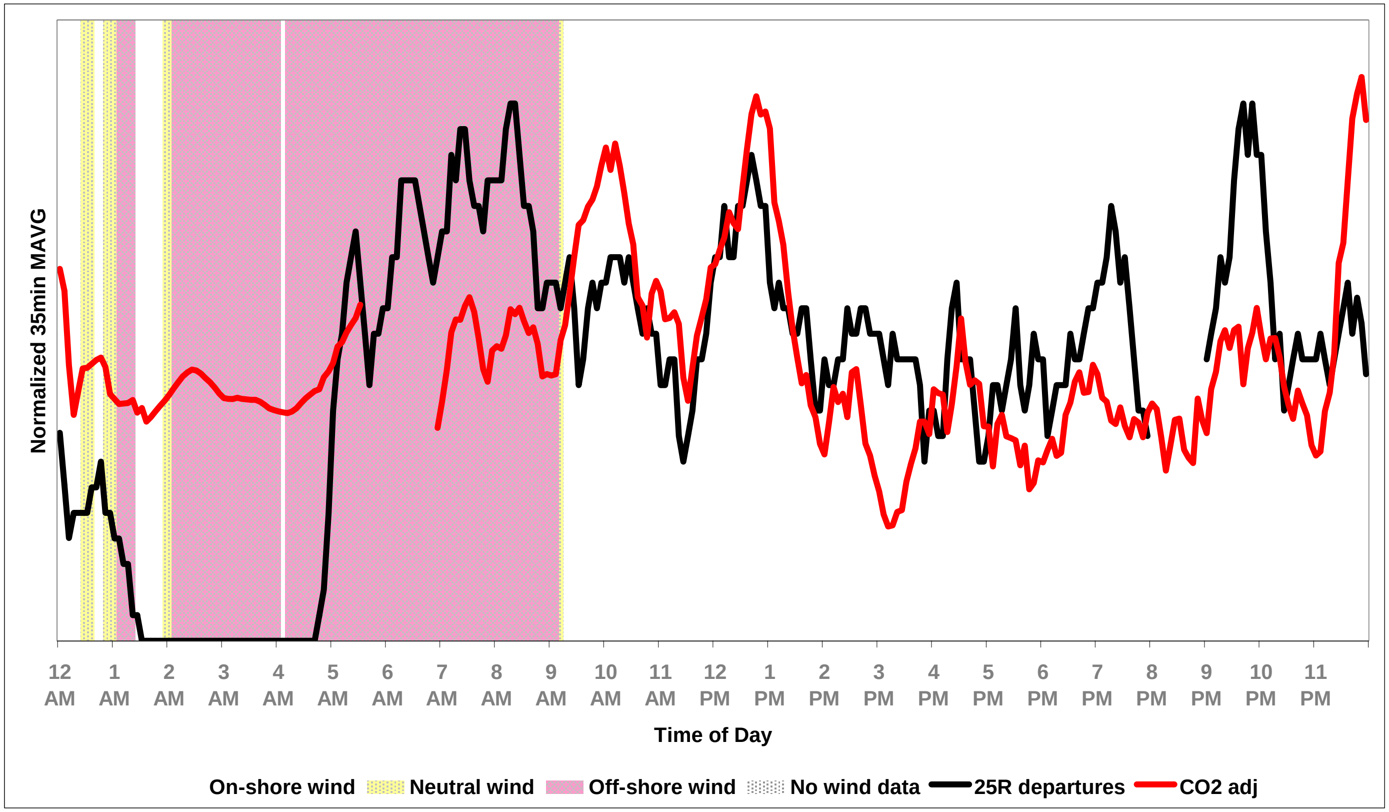
Site	**SR**	
Sample date	**Friday July 18, 2008**	
Aviation activity	**25R departures**	
Observable		
Description	**CO2**	
Daily peak value	**604.200**	**ppm**



*** Detected concentration as reported**

FIGURE 15
Detection Results for Carbon Dioxide (adjusted)* Compared to Runway 25R Departures

Site	**SR**	
Sample date	**Friday July 18, 2008**	
Aviation activity	**25R departures**	
Observable		
Description	**CO2 adj**	
Daily peak value	**244.200**	**ppm**



*** Detected concentration minus global avereage baseline of 360 ppm**

FIGURE 16
Detection Results for Methane Compared to Runway 25R Departures

Site	**SR**	
Sample date	**Friday July 18, 2008**	
Aviation activity	**25R departures**	
Observable		
Description	**CH4**	
Daily peak value	**2.179**	**ppm**

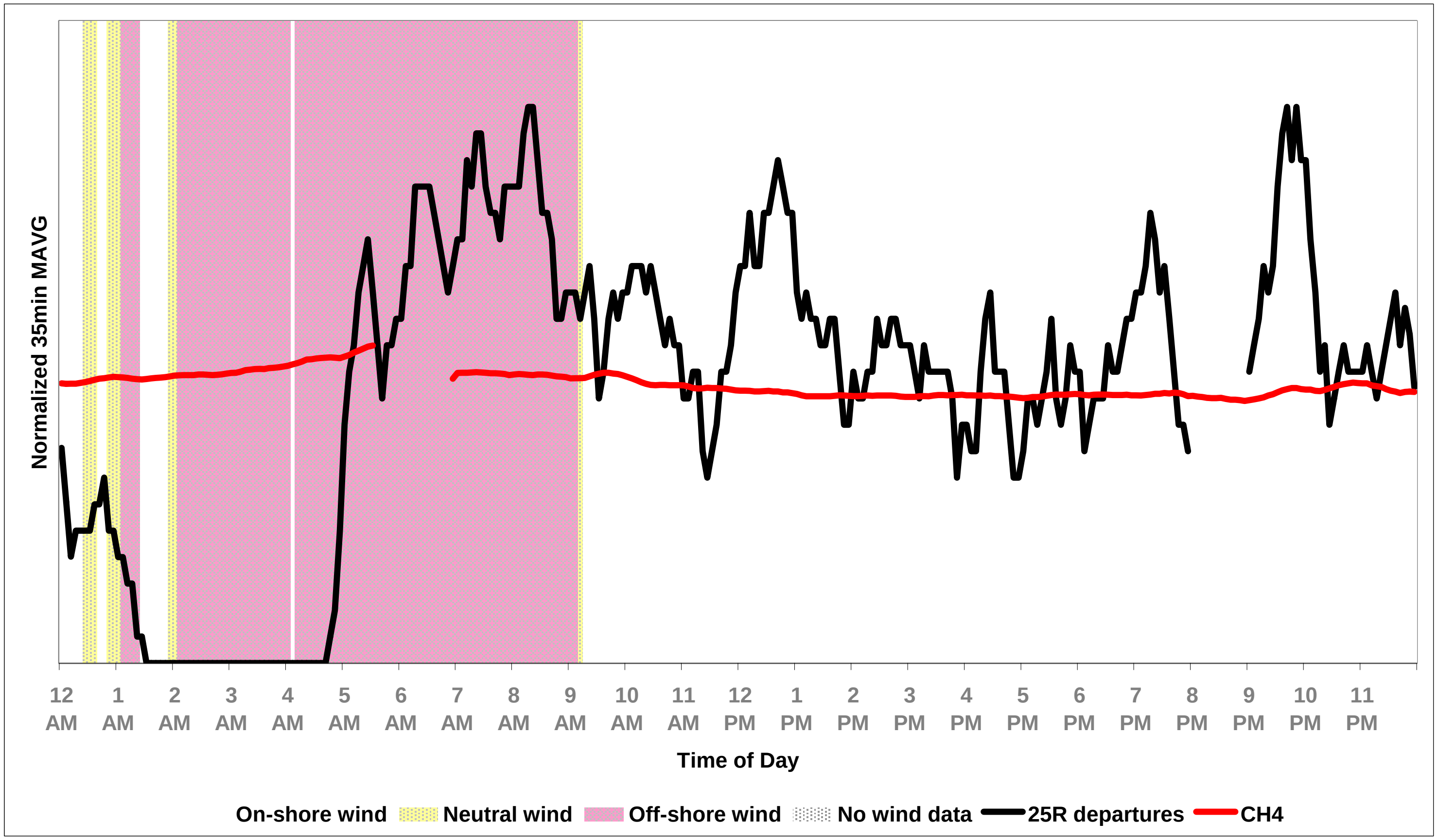


FIGURE 17
Detection Results for Non-methane Hydrocarbons Compared to Runway 25R Departures

Site	**SR**	
Sample date	**Friday July 18, 2008**	
Aviation activity	**25R departures**	
Observable		
Description	**NMHC**	
Daily peak value	**0.885**	**ppm**

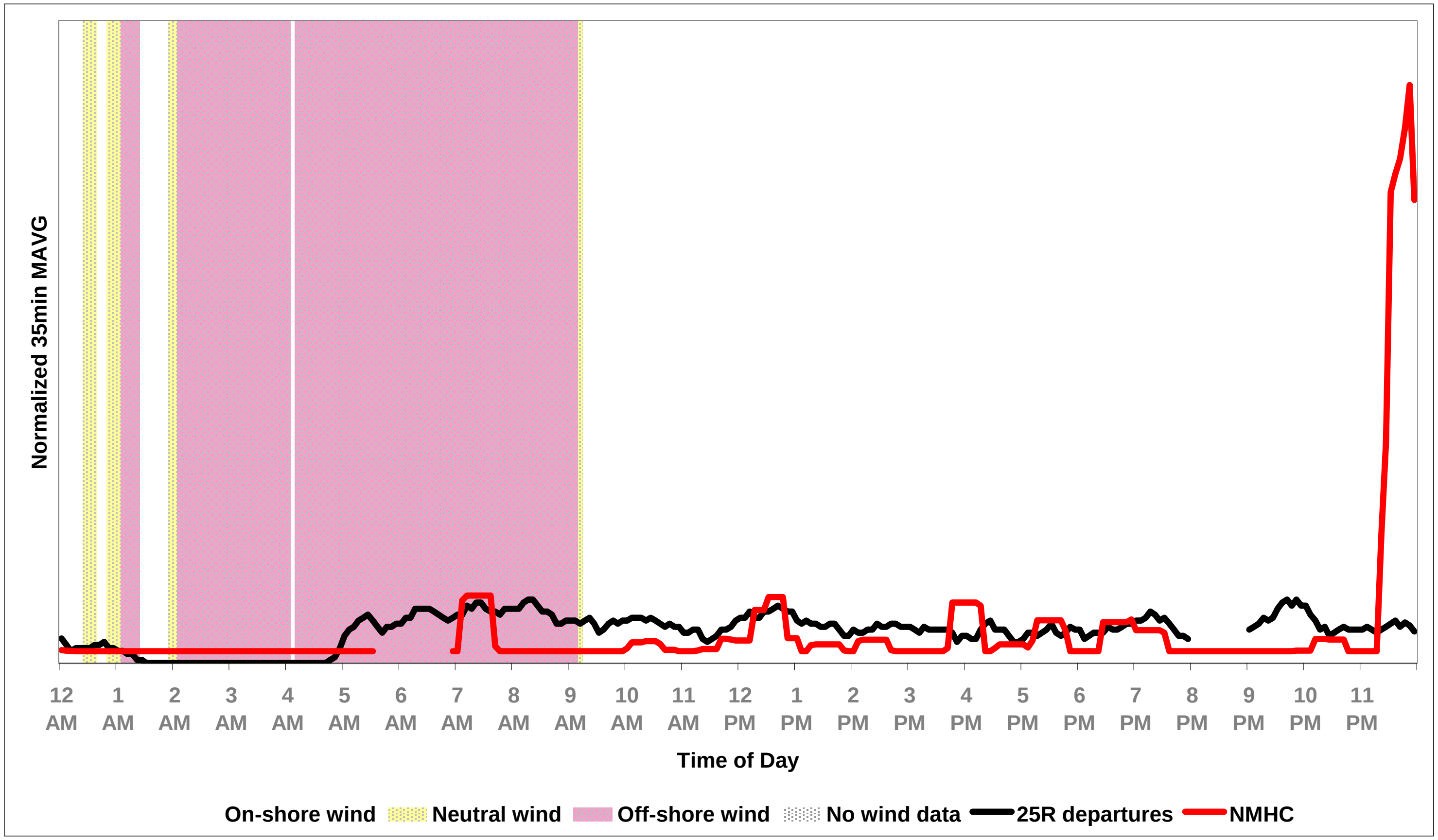


FIGURE 18

Detection Results for Sulfur Dioxide Compared to Runway 25R Departures

Site	**SR**	
Sample date	**Friday July 18, 2008**	
Aviation activity	**25R departures**	
Observable		
Description	**SO2**	
Daily peak value	**0.106**	**ppm**

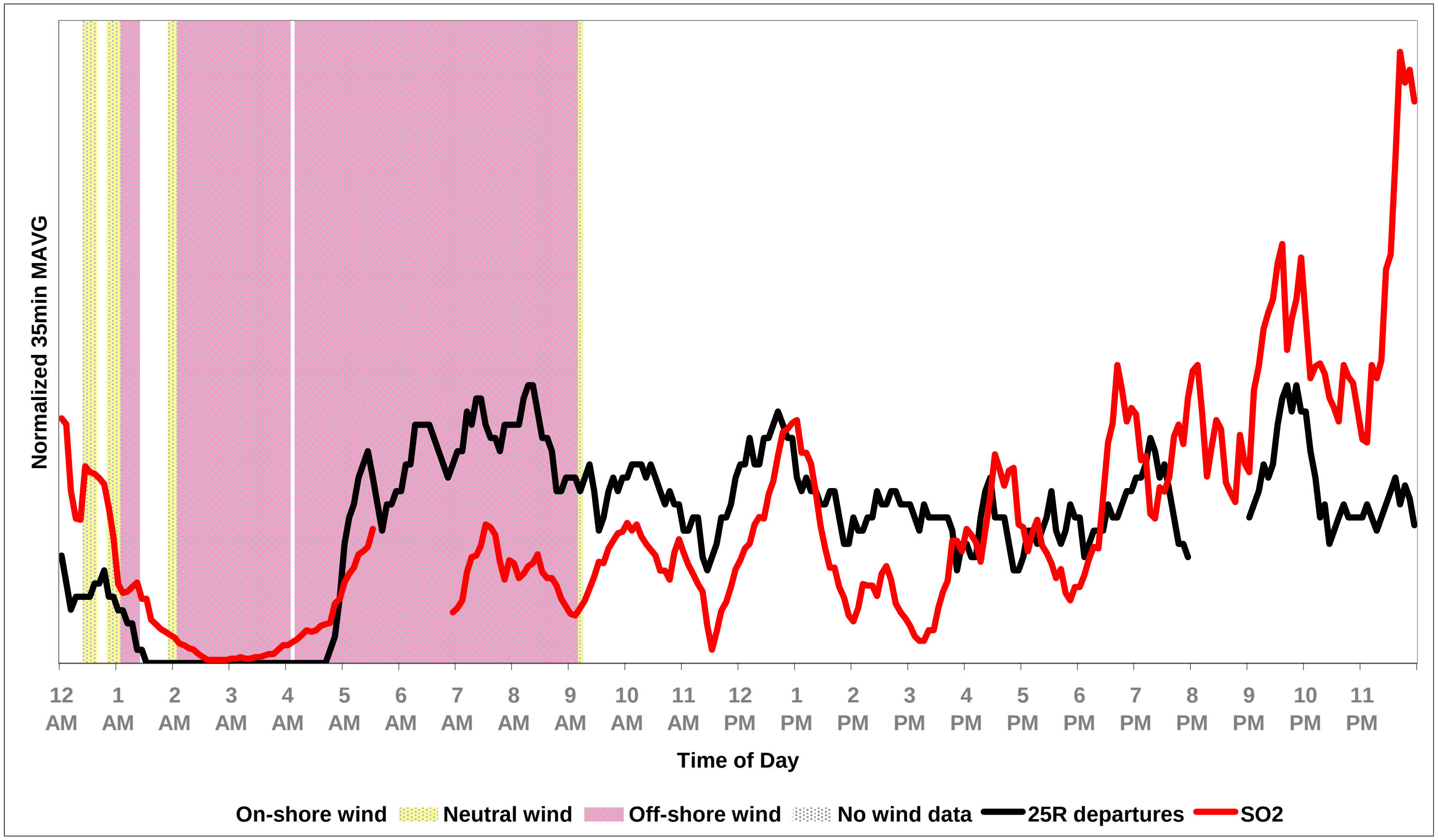
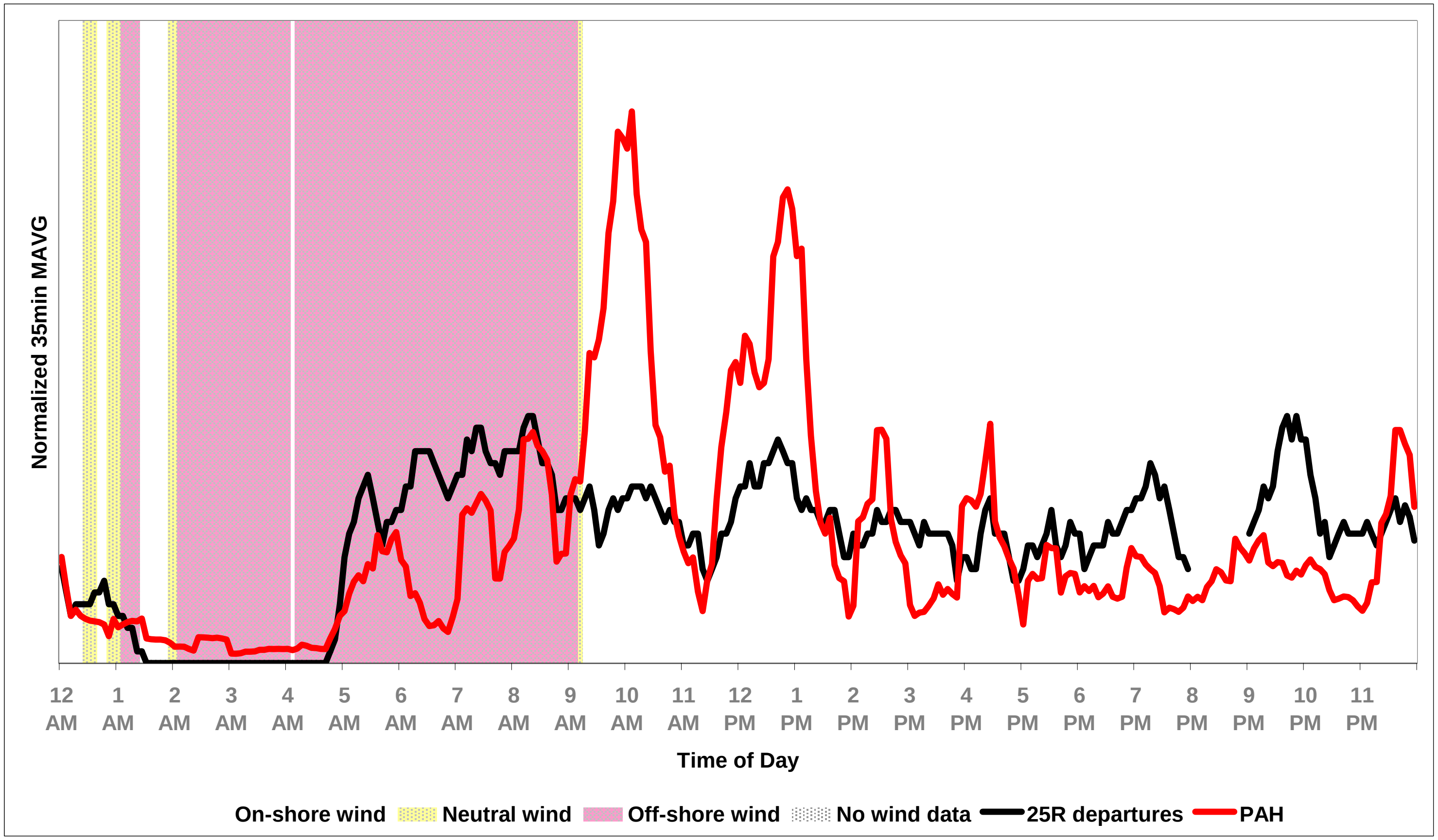


FIGURE 19

Detection Results for Polynuclear Aromatic Hydrocarbons Compared to Runway 25R Departures

Site	**SR**	
Sample date	**Friday July 18, 2008**	
Aviation activity	**25R departures**	
Observable		
Description	**PAH**	
Daily peak value	**521.700**	**fA PAH PID Current Signal**



Module J

Source-Oriented Air Dispersion Modeling

(Task 8)

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EXECUTIVE SUMMARY

Los Angeles World Airports (LAWA) has initiated a study intended to assess the potential impacts of emissions associated with Los Angeles International Airport (LAX) on air quality in neighborhoods that surround the airport. LAX is a source of air pollutants situated between the Pacific Ocean on the west and residential areas on the remaining three sides. Due to the local prevailing wind patterns of alternating land and sea breezes, emissions from the airport are carried into the neighboring residential areas. The potential for health impacts from these emissions has been a local concern. However, distinguishing any potential LAX-generated air quality impacts in the surrounding neighborhoods is confounded by the presence of other significant sources of emissions in the local region.

This report describes the air dispersion modeling methods and results developed during the Los Angeles Air Quality and Source Apportionment Study (AQSAS) Technology and Feasibility Demonstration Project (“Demonstration Project”). The objective of these dispersion modeling analyses for this study was to characterize the air quality impacts of the on-airport and near-airport emissions to support the siting of monitors for the Long Term Study.

An inventory of sources was developed for use in the dispersion modeling analyses. These sources were modeled using the EPA-approved model for near-field modeling, AERMOD. The model results were used to predict the dominant emission sources impacting air quality at LAX and the surrounding area. The model consisted of nearly 11,000 individual sources from the following source categories:

- Aircraft and related emission sources
- LAWA-owned on-airport stationary sources
- Individual stationary sources (on and off-airport), including two power plants and Chevron refinery
- Marine sources
- Aggregated sources
- Individual on-road segments

Pollutants modeled include: carbon monoxide (CO), oxides of nitrogen (NO_X), particulate less than 2.5 microns in diameter ($PM_{2.5}$), particulate matter less than 10 microns in diameter (PM_{10}), sulfur dioxide (SO_2), and volatile organic compounds (VOC). Analyses of potential impacts were focused on the meteorological period of June through August 2007 (summer period). Results were developed on an hourly basis to determine the worst-case short term impact and on a period (3-month) basis to assess the long term patterns. In addition, comparison evaluation was also conducted for potential ambient air impacts for other seasons (i.e., winter, spring, and fall of 2007) and summer time of additional years (i.e., 2003 through 2006). Details of modeling approach and configuration are described in the document entitled “Source Apportionment Protocol for the Los Angeles World Airports (LAWA) Study” in the Appendix B of this report.

Evaluation of the model results was conducted to determine significant sources of air pollution and their emissions; estimate the contribution of LAX sources on air pollution levels; and identify the methods and measurements that will be most successful in determining LAX’s air quality impact.

The dispersion modeling results from this study reveal several groups of sources including Chevron El Segundo Refinery (Chevron), Off-Airport Roadways, and Terminal Aircraft Parking Areas as the potential noticeable contributors to the air quality impacts near LAX. Several on-airport sources (e.g., Airport Runways, Airport Taxiways, and Airport Roadways) also contribute in narrow geographic areas inside or immediately adjacent to the Airport, with a much lower magnitude of impacts. Marine sources do not show significant impacts in the modeled domain. However, it seems this finding should be further evaluated by refining the marine emissions and assessing the potential sea-land breeze effects on the dispersion.

While impact patterns due to airport emissions are identifiable and distinctive for most analyzed cases, the highest concentrations in the modeling domain can be dominated by contributions from off-airport stationary sources (e.g., in the area near the emission sources of Chevron). Based on the results from the study, it seems patterns (e.g., locations and shape of concentration contours with respect to emission source locations) of long-term average (e.g., 3-month) concentration distribution for the airport sources are more distinctive than those for short-term (e.g., 1-hour) averages. In addition, the impacts from airport sources are more apparent in the concentration contour patterns of CO, NOx, SO_2, and VOC than those of PM_{10} and $PM_{2.5}$. The impacts due to emissions of PM_{10} and $PM_{2.5}$ from off-airport roads and large off-airport point source (e.g., Chevron) mask and obscure the impacts due to the on-airport sources.

Overall, key off-airport emission source groups (especially Chevron and Off-airport Roadways) are expected to create areas of elevated concentration in their respective vicinities. However, it seems the areas of elevated concentration and contour patterns resulting from airport emissions (e.g., Terminal Aircraft Parking Areas, Airport Roadways, Aircraft Taxiing, and Airport Runways) are readily identifiable with little overlap from other source groups (e.g., Chevron or off-airport roads). This finding is indicative that it will be possible to evaluate the apportionment of airport sources in areas near the airport. In particular, the dispersion modeling results can help identify and evaluate the strategies for placement of the monitor network for the next phase. Overall, the following aspects need to be considered in determining the placement of monitors:

- The monitors should be located nearby contours depicting pollutant concentration. These contours are based on the dispersion modeling analysis for different source group contributions.

- The distance to the monitors should consider the rate of concentration changes.

- The monitors should reflect seasonal variation of wind patterns (e.g., wind speed and direction).

Based on these considerations, along with the localized wind patterns, the modeling from the demonstration study indicates that the monitors should be placed within a few kilometers from the east/southeast/northeast boundary of the airport. Furthermore, impacts from the refinery and I-405/I-105 emissions can be significant in the study area.

Based on the dispersion modeling results obtained in this demonstration study, the following strategies for the monitor placement are recommended in identifying and assessing the airport source apportionment in the nearby areas (note that the recommendations may only be relevant to the modeled pollutants in this study):

- Locate monitor(s) in an area north and/or northeast of the refinery – these monitor(s) will help to capture the potential refinery downwind impacts toward the airport.

- Locate monitor(s) along the west side of I-405 (e.g., northwest corner of I-405/ I-105 intersection, southwest corner of I-405/Manchester intersection, and northwest corner of I405/El Segundo intersection) – these monitors will help to capture the airport impacts prior to the comingling of emissions with off-airport road emissions.

- Locate monitor(s) in the vicinity of elevated concentration areas inside the airport (e.g., cargo gate areas, east ends of runways) as well as downwind directions near those sources (e.g., PS4 and PS5 in the demonstration study) – these monitors will help to confirm the impacts from airport source groups with potential significant impacts.

- Locate monitor(s) near the airport (e.g., with a distance of a few kilometers) in the directions of east, southeast, and northeast of the airport boundary – these monitor(s) will capture the identifiable impacts experienced by the surrounding communities.

- Place monitor(s) in downwind directions of prevailing low (e.g., 1-2 m/s) and intermediate (4-5 m/s) wind speeds that may favor the occurrence of elevated concentrations around selected focus areas.

Furthermore, the modeling results of the source groups can be orders of magnitude different. The selection of monitoring equipment and related detection limits depends on the pollutants of interest (e.g., criteria pollutant vs. speciation of VOC and PM composition) and averaging periods (e.g., 1-hour vs. 3-month). For the six pollutants modeled in this demonstration study, concentrations of interest would be at least tens micrograms per cubic meter. These levels of concentrations should be factored in the selection of equipment and detection limits.

This demonstration study shows a promising technical approach/tool for airport source apportionment assessment. Nevertheless, several technical refinements will assist future dispersion modeling efforts. This modeling study elucidated a number of factors contributing to air pollution from and surrounding the LAX airport. As part of this project, additional future modeling refinements have been identified. These refinements may include:

- Obtain accurate source/stack information for Chevron, airport stationary sources, marine sources, and on-/off-airport individual stationary sources;
- Improve temporal profiles for emission sources with noticeable impacts in the area;
- Review and refine emission estimate methodologies for related sources (e.g., aircraft, GSE, motor vehicles, and marine emissions);
- Improve/update mobile source emission factors (including Diesel Particulate Matter); and
- Evaluate updated or more reliable emission data and source parameters for major point sources (e.g., Chevron) with identified significant impacts in the modeling domain.

SECTION 1 - INTRODUCTION

This report details the air dispersion modeling conducted in support of the study. Dispersion modeling is used to predict ambient impacts based on emission rates and source parameters

The following sections of this report contain a detailed description of:

- Modeling methods (Section 2)
- Emission source data (Section 3)
- Modeling results (Section 4)

In addition, a summary and on the path forward section is provided in Section 5.

SECTION 2 – MODELING METHODOLOGY

SELECTION OF MODEL

Air quality models use mathematical and numerical techniques to simulate the physical and chemical processes that affect air pollutants as they disperse and react in the atmosphere. A number of air quality models exist to predict ambient air quality impacts. These models may range from simple screening tools to complex models simulating atmospheric physics and chemistry for a large number of sources and chemical species.

The goal of this study was to predict impacts from on-airport sources and nearby sources in the study region. The study region is shown in Figure 1. As the study region is relatively small (approximately 8.5 by 8.5 km), a dispersion model suitable for near-field impacts is preferred. In addition, as this modeling study sought to attribute impacts to individual sources, a source-oriented model that could model individual sources is preferred. Based on these criteria and the need for a robust model that can handle large number of sources and hourly data, the EPA-approved AERMOD model was selected.

AERMOD is a refined, steady-state, multiple sources, Gaussian dispersion model and was promulgated in December 2005 as the preferred near-field regulatory model [40 CFR 51, 2005]. Following procedures outlined in the Guideline on Air Quality Models, [40 CFR 51, 2005] AERMOD modeling was performed using the regulatory default option for most model options. The latest AERMOD version (07026) was utilized in these analyses.

The model was run using regulatory default options with the exception of the “toxics” setting. The toxics model setting allows for an optimized model formulation for area sources (EPA, 2004a). Due to the large number of area sources in the model, this setting was selected to minimize model runtime.

METEOROLOGICAL DATA

One of the primary inputs to the dispersion model is meteorological data. The meteorological data provides information on wind speed, wind direction, and turbulence for each hour. These parameters drive the direction and distribution of the pollutants at each time step.

Meteorological processing followed standard AERMET procedures [EPA, 2004c]. The surface station selected is the Los Angeles International Airport weather station (LAX, 72295), located at the southern edge of the airport, near Freeway 105. Upper air data were obtained from the San Diego airport (NKX, 72293). Although NKX is located approximately 190 km distant from LAX, these data are the only upper air data in the region that contain the minimum amount of non-missing data. Surface characteristics used to develop the AERMET data are discussed in the following section.

LAND USE ANALYSIS

AERMOD utilizes planetary boundary layer (PBL) turbulence calculations to characterize the stability of the atmosphere, which is affected by the prevailing meteorological conditions and the land use and cover of the surrounding area. Land use for the area surrounding the meteorological station was calculated following the procedures outline in the AERMOD implementation guide [EPA, 2008a].

RECEPTOR GRIDS

The AERMOD model calculates impacts at discrete locations defined by the user. In this analysis, receptors were evenly spaced 200 m apart throughout the study domain. Note that receptors inside facilities were not excluded and as such, modeling results from this demonstration study are not applicable to typical regulatory requirements (e.g., permitting). In addition, selected runs were performed with 50-m spacing to allow for refined review of model impacts. Receptors were also placed at the monitor locations. Impacts were predicted at the ground level for all receptors except the monitors, which were given a height of 12 feet.

Receptor terrain elevations input to the model were interpolated from Digital Elevation Model (DEM) data obtained from the U.S. Geological Survey (USGS). DEM data consist of arrays of regularly spaced elevations and correspond to the 1:250,000 scale topographic quadrangle map series. The array elevations are at 3 arcsecond (roughly 90-meter) intervals and were interpolated using AERMAP, as incorporated into Trinity's *BREEZE*®-AERMOD software to determine elevations at the defined receptor intervals. Through the use of the AERMOD terrain preprocessor (AERMAP), AERMOD incorporates not only the receptor heights, but also an effective height (hill height scale) that represents the significant terrain features surrounding a given receptor that could lead to plume recirculation and other terrain interaction [EPA, 2004b].

A plot of the receptor locations and elevations is provided in Figure 2.

COORDINATE SYSTEM

All sources and data were developed in the Universal Transverse Mercator (UTM) Zone 11, North American Datum 1983 (NAD83).

MODEL PERIOD

The model was run for the meteorological period of June 2007 through August 2007 to coincide with the summer conditions of the measurement study period (i.e., June through August, 2008). Selected scenarios were also run for June - August of 2003 through 2006 and for spring, autumn, and winter 2007.

Impacts were calculated on an hourly basis to capture the maximum short-term impacts and for the entire period.

Details of modeling approach and configuration are described in the document entitled “Source Apportionment Protocol for the Los Angeles World Airports (LAWA) Study” in the Appendix B of this report.

SECTION 3 – MODELED SOURCE DATA

A source inventory was developed for criteria pollutants including on and off-airport sources. The source emissions development was described in detail in the Task 3 and Task 5 Reports. CO, NO_X, $PM_{2.5}$, PM_{10}, SO_2, and VOC emissions were estimated from each source. For source categories without $PM_{2.5}$ data, PM_{10} was assumed equal to $PM_{2.5}$. Information about the source was gathered to estimate the release characteristics of the emissions. Source elevations were determined using DEM data similar to the assignment of receptor elevations described previously. Details on how each source type was modeled are provided in the following sections.

AIRCRAFT AND RELATED EMISSION SOURCES (EDMS SOURCES)

Emissions from aircraft, ground support equipment, and on-airport roadways were described in the Task 5 Report. The source parameters were modeled according to the Emission and Dispersion Modeling System (EDMS). A brief summary of the source parameters are provided here. Additional details may be found in the EDMS manual [FAA, 2007].

Aircraft takeoff and landing are modeled as a two-dimensional grid of area sources extending along the runway center line starting up to an elevation of 1,000 feet (ft). The final vertical level is set at a height of one-half the mixing height plus 1,000 ft.

Gates, ground support equipment (GSE), and auxiliary power units (APU) are located at individual gates. Each gate is modeled as a single polygon area source with emissions aggregated from all of the sources (i.e. aircraft start-up, GSE, and APU) within that polygon. The height of the gates is set to 1.5 meters (m) for all gates. Note that the emission factors utilized in the EDMS program for GSE may have potential shortcomings inherited from the EPA database. As discussed in the Task 5 report, an attempt was made to inventory GSE emissions using these age categories as opposed to using the “default age distribution” option in EDMS. It is the opinion of the study team that the LAX-specific ages reported in the GSE Survey should produce a better representation of LAX-specific GSE emissions.

Airport parking facilities are modeled as polygon area sources. The height of each parking level is specified in the model.

On-airport roadways are modeled as a series of area sources with a height of zero and an initial vertical dispersion of three meters. Vehicle emissions from the Sepulveda tunnel were treated separately from the other on-road emissions. The Sepulveda tunnel is a two way tunnel passing perpendicularly underneath the LAX runways. The tunnel runs for 634 m in length and is 24 m wide. Total emissions were first calculated with EMFAC2007 emission factors in EDMS based on the vehicle emissions through the length of the tunnel. These emissions were then attributed to two source locations at either end of the tunnel. The tunnel emissions were modeled as volume sources with a height of 1.5 m and initial lateral and vertical dimensions of 11.2 m and 1.4 m, respectively.

Note that all EDMS sources are developed with hourly emissions data to represent hourly variability of emission sources based on airport activity. Figure 3 shows a plot of all aircraft and related emission sources. Figure 4 shows the zoomed in airport sources over an aerial photo of the airport.

LAWA-OWNED ON AIRPORT STATIONARY SOURCES

In addition to the aircraft, roadway and related sources, LAWA owns and operates stationary equipment that has the potential to emit air pollutants. These sources include 32 stationary internal combustion engines, four portable internal combustion engines, two turbines, and 30 boilers. The turbines and many of the boilers are part of the airport's Central Utility Plant (CUP). In addition, four cooling towers were also modeled. The emissions development was described previously in the Task 5 Report.

Each on-airport source was modeled using stack parameters provided by LAWA. The boilers and turbines were modeled as point sources. The engines were modeled as volume sources. Table 1 provides a summary of stack parameters. Figure 5 shows the locations of on-airport sources (including LAWA-owned on-airport stationary sources and other individual on-airport individual stationary point sources.). These sources were modeled as point sources in the dispersion modeling analyses.

Table 1

LAWA-Owned On-Airport Stationary Source Parameters

Point Sources	**Height (m)**	**Temperature (K)**	**Velocity (m/s)**	**Diameter (m)**
Boilers and Turbines	1.5	446	1.1	2.4
Cooling Towers	10	Ambient	1.0	1.0
Volume Sources	**Height (m)**	**Initial lateral (m)**	**Initial Vertical (m)**	
Internal Combustion Engines	1.5	3.05	3.05	

INDIVIDUAL STATIONARY SOURCES (ON- AND OFF-AIRPORT)

A review of sources near the Airport was conducted to determine individual inventory sources to include in the model. Data for individual stationary sources were collected from an SCAQMD online database (FIND), Los Angeles Department of Water and Power (LADWP), and NRG Energy as described in the Task 3 Report. Only individual sources thought to potentially have a significant impact on results were selected to be modeled separately. Specifically, any source with an emission rate for a single pollutant greater than five tons per year (tpy) was modeled as an individual point source in the analyses.

A summary of the owners of on-airport and off airport sources modeled as individual sources is shown in Table 2.

Table 2

Owners of Individually Modeled On and Off-Airport Sources

Off-Airport Sources	**On-Airport Sources**
Chevron	United Airlines
Scattergood Generating Facility	American Airlines
El Segundo Power Plant	Garrett Aviation Services
So Cal Gas Playa Vista	LAX Fuel Corporation
Raytheon Company	LSG Sky Chefs
Northrop Grumman Space & Mission	U.S. Post Office
Northrop Grumman Aircraft Division	
Boeing Satellite Systems	
The Aerospace Corp.	
Loyola Marymount	
Vought Aircraft Industries	
Hyperion WWTP	
Insync Media	
Merle Norman Cosmetics	
Electropoly Inc.	
Marvin Engineering Corp.	

Emissions for the individual sources were provided in SCAQMD's 2006 Annual Emission Report (AER) as provided in the FIND database[1]. The locations of the individual sources were provided in the CARB CHAPIS [2] data, or determined through the mapping of the street addresses provided in the FIND database, or through the mapping of known stack locations. With the exception of the power plants, no temporal data were available for the individual emission sources and emissions were assumed to be constant throughout the study period.

Stack parameters for Chevron, Scattergood Generating Facility and El Segundo Power plant were provided or developed based on specific data and are discussed further in the following sections.

Stack parameters for the remaining sources were not provided. Estimates for each stack were developed based on the types of sources expected at each facility and our team's professional experience with similar sources. VOC source parameters were developed separately from other pollutant parameters. The bulk of the VOC emissions were expected from surface coating and solvent operations. The other criteria pollutant emissions are expected to be from engines and boilers which exhaust at higher temperatures, heights, and exit velocity. A summary of the stack parameters for each VOC source is provided in Table 3-a. Stack parameters for all other pollutants are shown in Table 3-b. Figure 6 shows the location of these sources.

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[1] Note that three sources did not have AER data for 2006. These source's (Northrop Grumman Space & Mission, LSG Sky Chefs, and U.S. Post Office) emissions were either estimated from 2005 data, or from a previous LAWA Tenant emission inventory..

[2] The Community Health Air Pollution Information System (CHAPIS) was developed by ARB and the State's 35 local air districts.

Table 3 - a

Individually Modeled On-Airport and Off-Airport Source Parameters for VOC Emissions[1]

Off-Airport Point Sources	**Height (m)**	**Temperature (K)**	**Velocity (m/s)**	**Diameter (m)**
So Cal Gas Playa Vista	12	600	20	0.7
Raytheon Company	10	310	6	1
Northrop Grumman Space & Mission	10	500	6	1
Northrop Grumman Aircraft Division	12	330	4	2
Boeing Satellite Systems	12	310	6	1
The Aerospace Corp.	10	310	2	1
Loyola Marymount	10	310	2	1
Vought Aircraft Industries	6	310	2	1
Hyperion WWTP	11	330	4	2
Insync Media	6	330	4	1
Merle Norman Cosmetics	6	310	2	1
Electropoly Inc.	6	330	4	1
Marvin Engineering Corp.	6	310	2	1
On-Airport Point Sources	**Height (m)**	**Temperature (K)**	**Velocity (m/s)**	**Diameter (m)**
United Airlines	9	310	20	0.5
American Airlines	9	310	20	0.5
Garrett Aviation Services	8	310	4	1
LAX Fuel Corporation	10	310	2	1
LSG Sky Chefs	10	310	2	1
U.S. Post Office	10	310	2	1

[1] Source Parameters used to model VOC

Table 3 - b

Individually Modeled On-Airport and Off-Airport Source Parameters for Pollutants other Than VOC[1]

Off-Airport Point Sources	**Height (m)**	**Temperature (K)**	**Velocity (m/s)**	**Diameter (m)**
So Cal Gas Playa Vista	12	600	20	0.7
Raytheon Company	10	500	6	1
Northrop Grumman Space & Mission	10	500	6	1
Northrop Grumman Aircraft Division	12	330	4	2
Boeing Satellite Systems	12	400	6	1
The Aerospace Corp.	10	310	2	1
Loyola Marymount	10	310	2	1
Vought Aircraft Industries	6	310	2	1
Hyperion WWTP	11	330	4	2
Insync Media	6	330	4	1
Merle Norman Cosmetics	6	310	2	1
Electropoly Inc.	6	330	4	1
Marvin Engineering Corp.	6	310	2	1
On-Airport Point Sources	**Height (m)**	**Temperature (K)**	**Velocity (m/s)**	**Diameter (m)**
United Airlines	9	500	20	0.5
American Airlines	9	500	20	0.5
Garrett Aviation Services	8	310	4	1
LAX Fuel Corporation	10	310	2	1
LSG Sky Chefs	10	310	2	1
U.S. Post Office	10	310	2	1

[1] Source Parameters used to model CO, NO_x, SO_x, PM_{10}, and $PM_{2.5}$

Chevron. The Chevron facility was treated separately as it has the largest single point source emissions of all sources. Due to the large emissions from this facility, additional details for plant emission sources were developed.

Emission source parameters were obtained from the EPA's National Emissions Inventory database for 2002 [EPA 2008c]. The 2006 Chevron emission rates were ratioed with the 2002 NEI emission rates on a source-by-source basis to estimate emissions from each stack. The NEI source details were further supplemented by a review of aerial photos to provide source location parameters for the tank farms. Note that cooling tower emissions are not tracked by SCAQMD, thereby potentially excluding PM_{10} emissions from these sources.

As no temporal data for facility operations were available, emissions were assumed to be constant throughout the study period.

A summary of emission parameters and sources is provided in Table 4-a (Fugitive sources) and 4-b (Point Sources). A plot of the Chevron sources is shown in Figure 6 along with other off-airport point sources considered in the model.

Table 4-a

Chevron Source Parameters (Fugitive Sources)

Source Description	Height (m)	Temperature (K)	Velocity (m/s)	Diameter (m)
All Fugitive Sources	3.05	295.37	0.00009	0.0009

Table 4-b

Chevron Source Parameters (Vertical Sources)

Source ID	Height (m)	Temperature (K)	Velocity (m/s)	Diameter (m)
1176, 1795, 1781, 1822, 1139, 1767, 1698, 1805, 1836, 9020, 575, 9007	28.35	316.48	12.19	0.58
82	47.24	640.37	8.23	3.05
83	47.24	477.59	5.66	2.90
84	62.79	516.48	1.74	3.72
115	29.57	643.71	1.16	4.11
159	44.35	550.37	14.07	2.15
160	44.20	550.93	12.68	2.13
161	44.20	550.93	12.68	2.13
328	45.11	588.71	12.10	4.27
389	31.06	745.37	0.85	1.33
390	30.48	865.93	2.22	1.32
398	31.00	714.82	1.33	1.28
428	46.63	745.37	4.08	1.22
451	49.99	449.82	2.42	2.29
453	24.69	616.48	6.04	1.37
466	55.17	616.48	12.65	1.31
467	36.27	598.71	3.87	1.36
468	55.17	616.48	12.49	1.31
471	36.73	647.04	8.15	2.59
472	36.58	575.93	1.98	2.59
473	36.58	575.93	1.98	2.59
502	24.99	488.71	3.23	1.37
504	24.99	663.71	2.01	1.41
580	35.66	515.93	2.72	1.55
583	35.39	570.37	7.76	1.53
614	35.39	570.37	7.76	1.53
615	35.39	570.37	7.76	1.53
617	35.05	566.48	5.12	1.89
618	35.05	566.48	5.12	1.89
619	35.05	566.48	5.12	1.89
620	35.05	566.48	5.12	1.89
623	39.32	560.37	1.63	1.91
625	39.32	560.37	1.28	1.91
641	51.82	544.26	5.12	3.84
643	54.80	582.59	2.69	3.92
3031	36.58	575.93	1.98	2.59

Power Plants. Actual stack parameters for the El Segundo power plant (NRG Energy) and Scattergood power plant (LADWP) were available. Actual hourly emissions for June and July 2008 were provided. The hourly data were used in the model for each corresponding hour of meteorological data for June and July 2007. August data were estimated based on the average of June and July for each day.

Table 5 provides a summary of the stack data for the two power plants and their locations are shown in Figure 6.

Table 5

Power Plant Source Parameters

Source Description	Height (m)	Temperature (K)	Velocity (m/s)	Diameter (m)
Scattergood Stack 1	91.4	418.7	16.9	6.1
Scattergood Stack 2	100.6	405.9	13.5	7.2
El Segundo Stack 3	65.6	390.8	15.4	6.5
El Segundo Stack 4	65.6	390.8	15.4	6.5

MARINE SOURCES

Marine emissions were developed based on data provided by the Air Resource Board (ARB) as described in the Task 3 Report. Marine emissions to be included in the model were selected based on proximity to the study area. The locations of ship sources included the El Segundo buoys and a selected number of shipping lanes nearest the study area. For the buoys, the locations were determined by mapping historical aerial photographs that had vessels stationed at both buoys. No source parameters were provided for the ship emission sources. Parameters were estimated based on ship data for similar modeling analyses. Each ship source was assumed to emit at a height of 37.5 m with a temperature of 356 K, a velocity of 14.0 m/s and a diameter of 1.7 m. The height above sea level was set to zero. As no temporal data for ship and buoy operations were available, emissions were assumed to be constant throughout the study period. It is expected that effort will be made in future studies to improve the emission and source data (e.g., emission rates, temporal variation, and release parameters).

A plot of the shipping lanes and buoy source locations is provided in Figure 7. Note that each shipping lane segment shown in the figure was modeled as a point source located at the middle point of the lane. The total emissions from the whole segment were attributed to the modeled point source. The treatment is considered conservative because a point source with concentrated emissions will typically result in high impacts in the modeling domain.

AGGREGATED SOURCES

The ARB Community Health Air Pollution Information System (CHAPIS) provides emissions data on 1-km by 1-km grid cells for the following categories of sources:

- *Aggregated Stationary Source* – small industrial facilities and businesses[3]
- *On-road Sources* – vehicle traffic
- *Off-road Sources* – non-road mobile sources such as construction equipment, trains, and lawn mowers.
- *Area-Wide Sources* – widely dispersed sources such as the use of consumer products (hairspray, home automotive products, home cleaners, etc.) and other dispersed solvent uses, such as painting.

A complete description of the CHAPIS data and adjustments to emissions is provided in the Task 3 Report.

In order to process the aggregate emission data using AERMOD each 1-km by 1-km modeling grid cell (henceforth referred to as major grid cell) was further sub-divided into 3 rows and 3 columns. Thus, the new sub-grid represented a 333.33 m by 333.33 m resolution grid (henceforth referred to as minor grid cell). Each minor grid cell was treated as a volume source, with equal emissions distributed in each of the minor grid cells within a single major grid cell. Emission adjustments were carried in the minor grid cells present over the shoreline of the Pacific Ocean to account for reduced land emissions in those particular grids. Emission adjustments were made in the cells by making sure that mass consistency was maintained throughout the major grid cell.

Diurnal temporal factors were incorporated into AERMOD in order to capture the hourly variation of emissions. Temporal factors for off-road, area-wide and aggregated point sources were taken from EPA’s Emissions Modeling Clearinghouse Temporal Allocation [EPA, 2008b]. On-road temporal factors were based on the SCAG Transportation model and Freeway Performance Measurement System (PeMS) data as described below for the freeway links, where the weighted average of the freeway link temporals were used [UCB, 2008]. The temporal data are summarized in Table 6.

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[3] The aggregate point source data does not include larger industrial facilities that are kept separately in the CHAPIS database. The aggregate data from CHAPIS was adjusted to account for the difference in the large industrial facilities it keeps separate from the aggregrate data and the individual on and off-airport sources that were modeled so that emissions were not double counted or missed.

Table 6

Temporal ratios for Off-road, Area, Aggregated Point, and On-road sources

Hour	Off-Road, Area, Aggregated Point[1]	On-Road[2]
0	0.0198	0.0129
1	0.0186	0.0095
2	0.0182	0.0082
3	0.0187	0.0085
4	0.0210	0.0133
5	0.0250	0.0257
6	0.0311	0.0599
7	0.0388	0.0612
8	0.0467	0.0618
9	0.0528	0.0466
10	0.0571	0.0473
11	0.0604	0.0478
12	0.0620	0.0480
13	0.0631	0.0477
14	0.0635	0.0480
15	0.0624	0.0745
16	0.0594	0.0767
17	0.0548	0.0784
18	0.0531	0.0746
19	0.0509	0.0474
20	0.0425	0.0308
21	0.0327	0.0291
22	0.0257	0.0243
23	0.0218	0.0178

1. Based on EPA recommended temporal factor estimates.
2. Based on Southern California Air Quality Studies.

Based on the types of sources expected to be found for each of the above CHAPIS categories, source parameters were estimated. Emissions release height is taken to be three meters for aggregated point source, off-road, and area-wide sources. The on-road release height is assumed to be zero. For all source categories, the initial lateral dimension is assumed to be 38.7 m, while the initial vertical dimension is assumed to be 1.4 m.

A plot of the 1km by 1km major grid cells is shown in Figure 8.

INDIVIDUAL ON-ROAD SEGMENTS

As emissions from the two large freeways near the airport (105 and 405) are expected to have a significant impact on air quality, these sources were modeled separately from the aggregated on-road sources. The development of emissions for these two freeways was described in detail in the Task 3 Report.

The 105 and 405 were modeled as volume sources separated by a distance of two times the width of the road. The vehicle emissions were modeled at a release height of zero, an initial lateral dimension of two times the road width divided by 2.15, [EPA, 2004a] and in initial vertical dimension of three meters.

Temporal data for the 105 and 405 freeways was developed through a combination of the SCAG Transportation Model summer 2008 link data that is provided in four separate time periods[4] and PeMS link data that was used to determine the relative hourly temporal distribution within each of the four time periods.

A plot of the 105 and 405 sources is provided in Figure 9.

SUMMARY OF SOURCE EMISSIONS AND INPUT

In total, the modeling included 10,669 individually located sources. Of those, 4,922 are area sources, 5,528 are volume sources and 219 are point sources.

A summary of emissions from each source type is provided in Table 7. Table 8 shows the emissions for the GATES source group, which includes emissions from aircraft engine start-up, GSE, and APU. Note that the EDMS Version 5.0.2 (the latest version available during this demonstration study) only provides emissions of VOC from aircraft engine start-up. Moreover, it does not calculate emissions of PM_{10} or $PM_{2.5}$ from APU. These emissions will be accounted for in the future version of EDMS (to be utilized in the future study if available).

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[4] The four time periods provided by the SCAG Traffic Model are: AM from 6am to 9 am, MD from 9 am to 3 pm, PM from 3 pm to 7 pm, and NT from 7 pm to 6 am.

Table 7

On and Off Airport Inventory of Emissions (Tons in 3-month)

Source Group	**CO**	**VOC**	**NO_x**	**SO_x**	**PM_{10}**	**$PM_{2.5}$**
Aircraft	435.72	188.46	737.34	66.24	15.07	15.07
GSE	501.25	30.99	222.40	8.93	8.50	8.26
APU	38.01	2.90	30.02	4.46	NC	NC
Parking Facilities	28.43	4.36	6.28	0.02	0.09	0.07
Roadways[1]	138.89	11.43	58.84	0.30	3.98	3.11
Roadways[2]	3509.96	353.09	582.26	7.19	169.14	32.22
Stationary Sources[3]	8.71	0.27	30.79	0.32	1.30	1.30
Stationary Sources[4]	13.77	3.90	6.76	0.18	4.45	2.96
Stationary Sources[5]	240.34	157.42	67.51	4.89	21.09	19.99
Chevron	224.71	158.90	253.59	99.85	70.81	70.81
Marine Sources	139.66	69.87	1739.16	1180.23	156.05	152.16
Off-Road Sources	928.06	112.16	333.47	5.30	18.61	16.69
Area Sources	46.93	186.42	26.22	0.38	15.08	3.81
Total	**6,254.4**	**1,280.2**	**4,094.6**	**1,378.3**	**484.2**	**326.4**

1. On-airport roadways
2. Off-airport roadways
3. Stationary sources (on-airport, LAX owned)
4. Stationary sources (on-airport, non-LAX owned)
5. Stationary sources (off-airport, not including Chevron)

NC = Not Calculated in EDMS Version 5.0.2

Table 8

Emissions of GATES Source Group (Tons in 3-month)

Source Description	CO	VOC	NO_x	SO_x	PM_{10}	$PM_{2.5}$
Aircraft Engine Start-up	NC	131.06	NC	NC	NC	NC
GSE	501.25	30.99	222.40	8.93	8.50	8.26
APU	38.01	2.90	30.02	4.46	NC	NC
GATES Total	**539.26**	**164.95**	**252.42**	**13.39**	**8.50**	**8.26**

NC = Not Calculated in EDMS Version 5.0.2

SECTION 4 – MODELING RESULTS

The AERMOD dispersion modeling results for the modeled pollutants are documented in this section. In the modeling analyses, emission source groups in the model runs were established based on the types of emission sources. Modeling results from these source groups were generated and evaluated for their potential impacts in the modeling domain. Table 9 describes these modeled emission source groups utilized in the modeled runs.

Table 9

Description of Modeled Emission Groups

Source Group	Description
ALL	All modeled sources
	Source Groups Inside the Airport Boundary*
APPNT	Point sources inside the airport boundary
ENGINES	Airport generators + boilers + cooling towers
PARK	Airport parking
ROADS	Internal airport roads + Sepulveda Tunnel
GATES	Aircraft engine start-up, APU, and GSE for Cargo and commercial aircrafts at gates
TAXI	Taxiways
TF250240	Takeoff and Climbout – Heading 250/240
TF6070	Takeoff and Climbout – Heading 60/70
LD250240	Approach – Heading 250/240
LD6070	Approach –Heading 60/70
RUNWAY	Runways
EDMS	Includes PARK + ROADS + GATES + TAXI + TF250240 + LD25040 + LD6070 + TF6070 + RUNWAY
ONARPRT	All sources within airport boundary (EDMS+APPNT+ENGINES)
	Source Groups Outside the Airport Boundary
CAAGP	Chapis data: Aggregated point sources
CAARE	Chapis data: Area-wide sources
CAOFF	Chapis data: Off-road sources
CAONR	Chapis data: On-road sources
CHEVRON	Chevron facility
POWER	Power plants
SHIPS	Ships
OFFAPPNT	Point sources outside airport boundary
OFFAPRD	Off-airport roads
OFFARPRT	All sources outside airport boundary

* The takeoff sources go beyond the physical airport boundary.

The modeling analyses are to identify the potential impact patterns and characteristics due to emissions from both on-airport and off-airport activities that may contribute to the air quality in the area. Results and findings from these modeling analyses are discussed in the following sections and will provide insights for siting the monitors for the Long Term Study. All figures discussed in this section are documented in Appendix A. Note that the maximum 1-hour concentration contours shown in these figures are developed based on the highest 1-hour concentrations for the modeled pollutants at each receptor among all modeled hours in the study. The 3-month average concentration contours are based on the 3-month average concentrations for the modeled pollutants at each receptor among all modeled hours in the study. Moreover, these modeling results only reflect the impacts from the emissions considered in the analyses based on the due diligence performed at the best effort to identify all potential significant emission sources in the modeling area.

CARBON MONOXIDE (CO)

The CO modeling results based on the meteorological period of June – August, 2007 (summer) are presented in Table 10. Note that results in the table are not additive because they represent the highest impacts from individual modeled source groups that may occur at different locations and time. As shown in the table, the CO impacts in the modeling domain are mainly from the following emissions source groups: CHEVRON (included in OFFARPRT) and GATES (included in EDMS and ONARPRT). The CHEVRON source group represents the emissions from the Chevron Refinery located about 3 kilometers south of the airport. The GATES source group represents emissions from both cargo and passenger aircraft emissions parked at the gates/terminals. The highest 1-hour concentration (100,576 $\mu g/m^3$) in the modeling domain was dominated by the CHEVRON source group (with CO emissions of about 225 tons for a 3-month period). The highest 1-hour CO concentration contributed by the airport sources is 30,891$\mu g/m^3$, which is about 31% of the highest concentration contributed by all modeled sources. Note that the percentage here is intended to show the relative impact magnitude of the airport sources compared to that of all modeled sources. The highest concentration due to the airport sources may not occur at the same location/time as the highest concentration due to all modeled sources. The highest 3-month concentration (2,638 $\mu g/m^3$) is mainly attributable to the airport emissions, especially the emissions from the GATES source group, whose impact accounts for 2,513 $\mu g/m^3$, over 95% of the highest concentration by all modeled sources.

Details of the CO concentration contours due to emissions from the major contributing source groups (including all modeled sources, CHEVRON, airport sources, and GATES) are shown in Figures 10 through 13 for the 1-hour averaging period. As shown in Figure 10, several areas of high concentration are observed in the modeling domain. Of which, the highest 1-hour CO concentration occurs at about 3 kilometers south of the airport. As shown in Figure 11 (concentrations caused by the CHEVRON source group), these elevated concentrations occur near the Chevron Refinery.

1-hour CO concentrations contributed by the airport sources are shown in Figure 12. Several high CO concentrations are predicted inside the airport at the following areas: near the southeast corner of the north runway, south side and northeast corner of the south runway, and the central terminal area. As shown in Figure 13, these high concentration areas are caused by the emissions from activities included in the GATES source group, which includes emissions due to aircraft engine start-up, GSE and APU activities at the gates. In particular, the high CO concentration areas near the runways are contributed by cargo aircraft parked in the adjacent areas. Note that, in this study, all emissions due to the Ground Power Units (GPU) and generators used at the airport are allocated to the south runway Cargo 1 area (CG1) because the exact locations of these sources can not be determined until being used. This approach may produce bias for the impact near that CG1 location. The impact of the ~5000 $\mu g/m^3$ 1-hour CO concentration level contributed from the airport emissions extends to about 1 kilometer distance from the northeast and southeast airport boundary.

Figures 14 through 17 present the 3-month concentration contours for the major contributing source groups (including all modeled sources, CHEVRON, airport sources, and GATES). Note that the 30-$\mu g/m^3$ contour in the figure stops around Sentinela Street on the north and Prairie Street on the east because receptors placed in the model runs only extend to locations along Sentinela Street and Prairie Street (see Figure 2 for receptor network used in the analysis). Similar open contours in other figures should also be interpreted in the same manner. Overall, the elevated 3-month CO concentrations occur in the same areas as the elevated 1-hour concentrations (compare Figure 14 to Figure 10). The major difference between the 3-month results and the 1-hour results is that the highest concentration in the modeling domain is predominantly caused by the airport sources, especially the GATES source group. The 3-month concentration impact due to the CHEVRON source group is limited to the area near the source (Figure 15). As shown in Figure 16, the 3-month CO impacts due to the airport sources mainly extend to the nearby area northeast of the airport. More than 95% of the highest 3-month CO concentration (which occurs inside the airport) is due to the GATES source group (Figure 17).

Table 10

CO Modeling Results (Summer 2007)

Source Group	Max 1-Hour Conc. (μg/m³)	3-Month Conc. (μg/m³)
ALL	**100576.0**	**2637.7**
Source Groups Inside the Airport Boundary		
APPNT	66.9	8.3
ENGINES	1347.1	12.7
PARK	374.3	31.8
ROADS	3972.2	200.4
GATES	**29440.3**	**2513.1**
TAXI	3235.7	150.2
TF250240	8.2	0.2
TF6070	2.0	0.0
LD250240	13.4	0.7
LD6070	7.0	0.0
RUNWAY	492.3	21.7
EDMS	**30888.1**	**2631.0**
ONARPRT	**30890.9**	**2631.3**
Source Groups Outside the Airport Boundary		
CAAGP	3.2	0.3
CAARE	2.1	0.2
CAOFF	47.7	3.6
CAONR	293.2	14.3
CHEVRON	**100498.4**	**1853.4**
POWER	37.4	2.3
SHIPS	4.4	0.2
OFFAPPNT	20.4	2.0
OFFAPRD	7556.6	441.8
OFFARPRT	**100539.6**	**1857.1**

NITROGEN OXIDES (NO_X)

The NO_X modeling results based on the meteorological period of June – August, 2007 (summer) are presented in Table 11. As shown in the table, the NO_X impacts in the modeling domain are mainly contributed by the following emissions source groups: CHEVRON (included in OFFARPRT) and GATES (included in EDMS and ONARPRT). The highest 1-hour NO_X concentration contributed by all modeled sources is 52,407 μg/m³. Of which, 52,373 μg/m³ is due to the CHEVRON emissions. The highest 1-hour NO_X concentration due to the airport sources is about 8,113 μg/m³ (about 15% of the highest impact from all modeled sources). In addition, the highest impact from the off-airport roads (3,360 μg/m³) is about 6% of the highest impact from all modeled sources. In short, the highest 1-hour NO_X impact in the modeling domain is contributed by the CHEVRON source group.

The highest 3-month NO_X concentration contributed by all modeled sources is 977 μg/m³. Of this concentration, 972μg/m³ is contributed by the CHEVRON source group. The highest 3-month NO_X concentration due to the airport sources is 869 μg/m³ (about 89% of the highest impact from all modeled sources). The GATES source group contributes more than 98% of the total airport impact at the receptor where the highest 3-month impact occurs. In addition, the highest 3-month impact from the off-airport roads (177μg/m³) is about 18% of the highest impact from all modeled sources (note that the highest concentration due to the off-airport roads occurs at different location from that of the highest concentration for all modeled sources. In short, while the highest 3-month NO_X impact in the modeling domain is contributed by the CHEVRON source group, the airport sources also cause significant 3-month impacts in the areas near the sources.

As shown in Figure 18, the elevated 1-hour NO_X impacts are predicted in the following areas: area near the Chevron Refinery, southeast corner of the north runway, south side of the south runway, and the terminal area. In addition, a segment of I-405 between El Segundo Road and Rosecrans Road also shows elevated 1-hour NO_X impact immediately adjacent to the road. As shown in Figure 19, the NO_X emissions from Chevron Refinery contribute to at least 500 μg/m³ of 1-hour NO_X concentration in the area between the facility and the airport. Figure 20 shows the 1-hour NO_X impact due to the airport sources and Figure 21 shows the concentration contours due to the GATES source group. Comparing these two plots reveals that the impact due to the GATES source group dominates over impacts from other airport source groups. The 1,000 μg/m³ contour due to the airport sources covers the area extending about 2-3 kilometers from the airport boundary of the south side, east side, and north side.

Figure 22 presents the 3-month NOx concentration contours resulted from all modeled sources. Several relatively high 3-month NOx concentration areas are observed in the modeling domain: area around Chevron Refinery, southeast corner of the north runway, south side of the south runway, and the terminal area. As shown in Figure 23, the high 3-month NOx concentration area outside the airport is mainly corresponding to the emissions from the Chevron Refinery (with a 3-month NOx emission of about 254 tons). Figure 24 indicates the identified areas with relatively high 3-month NOx concentrations within the airport are caused by the airport sources and Figure 25 further confirm that the GATES source group is the major contributor of these concentrations. Note that the 10-μg/m³ contour in Figures 24 and 25 stops around Sentinela Street on the north and Prairie Street on the east because receptors placed in the model runs only extend to locations along Sentinela Street and Prairie Street (see Figure 2 for receptor network used in the analysis). Similar open contours in other figures should be interpreted in the same manner. In addition, the airport sources could cause an impact of 10 µg/m³ 3-month NOx concentration within areas about 2 kilometers from the southeast airport boundary and about 2-3 kilometers extending from north, northeast, and east boundary of the airport.

Overall, while the Chevron emissions dominate the contribution for the highest 1-hour NOx concentration in the modeling domain, the airport sources (especially the GATES sources) contributed to several areas with elevated 1-hour NOx concentrations within the airport boundary. Similar patterns are also shown in the 3-month NOx impacts.

Table 11

NOx Modeling Results (Summer 2007)

Source Group	Max 1-Hour Conc. (µg/m³)	3-Month Conc. (µg/m³)
ALL	**52406.5**	**977.0**
Source Groups Inside the Airport Boundary		
APPNT	26.5	3.3
ENGINES	319.5	29.4
PARK	856.5	75.9
ROADS	823.8	53.5
GATES	**7644.7**	**853.1**
TAXI	454.6	21.8
TF250240	63.5	6.2
TF6070	9.8	0.0
LD250240	15.4	2.0
LD6070	12.3	0.1
RUNWAY	320.0	19.4
EDMS	**8111.6**	**868.8**
ONARPRT	**8113.1**	**869.1**
Source Groups Outside the Airport Boundary		
CAAGP	2.3	0.2
CAARE	1.2	0.1
CAOFF	23.1	1.6
CAONR	31.2	1.4
CHEVRON	**52372.7**	**971.8**
POWER	5.3	0.2
SHIPS	54.4	2.2
OFFAPPNT	24.2	2.5
OFFAPRD	**3360.2**	**176.6**
OFFARPRT	**52396.0**	**974.7**

PARTICULATE MATTER NOT GREATER THAN 10 MICRONS (PM_{10})

The PM_{10} modeling results based on the meteorological period of June – August, 2007 (summer) are presented in Table 12. As shown in the table, the PM_{10} impacts in the modeling domain are mainly contributed by CHEVRON (included in OFFARPRT). In addition, emissions from OFFAPRD and GATES (included in EDMS and ONARPRT) also contribute noticeable concentrations. The highest 1-hour PM_{10} concentration contributed by all modeled sources is 10,650 $\mu g/m^3$. Of which, 10,643 $\mu g/m^3$ comes from the CHEVRON source group. The highest 1-hour PM_{10} concentration due to the airport sources is about 379 $\mu g/m^3$ (about 4% of the highest impact from all modeled sources). In addition, the highest impact from the off-airport roads (1,519 $\mu g/m^3$) is about 14% of the highest impact from all modeled sources.

The highest 3-month PM_{10} concentration due to the CHEVRON source group (197 $\mu g/m^3$) contributes almost all of the highest 3-month PM_{10} concentration contributed by all modeled sources (197 $\mu g/m^3$). In addition, the highest 3-month impact from the off-airport roads (73 $\mu g/m^3$) is about 37% of the highest impact from all modeled sources. The highest 3-month PM_{10} concentration due to the airport sources is 43 $\mu g/m^3$ (about 22% of the highest impact from all modeled sources). The GATES source group contributes more than 98% of the total airport impact.

In short, while the highest PM_{10} impact in the modeling domain is dominantly contributed by the CHEVRON source group for both 1-hour and 3-month averaging periods, the off-airport roads (mainly I-405) and the airport sources (mainly the GATES source group) also cause locally elevated impacts in areas near those sources (e.g., along the highway or within the airport). However, the 3-month impact due to the airport sources is in much less magnitude than the impact due to the CHEVRON or OFFAPRD sources.

As shown in Figure 26, elevated 1-hour PM_{10} impacts in the modeling domain are mainly attributed by CHEVRON and off-airport roads. The CHEVRON impact based on 71-tons PM_{10} emissions for a 3-month period centers around the refinery with its 200 $\mu g/m^3$ contour reaching the airport south boundary (Figure 27). Figure 28 shows that PM_{10} emissions from the Highway I-405 result in elevated 1-hour PM10 concentrations (e.g., the distinctive 400 $\mu g/m^3$ contour) along the highway. Figure 29 shows several elevated 1-hour PM_{10} concentration areas within the airport due to the airport sources. As shown in Figure 30, these focus areas with elevated 1-hour PM_{10} concentrations at the airport (note the different scale of the contours) are caused mainly by the emissions from the GATES source group. Note that the 1-hour PM_{10} concentrations in these airport focus areas are in general much lower than the concentrations at focus areas resulting from the CHEVRON or off-airport road emissions. The airport sources result in a 1-hour PM_{10} contour of 50 $\mu g/m^3$ extending to a distance of about 1 km from the north, south, and east side of the airport.

Figure 31 presents the 3-month PM_{10} concentration contours due to all modeled sources. These 3-month PM_{10} contours show similar patterns as those of the 1-hour contours, with elevated concentration areas around the Chevron Refinery, the I-405 Highway, and a few spots inside the airport. Contribution due to the CHEVRON source group shows impacts centering the facility with a 5 $\mu g/m^3$ 3-month concentration contour extending about 1.5 km in the northeast direction from the facility (Figure 32). Impact due to emissions from Highway I-405 (in the OFFAPRD source group) concentrates along both sides of the road (Figure 33). The 5 $\mu g/m^3$ 3-month concentration contour extends about 1.5 km from the road on the east side and about 0.5 km from the road on the west side. As shown in Figures 34 and 35, the 3-month average impact due to the airport sources (mainly contributed by the GATES source group) is mostly bounded within the airport boundary by a concentration contour of 5 $\mu g/m^3$ (i.e., the 3-month PM_{10} impact due to the airport sources is mostly less than 5 $\mu g/m^3$ beyond the airport boundary). Note that the 1-$\mu g/m^3$ contour in Figure 34 stops around Sentinela Street on the north and Prairie Street on the east because receptors placed in the model runs only extend to locations along Sentinela Street and Prairie Street (see Figure 2 for receptor network used in the analysis). Similar open contours in other figures should be interpreted in the same manner.

Table 12

PM_{10} Modeling Results (Summer 2007)

Source Group	**Max 1-Hour Conc. (μg/m³)**	**3-Month Conc. (μg/m³)**
ALL	**10650.4**	**197.2**
Source Groups Inside the Airport Boundary		
APPNT	60.5	13.0
ENGINES	19.7	0.3
PARK	8.9	0.8
ROADS	73.9	3.8
GATES	**376.7**	**41.9**
TAXI	32.2	1.6
TF250240	0.9	0.1
TF6070	0.1	0.0
LD250240	0.4	0.0
LD6070	0.3	0.0
RUNWAY	61.0	2.2
EDMS	**378.5**	**42.6**
ONARPRT	**378.5**	**42.7**
Source Groups Outside the Airport Boundary		
CAAGP	0.2	0.0
CAARE	0.7	0.1
CAOFF	1.1	0.1
CAONR	2.8	0.1
CHEVRON	**10643.3**	**196.7**
POWER	3.4	0.2
SHIPS	5.2	0.3
OFFAPPNT	3.4	0.4
OFFAPRD	**1519.4**	**73.4**
OFFARPRT	**10649.9**	**197.1**

PARTICULATE MATTER NOT GREATER THAN 2.5 MICRONS ($PM_{2.5}$)

The $PM_{2.5}$ modeling results based on the meteorological period of June – August, 2007 (summer) are presented in Table 13. As shown in the table, the $PM_{2.5}$ impacts in the modeling domain are mainly contributed by CHEVRON (included in OFFARPRT). In addition, emissions from GATES (included in EDMS and ONARPRT) and OFFAPRD also contribute noticeable concentrations.

For the 1-hour averaging period, the highest $PM_{2.5}$ concentration is predicted to be 10,645 μg/m^3 contributed from all modeled sources. Of which, almost all the contribution comes from the CHEVRON source group. The airport sources may result in a maximum impact of 365 μg/m^3, which is about 3% of the highest concentration for all modeled sources. The highest impact due to the off-airport roads (e.g., I-405) is 162 μg/m^3 (about 1.5% of the highest concentration for all modeled sources).

For the 3-month averaging period, the highest $PM_{2.5}$ concentration is predicted to 197 μg/m^3 contributed from all modeled sources. Of which, almost all the contribution comes from the CHEVRON source group. Moreover, the airport sources may result in a maximum impact of 41 μg/m^3, which is about 21% of the highest concentration for all modeled sources. The highest impact due to the off-airport roads (e.g., I-405) is 10 μg/m^3 (about 5% of the highest concentration for all modeled sources).

In short, the highest $PM_{2.5}$ impact is dominantly contributed by the CHEVRON source group for both 1-hour and 3-month averaging periods. The airport sources or off-airport roads contribute much less magnitude of impact in the modeling domain in general (except at areas close to the emission sources).

Figure 36 presents the 1-hour $PM_{2.5}$ impact due to all modeled sources. As shown in the figure, most of the contours center around the Chevron Refinery. It is confirmed in Figure 37 that the highest impact is dominantly contributed by the CHEVRON source group. Figure 38 shows the 1-hour impact due to the off-airport roads. Of note are the concentration contours of 20-40 μg/m^3 covering the areas adjacent to Highway I-45. Figure 39 indicates that the airport sources contribute to several elevated concentration spots within the airport and results a 1-hour concentration level of 50 μg/m^3 extending to about 1 km distance from the north, east, and south side of the airport. Figure 40 confirms that the airport source impact is mainly contributed by the GATES source group.

As for the 3-month $PM_{2.5}$ impact, Figure 41 presents the concentrations resulted from all modeled sources. Of note is the high concentration areas located near the Chevron Refinery. This is confirmed in Figure 42, which shows that the elevated concentrations are mainly caused by the CHEVRON source group. Figure 43 show that the emissions from Highway I-405 cause a 3-month $PM_{2.5}$ concentration of about 1 μg/m^3 along the road. Several concentration contours are also observed inside the airport in Figure 41. Figures 44 and 45 confirm that these contours are contributed by the airport sources (mainly the GATES source group). Note that the 1-μg/m^3 contour in Figure 44 stops at Sentinela Street on the north and Prairie Street on the east because receptors placed in the model runs only extend to locations along Sentinela Street and Prairie Street (see Figure 2 for receptor network used in the analysis). Similar open contours in other figures should be interpreted in the same manner.

Table 13

$PM_{2.5}$ Modeling Results (Summer 2007)

Source Group	Max 1-Hour Conc. (μg/m^3)	3-Month Conc. (μg/m^3)
ALL	**10644.9**	**197.0**
Source Groups Inside the Airport Boundary		
APPNT	36.4	7.8
ENGINES	19.7	0.3
PARK	8.2	0.7
ROADS	53.4	3.1
GATES	**365.0**	**40.6**
TAXI	32.2	1.6
TF250240	0.9	0.1
TF6070	0.1	0.0
LD250240	0.4	0.0
LD6070	0.3	0.0
RUNWAY	61.0	2.2
EDMS	**366.5**	**41.2**
ONARPRT	**366.5**	**41.3**
Source Groups Outside the Airport Boundary		
CAAGP	0.2	0.0
CAARE	0.2	0.0
CAOFF	1.0	0.1
CAONR	1.9	0.1
CHEVRON	**10643.3**	**196.7**
POWER	3.4	0.2
SHIPS	5.0	0.3
OFFAPPNT	3.3	0.3
OFFAPRD	**161.9**	**9.9**
OFFARPRT	**10644.4**	**196.9**

SULFUR DIOXIDE (SO_2)

The SO_2 modeling results based on the meteorological period of June – August, 2007 (summer) are presented in Table 14. As shown in the table, the SO_2 impacts in the modeling domain are mainly contributed by CHEVRON (included in OFFARPRT). The highest impacts due to emissions from airport sources (e.g., GATES, RUNWAY, TAXI source groups) are much less than the highest impacts due to the CHEVRON source group (note that the highest impacts may not occur at the same location/time).

For 1-hour averaging period, the highest concentration from all modeled sources is 66,529 $\mu g/m^3$. Almost all of it is contributed by the CHEVRON source group. Emissions from the airport sources generate the highest concentration of 560 $\mu g/m^3$ (less than 1% of the highest concentration in the domain). The airport impact is mainly contributed by emissions from the GATES, RUNWAY, and TAXI source groups. For 3-month averaging period, similar patterns are observed as for the 1-hour averaging period. The CHEVRON source group contributes almost 100% to the highest 3-month concentration in the domain (1,218 $\mu g/m^3$).

As shown in Figure 46 and Figure 47, the impact due to the CHEVRON source group overwhelmingly mask the impact from other source groups. In other words, the short-term impact in the domain (especially outside the airport) is dominantly contributed by the CHEVRON group. This source group can generate a concentration level of 500 $\mu g/m^3$ and up for the general area south of the airport. Figure 48 shows the impact due to the off-airport road. While the impact is in general along the roads (especially Highway I-405), the magnitude of impact is low (about 2 $\mu g/m^3$). Figure 49 demonstrates the impact due to the airport sources. Several elevated 1-hour SO_2 concentration spots are predicated around the runways and gates in a concentration level of 300-500 $\mu g/m^3$. Overall, a concentration level of 100 $\mu g/m^3$ due to the airport sources can reach outside the airport boundary to about a 1-2 kilometer distance. Figure 50 shows that the GATES source group is the main contributors to the elevated concentration spots in the airport. Moreover, Figures 51 and 52 show that emissions from the RUNWAY and TAXI source groups generate distinctive patterns (about 100 $\mu g/m^3$) along the South runway in the airport. This result implies that aircraft activities on the South runway should be further evaluated.

For 3-month averaging period, Figure 53 shows the concentration contours contributed by all modeled sources. While the CHEVRON source group creates the highest concentration spot in the domain, its impact at a level of 20 $\mu g/m^3$ is limited to the area about 1-2 kilometers from the source. This finding is confirmed in Figure 54 which shows the impact due to the CHEVRON source group. Figure 55 shows the 3-month impact due to off-airport roads. While distinctive pattern of impact is observed for this source group, its impact magnitude is low (0.1 $\mu g/m^3$). Figure 56 shows the impact due to the airport sources. Several elevated concentration spots (about 30-50 $\mu g/m^3$) are observed near the runways. A concentration level of 10 μg/m^3 can reach out to a distance of about 1 kilometer on the east side of the airport. As shown in Figures 57, 58, and 59, these overall impacts are contributed by the GATES, RUNWAY, and TAXI source groups. Note that the 0.5-μg/m^3 contour in Figures 58 and 59 stops around Sentinela Street on the north and Prairie Street on the east because receptors placed in the model runs only extend to locations along Sentinela Street and Prairie Street (see Figure 2 for receptor network used in the analysis). Similar open contours in other figures should be interpreted in the same manner. Overall, while the SO_2 impacts and related patterns due to the airport sources can be recognized from individual source group results, in general impacts from the CHEVRON source group are in much high magnitude.

Table 14

SO_2 Modeling Results (Summer 2007)

Source Group	**Max 1-Hour Conc. (μg/m^3)**	**3-Month Conc. (μg/m^3)**
ALL	**66528.5**	**1218.0**
Source Groups Inside the Airport Boundary		
APPNT	1.6	0.1
ENGINES	22.7	1.0
PARK	0.6	0.1
ROADS	11.4	0.6
GATES	**559.7**	**71.4**
TAXI	**177.2**	**8.6**
TF250240	3.6	0.4
TF6070	0.6	0.0
LD250240	2.4	0.3
LD6070	1.8	0.0
RUNWAY	**272.4**	**20.8**
EDMS	**560.3**	**72.9**
ONARPRT	**560.4**	**72.9**
Source Groups Outside the Airport Boundary		
CAAGP	0.1	0.0
CAARE	0.0	0.0
CAOFF	0.3	0.0
CAONR	0.8	0.0
CHEVRON	**66528.5**	**1216.4**
POWER	0.3	0.0
SHIPS	76.6	3.5
OFFAPPNT	0.3	0.0
OFFAPRD	11.3	0.6
OFFARPRT	**66528.5**	**1217.8**

VOLATILE ORGANIC COMPOUNDS (VOC)

The VOC modeling results based on the meteorological period of June – August, 2007 (summer) are presented in Table 15. As shown in the table, the VOC impacts in the modeling domain are mainly contributed by emissions from CHEVRON (included in OFFARPRT) and GATES (included in EDMS and ONARPRT.

For the 1-hour averaging period, the highest VOC concentration from all modeled sources is 16,180 μg/m^3, which is dominantly contributed by the GATES source group. The CHEVRON source group results the highest concentration of about 10,569 μg/m^3, which is about 65% of the highest concentration from all modeled sources.

For the 3-month averaging period, the highest VOC concentration from all modeled sources is 783 μg/m^3, which is dominantly contributed by the CHEVRON source group. The airport sources (mainly the GATES source group) results the highest concentration of about 492 μg/m^3 (63% of the highest concentration by all modeled sources, which may occur at different location/time from the highest impact due to the airport sources). In addition, several other emission source groups (including OFFAPRD, TAXI, ROADS, and RUNWAY) also contribute noticeable but much smaller concentrations.

Figure 60 shows the 1-hour VOC concentration contours contributed by all modeled sources. Several elevated concentration spots are observed around the runways and gates in the airport. Emissions from the Chevron Refinery also create an elevated concentration area near the site. Figure 61 confirms the 1-hour concentration contribution from the CHEVRON source group. Its impact could reach as least 200 μg/m^3 level for the area south of the airport. Figure 62 shows the 1-hour impact due to the emissions from off-airport roads. This figure indicates that emissions from Highway I-405 could produce 1-hour VOC concentrations along the highway in a level of 50-100 μg/m^3. Figure 63 reveals several spots (near the runway and gates) with elevated 1-hour VOC concentrations due to the airport sources. A 2,000 μg/m^3 1-hour VOC concentration contour contributed by the airport sources could reach a distance of about 1 km north, south, and east of the airport boundary. Figure 64 confirms that these impacts are dominantly contributed by the GATES source group. In addition, Figure 65 shows that emissions from aircraft taxi-ing also create 1-hour VOC concentration in a level of 200 μg/m^3 on the south taxiway. In contrast, lower impact is predicted on the north taxiway due to aircraft taxi-ing. Figure 66 also indicates higher concentrations on the south runway due to the aircraft emissions. A contour level of 20 μg/m^3 could extend to areas east of the airport. Moreover, Figure 67 shows that airport road emissions may also result in impact of 20 μg/m^3 level beyond the airport boundary.

For 3-month averaging period, Figure 68 shows the VOC impacts from all modeled sources. Compared to the 1-hour impact patterns, similar areas (i.e., area near Chevron Refinery and spots around runway/gates in the airport) with elevated

VOC concentrations are found. Note that the 10-μg/m^3 contour in Figure 68 stops around Sentinela Street on the north and Prairie Street on the east because receptors placed in the model runs only extend to locations along Sentinela Street and Prairie Street (see Figure 2 for receptor network used in the analysis). Similar open contours in Figure 73 should be interpreted in the same manner. Figure 69 confirms the contribution from the CHEVRON source group. Figure 70 shows impacts along Highway I-405 due to mobile emissions on the road. This figure indicates that emissions from Highway I-405 could produce 3-month VOC concentrations along the highway in a level of 5-10 μg/m^3. As shown in Figure 71, while elevated 3-month VOC impact contributed by the airport sources is limited to several spots within the airport, a concentration level of 10 μg/m^3 produced by the airport sources could reach a distance of several kilometers northeast of the airport. While Figure 72 confirms that the GATES source group is the dominant contributor to the airport source impacts, emissions of VOC from airport roads, taxi-ing and runways could also make noticeable impacts within and beyond the airport boundary (Figures 73 through 75). It should be noted that impacts due to emissions from airport roads, taxi-ing, and runways are in much less magnitude than those due to the GATES emissions. However, the patterns of concentration contours due to these source groups are distinctive and thus could be a good tool for airport source apportionment study.

Table 15

VOC Modeling Results (Summer 2007)

Source Group	Max 1-Hour Conc. (μg/m³)	3-Month Conc. (μg/m³)
ALL	**16179.6**	**782.6**
Source Groups Inside the Airport Boundary		
APPNT	28.2	2.7
ENGINES	82.6	0.9
PARK	78.4	6.7
ROADS	**240.0**	**12.4**
GATES	**16137.6**	**476.8**
TAXI	**586.9**	**18.9**
TF250240	0.4	0.0
TF6070	0.0	0.0
LD250240	1.3	0.1
LD6070	0.7	0.0
RUNWAY	**138.8**	**2.7**
EDMS	**16174.4**	**491.4**
ONARPRT	**16174.4**	**491.6**
Source Groups Outside the Airport Boundary		
CAAGP	7.2	0.7
CAARE	9.0	0.8
CAOFF	5.2	0.5
CAONR	27.0	1.3
CHEVRON	**10569.2**	**780.6**
POWER	2.4	0.1
SHIPS	2.2	0.1
OFFAPPNT	106.6	11.4
OFFAPRD	**777.9**	**44.7**
OFFARPRT	**10573.2**	**781.5**

REVIEW OF SEASONAL RESULTS

In this study, potential impacts due to variation of seasonal meteorological conditions in the year of 2007 are evaluated. The evaluation assumes emissions from all modeled sources are the same for all seasons.

Tables 16 through 21 document the maximum 1-hour modeling results for the six modeled pollutants. For 1-hour averaging period, the maximum concentrations during summer are higher than during other seasons for all modeled pollutants except for VOC. For VOC, the maximum concentration is highest in fall and lowest in summer. Because of the complexity of dispersion phenomenon, exact causes of this difference between pollutants are not clear at this moment. The highest concentrations for each season in the modeling domain are contributed dominantly by the CHEVRON source group for all pollutants. Interestingly, modeling results shows significant seasonal variation for the 1-hour impacts contributed by the on-airport emissions from GATES and on-airport roads (ROADS). For example, the modeled highest 1-hour CO concentration due to GATES is 29,440 μg/m^3 in summer, 77,423 μg/m^3 in fall (2.6 times of the summer value), 50,500 μg/m^3 in winter (1.7 times of the summer value), and 34,041 μg/m^3 in spring (1.2 times of the summer value).

Tables 22 through 27 document the 3-month average modeling results. These results show that similar source contributions are attributed to the impacts for different seasons. Moreover, while the highest 1-hour concentrations are close in different seasons, 3-month average concentrations show wider variation in different seasons. For example, the highest 3-month CO concentration in winter is 3.3 times of the highest summer 3-month concentration while the highest 1-hour CO concentration in winter is only 92% of the summer value. As to the airport source concentration, modeling results shows significant seasonal variation for the 3-month impacts contributed by the on-airport emissions from GATES and on-airport roads (ROADS). For example, the modeled highest 3-month CO concentration due to GATES is 2,513μg/m^3 in summer, 4,003 μg/m^3 in fall (1.6 times of the summer value), 4,042 μg/m^3 in winter (1.6 times of the summer value), and 3,509 μg/m^3 in spring (1.4 times of the summer value). Moreover, for the 3-month averaging period, the maximum concentrations during winter time are higher than during other seasons for all modeled pollutants except for VOC. For VOC, the maximum concentration is highest in fall but with less difference across different seasons than for other pollutants. Since VOC is potentially a good fingerprint for airport source apportionment, it will be of interest to further assess the impact patterns under different dispersion conditions (e.g., ambient conditions, emission source characteristics and parameters).

In summary, significant seasonal variations in modeled impacts are observed for both 1-hour and 3-month concentrations due to the airport sources (especially GATES and ROADS) for all modeled pollutants. The pattern and magnitude of variation in different seasons vary for different pollutants and source groups. This is understandable because the changes of meteorological conditions in different seasons may have different effects on emission sources with different release characteristics (e.g., point sources vs. area sources).

Figures 76 through 79 show the 1-hour VOC concentration contours for all modeled sources in the four modeled seasons. While similar elevated concentration areas due to the airport sources are observed in the figures, the shape and extend of the concentration contours are quite different in different season. For the summer 1-hour concentrations of 2,000 µg/m^3 level contributed by the airport sources, the contour boundary is mostly limited within the airport boundary and extends outside the airport boundary at the north/southeast and southeast directions (Figure 76). The same concentration level is observed extending outside the airport in all directions in fall (Figure 77). The 2,000 µg/m^3 contours in winter and spring extends a bit farther north compared to the summer contour.

Figures 80 through 83 show the 3-month VOC concentration contours for all modeled sources in the four modeled seasons. As shown in the figures, similar elevated concentration areas due to the airport sources are observed. The extend of the 3-month concentration contours of 100 µg/m^3 level is mostly within the airport boundary across seasons. However, the shape and orientation of the contours are in different seasons: the summer contours of 100 µg/m^3 level are more limited around the focus areas and oriented in the west-east direction; the contours of the same concentration level in fall are extending further in the west-east direction; the winter contours are oriented towards the northwest-southeast direction; and the spring contours are oriented towards the west-east direction.

Table 16

Maximum 1-hour CO Modeling Results for Seasonal Evaluation

Source Group	Summer (μg/m^3)	Fall (μg/m^3)	Winter (μg/m^3)	Spring (μg/m^3)
ALL	100576.0	98300.0	93462.7	94700.0
Source Groups Inside the Airport Boundary				
APPNT	66.9	84.6	80.4	87.6
ENGINES	1347.1	1370.4	1299.8	1343.0
PARK	374.3	435.1	387.2	419.1
ROADS	3972.2	6301.8	5584.1	5635.2
GATES	29440.3	77422.7	50500.2	34060.8
TAXI	3235.7	3656.3	2837.7	2801.2
TF250240	8.2	5.5	8.3	6.3
TF6070	2.0	0.3	0.4	0.2
LD250240	13.4	5.6	8.7	10.5
LD6070	7.0	4.6	2.5	6.0
RUNWAY	492.3	534.8	475.1	375.6
EDMS	30888.1	77776.4	50737.2	34368.7
ONARPRT	30890.9	77776.5	50737.2	34368.8
Source Groups Outside the Airport Boundary				
CAAGP	3.2	5.2	6.1	4.5
CAARE	2.1	2.7	3.1	2.4
CAOFF	47.7	94.9	94.3	61.3
CAONR	293.2	399.0	483.9	339.0
CHEVRON	100498.4	98100.0	93005.9	94610.5
POWER	37.4	12.4	31.4	10.2
SHIPS	4.4	4.7	4.2	3.9
OFFAPPNT	20.4	17.6	20.4	16.4
OFFAPRD	7556.6	22048.6	30394.7	20738.1
OFFARPRT	100539.6	98152.9	93263.3	94669.1

Table 17

Maximum 1-hour NO_X Modeling Results for Seasonal Evaluation

Source Group	Summer (μg/m³)	Fall (μg/m³)	Winter (μg/m³)	Spring (μg/m³)
ALL	52406.5	51200.0	48593.6	49300.0
Source Groups Inside the Airport Boundary				
APPNT	26.5	32.7	31.1	33.9
ENGINES	319.5	288.7	536.5	347.2
PARK	856.5	1059.7	977.9	1061.8
ROADS	823.8	1316.6	1800.0	1179.6
GATES	7644.7	13626.3	9886.8	8960.2
TAXI	454.6	522.3	412.4	528.8
TF250240	63.5	47.3	86.7	41.2
TF6070	9.8	10.9	10.1	13.3
LD250240	15.4	16.7	23.2	12.7
LD6070	12.3	14.6	5.7	14.1
RUNWAY	320.0	369.4	431.4	376.1
EDMS	8111.6	13673.2	9962.1	9018.5
ONARPRT	8113.1	13673.3	9962.4	9018.7
Source Groups Outside the Airport Boundary				
CAAGP	2.3	3.8	4.5	3.3
CAARE	1.2	1.7	1.9	1.4
CAOFF	23.1	45.1	44.5	29.5
CAONR	31.2	41.3	56.3	38.6
CHEVRON	52372.7	51100.0	48468.2	49304.3
POWER	5.3	1.1	2.9	1.7
SHIPS	54.4	57.9	52.5	49.0
OFFAPRD	3360.2	4697.0	6844.7	4632.5
OFFAPPNT	24.2	26.5	28.7	23.3
OFFARPRT	52396.0	51139.3	48534.8	49334.2

Table 18

Maximum 1-hour PM_{10} Modeling Results for Seasonal Evaluation

Source Group	Summer (μg/m³)	Fall (μg/m³)	Winter (μg/m³)	Spring (μg/m³)
ALL	10650.4	10400.0	9887.1	10000.0
Source Groups Inside the Airport Boundary				
APPNT	60.5	59.5	53.3	57.4
ENGINES	19.7	40.9	28.8	27.7
PARK	8.9	11.0	10.2	11.0
GATES	376.7	635.1	484.9	440.2
ROADS	73.9	117.0	114.9	105.2
TAXI	32.2	37.1	30.5	31.9
TF250240	0.9	0.6	1.1	0.6
TF6070	0.1	0.1	0.1	0.1
LD250240	0.4	0.5	0.6	0.3
LD6070	0.3	0.3	0.2	0.3
RUNWAY	61.0	53.3	47.0	57.3
EDMS	378.5	641.0	489.5	444.0
ONARPRT	378.5	641.0	489.7	444.4
Source Groups Outside the Airport Boundary				
CAAGP	0.2	0.3	0.4	0.3
CAARE	0.7	1.0	1.1	0.9
CAOFF	1.1	2.3	2.2	1.5
CAONR	2.8	3.7	4.9	3.5
CHEVRON	10643.3	10400.0	9849.8	10000.0
POWER	3.4	1.1	2.8	0.9
SHIPS	5.2	7.0	5.9	4.7
OFFAPPNT	3.4	3.8	4.1	3.2
OFFAPRD	1519.4	2990.0	4148.2	2782.7
OFFARPRT	10649.9	10397.7	9884.5	10029.7

Table 19

Maximum 1-hour PM$_{2.5}$ Modeling Results for Seasonal Evaluation

Source Group	Summer (μg/m^3)	Fall (μg/m^3)	Winter (μg/m^3)	Spring (μg/m^3)
ALL	10644.9	10400.0	9856.3	10000.0
Source Groups Inside the Airport Boundary				
APPNT	36.4	35.8	32.1	34.5
ENGINES	19.7	40.9	28.8	27.7
PARK	8.2	10.1	9.3	10.1
ROADS	53.4	84.5	98.9	76.2
GATES	365.0	614.9	469.8	426.5
TAXI	32.2	37.1	30.5	31.9
TF250240	0.9	0.6	1.1	0.6
TF6070	0.1	0.1	0.1	0.1
LD250240	0.4	0.5	0.6	0.3
LD6070	0.3	0.3	0.2	0.3
RUNWAY	61.0	53.3	47.0	57.3
EDMS	366.5	619.2	473.8	429.8
ONARPRT	366.5	619.1	474.0	430.1
Source Groups Outside the Airport Boundary				
CAAGP	0.2	0.2	0.3	0.2
CAARE	0.2	0.3	0.3	0.2
CAOFF	1.0	2.0	2.0	1.3
CAONR	1.9	2.6	3.4	2.4
CHEVRON	10643.3	10400.0	9849.8	10019.7
POWER	3.4	1.1	2.8	0.9
SHIPS	5.0	6.8	5.7	4.6
OFFAPPNT	3.3	3.8	4.1	3.2
OFFAPRD	161.9	387.0	513.4	357.1
OFFARPRT	10644.4	10389.3	9853.8	10021.1

Table 20

Maximum 1-hour SO_2 Modeling Results for Seasonal Evaluation

Source Group	Summer (μg/m³)	Fall (μg/m³)	Winter (μg/m³)	Spring (μg/m³)
ALL	66528.5	63273.7	60004.6	61292.0
Source Groups Inside the Airport Boundary				
APPNT	1.6	1.5	1.0	1.1
ENGINES	22.7	22.7	21.1	22.1
PARK	0.6	0.7	0.6	0.7
ROADS	11.4	19.4	16.0	15.7
GATES	559.7	768.9	683.1	628.5
TAXI	177.2	218.6	153.9	182.7
TF250240	3.6	2.6	4.3	2.2
TF6070	0.6	0.6	0.5	0.5
LD250240	2.4	2.4	3.5	1.8
LD6070	1.8	2.4	1.0	2.4
RUNWAY	272.4	301.1	193.1	250.7
EDMS	560.3	769.5	683.3	628.6
ONARPRT	560.4	769.5	683.3	628.6
Source Groups Outside the Airport Boundary				
CAAGP	0.1	0.1	0.2	0.1
CAARE	0.0	0.0	0.0	0.0
CAOFF	0.3	0.6	0.6	0.4
CAONR	0.8	1.1	1.3	0.9
CHEVRON	66528.4	63273.6	60004.2	61291.8
POWER	0.3	0.1	0.2	0.1
SHIPS	76.6	88.3	79.4	66.0
OFFAPPNT	0.3	0.2	0.3	0.2
OFFAPRD	11.3	34.5	43.4	31.2
OFFARPRT	66528.5	63273.7	60004.6	61292.0

Table 21

Maximum 1-hour VOC Modeling Results for Seasonal Evaluation

Source Group	Summer ($\mu g/m^3$)	Fall ($\mu g/m^3$)	Winter ($\mu g/m^3$)	Spring ($\mu g/m^3$)
ALL	16179.6	20700.0	18014.2	18200.0
Source Groups Inside the Airport Boundary				
APPNT	28.2	29.9	27.3	25.3
ENGINES	82.6	84.0	79.8	82.5
PARK	78.4	93.4	93.5	94.5
ROADS	240.0	380.4	364.1	343.7
GATES	16137.6	20628.2	17856.2	18095.6
TAXI	586.9	590.1	585.3	590.5
TF250240	0.4	0.3	0.3	0.2
TF6070	0.0	0.0	0.0	0.0
LD250240	1.3	0.8	1.3	0.9
LD6070	0.7	0.5	0.6	0.6
RUNWAY	138.8	148.6	145.1	116.7
EDMS	16174.4	20734.5	17991.5	18223.9
ONARPRT	16174.4	20734.5	17991.5	18224.6
Source Groups Outside the Airport Boundary				
CAAGP	7.2	11.7	13.8	10.2
CAARE	9.0	11.3	13.2	9.8
CAOFF	5.2	7.5	7.7	5.5
CAONR	27.0	33.8	42.8	29.7
CHEVRON	10569.2	12500.0	12533.5	10006.3
POWER	2.4	0.8	2.1	0.7
SHIPS	2.2	2.4	2.1	1.9
OFFAPPNT	106.6	94.8	177.2	120.0
OFFAPRD	777.9	2580.0	3332.8	2436.9
OFFARPRT	10573.2	12524.0	12534.9	10006.5

Table 22

3-Month Average CO Modeling Results for Seasonal Evaluation

Source Group	Summer (μg/m³)	Fall (μg/m³)	Winter (μg/m³)	Spring (μg/m³)
ALL	2637.7	5106.0	8496.4	5480.7
Source Groups Inside the Airport Boundary				
APPNT	8.3	4.5	2.6	3.3
ENGINES	12.7	44.9	33.6	18.9
PARK	31.8	46.1	48.1	43.4
ROADS	200.4	410.8	462.3	364.6
GATES	2513.1	4002.6	4041.8	3508.8
TAXI	150.2	205.3	163.9	205.1
TF250240	0.2	0.1	0.1	0.1
TF6070	0.0	0.0	0.0	0.0
LD250240	0.7	0.3	0.3	0.3
LD6070	0.0	0.0	0.0	0.1
RUNWAY	21.7	21.4	15.2	19.4
EDMS	2631.0	4256.6	4265.3	3745.5
ONARPRT	2631.3	4257.1	4265.8	3745.9
Source Groups Outside the Airport Boundary				
CAAGP	0.3	0.5	0.6	0.5
CAARE	0.2	0.3	0.3	0.3
CAOFF	3.6	6.6	8.6	6.5
CAONR	14.3	28.4	30.7	24.4
POWER	2.3	0.1	0.3	0.1
SHIPS	0.2	0.2	0.1	0.2
CHEVRON	1853.4	5026.6	8423.5	5458.8
OFFAPPNT	2.0	2.1	1.0	2.0
OFFAPRD	441.8	678.2	929.8	647.1
OFFARPRT	1857.1	5048.2	8448.2	5469.2

Table 23

3-Month Average NO_X Modeling Results for Seasonal Evaluation

Source Group	Summer (µg/m³)	Fall (µg/m³)	Winter (µg/m³)	Spring (µg/m³)
ALL	977.0	2649.9	4415.3	2854.2
Source Groups Inside the Airport Boundary				
APPNT	3.3	1.9	1.1	1.4
ENGINES	29.4	23.2	13.7	17.3
PARK	75.9	149.5	147.2	132.5
ROADS	53.5	97.2	102.3	80.0
GATES	853.1	1300.1	1181.2	1152.6
TAXI	21.8	29.3	22.8	29.3
TF250240	6.2	2.1	2.5	2.1
TF6070	0.0	0.0	0.0	0.0
LD250240	2.0	0.9	0.7	0.8
LD6070	0.1	0.1	0.0	0.1
RUNWAY	19.4	17.3	13.9	17.3
EDMS	868.8	1372.0	1250.1	1186.9
ONARPRT	869.1	1372.4	1250.3	1187.3
Source Groups Outside the Airport Boundary				
CAAGP	0.2	0.4	0.4	0.4
CAARE	0.1	0.2	0.2	0.2
CAOFF	1.6	3.1	4.0	3.1
CAONR	1.4	2.9	3.4	2.6
CHEVRON	971.8	2619.3	4388.3	2844.3
POWER	0.2	0.0	0.0	0.0
SHIPS	2.2	2.5	1.1	2.1
OFFAPPNT	2.5	2.3	1.6	2.2
OFFAPRD	176.6	255.2	326.7	283.0
OFFARPRT	974.7	2630.3	4398.3	2850.6

Table 24

3-Month Average PM_{10} Modeling Results for Seasonal Evaluation

Source Group	Summer (µg/m³)	Fall (µg/m³)	Winter (µg/m³)	Spring (µg/m³)
ALL	197.2	536.2	895.7	579.7
Source Groups Inside the Airport Boundary				
APPNT	13.0	6.5	1.8	4.8
ENGINES	0.3	2.3	1.1	1.8
PARK	0.8	1.6	1.5	1.4
ROADS	3.8	7.8	8.9	7.0
GATES	41.9	63.5	57.6	56.5
TAXI	1.6	2.1	1.7	2.2
TF250240	0.1	0.0	0.0	0.0
TF6070	0.0	0.0	0.0	0.0
LD250240	0.0	0.0	0.0	0.0
LD6070	0.0	0.0	0.0	0.0
RUNWAY	2.2	2.7	2.4	2.5
EDMS	42.6	66.0	60.4	58.1
ONARPRT	42.7	66.5	60.7	58.3
Source Groups Outside the Airport Boundary				
CAAGP	0.0	0.0	0.0	0.0
CAARE	0.1	0.1	0.1	0.1
CAOFF	0.1	0.2	0.2	0.2
CAONR	0.1	0.3	0.3	0.2
CHEVRON	196.7	532.3	891.8	578.2
POWER	0.2	0.0	0.0	0.0
SHIPS	0.3	0.3	0.1	0.3
OFFAPPNT	0.4	0.2	0.2	0.3
OFFAPRD	73.4	111.0	143.3	114.0
OFFARPRT	197.1	535.4	895.0	579.5

Table 25

3-Month Average $PM_{2.5}$ Modeling Results for Seasonal Evaluation

Source Group	Summer ($\mu g/m^3$)	Fall ($\mu g/m^3$)	Winter ($\mu g/m^3$)	Spring ($\mu g/m^3$)
ALL	197.0	533.6	892.8	578.7
Source Groups Inside the Airport Boundary				
APPNT	7.8	4.0	1.1	2.9
ENGINES	0.3	2.3	1.1	1.8
PARK	0.7	1.4	1.4	1.3
ROADS	3.1	5.6	6.5	5.1
GATES	40.6	61.5	55.8	54.8
TAXI	1.6	2.1	1.7	2.2
TF250240	0.1	0.0	0.0	0.0
TF6070	0.0	0.0	0.0	0.0
LD250240	0.0	0.0	0.0	0.0
LD6070	0.0	0.0	0.0	0.0
RUNWAY	2.2	2.7	2.4	2.5
EDMS	41.2	63.8	58.3	56.1
ONARPRT	41.3	64.1	58.5	56.3
Source Groups Outside the Airport Boundary				
CAAGP	0.0	0.0	0.0	0.0
CAARE	0.0	0.0	0.0	0.0
CAOFF	0.1	0.1	0.2	0.1
CAONR	0.1	0.2	0.2	0.2
CHEVRON	196.7	532.3	891.8	578.2
POWER	0.2	0.0	0.0	0.0
SHIPS	0.3	0.3	0.1	0.3
OFFAPPNT	0.3	0.2	0.2	0.3
OFFAPRD	9.9	14.9	19.7	15.2
OFFARPRT	196.9	532.8	892.2	578.5

Table 26

3-Month Average SO_2 Modeling Results for Seasonal Evaluation

Source Group	Summer (µg/m^3)	Fall (µg/m^3)	Winter (µg/m^3)	Spring (µg/m^3)
ALL	1218.0	3432.5	5814.1	3791.3
Source Groups Inside the Airport Boundary				
APPNT	0.1	0.1	0.0	0.1
ENGINES	1.0	1.2	0.8	1.1
PARK	0.1	0.1	0.1	0.1
ROADS	0.6	1.1	1.3	1.1
GATES	71.4	104.0	90.3	92.7
TAXI	8.6	11.3	8.8	10.9
TF250240	0.4	0.1	0.2	0.1
TF6070	0.0	0.0	0.0	0.0
LD250240	0.3	0.1	0.1	0.1
LD6070	0.0	0.0	0.0	0.0
RUNWAY	20.8	16.2	10.3	16.9
EDMS	72.9	110.2	96.2	95.9
ONARPRT	72.9	110.2	96.2	95.9
Source Groups Outside the Airport Boundary				
CAAGP	0.0	0.0	0.0	0.0
CAARE	0.0	0.0	0.0	0.0
CAOFF	0.0	0.0	0.1	0.0
CAONR	0.0	0.1	0.1	0.1
CHEVRON	1216.4	3429.6	5811.8	3789.0
POWER	0.0	0.0	0.0	0.0
SHIPS	3.5	4.5	2.0	3.6
OFFAPPNT	0.0	0.0	0.0	0.0
OFFAPRD	0.6	1.0	1.3	0.9
OFFARPRT	1217.8	3431.3	5813.0	3791.1

Table 27

3-Month Average VOC Modeling Results for Seasonal Evaluation

Source Group	Summer (μg/m^3)	Fall (μg/m^3)	Winter (μg/m^3)	Spring (μg/m^3)
ALL	782.6	875.4	782.5	733.7
Source Groups Inside the Airport Boundary				
APPNT	2.7	2.0	0.9	1.8
ENGINES	0.9	2.8	2.1	1.2
PARK	6.7	13.2	13.4	12.1
ROADS	12.4	25.4	29.2	22.9
GATES	476.8	838.2	743.5	700.0
TAXI	18.9	27.1	21.4	27.9
TF250240	0.0	0.0	0.0	0.0
TF6070	0.0	0.0	0.0	0.0
LD250240	0.1	0.0	0.0	0.0
LD6070	0.0	0.0	0.0	0.0
RUNWAY	2.7	2.9	2.0	2.6
EDMS	491.4	866.8	774.2	726.3
ONARPRT	491.6	867.1	774.6	726.7
Source Groups Outside the Airport Boundary				
CAAGP	0.7	1.2	1.3	1.2
CAARE	0.8	1.4	1.3	1.3
CAOFF	0.5	0.8	0.8	0.7
CAONR	1.3	2.6	2.8	2.2
CHEVRON	780.6	862.0	686.1	606.8
POWER	0.1	0.0	0.0	0.0
SHIPS	0.1	0.1	0.0	0.1
OFFAPPNT	11.4	10.4	4.7	11.2
OFFAPRD	44.7	71.8	103.7	63.8
OFFARPRT	781.5	865.0	688.2	608.7

REVIEW OF OTHER YEARS RESULTS

In this study, modeling analyses utilizing the meteorological data of summer months (June through August) from 2003 through 2007 were conducted. The evaluation assumes emissions from all modeled sources are the same for all modeled periods. Tables 28 through 33 document the maximum 1-hour modeling results for the six modeled pollutants. Tables 34 through 39 document the 3-month average modeling results. These results show that similar source contributions are attributed to the impacts for different years of meteorological data.

Table 28

Maximum 1-hour Average CO Modeling Results (Summer, 2003-2007)

Source Group	2003 (μg/m^3)	2004 (μg/m^3)	2005 (μg/m^3)	2006 (μg/m^3)	2007 (μg/m^3)
ALL	81732.9	88473.1	92523.4	83975.8	100576.0
Source Groups Inside the Airport Boundary					
APPNT	65.8	82.3	61.6	77.1	66.9
ENGINES	1241.0	1206.8	1227.8	1074.0	1347.1
PARK	397.5	28.6	340.0	376.0	374.3
ROADS	3657.4	184.3	3384.3	3835.1	3972.2
GATES	42461.5	30567.5	32046.5	30476.4	29440.3
TAXI	3265.5	132.0	3744.5	2870.0	3235.7
TF250240	8.5	0.1	9.9	9.0	8.2
TF6070	3.0	0.0	3.3	3.0	2.0
LD250240	25.8	11.5	9.5	10.1	13.4
LD6070	15.7	9.5	9.4	5.4	7.0
RUNWAY	481.1	16.4	391.1	409.8	492.3
EDMS	42774.3	30798.6	32208.3	30533.0	30888.1
ONARPRT	42774.3	2203.4	32209.8	30533.0	30890.9
Source Groups Outside the Airport Boundary					
CAAGP	4.0	3.0	3.9	4.7	3.2
CAARE	2.3	2.0	2.3	2.5	2.1
CAOFF	52.4	46.2	51.4	50.3	47.7
CAONR	285.0	162.1	234.5	226.7	293.2
CHEVRON	81643.7	88401.1	92426.0	83881.1	100498.4
POWER	35.3	1.3	40.3	38.8	37.4
SHIPS	4.1	0.1	5.0	5.0	4.4
OFFAPPNT	22.5	24.2	19.5	22.1	20.4
OFFAPRD	9494.5	6088.5	7259.2	8277.0	7556.6
OFFARPRT	81690.5	88439.5	92472.3	83924.0	100539.6

Table 29

Maximum 1-hour Average NO_X Modeling Results (Summer, 2003-2007)

Source Group	**2003 ($\mu g/m^3$)**	**2004 ($\mu g/m^3$)**	**2005 ($\mu g/m^3$)**	**2006 ($\mu g/m^3$)**	**2007 ($\mu g/m^3$)**
ALL	42593.2	46113.6	48200.1	43762.4	52406.5
Source Groups Inside the Airport Boundary					
APPNT	25.4	31.8	25.0	29.8	26.5
ENGINES	291.5	319.0	301.9	1386.6	319.5
PARK	1007.5	846.4	887.1	894.0	856.5
ROADS	829.2	715.5	733.5	966.8	823.8
GATES	9346.4	6719.0	8701.6	8697.5	7644.7
TAXI	496.7	444.0	558.5	454.6	454.6
TF250240	103.8	63.6	68.1	96.4	63.5
TF6070	12.1	9.9	10.8	11.3	9.8
LD250240	18.5	14.6	16.8	15.1	15.4
LD6070	29.1	20.0	13.8	14.9	12.3
RUNWAY	306.7	229.1	287.9	327.3	320.0
EDMS	9376.7	6777.1	8744.0	8761.3	8111.6
ONARPRT	9377.3	6777.1	8744.5	8761.5	8113.1
Source Groups Outside the Airport Boundary					
CAAGP	2.9	2.2	2.9	3.4	2.3
CAARE	1.4	1.2	1.4	1.5	1.2
CAOFF	25.0	22.0	24.3	23.8	23.1
CAONR	30.4	17.9	23.5	25.8	31.2
CHEVRON	42547.0	46068.4	48165.9	43712.9	52372.7
POWER	5.0	5.3	5.2	4.6	5.3
SHIPS	50.9	56.1	61.8	61.0	54.4
OFFAPPNT	24.8	31.8	26.7	32.1	24.2
OFFAPRD	4301.2	2880.4	3726.0	4521.4	3360.2
OFFARPRT	42577.6	46102.1	48189.7	43750.4	52396.0

Table 30

Maximum 1-hour Average PM$_{10}$ Modeling Results (Summer, 2003-2007)

Source Group	**2003 (μg/m^3)**	**2004 (μg/m^3)**	**2005 (μg/m^3)**	**2006 (μg/m^3)**	**2007 (μg/m^3)**
ALL	8654.5	9368.8	9797.7	8891.5	10650.4
Source Groups Inside the Airport Boundary					
APPNT	59.5	63.2	58.8	64.4	60.5
ENGINES	18.2	17.7	17.9	15.7	19.7
PARK	10.5	8.8	9.2	9.3	8.9
ROADS	68.8	58.0	63.5	71.8	73.9
GATES	461.7	332.2	427.6	425.5	376.7
TAXI	35.5	33.7	38.2	32.4	32.2
TF250240	1.8	1.1	1.2	1.1	0.9
TF6070	0.2	0.1	0.1	0.1	0.1
LD250240	0.6	0.4	0.4	0.5	0.4
LD6070	0.7	0.4	0.3	0.4	0.3
RUNWAY	58.2	49.6	47.8	56.6	61.0
EDMS	464.4	335.3	431.1	430.0	378.5
ONARPRT	464.4	335.4	431.0	430.1	378.5
Source Groups Outside the Airport Boundary					
CAAGP	0.3	0.2	0.3	0.3	0.2
CAARE	0.8	0.6	0.8	0.9	0.7
CAOFF	1.2	1.1	1.2	1.2	1.1
CAONR	2.7	1.6	2.1	2.3	2.8
CHEVRON	8646.5	9362.1	9788.4	8883.4	10643.3
POWER	3.2	3.4	3.6	3.5	3.4
SHIPS	6.3	6.8	7.4	7.4	5.2
OFFAPPNT	3.3	4.6	3.8	4.6	3.4
OFFAPRD	1912.1	1233.7	1491.0	1704.9	1519.4
OFFARPRT	8654.1	9368.3	9797.2	8891.0	10649.9

Table 31

Maximum 1-hour Average $PM_{2.5}$ Modeling Results (Summer, 2003-2007)

Source Group	**2003 (µg/m³)**	**2004 (µg/m³)**	**2005 (µg/m³)**	**2006 (µg/m³)**	**2007 (µg/m³)**
ALL	8648.2	9364.1	9790.1	8886.0	10644.9
Source Groups Inside the Airport Boundary					
APPNT	35.8	38.0	35.4	38.8	36.4
ENGINES	18.2	17.7	17.9	15.7	19.7
PARK	9.6	8.1	8.5	8.5	8.2
ROADS	49.9	42.0	46.3	57.6	53.4
GATES	447.4	321.9	414.4	412.3	365.0
TAXI	35.5	33.7	38.2	32.4	32.2
TF250240	1.8	1.1	1.2	1.1	0.9
TF6070	0.2	0.1	0.1	0.1	0.1
LD250240	0.6	0.4	0.4	0.5	0.4
LD6070	0.7	0.4	0.3	0.4	0.3
RUNWAY	58.2	49.6	47.8	56.6	61.0
EDMS	449.6	324.6	417.1	416.3	366.5
ONARPRT	449.6	324.6	417.1	416.3	366.5
Source Groups Outside the Airport Boundary					
CAAGP	0.2	0.1	0.2	0.2	0.2
CAARE	0.2	0.2	0.2	0.2	0.2
CAOFF	1.1	1.0	1.1	1.1	1.0
CAONR	1.9	1.1	1.5	1.6	1.9
CHEVRON	8646.5	9362.1	9788.4	8883.4	10643.3
POWER	3.2	3.4	3.6	3.5	3.4
SHIPS	6.1	6.6	7.2	7.2	5.0
OFFAPPNT	3.2	4.5	3.8	4.6	3.3
OFFAPRD	206.5	136.3	174.9	212.6	161.9
OFFARPRT	8647.8	9363.6	9789.6	8885.5	10644.4

Table 32

Maximum 1-hour Average SO_2 Modeling Results (Summer, 2003-2007)

Source Group	2003 (μg/m^3)	2004 (μg/m^3)	2005 (μg/m^3)	2006 (μg/m^3)	2007 (μg/m^3)
ALL	53741.7	57019.6	60143.0	53572.6	66528.5
Source Groups Inside the Airport Boundary					
APPNT	1.5	1.4	1.6	1.6	1.6
ENGINES	26.2	19.8	20.2	21.4	22.7
PARK	0.6	0.6	0.6	0.6	0.6
ROADS	10.5	8.5	10.0	11.2	11.4
GATES	691.6	485.0	620.4	611.0	559.7
TAXI	183.8	175.1	202.6	165.6	177.2
TF250240	8.6	4.8	4.3	4.8	3.6
TF6070	0.8	0.6	0.7	0.7	0.6
LD250240	3.8	2.8	3.0	2.6	2.4
LD6070	6.0	3.0	1.9	2.8	1.8
RUNWAY	255.3	262.7	252.7	287.1	272.4
EDMS	692.3	485.2	620.6	616.3	560.3
ONARPRT	692.3	485.2	620.7	616.3	560.4
Source Groups Outside the Airport Boundary					
CAAGP	0.1	0.1	0.1	0.1	0.1
CAARE	0.0	0.0	0.0	0.0	0.0
CAOFF	0.4	0.3	0.4	0.4	0.3
CAONR	0.8	0.4	0.6	0.6	0.8
CHEVRON	53741.7	57019.5	60142.8	53572.5	66528.5
POWER	0.3	0.3	0.3	0.3	0.3
SHIPS	77.8	82.0	93.5	92.6	76.6
OFFAPPNT	0.3	0.3	0.3	0.3	0.3
OFFAPRD	13.5	9.6	10.8	12.5	11.3
OFFARPRT	53741.7	57019.6	60143.0	53572.6	66528.5

Table 33

Maximum 1-hour Average VOC Modeling Results (Summer, 2003-2007)

Source Group	2003 (μg/m³)	2004 (μg/m³)	2005 (μg/m³)	2006 (μg/m³)	2007 (μg/m³)
ALL	13608.7	14703.6	18420.8	16040.3	16179.6
Source Groups Inside the Airport Boundary					
APPNT	25.3	29.2	30.1	31.4	28.2
ENGINES	76.2	74.1	75.3	65.9	82.6
PARK	99.4	81.8	81.2	82.7	78.4
ROADS	222.9	188.6	209.8	233.4	240.0
GATES	13568.8	14627.6	18384.4	15961.2	16137.6
TAXI	682.0	421.0	684.5	436.4	586.9
TF250240	0.4	0.4	0.4	0.5	0.4
TF6070	0.0	0.0	0.0	0.0	0.0
LD250240	1.2	0.9	1.0	1.3	1.3
LD6070	1.2	1.1	1.0	0.6	0.7
RUNWAY	113.5	99.7	113.5	214.7	138.8
EDMS	13603.5	14667.5	18413.9	16032.1	16174.4
ONARPRT	13603.6	14667.6	18415.9	16032.6	16174.4
Source Groups Outside the Airport Boundary					
CAAGP	9.1	6.8	8.9	10.5	7.2
CAARE	10.0	8.7	9.3	10.0	9.0
CAOFF	5.7	4.8	5.5	5.7	5.2
CAONR	26.3	15.2	19.9	19.5	27.0
CHEVRON	10060.2	12461.2	10685.4	10629.6	10569.2
POWER	2.3	2.5	2.6	2.5	2.4
SHIPS	2.1	2.3	2.6	2.5	2.2
OFFAPPNT	202.9	197.8	195.3	187.5	106.6
OFFAPRD	962.3	464.8	553.0	666.8	777.9
OFFARPRT	10060.3	12461.6	10694.0	10638.0	10573.2

Table 34

3-Month Average CO Modeling Results (Summer, 2003-2007)

Source Group	**2003 (μg/m³)**	**2004 (μg/m³)**	**2005 (μg/m³)**	**2006 (μg/m³)**	**2007 (μg/m³)**
ALL	2469.4	2209.9	2358.4	2307.2	2637.7
Source Groups Inside the Airport Boundary					
APPNT	8.4	5.8	8.2	8.9	8.3
ENGINES	10.2	11.2	9.8	10.7	12.7
PARK	33.8	37.4	32.3	31.5	31.8
ROADS	221.9	430.7	190.7	199.4	200.4
GATES	2362.3	2089.4	2249.8	2207.2	2513.1
TAXI	168.1	7.3	158.5	153.5	150.2
TF250240	0.2	3.0	0.2	0.2	0.2
TF6070	0.0	2047.4	0.0	0.0	0.0
LD250240	0.6	0.5	0.7	0.7	0.7
LD6070	0.1	0.1	0.1	0.1	0.0
RUNWAY	23.2	4.6	21.5	21.6	21.7
EDMS	2463.6	2203.1	2352.5	2301.1	2631.0
ONARPRT	2463.8	346.1	2352.8	2301.3	2631.3
Source Groups Outside the Airport Boundary					
CAAGP	0.3	0.3	0.3	0.3	0.3
CAARE	0.2	0.2	0.2	0.2	0.2
CAOFF	3.7	3.0	3.4	3.4	3.6
CAONR	14.5	12.3	13.4	13.2	14.3
CHEVRON	2209.2	2043.8	1909.9	1845.5	1853.4
POWER	1.8	3107.2	1.8	2.0	2.3
SHIPS	0.2	2876.8	0.2	0.2	0.2
OFFAPPNT	2.7	1.7	2.5	2.6	2.0
OFFAPRD	462.9	416.0	424.1	406.7	441.8
OFFARPRT	2212.3	30799.4	1912.9	1848.5	1857.1

Table 35

3-Month Average NO_X Modeling Results (Summer, 2003-2007)

Source Group	2003 (μg/m^3)	2004 (μg/m^3)	2005 (μg/m^3)	2006 (μg/m^3)	2007 (μg/m^3)
ALL	1177.5	1073.4	1010.3	984.4	977.0
Source Groups Inside the Airport Boundary					
APPNT	3.5	2.3	3.4	3.7	3.3
ENGINES	36.1	23.6	34.2	38.2	29.4
PARK	76.6	73.1	72.9	72.8	75.9
ROADS	52.3	44.5	51.3	49.1	53.5
GATES	800.1	719.9	784.9	761.2	853.1
TAXI	24.5	19.0	22.9	22.3	21.8
TF250240	6.2	4.5	6.0	5.9	6.2
TF6070	0.0	0.0	0.0	0.0	0.0
LD250240	1.7	8654.5	1.9	1.8	2.0
LD6070	0.1	0.1	0.1	0.1	0.1
RUNWAY	21.9	14.5	19.0	19.4	19.4
EDMS	809.7	732.0	795.3	773.0	868.8
ONARPRT	810.1	732.3	795.7	773.4	869.1
Source Groups Outside the Airport Boundary					
CAAGP	0.2	0.2	0.2	0.2	0.2
CAARE	0.1	0.1	0.1	0.1	0.1
CAOFF	1.7	1.4	1.6	1.6	1.6
CAONR	1.6	1.3	1.4	1.4	1.4
CHEVRON	1173.9	1069.1	1006.2	980.4	971.8
POWER	0.2	0.1	0.2	0.2	0.2
SHIPS	2.2	1.8	2.2	2.2	2.2
OFFAPPNT	2.9	2.0	2.8	2.8	2.5
OFFAPRD	179.6	165.4	167.9	161.2	176.6
OFFARPRT	1176.7	1071.6	1008.9	983.2	974.7

Table 36

3-Month Average PM_{10} Modeling Results (Summer, 2003-2007)

Source Group	2003 (µg/m³)	2004 (µg/m³)	2005 (µg/m³)	2006 (µg/m³)	2007 (µg/m³)
ALL	235.8	217.3	203.1	197.0	197.2
Source Groups Inside the Airport Boundary					
APPNT	12.1	8.9	12.9	13.7	13.0
ENGINES	0.2	0.3	0.2	0.2	0.3
PARK	0.8	0.8	0.8	0.8	0.8
ROADS	4.2	3.5	3.6	3.8	3.8
GATES	39.4	35.4	38.6	37.4	41.9
TAXI	1.7	1.4	1.6	1.6	1.6
TF250240	0.1	0.1	0.1	0.1	0.1
TF6070	0.0	0.0	0.0	0.0	0.0
LD250240	0.0	0.0	0.0	0.0	0.0
LD6070	0.0	0.0	0.0	0.0	0.0
RUNWAY	2.4	2.0	2.2	2.1	2.2
EDMS	39.9	36.0	39.2	38.0	42.6
ONARPRT	40.0	36.1	39.3	38.1	42.7
Source Groups Outside the Airport Boundary					
CAAGP	0.0	0.0	0.0	0.0	0.0
CAARE	0.1	0.1	0.1	0.1	0.1
CAOFF	0.1	0.1	0.1	0.1	0.1
CAONR	0.1	0.1	0.1	0.1	0.1
CHEVRON	235.2	216.8	202.6	196.5	196.7
POWER	0.2	0.1	0.2	0.2	0.2
SHIPS	0.3	0.2	0.3	0.3	0.3
OFFAPPNT	0.3	0.3	0.4	0.4	0.4
OFFAPRD	75.6	68.6	69.8	67.0	73.4
OFFARPRT	235.7	217.2	203.0	197.0	197.1

Table 37

3-Month Average $PM_{2.5}$ Modeling Results (Summer, 2003-2007)

Source Group	2003 (μg/m³)	2004 (μg/m³)	2005 (μg/m³)	2006 (μg/m³)	2007 (μg/m³)
ALL	235.5	217.1	202.9	196.8	197.0
Source Groups Inside the Airport Boundary					
APPNT	7.4	5.4	7.8	8.3	7.8
ENGINES	0.2	0.3	0.2	0.2	0.3
PARK	0.7	0.7	0.7	0.7	0.7
ROADS	3.0	2.6	3.0	2.9	3.1
GATES	38.2	34.3	37.4	36.3	40.6
TAXI	1.7	1.4	1.6	1.6	1.6
TF250240	0.1	0.1	0.1	0.1	0.1
TF6070	0.0	0.0	0.0	0.0	0.0
LD250240	0.0	0.0	0.0	0.0	0.0
LD6070	0.0	0.0	0.0	0.0	0.0
RUNWAY	2.4	2.0	2.2	2.1	2.2
EDMS	38.6	34.8	37.9	36.8	41.2
ONARPRT	38.7	34.9	37.9	36.8	41.3
Source Groups Outside the Airport Boundary					
CAAGP	0.0	0.0	0.0	0.0	0.0
CAARE	0.0	0.0	0.0	0.0	0.0
CAOFF	0.1	0.1	0.1	0.1	0.1
CAONR	0.1	0.1	0.1	0.1	0.1
CHEVRON	235.2	216.8	202.6	196.5	196.7
POWER	0.2	0.1	0.2	0.2	0.2
SHIPS	0.3	0.2	0.3	0.3	0.3
OFFAPPNT	0.3	0.2	0.3	0.3	0.3
OFFAPRD	10.3	9.4	9.5	9.1	9.9
OFFARPRT	235.5	217.0	202.8	196.7	196.9

Table 38

3-Month Average SO_2 Modeling Results (Summer, 2003-2007)

Source Group	2003 (µg/m³)	2004 (µg/m³)	2005 (µg/m³)	2006 (µg/m³)	2007 (µg/m³)
ALL	1348.4	1424.3	1165.5	1084.0	1218.0
Source Groups Inside the Airport Boundary					
APPNT	0.1	0.1	0.1	0.1	0.1
ENGINES	0.9	0.9	1.0	1.0	1.0
PARK	0.1	0.1	0.1	0.1	0.1
ROADS	0.7	0.6	0.6	0.6	0.6
GATES	68.3	60.1	66.2	64.3	71.4
TAXI	9.8	7.6	9.1	9.0	8.6
TF250240	0.4	0.3	0.4	0.4	0.4
TF6070	0.0	0.0	0.0	0.0	0.0
LD250240	0.3	0.2	0.3	0.3	0.3
LD6070	0.0	0.0	0.0	0.0	0.0
RUNWAY	23.1	16.8	22.6	22.1	20.8
EDMS	69.4	61.6	67.2	65.5	72.9
ONARPRT	69.4	61.6	67.2	65.5	72.9
Source Groups Outside the Airport Boundary					
CAAGP	0.0	0.0	0.0	0.0	0.0
CAARE	0.0	0.0	0.0	0.0	0.0
CAOFF	0.0	0.0	0.0	0.0	0.0
CAONR	0.0	0.0	0.0	0.0	0.0
CHEVRON	1345.8	1422.7	1163.5	1082.0	1216.4
POWER	0.0	0.0	0.0	0.0	0.0
SHIPS	3.9	3.1	3.8	4.0	3.5
OFFAPPNT	0.0	0.0	0.0	0.0	0.0
OFFAPRD	0.7	0.6	0.6	0.6	0.6
OFFARPRT	1348.3	1424.2	1165.4	1083.9	1217.8

Table 39

3-Month Average VOC Modeling Results (Summer, 2003-2007)

Source Group	2003 (μg/m³)	2004 (μg/m³)	2005 (μg/m³)	2006 (μg/m³)	2007 (μg/m³)
ALL	481.7	624.9	656.0	556.1	782.6
Source Groups Inside the Airport Boundary					
APPNT	2.9	1.9	2.7	2.7	2.7
ENGINES	0.6	0.8	0.7	0.6	0.9
PARK	6.9	6.5	6.4	6.4	6.7
ROADS	13.8	11.4	12.0	12.3	12.4
GATES	402.4	408.2	402.7	395.0	476.8
TAXI	20.5	16.9	20.0	19.1	18.9
TF250240	0.0	0.0	0.0	0.0	0.0
TF6070	0.0	0.0	0.0	0.0	0.0
LD250240	0.0	0.0	0.0	0.0	0.1
LD6070	0.0	0.0	0.0	0.0	0.0
RUNWAY	3.0	2.1	2.7	2.8	2.7
EDMS	415.5	421.9	415.8	407.4	491.4
ONARPRT	415.7	422.1	415.9	407.6	491.6
Source Groups Outside the Airport Boundary					
CAAGP	0.7	0.6	0.7	0.7	0.7
CAARE	0.8	0.7	0.8	0.7	0.8
CAOFF	0.4	0.4	0.4	0.4	0.5
CAONR	1.3	1.1	1.2	1.2	1.3
CHEVRON	480.1	623.3	654.7	554.6	780.6
POWER	0.1	0.1	0.1	0.1	0.1
SHIPS	0.1	0.1	0.1	0.1	0.1
OFFAPPNT	15.4	9.0	13.0	13.5	11.4
OFFAPRD	47.3	42.3	43.1	41.2	44.7
OFFARPRT	481.0	624.1	655.6	555.5	781.5

SECTION 5 – SUMMARY AND PATH FORWARD

SUMMARY OF RESULTS AND IMPLICATIONS

The dispersion modeling results from this study reveal several groups of sources including Chevron El Segundo Refinery (CHEVRON), Off-Airport Roadways (OFFAPRD), and Terminal Aircraft Parking Areas (GATES) as the potential noticeable contributors to the air quality impacts near LAX. Several on-airport sources (e.g., Airport Runways (RUNWAY), Airport Taxiways (TAXI), and Airport Roadways (ROADS) also contribute in narrow geographic areas inside or immediately adjacent to the Airport, with a much lower magnitude of impacts. Marine sources (SHIPS) do not show significant impacts in the modeled domain. However, it seems this finding should be further evaluated by refining the marine emissions and assessing the potential sea-land breeze effects on the dispersion.

The CHEVRON emissions show dominant impacts for all modeled pollutants except VOC. The VOC emissions from the GATES source group contribute higher impact than the CHEVRON group. Furthermore, the OFFAPRD source group shows noticeable impacts for all modeled pollutants along the highways near the airport (e.g., I-405 and I-105).

Table 40 lists the major contributors of potential air quality impacts due to different groups of emissions. While impact patterns due to airport emissions are identifiable and distinctive for most analyzed cases, the highest concentrations in the modeling domain can be dominated by contributions from off-airport stationary sources (e.g., in the area near the emission sources of Chevron). Based on the results from the study, it seems patterns (e.g., locations and shapes of concentration contours with respect to emission source locations) of long-term average (e.g., 3-month) concentration distribution for the airport sources are more distinctive than those for short-term (e.g., 1-hour) averages. In addition, the airport source impacts are more apparently shown in the concentration contour patterns of CO, NOx, SO_2, VOC than those of PM_{10} and $PM_{2.5}$. The impacts due to emissions of PM_{10} and $PM_{2.5}$ from off-airport roads and large off-airport point sources (e.g., CHEVRON) may mask or obscure the impacts due to the airport sources.

Overall, while several off-airport emission source groups (especially the CHEVRON and OFFAPRD source groups) are expected to create elevated concentration areas in the vicinity of their own locations, it seems the elevated concentration areas and contour patterns contributable to airport emissions (e.g., GATES, ROADS, TAXI, and RUNWAY) are readily identifiable with little overlapping among the impact areas of interest contributed by other source groups (e.g., Chevron or off-airport roads). This finding indicates encouraging possibility to evaluate the apportionment due to airport sources in the nearby areas. In particular, the dispersion modeling results can help to identify and evaluate the strategies for placement of the monitor network in the next phase. Overall, the following consideration is necessary in determining the placement of monitors:

- The monitors should be located nearby contours depicting pollutant concentration. These contours are based on the dispersion modeling analysis for different source group contributions.
- The distance to the monitors should consider the rate of concentration changes.
- The monitors should reflect seasonal variation of wind patterns (e.g., wind speed and direction).

Figure 84 shows the seasonal wind patterns (frequency of wind speed at different directions) based on the 2007 data. Considering that the airport aircraft activities primarily occur from early morning to late evening, Figure 85 shows the seasonal wind patterns for the hours between 8am and 11pm of the 2007 data. The wind direction in the wind rose plots indicates the direction where the wind is blowing from. Wind patterns in both Figure 84 and Figure 85 show that, for summer, fall, and spring, the prevailing wind direction is from southwest/west. In winter, the prevailing wind comes from the west/northwest along with less frequent but noticeable winds from all other directions. Since air dispersion and impacts occur in downwind directions, the placement of monitors should primarily consider the areas located east, northeast, and southeast of the airport in order to capture the anticipated airport impacts. This finding is also supported by the dispersion modeling results discovered in this demonstration study. Regarding the wind pattern in the area, another interesting note is that there is quite frequent calm wind (e.g., with no or very low wind speed with almost unidentifiable wind direction) in the area across different seasons. The calm wind hours range from about 7% in summer to abut 16% in winter, when only the hours between 8am and 11pm are considered. Calm wind conditions can result in significant concentrations near the emission sources due to limited dispersion/mixing of the emissions with ambient air. However, these elevated concentrations would be limited in areas only immediately to the sources with significant emissions.

As shown by the concentration contours documented in Figures 10 through 83, pollutant concentrations due to the airport emissions decrease quickly as the pollutants disperse downwind. The pollutant concentrations decrease by tens of times between the elevated concentration areas inside the airport (e.g., the gate areas) and the airport boundary at the east/southeast/northeast sides. Within a distance of a few kilometers, the concentrations drop by hundreds of times from the peak concentrations. These findings conclude that the monitor placement should focus on the areas within a few kilometers from the east/southeast/northeast boundary of the airport. Furthermore, impacts from the refinery and I-405/I-105 emissions can also be significant in the study area.

Overall, based on the dispersion modeling results obtained in this demonstration study, the following strategies for the monitor placement are recommended in identifying and assessing the airport source apportionment in the nearby areas (note that the recommendations may only be relevant to the modeled pollutants in this study):

- Locate monitor(s) in the area north and northeast of the refinery – these monitors will help to capture the potential refinery downwind impacts toward the airport.
- Locate monitor(s) along the west side of I-405 (e.g., northwest corner of I-405/I-105 intersection, southwest corner of I-405/Manchester intersection, and northwest corner of I405/El Segundo intersection) – these monitors will help to capture the potential impacts from the off-airport road emissions toward the airport.
- Locate monitor(s) in the vicinity of elevated concentration areas inside the airport (e.g., cargo gate areas, east ends of runways) as well as downwind directions near those sources (e.g., PS4 and PS5 in the demonstration study) – these monitors will help to confirm the impacts from airport source groups with potential significant impacts.
- Locate monitor(s) in the vicinity areas (e.g., with a distance of a few kilometers) in the directions of east, southeast,, and northeast of the airport boundary – these monitor will likely capture the identifiable impacts due to airport emissions.
- Place monitor(s) in downwind directions of prevailing low (e.g., 1-2 m/s) and intermediate (4-5 m/s) wind speeds that may favor the occurrence of elevated concentrations around selected focus areas.

Furthermore, the modeling results of different pollutants emitted from various source groups could be orders of magnitude different. The selection of monitoring equipment and related detection limits depends on the pollutants of interest (e.g., criteria pollutant vs. speciation of VOC and PM composition) and averaging periods (e.g., 1-hour vs. 3-month). For the six pollutants modeled in this demonstration study, concentrations of interest would be at least tens micrograms per cubic meter. These levels of concentrations should be factored in the selection of equipment and detection limits.

Table 40

Summary of Air Quality Impact Contributors

Pollutant	Averaging Period	Focus Areas	Major Contributors
CO	1-Hour	3km South of Airport	Chevron
	3-Month	Airport Gates	Gates
NO_X	1-Hour	3km South of Airport	Chevron
	3-Month	3km South of Airport, Airport Gates	Chevron, Gates
PM_{10}	1-Hour	3km South of Airport, Off-airport Roads, Gates	Chevron, Highways, Gates
	3-Month	3km South of Airport, Off-airport Roads	Chevron, Highways
$PM_{2.5}$	1-Hour	3km South of Airport, Off-airport Roads	Chevron, Highways
	3-Month	3km South of Airport, Off-airport Roads	Chevron, Highways
SO_2	1-Hour	3km South of Airport	Chevron
	3-Month	3km South of Airport	Chevron
VOC	1-Hour	3km South of Airport; Inside Airport	Chevron, Airport Sources
	3-Month	3km South of Airport; Inside Airport	Chevron, Airport Sources

PATH FORWARD – REFINEMENTS OF DISERPSION MODELING ANALYSES

While this demonstration study shows promising technical approach/tools for airport source apportionment assessment, refinements of several technical aspects in the next phase are desired. This modeling study elucidated a number of factors contributing to air pollution from and surrounding the LAX airport. As part of this project, additional refinements were identified to refine the modeling estimates. Specific areas for refinements include:

- Obtain and/or develop stack data for sources that were not available. This includes:
    - LAWA stationary sources
    - Chevron
    - Marine sources
    - On and Off-Airport Individual Stationary Sources
- Develop temporal data for sources that did not have it available. This includes:
    - LAWA stationary sources
    - Chevron
    - Marine sources
    - On and off-airport individual stationary sources
    - Aggregated sources to include changes related to weekend/weekday and seasonal variability
    - On-road data to include changes related to weekend/weekday and seasonal variability
    - Refine on-road sources (CHAPIS and on-airport) to include fugitive dust from roads
- Review and refine emission estimate methodologies for related sources (e.g., aircraft, GSE, motor vehicles, and marine emissions)
- Improve/update mobile source emission factors (including Diesel Particulate Matter); and
- Evaluate updated or more reliable emission data and source parameters for major point sources (e.g., Chevron) with identified significant impacts in the modeling domain.

SECTION 6

REFERENCES

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Appendix A
Report Figures

Figure 1 - Study Region

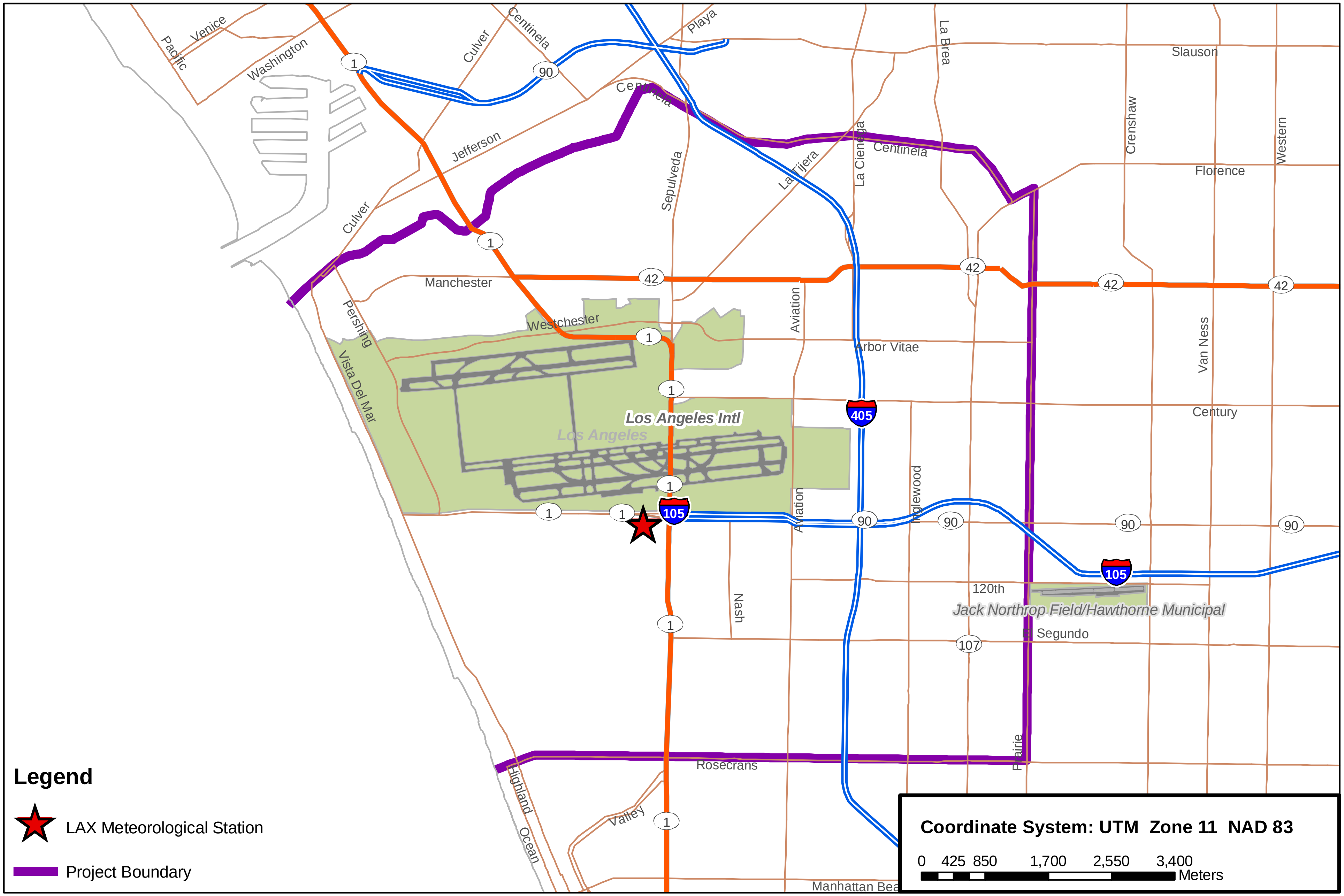


Figure 2 - Receptor Network

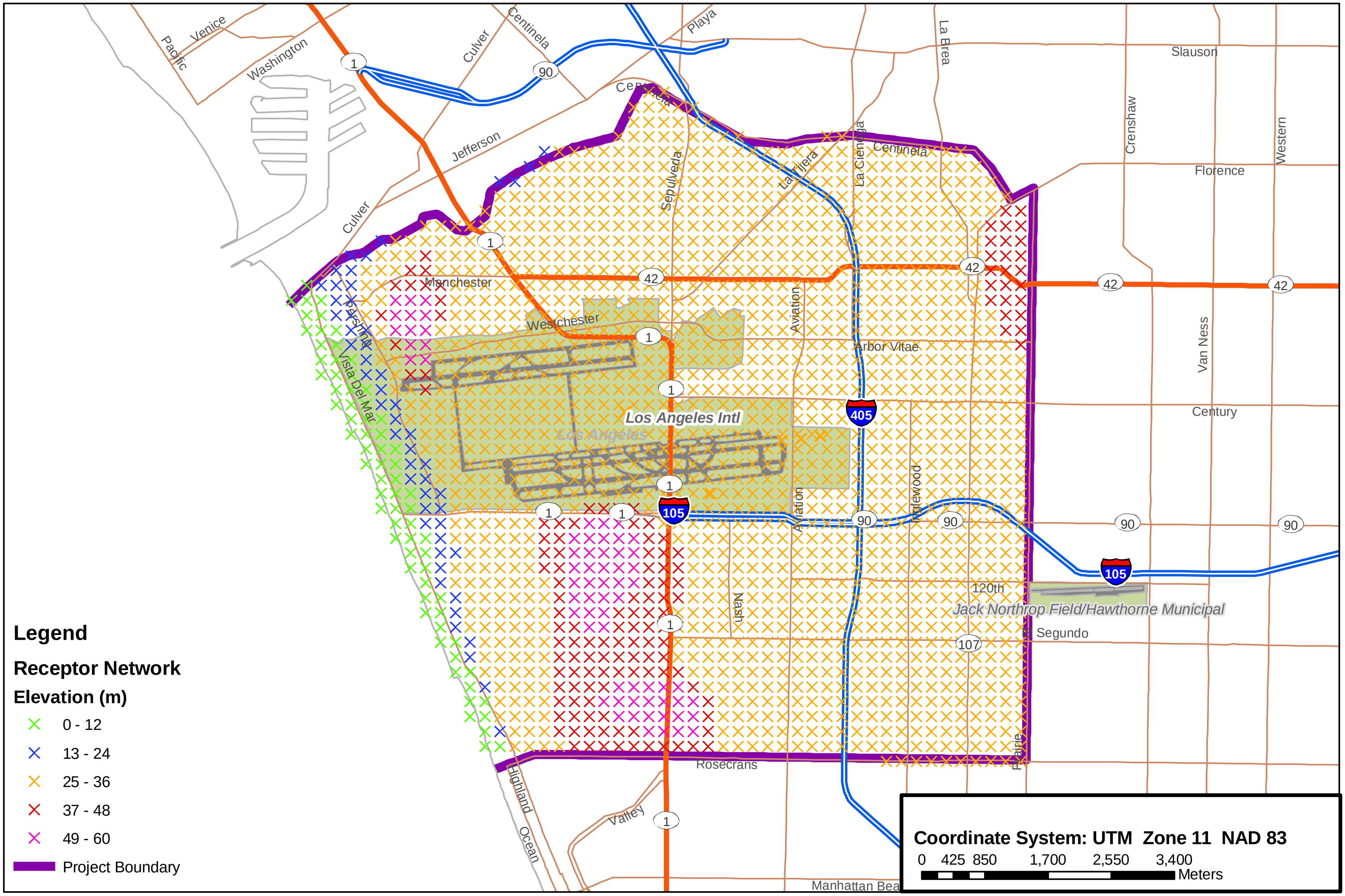


Figure 3 - Aircraft and Related Emission Sources (EDMS)

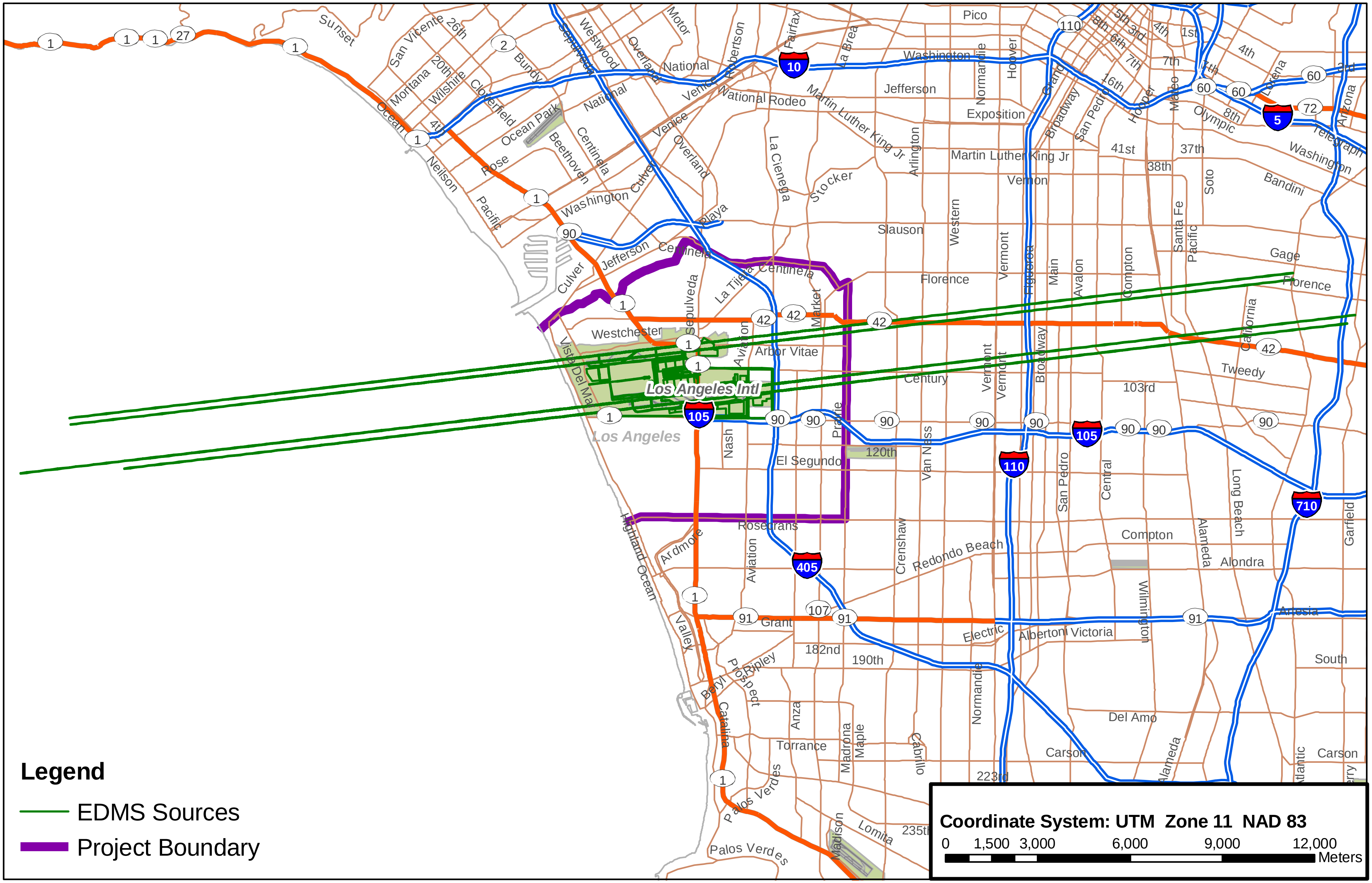


Figure 4 - Aircraft and Related Emission Sources (EDMS) - Close Up

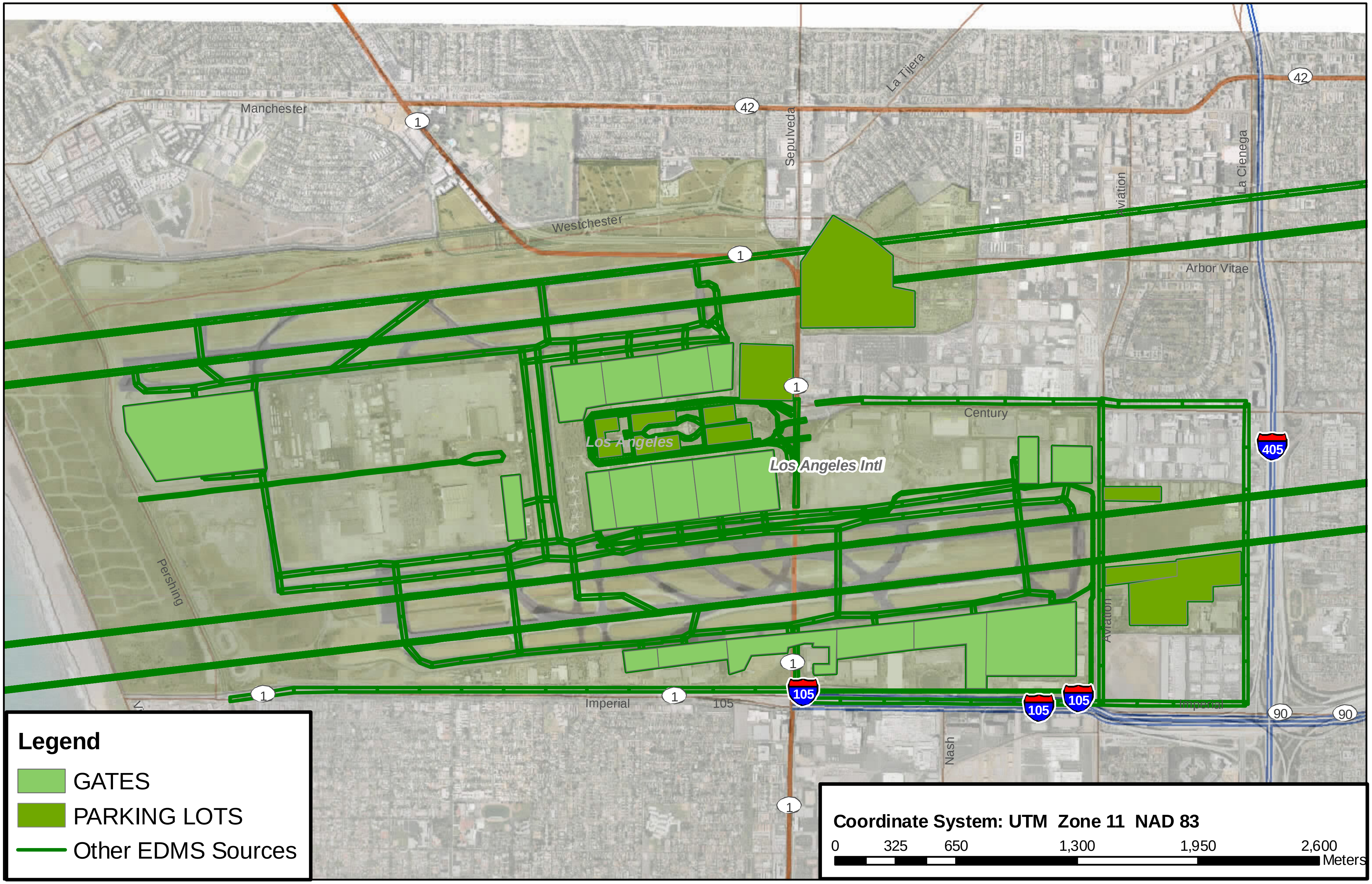


Figure 5 - On-Airport Point Stationary Sources

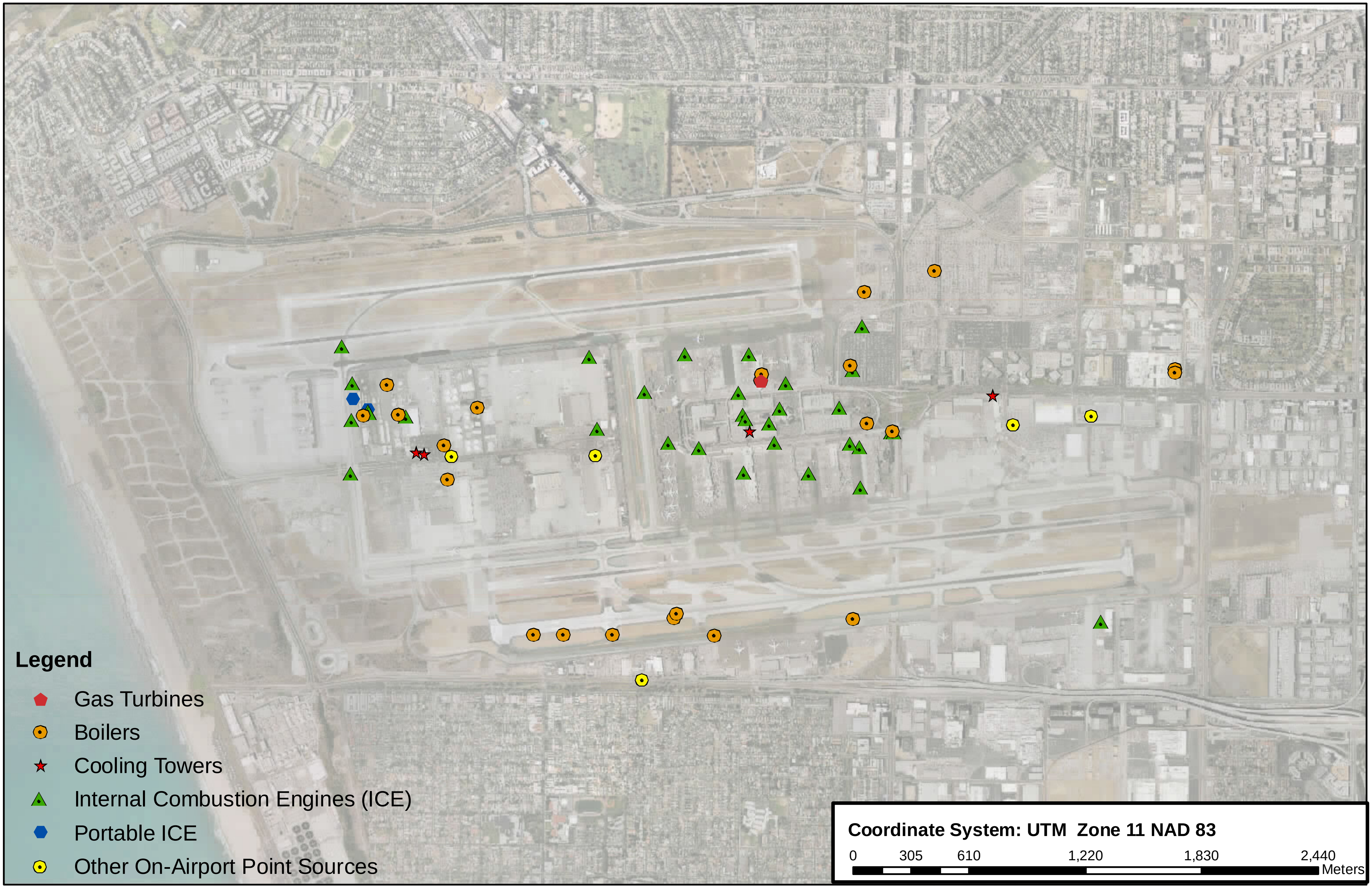


Figure 6 - Off-Airport Stationary Emission Sources

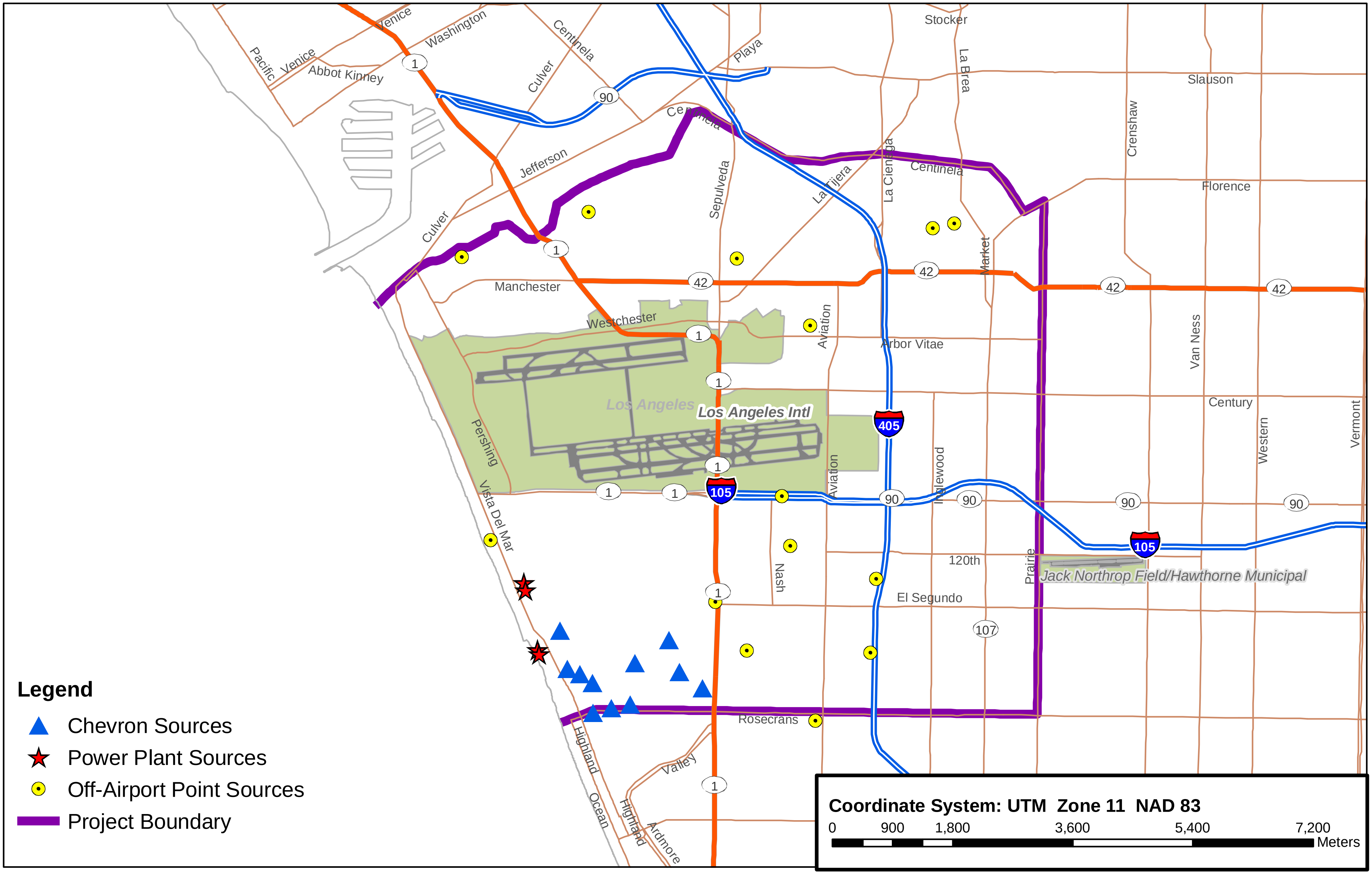


Figure 7 - Marine Emission Sources

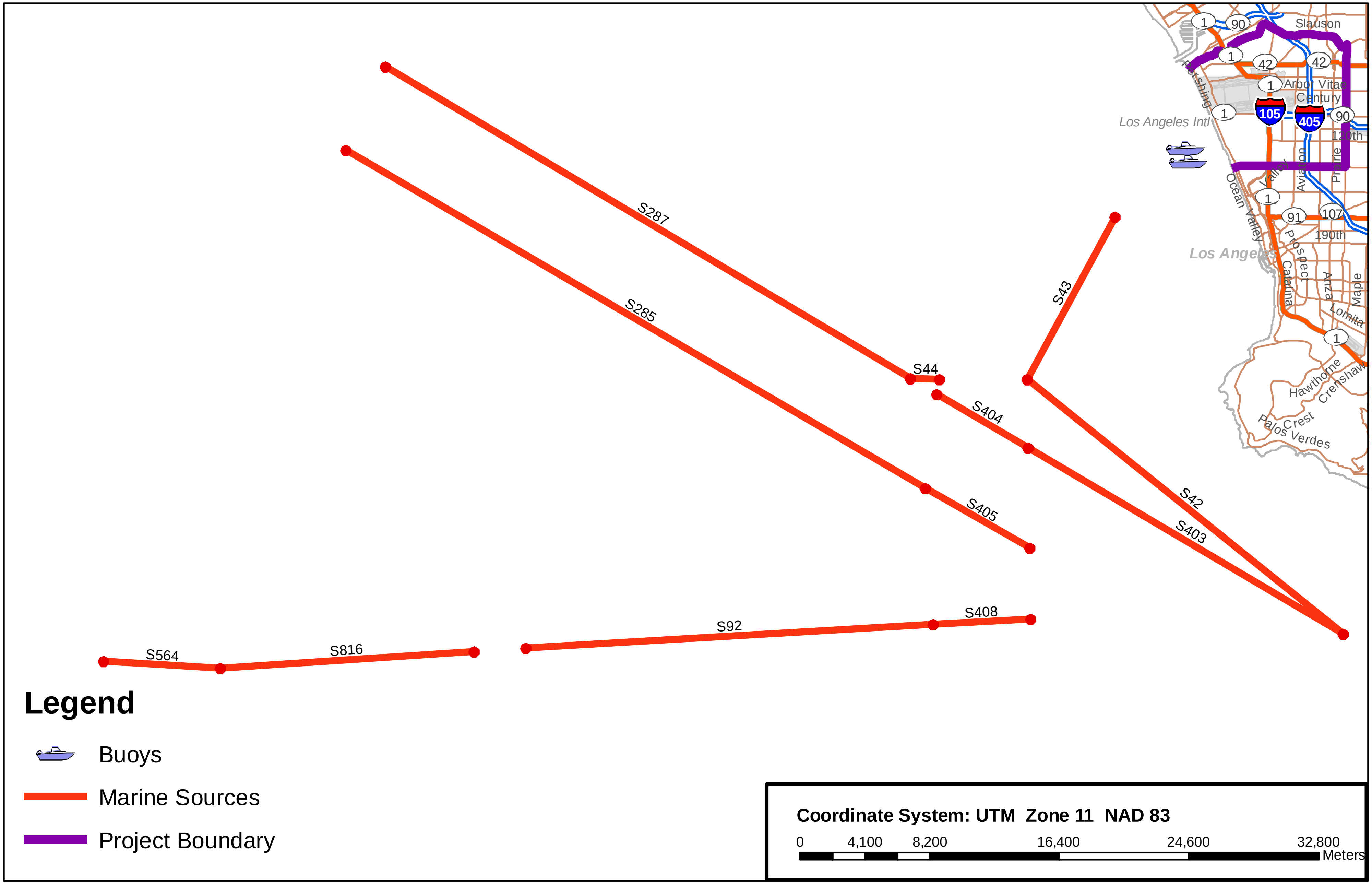


Figure 8 - Aggregated Point Emission Sources

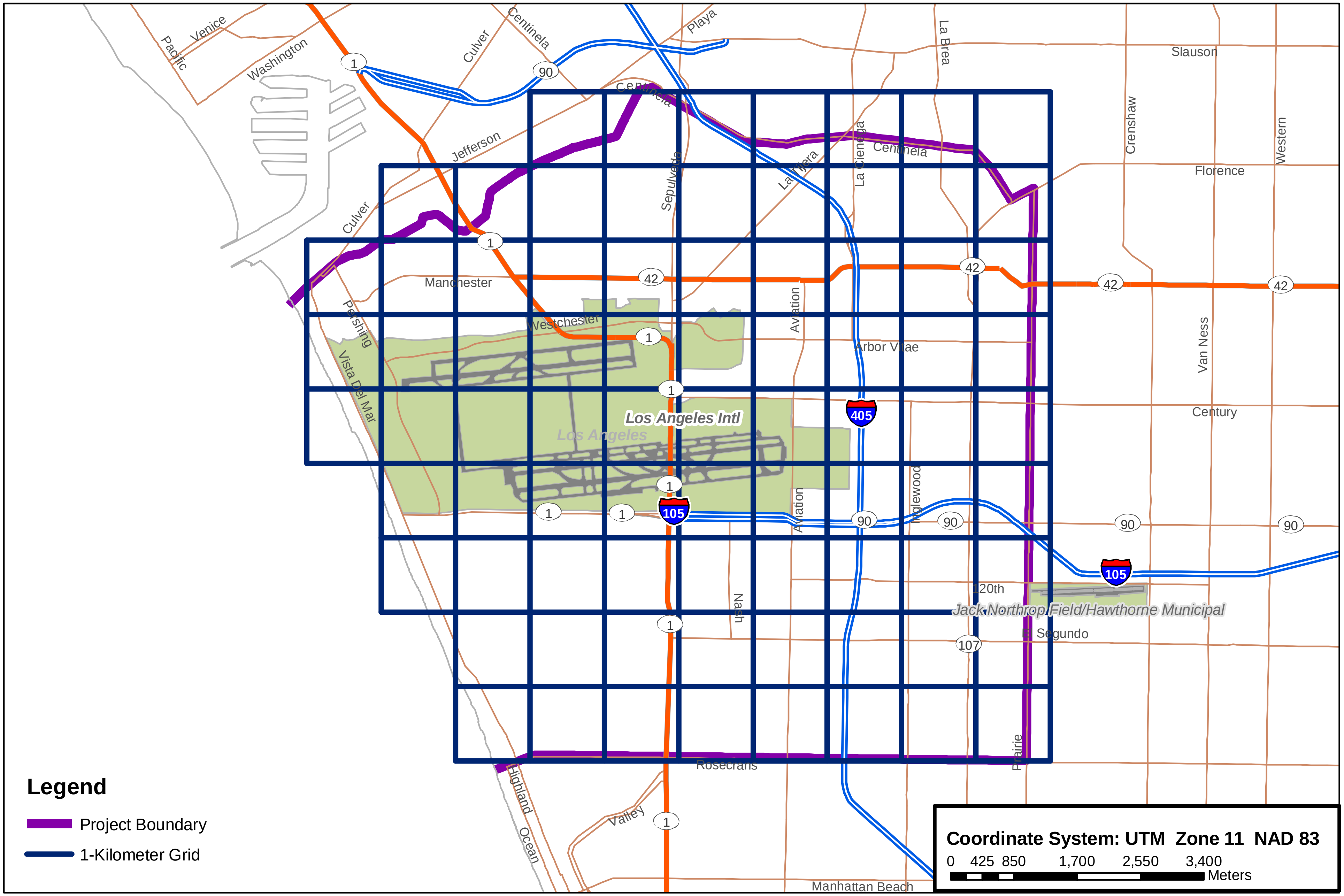


Figure 9 - Off-Airport Individual Road Emission Sources

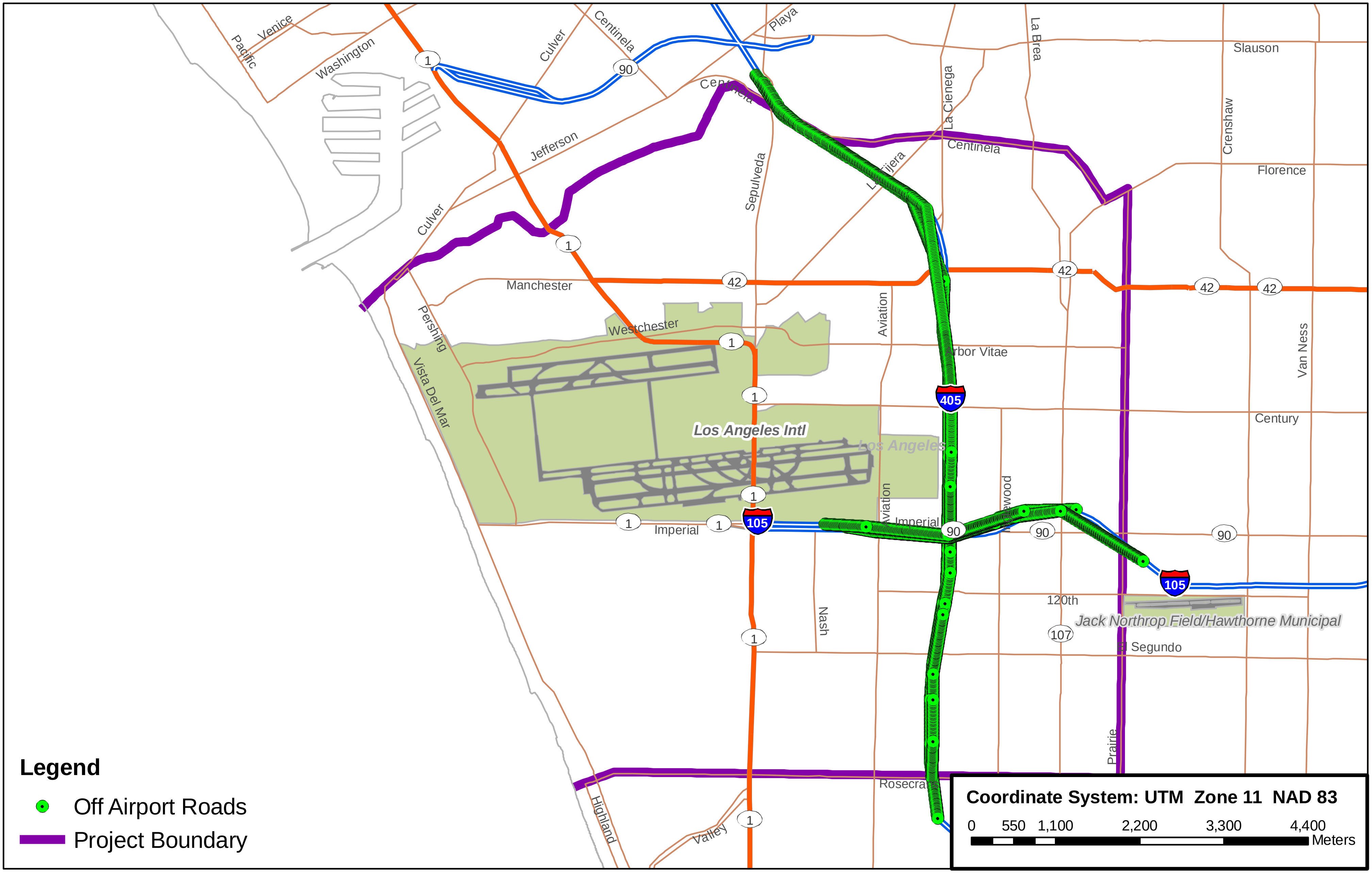
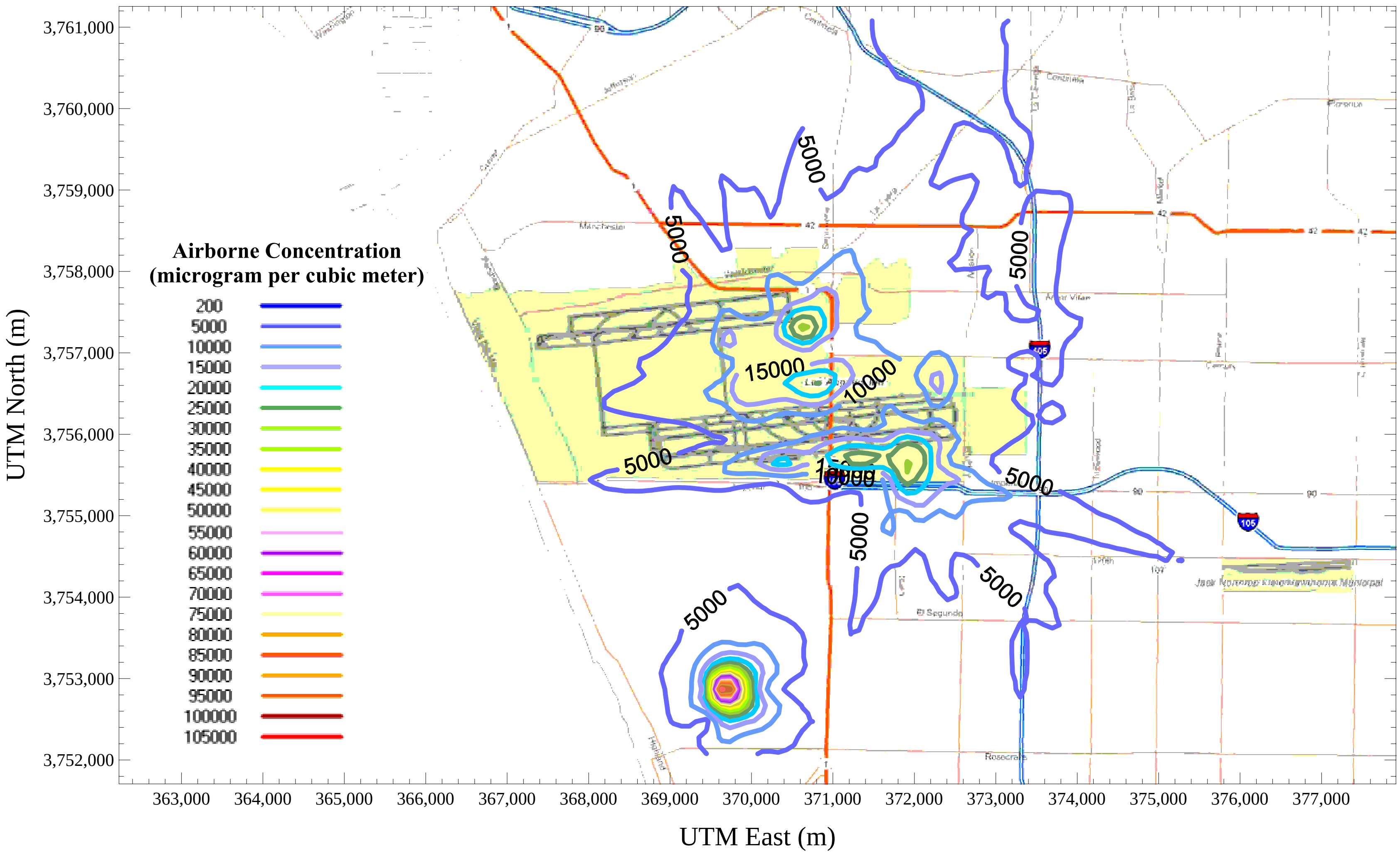
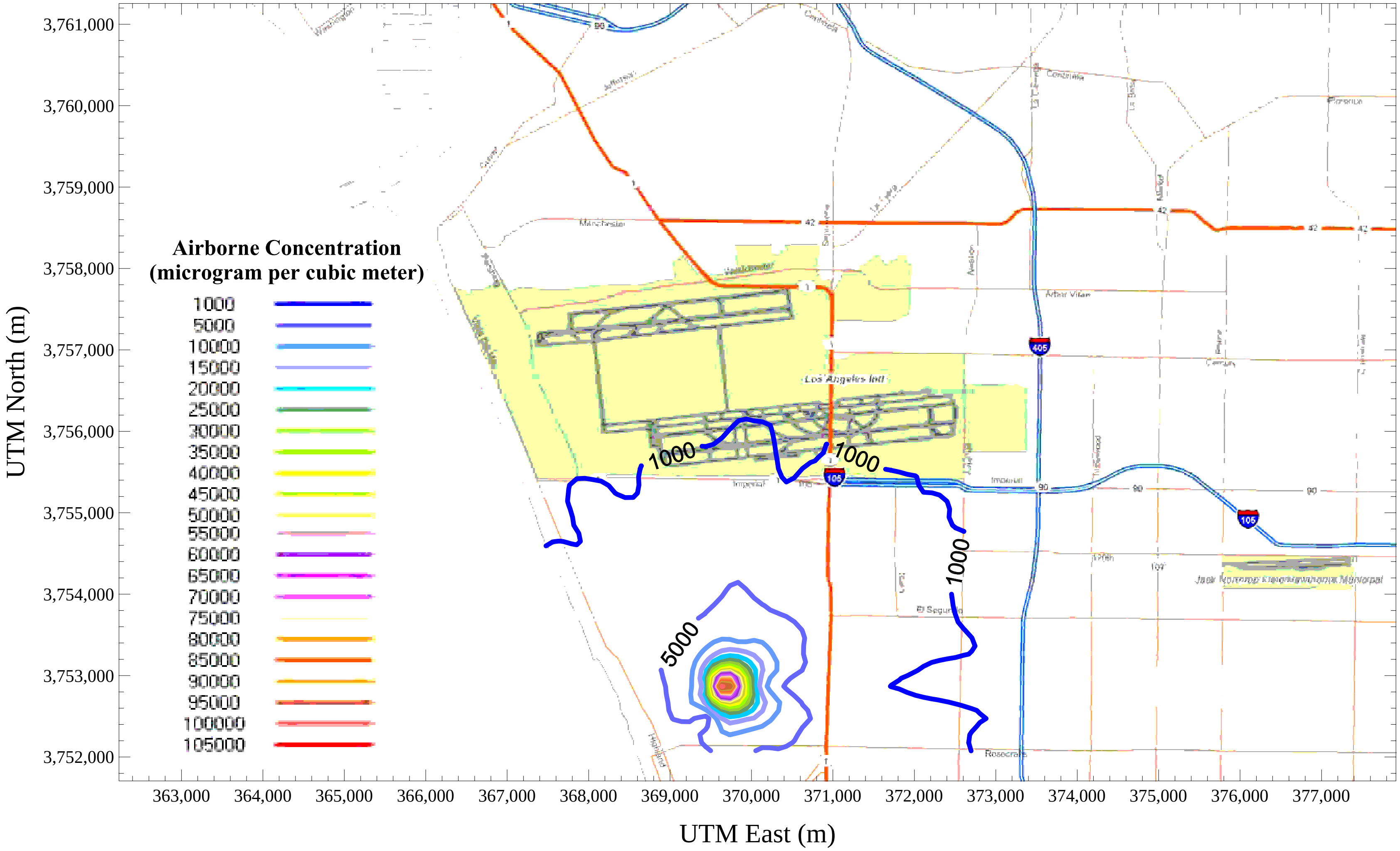


Figure 10 - Maximum 1-hour CO Concentrations from All Sources - Summer 2007



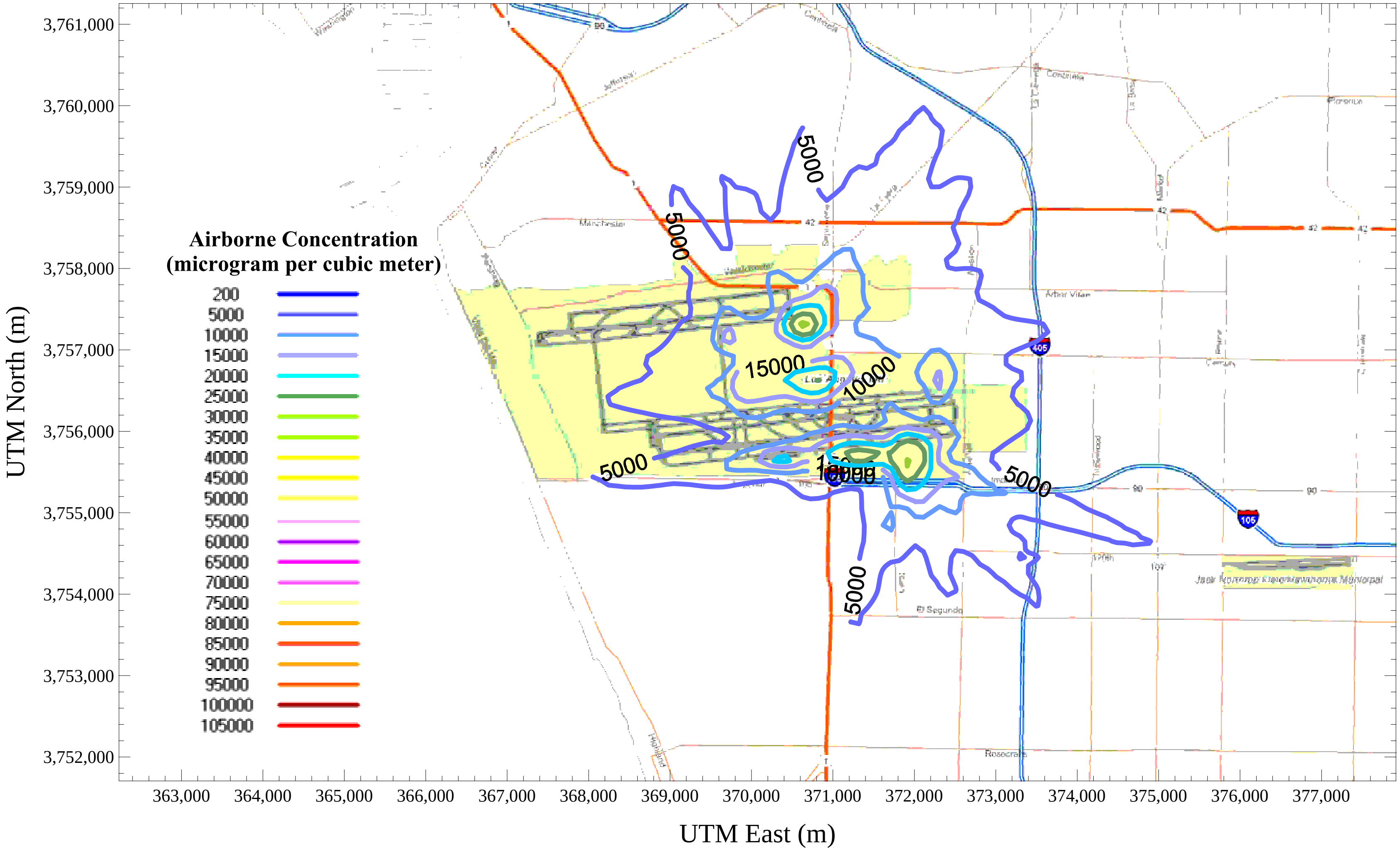
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 11 - Maximum 1-hour CO Concentrations from Chevron Sources - Summer 2007



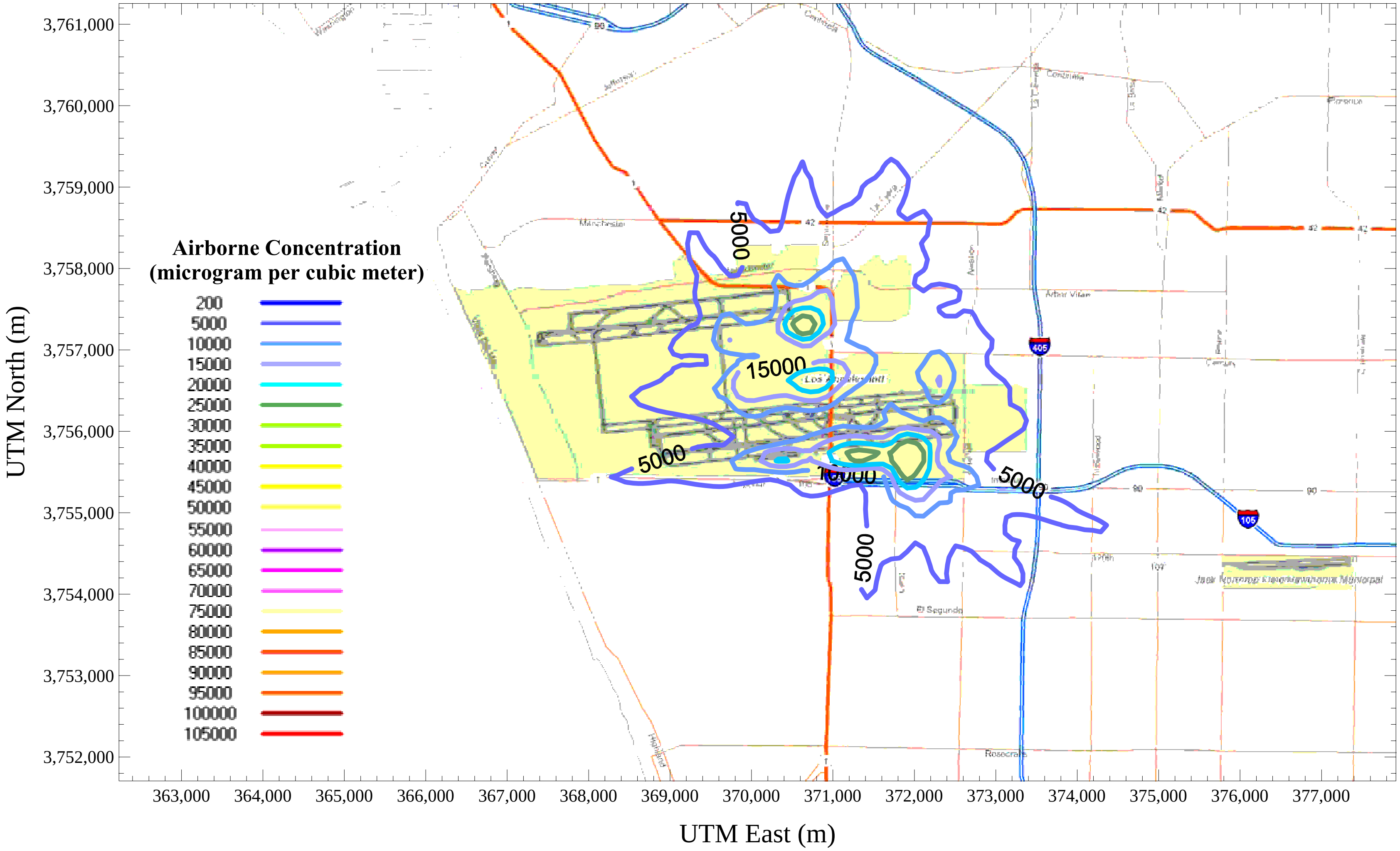
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 12 - Maximum 1-hour CO Concentrations from Airport Sources - Summer 2007



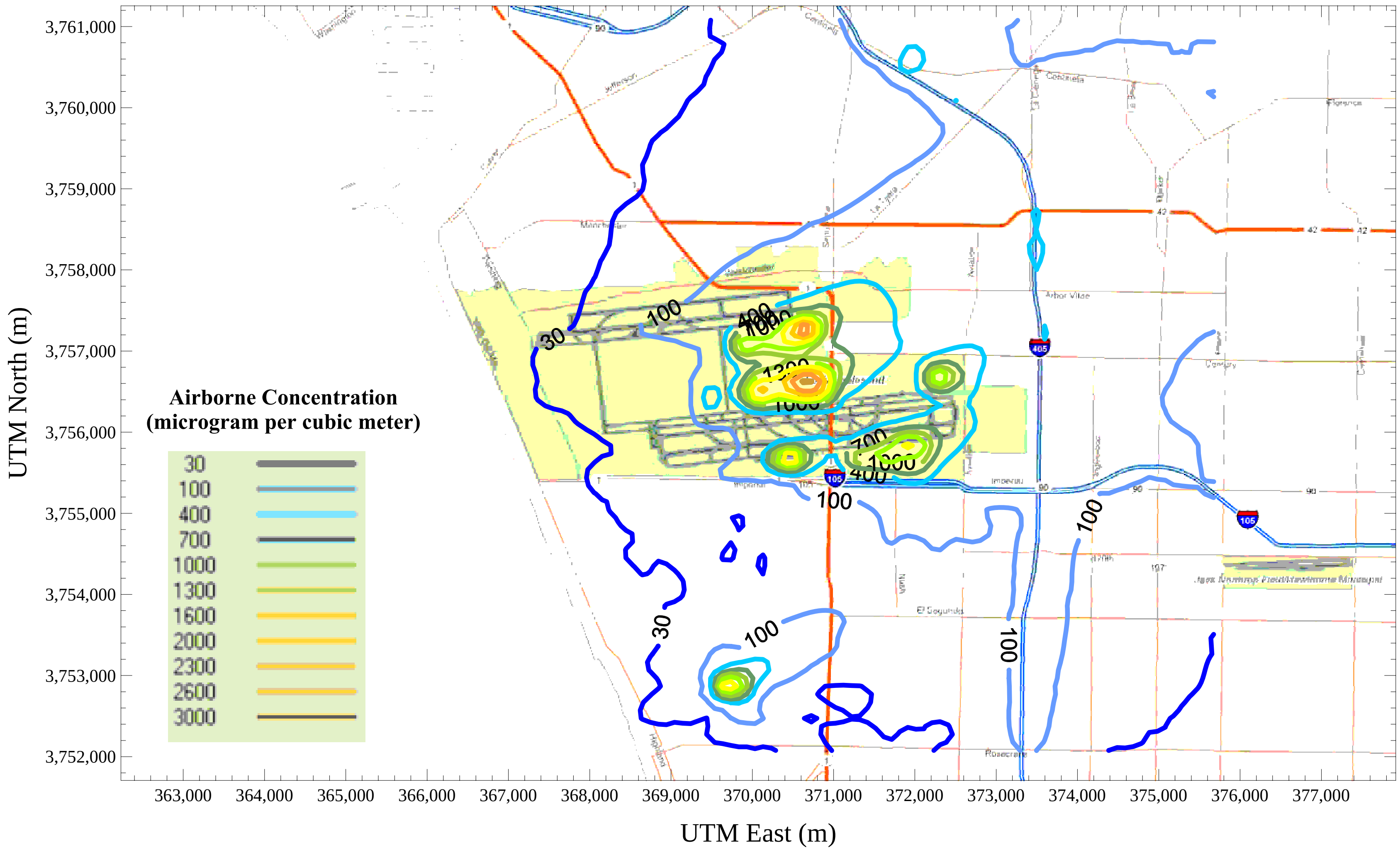
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 13 - Maximum 1-hour CO Concentrations from Gate Sources - Summer 2007



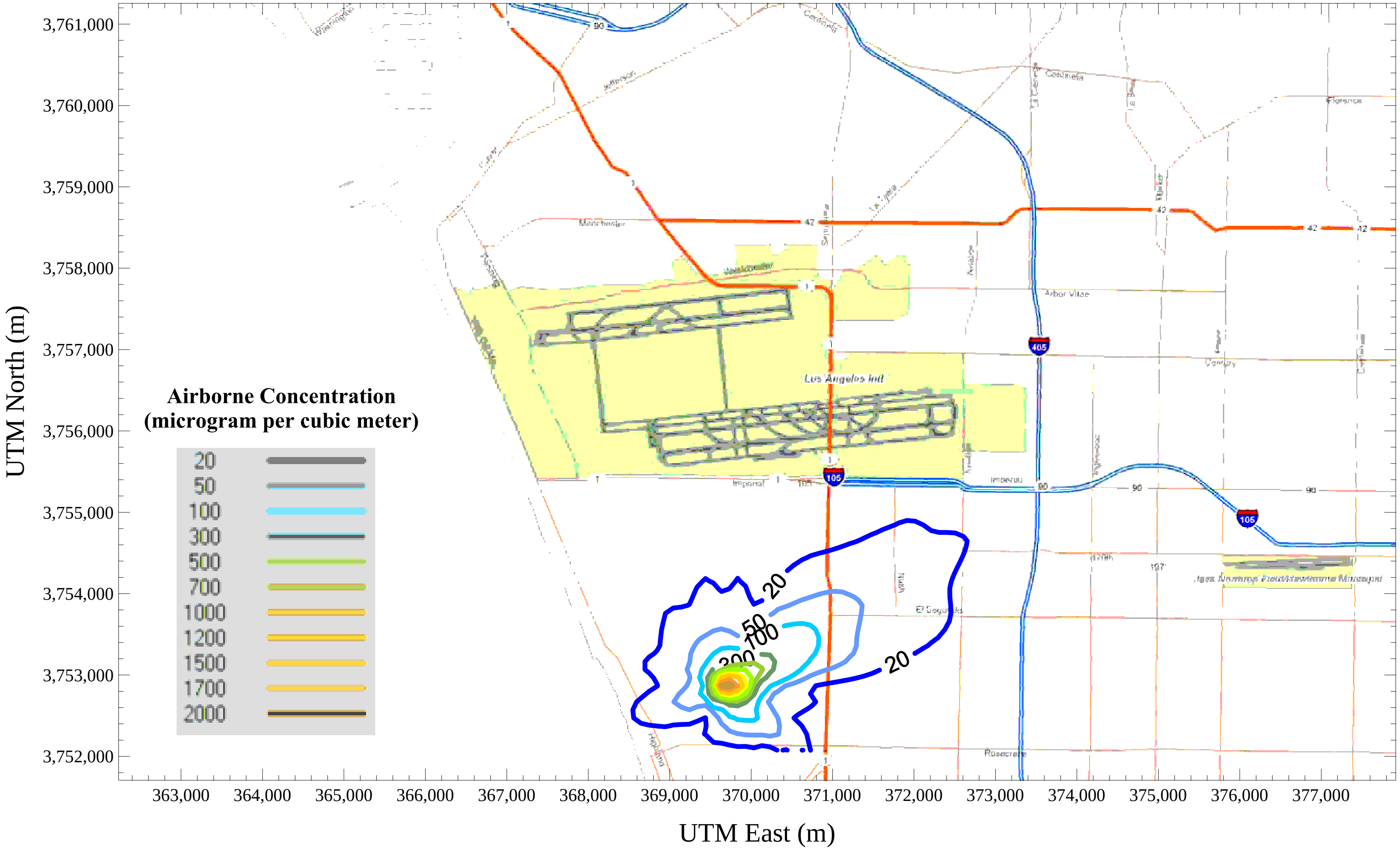
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 14 - 3-month CO Concentrations from All Sources - Summer 2007



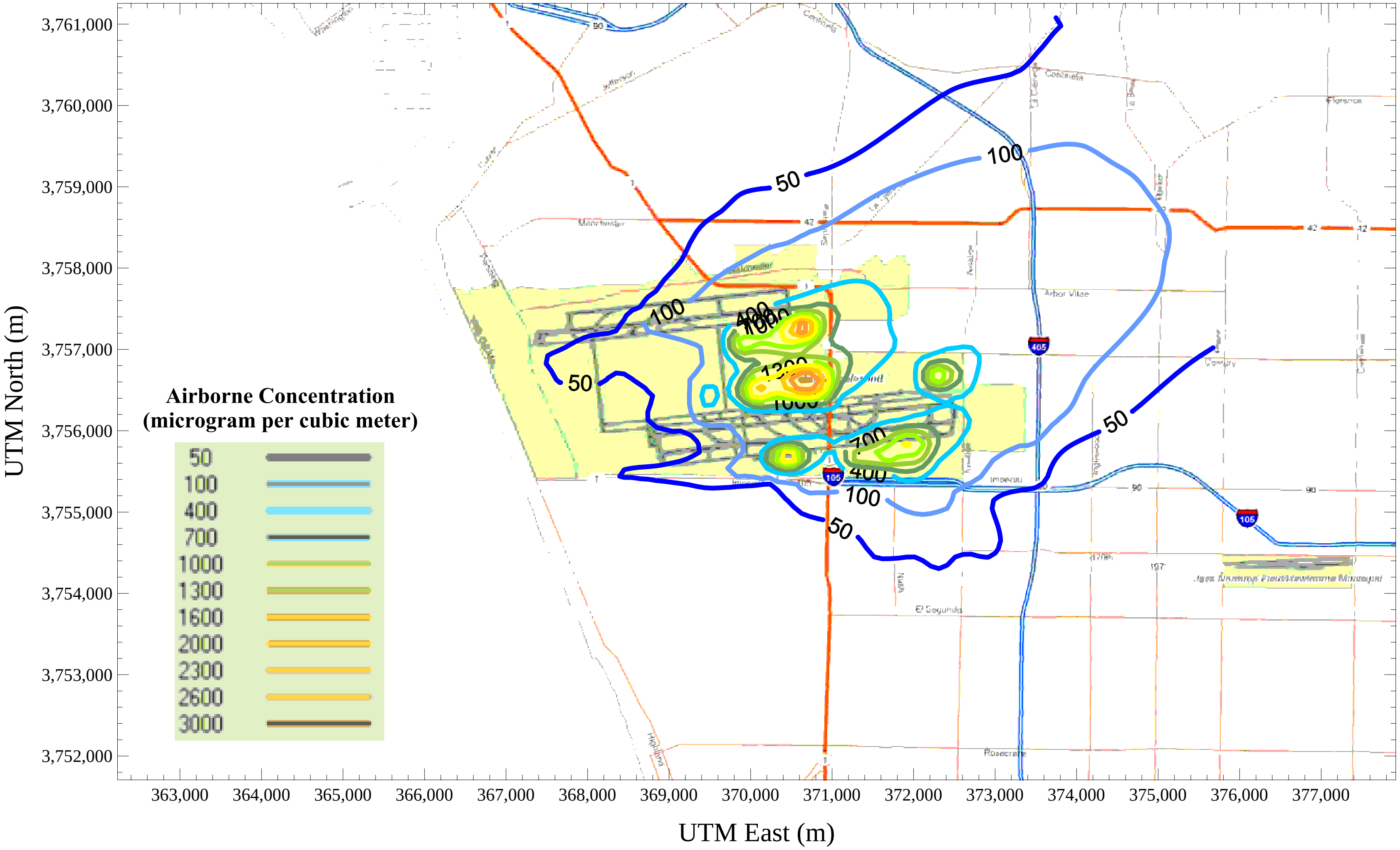
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 15 - 3-month CO Concentrations from Chevron Sources - Summer 2007



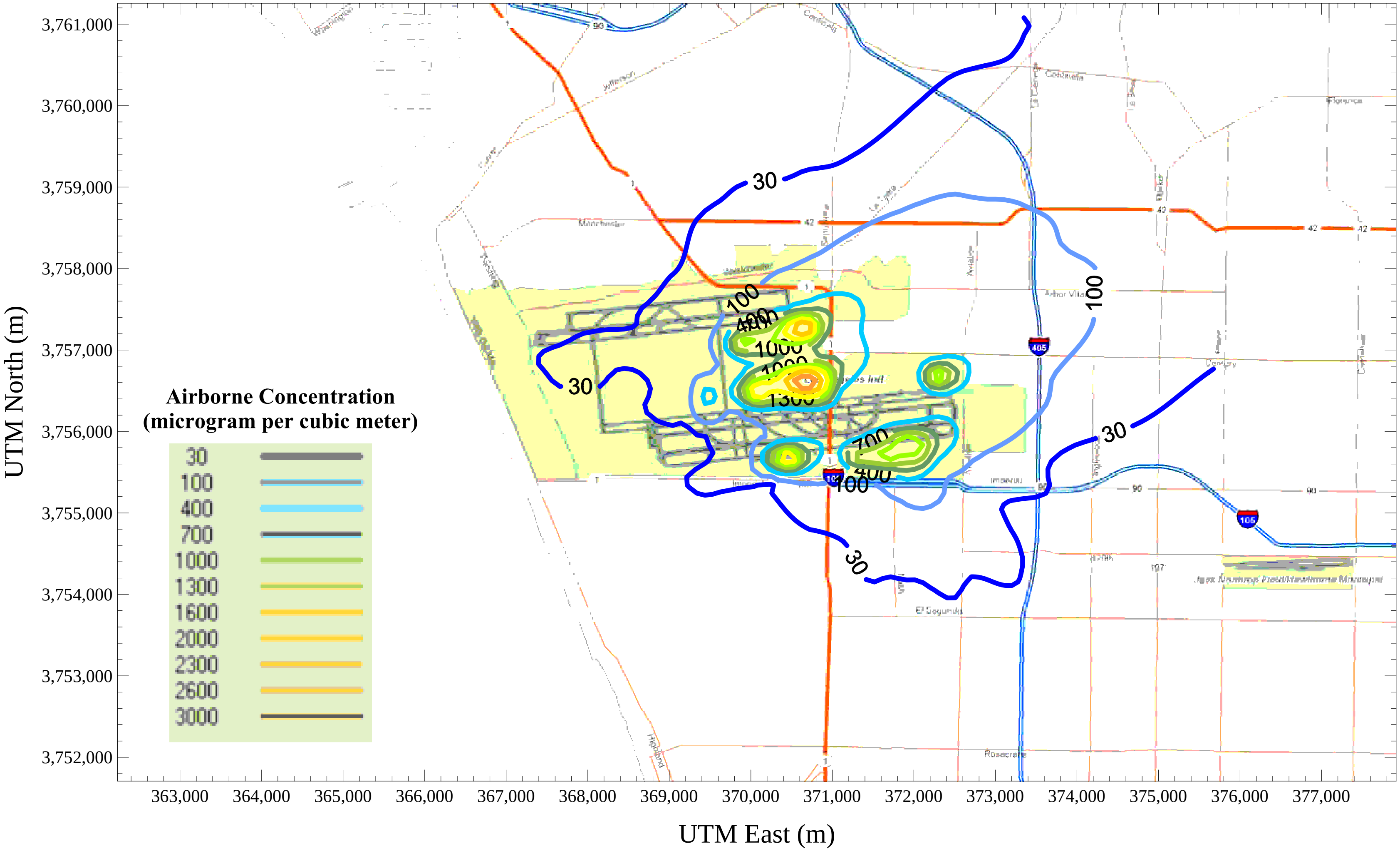
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 16 - 3-month CO Concentrations from Airport Sources - Summer 2007



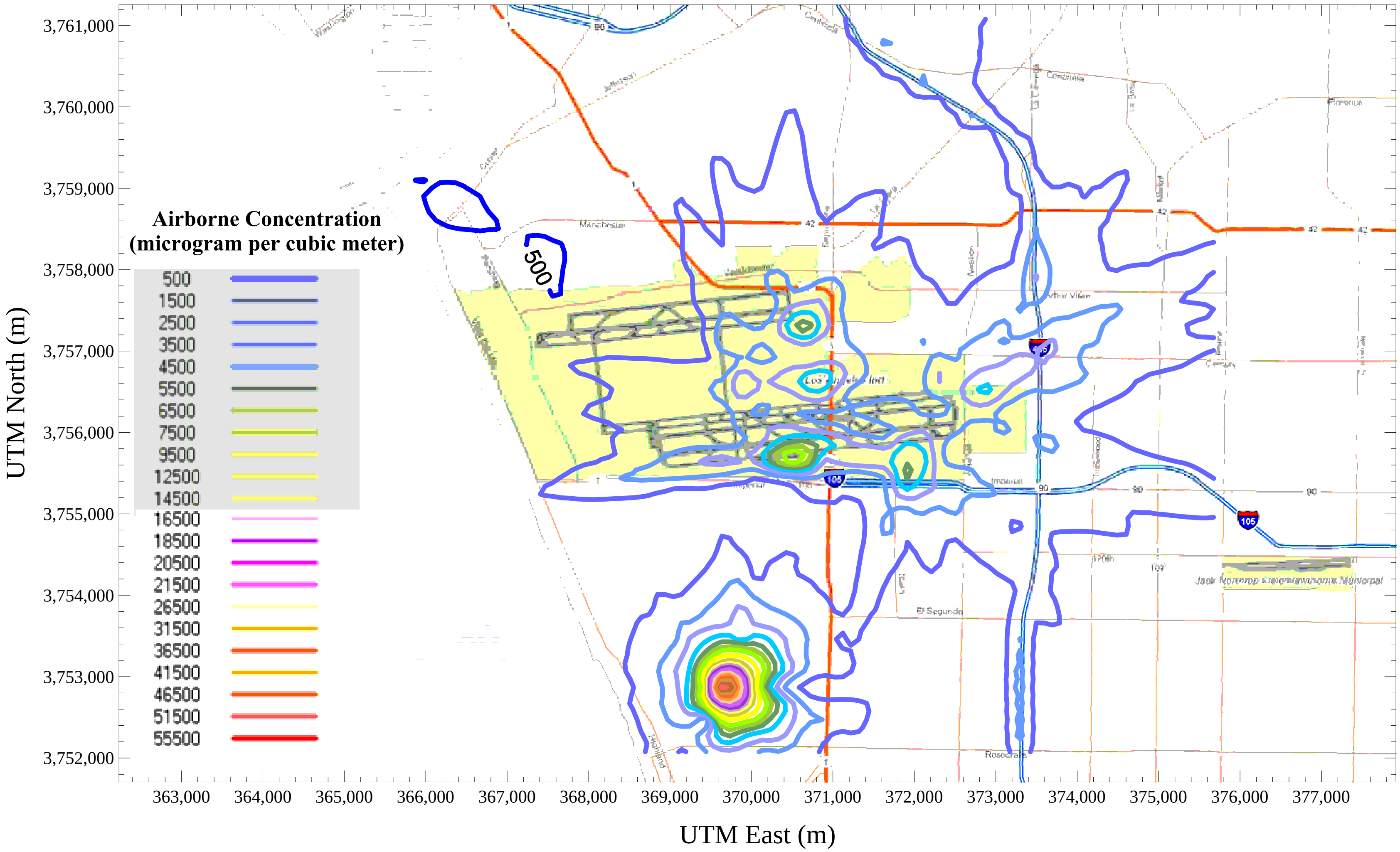
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 17 - 3-month CO Concentrations from Gate Sources - Summer 2007



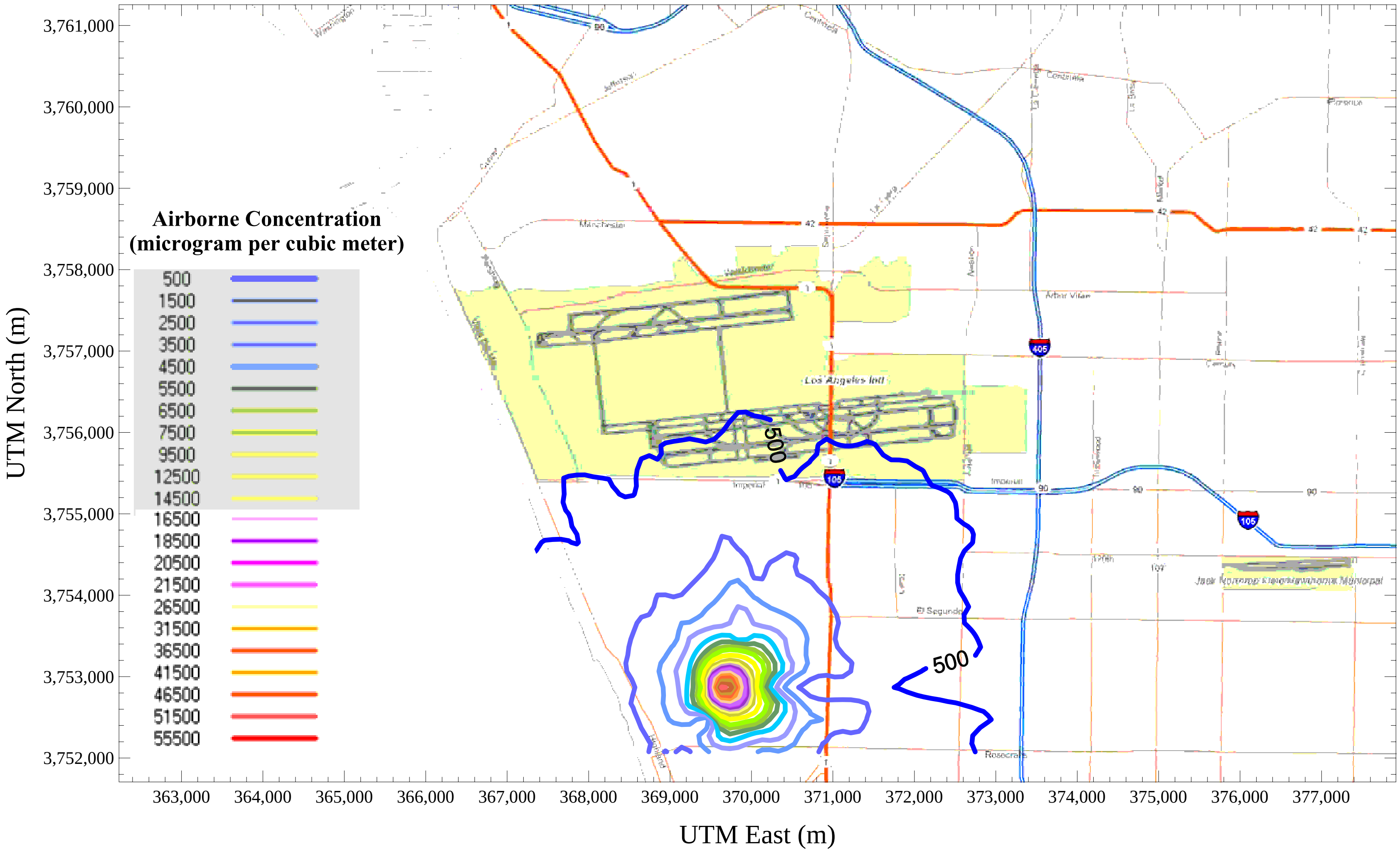
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 18 - Maximum 1-hour NOx Concentrations from All Sources - Summer 2007



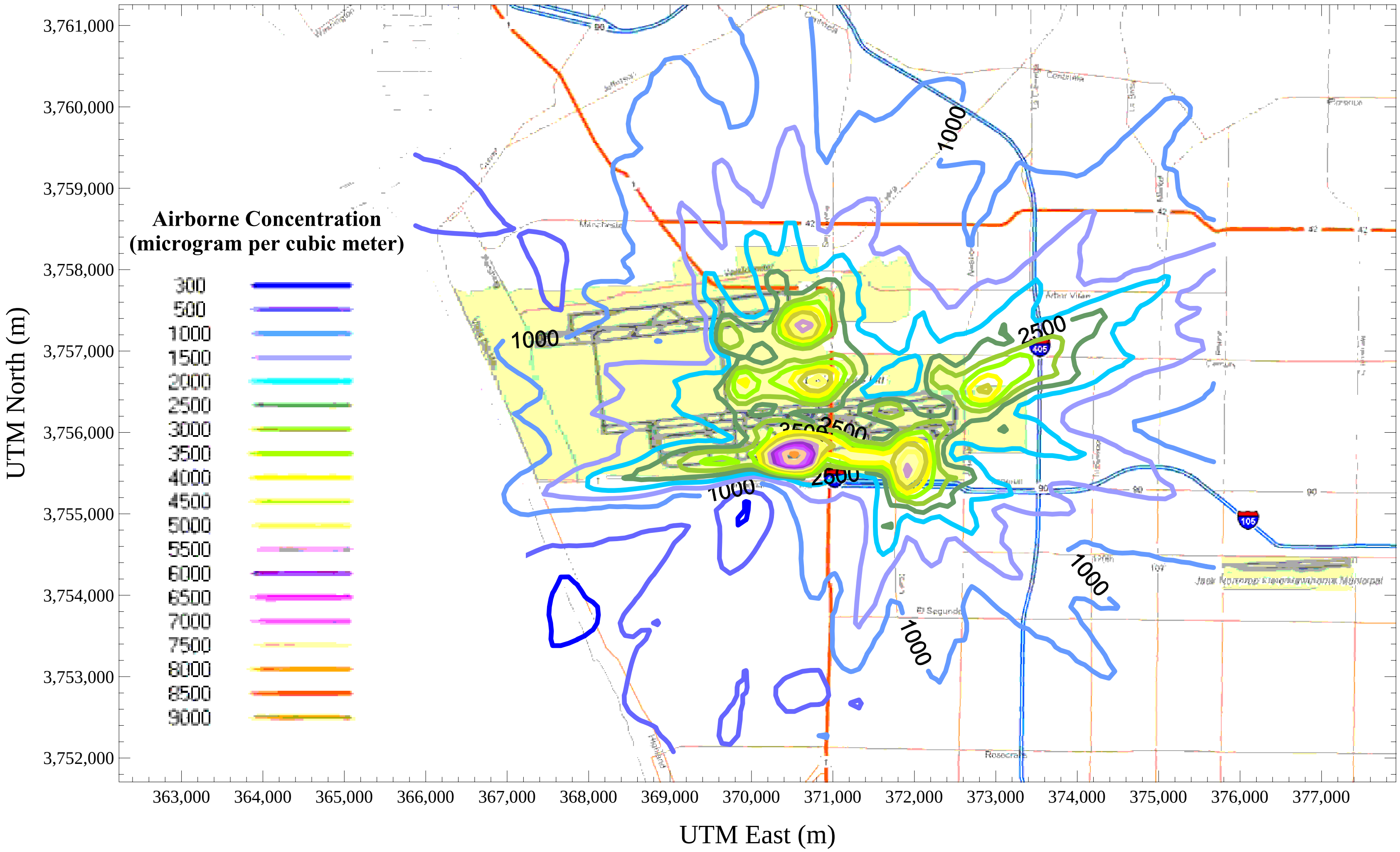
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 19 - Maximum 1-hour NOx Concentrations from Chevron Sources - Summer 2007



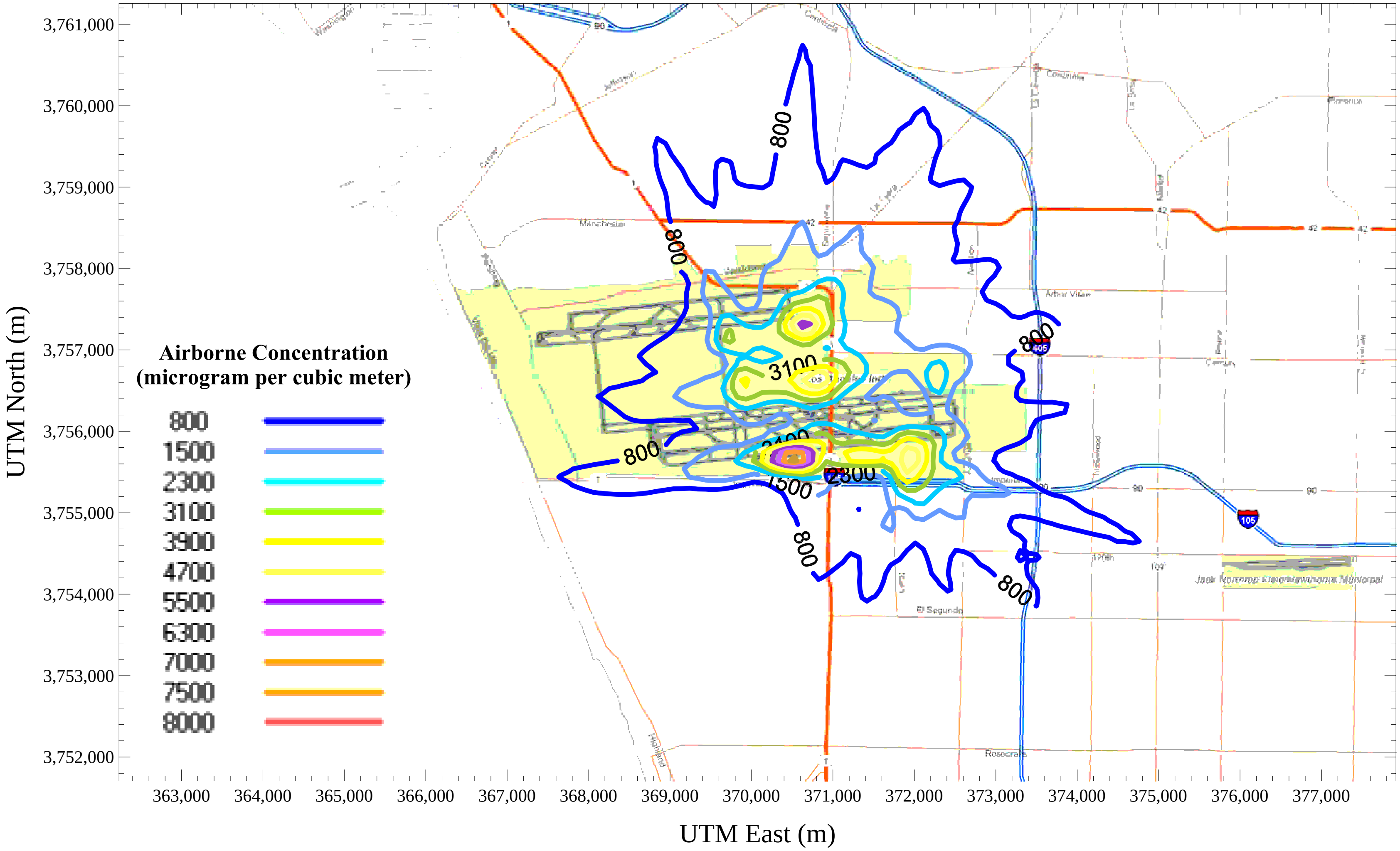
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 20 - Maximum 1-hour NOx Concentrations from Airport Sources - Summer 2007



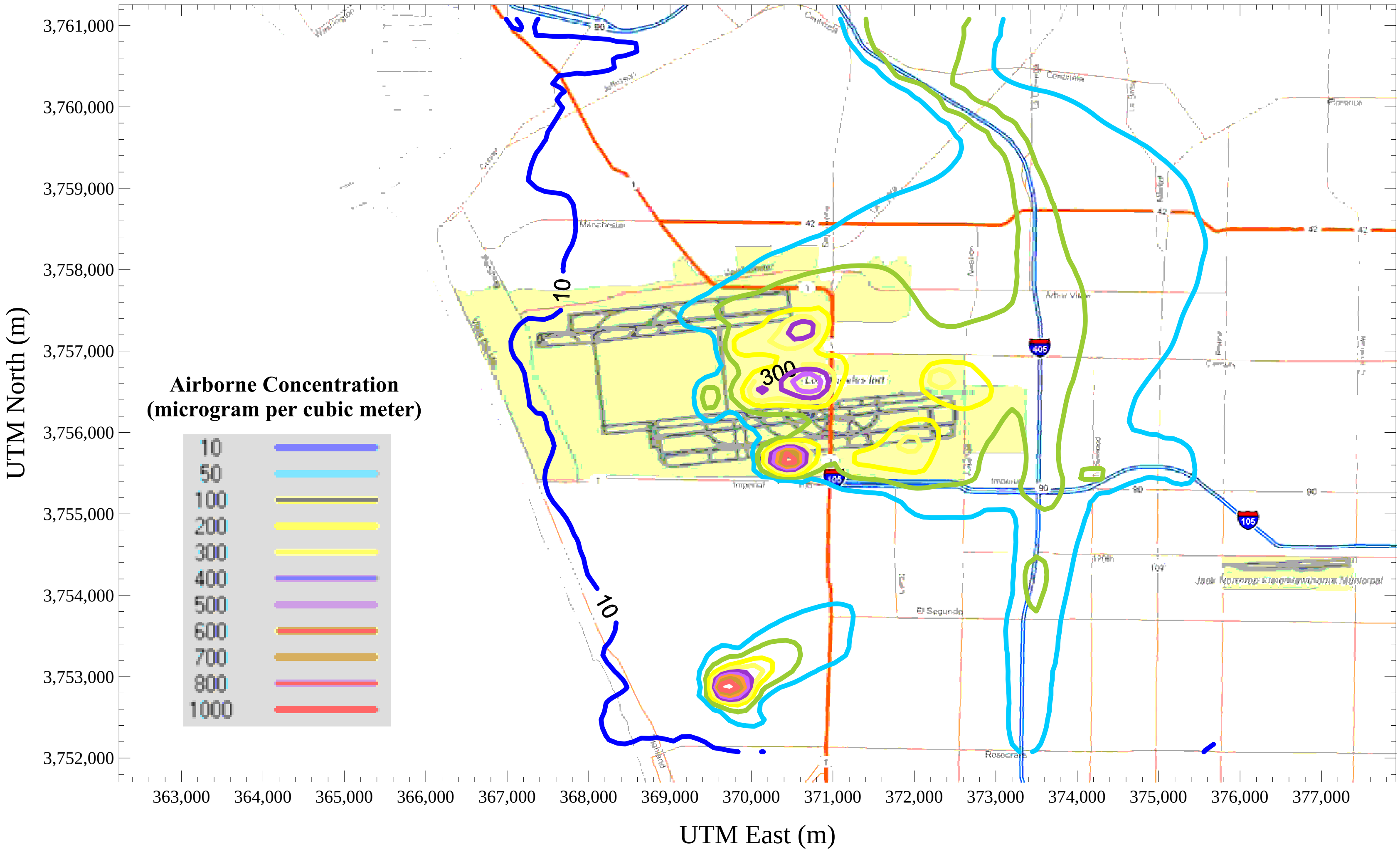
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 21 - Maximum 1-hour NOx Concentrations from Gate Sources - Summer 2007



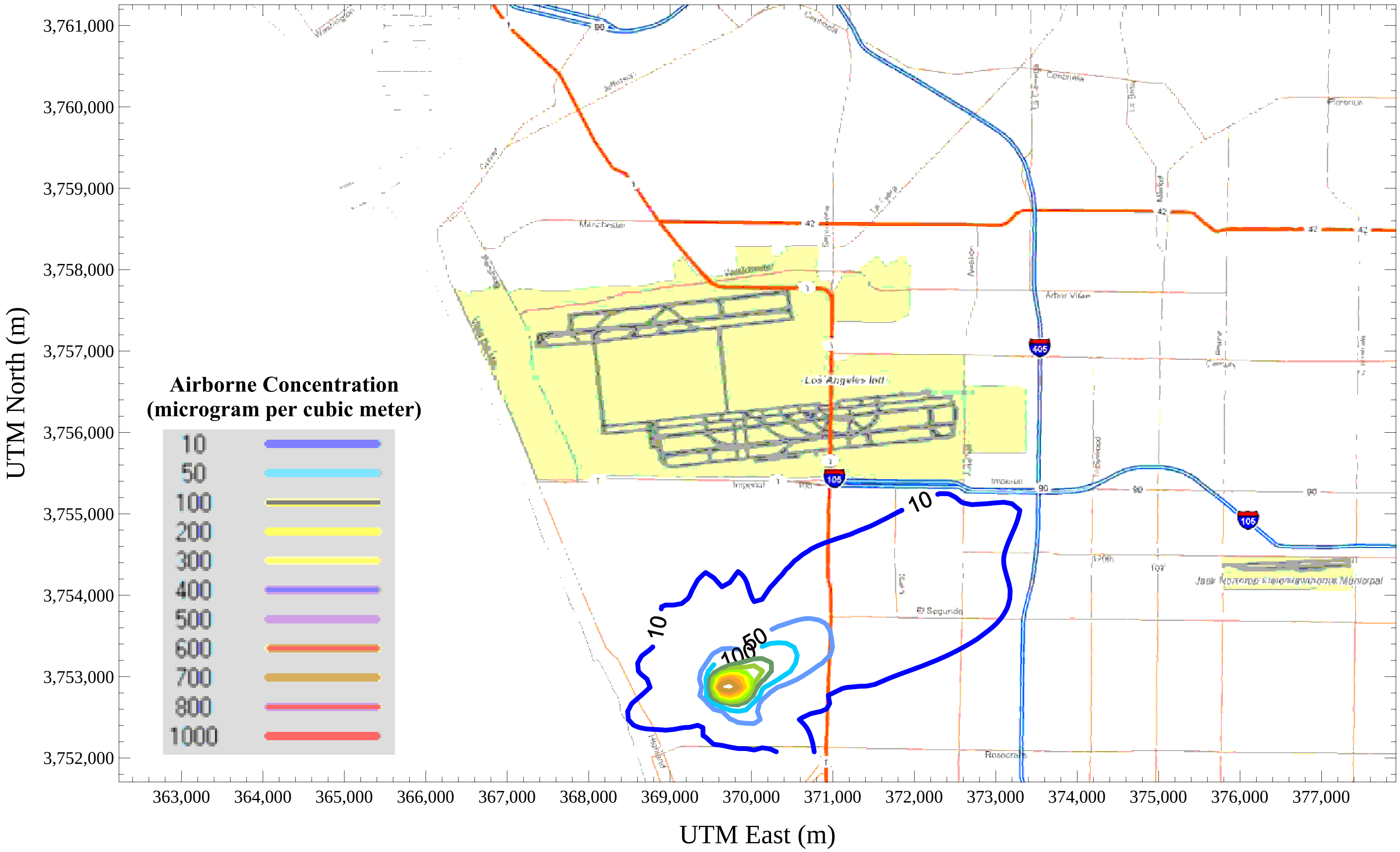
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 22 - 3-month NOx Concentrations from All Sources - Summer 2007



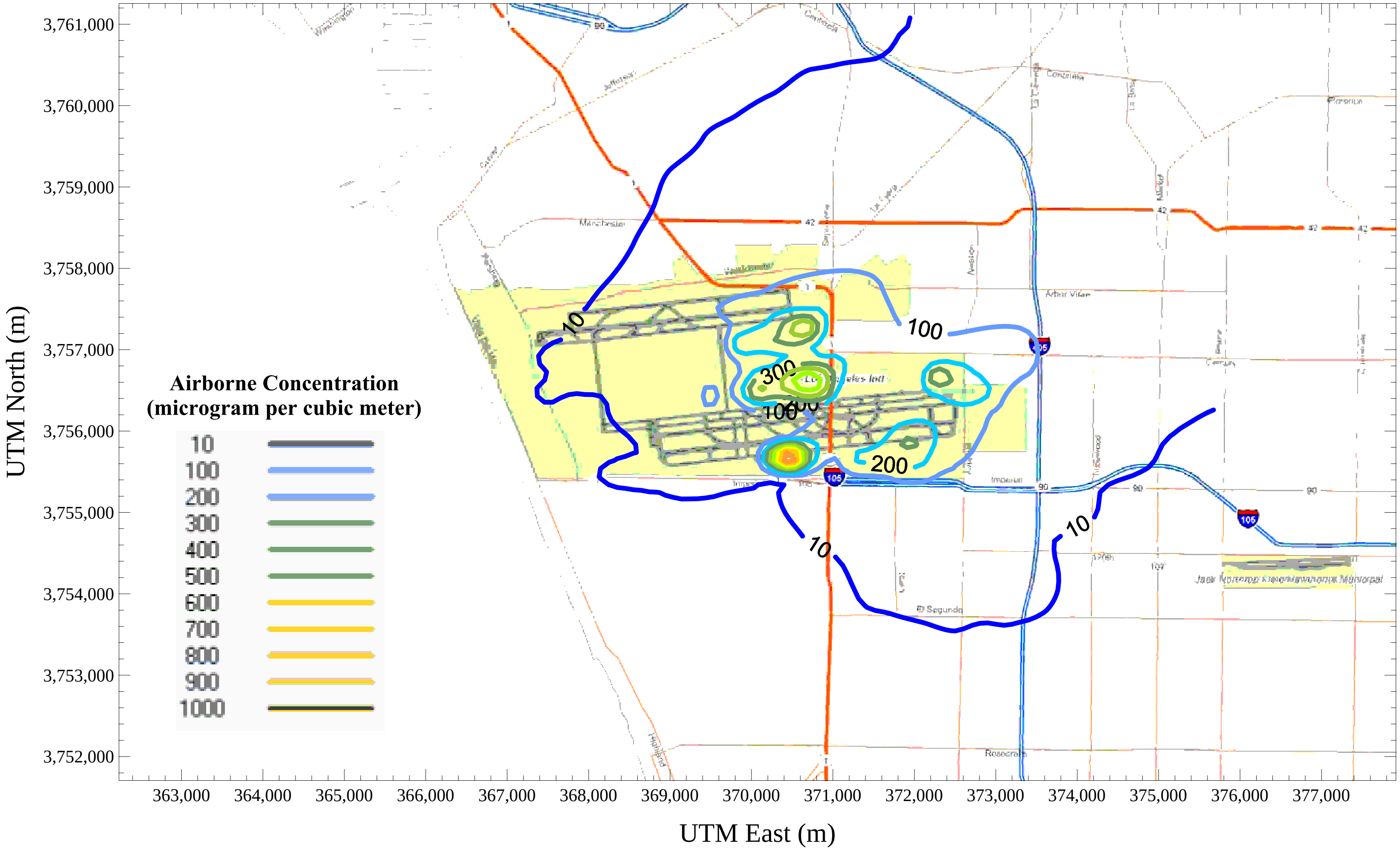
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 23 - 3-month NOx Concentrations from Chevron Sources - Summer 2007



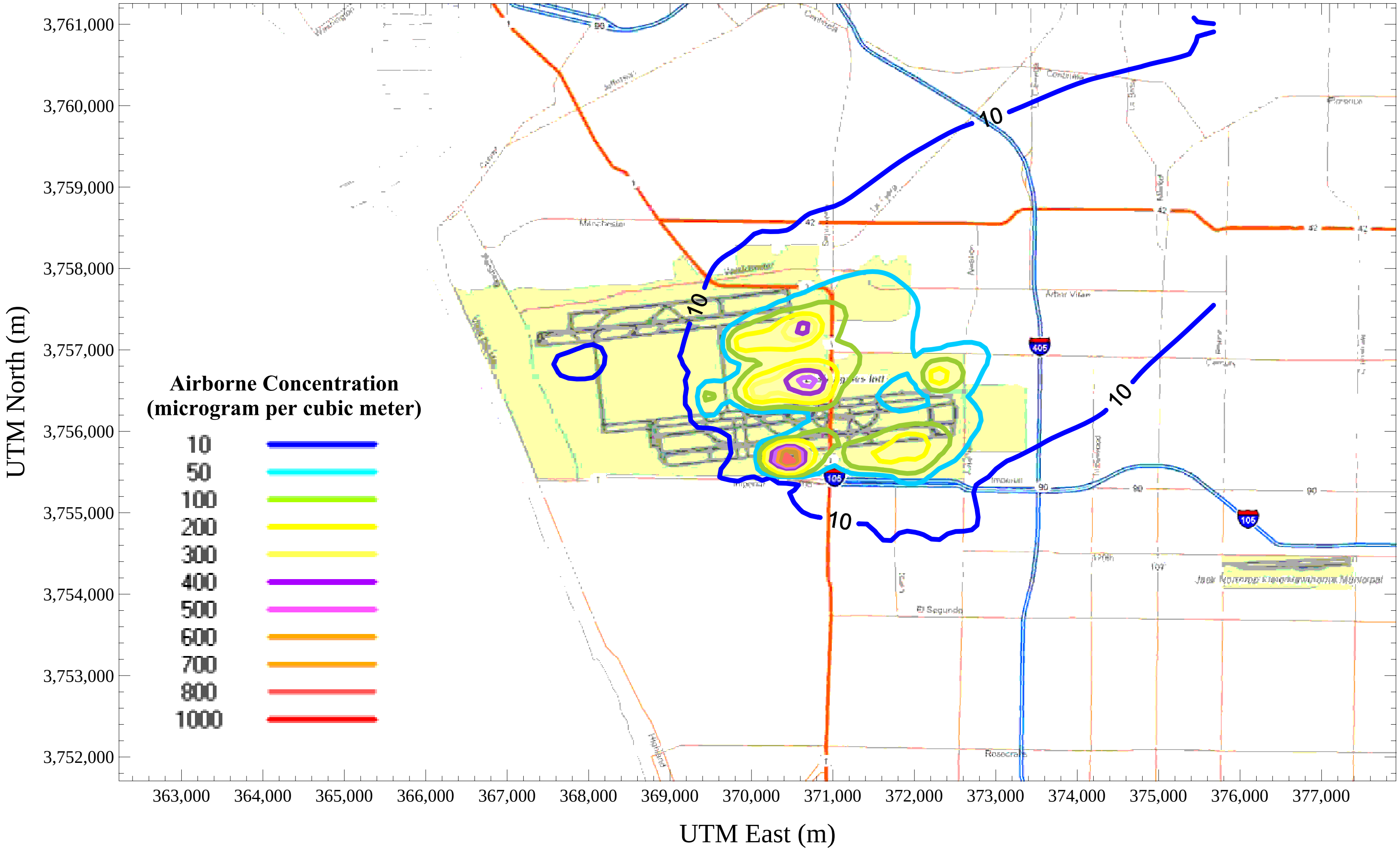
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 24 - 3-month NOx Concentrations from Airport Sources - Summer 2007



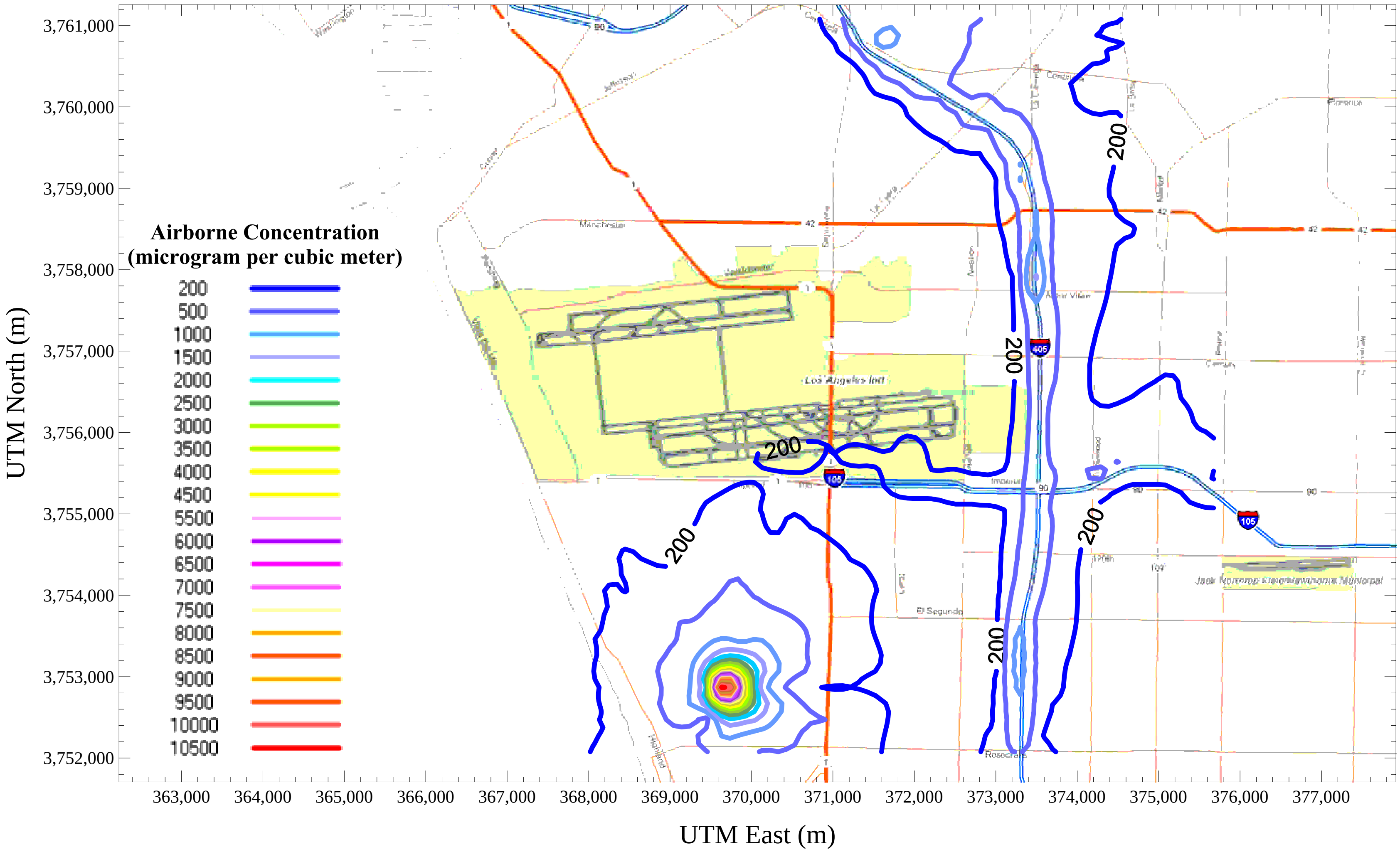
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 25 - 3-month NOx Concentrations from Gate Sources - Summer 2007



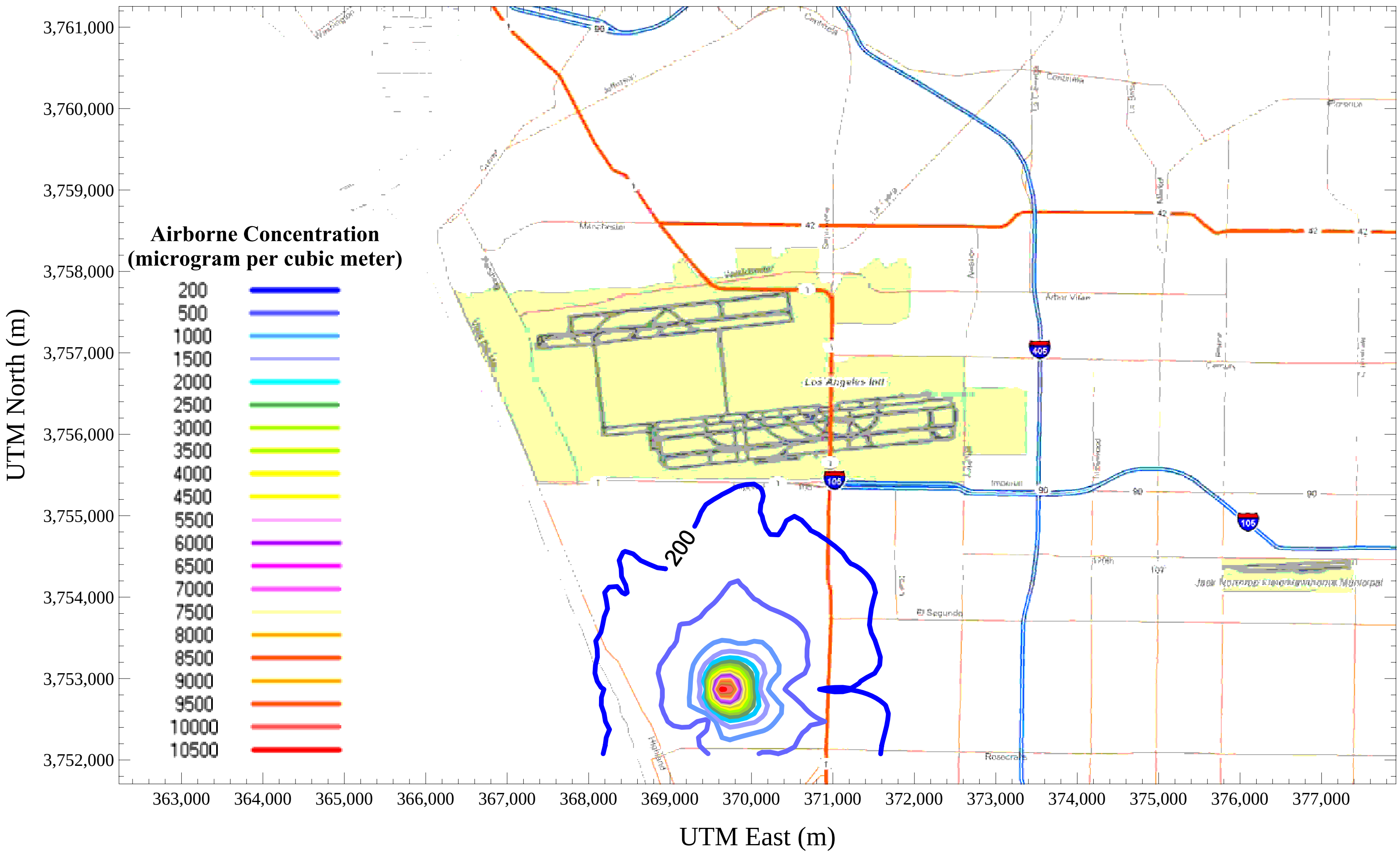
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 26 - Maximum 1-hour PM10 Concentrations from All Sources - Summer 2007



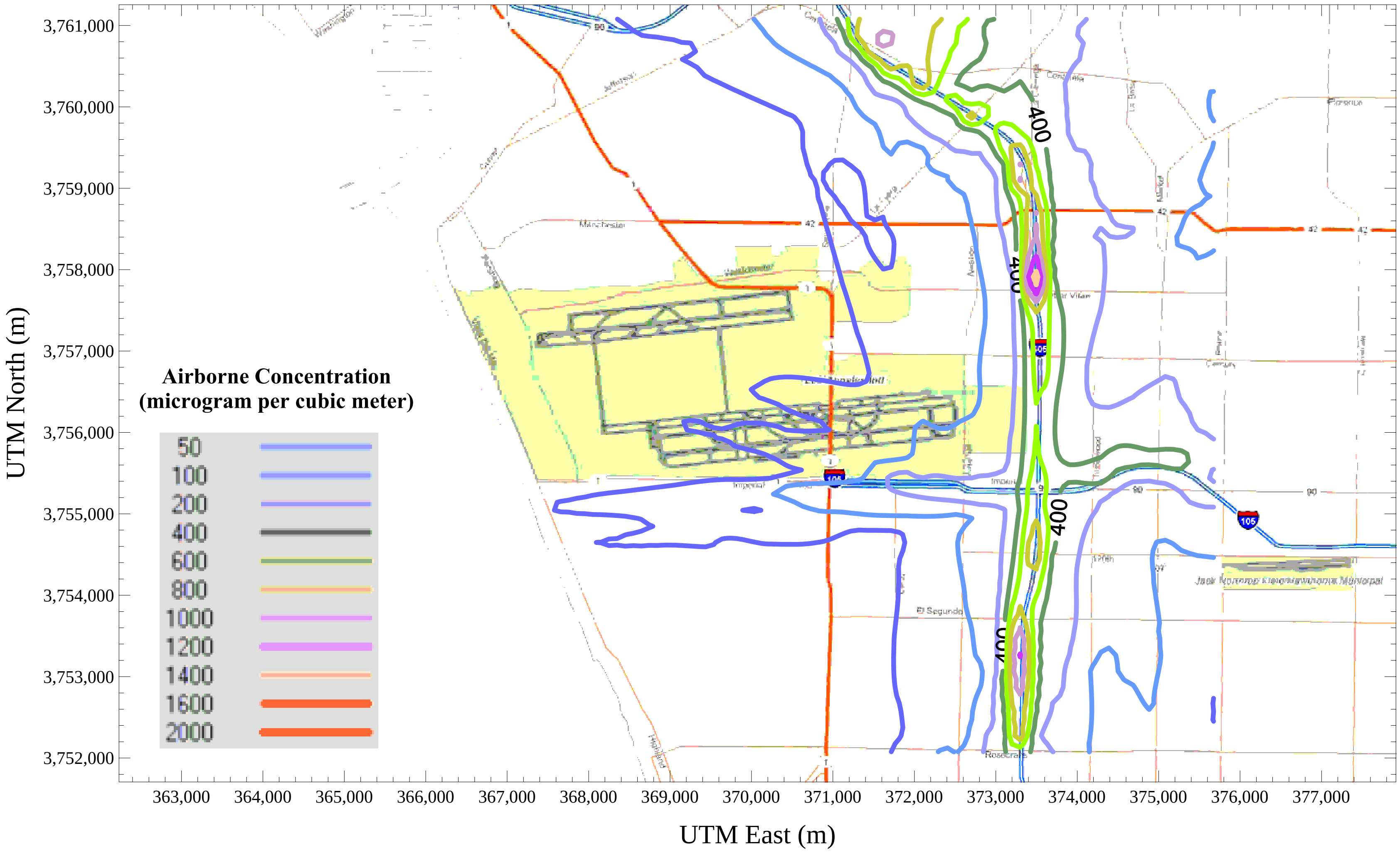
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 27 - Maximum 1-hour PM10 Concentrations from Chevron Sources - Summer 2007



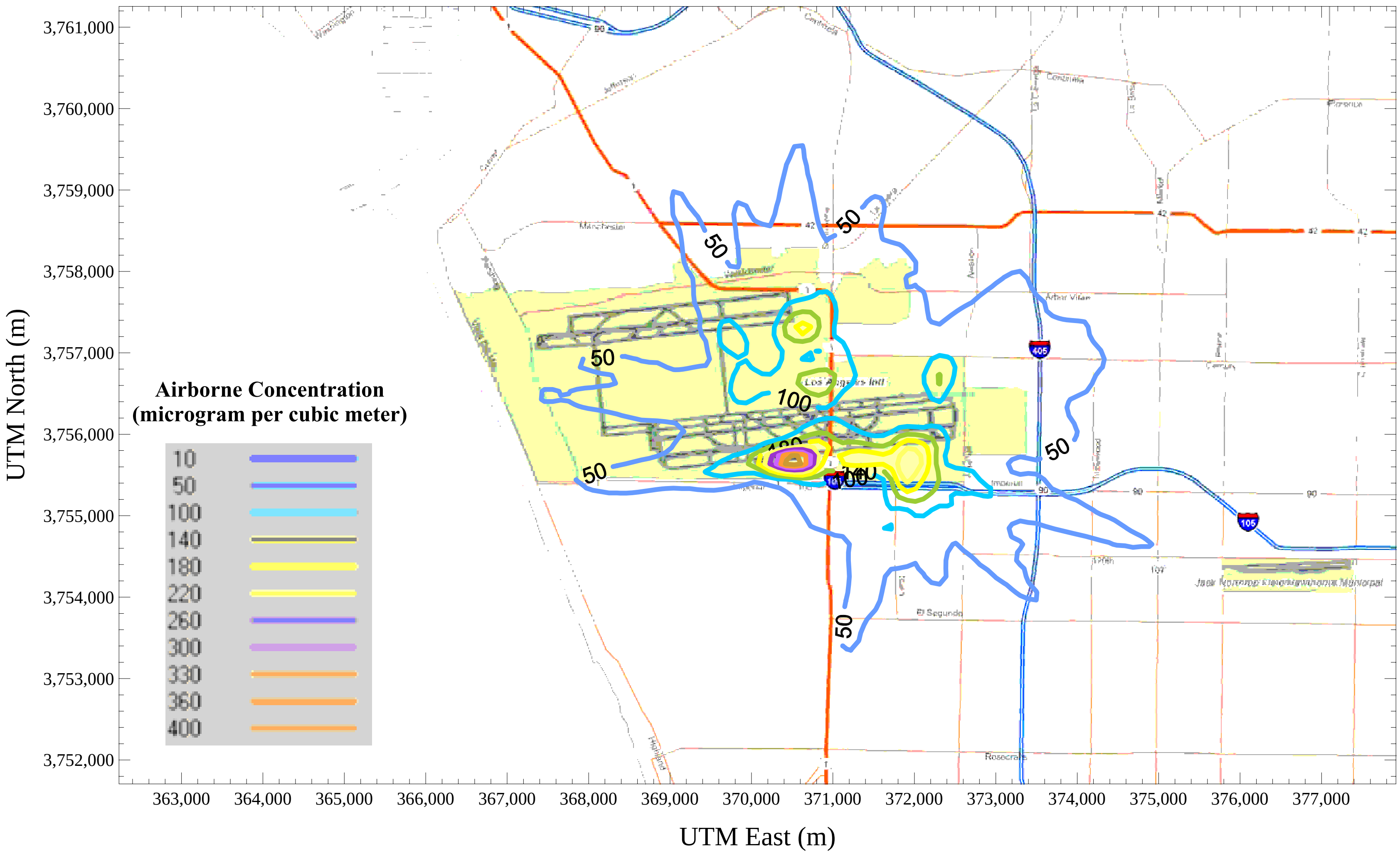
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 28 - Maximum 1-hour PM10 Concentrations from Off-airport Road Sources - Summer 2007



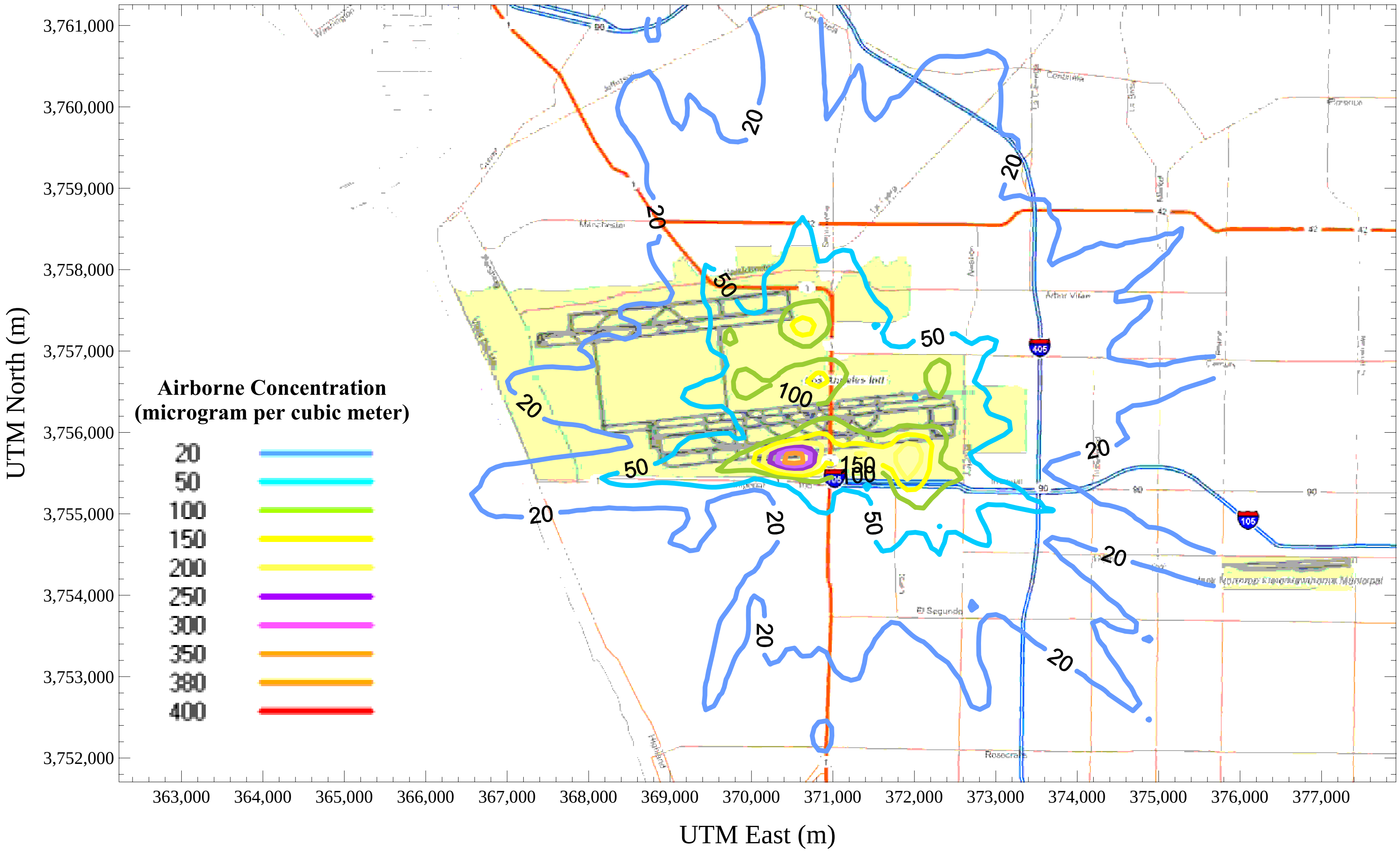
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 29 - Maximum 1-hour PM10 Concentrations from Airport Sources - Summer 2007



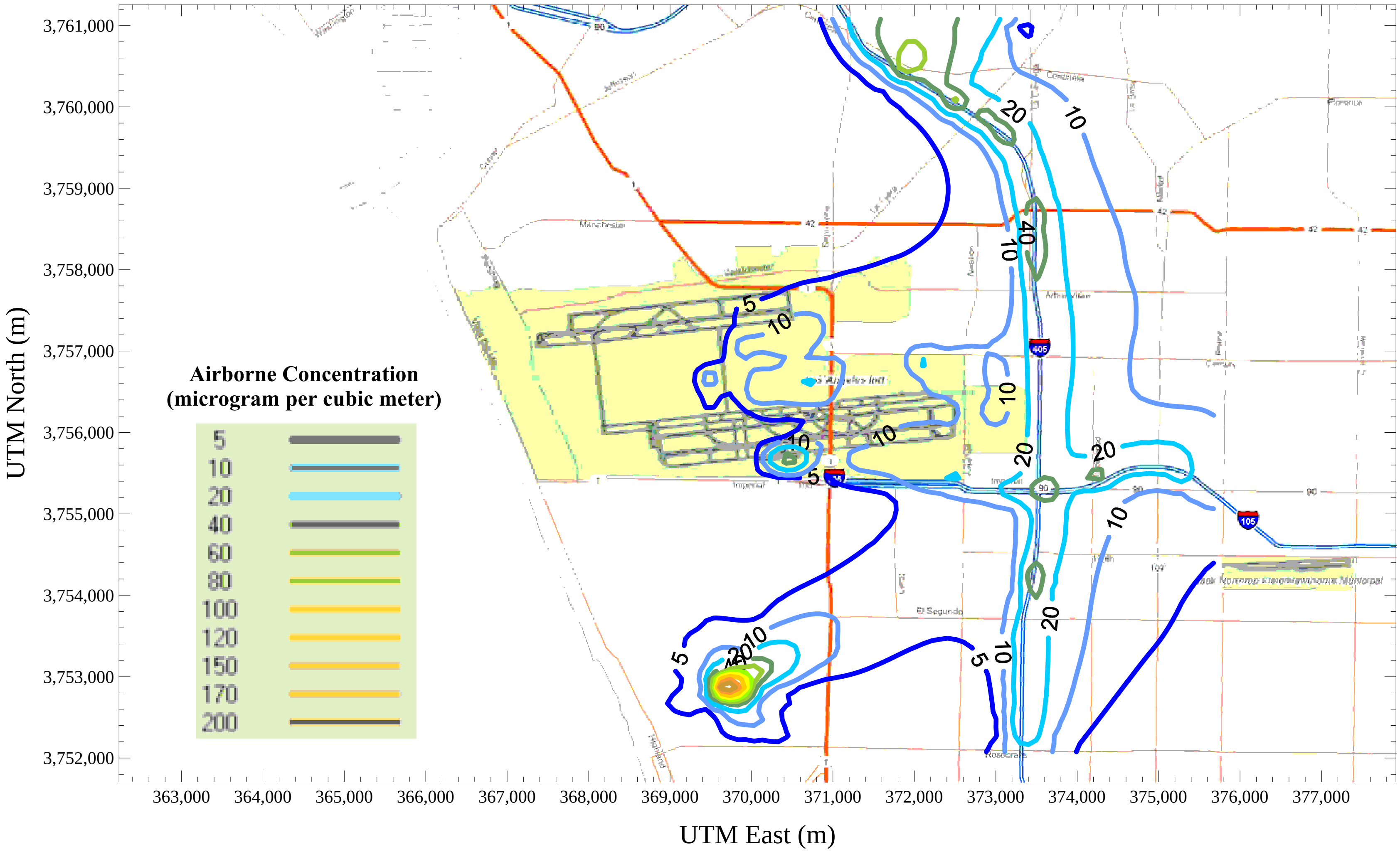
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 30 - Maximum 1-hour PM10 Concentrations from Gate Sources - Summer 2007



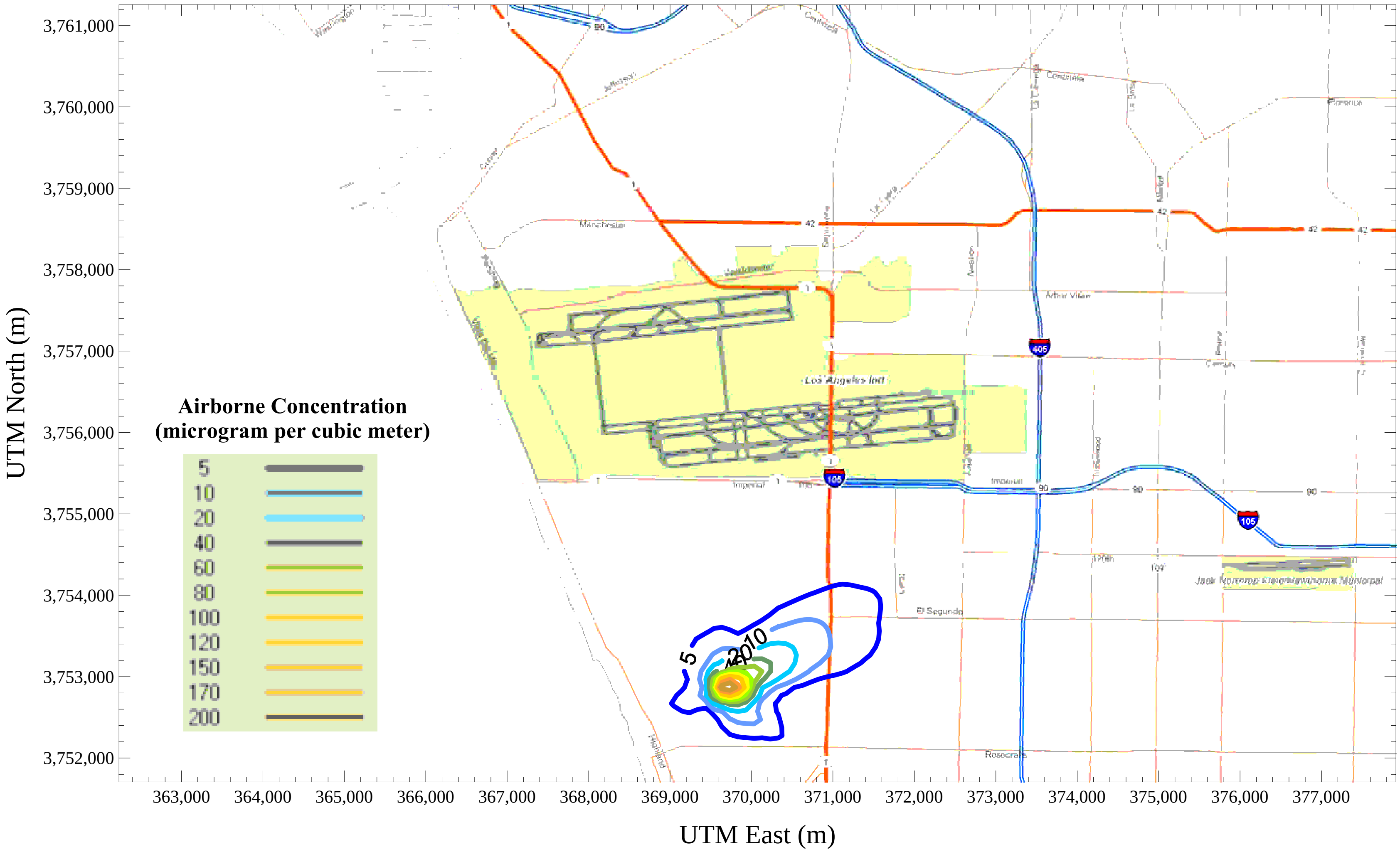
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 31 - 3-month PM10 Concentrations from All Sources - Summer 2007



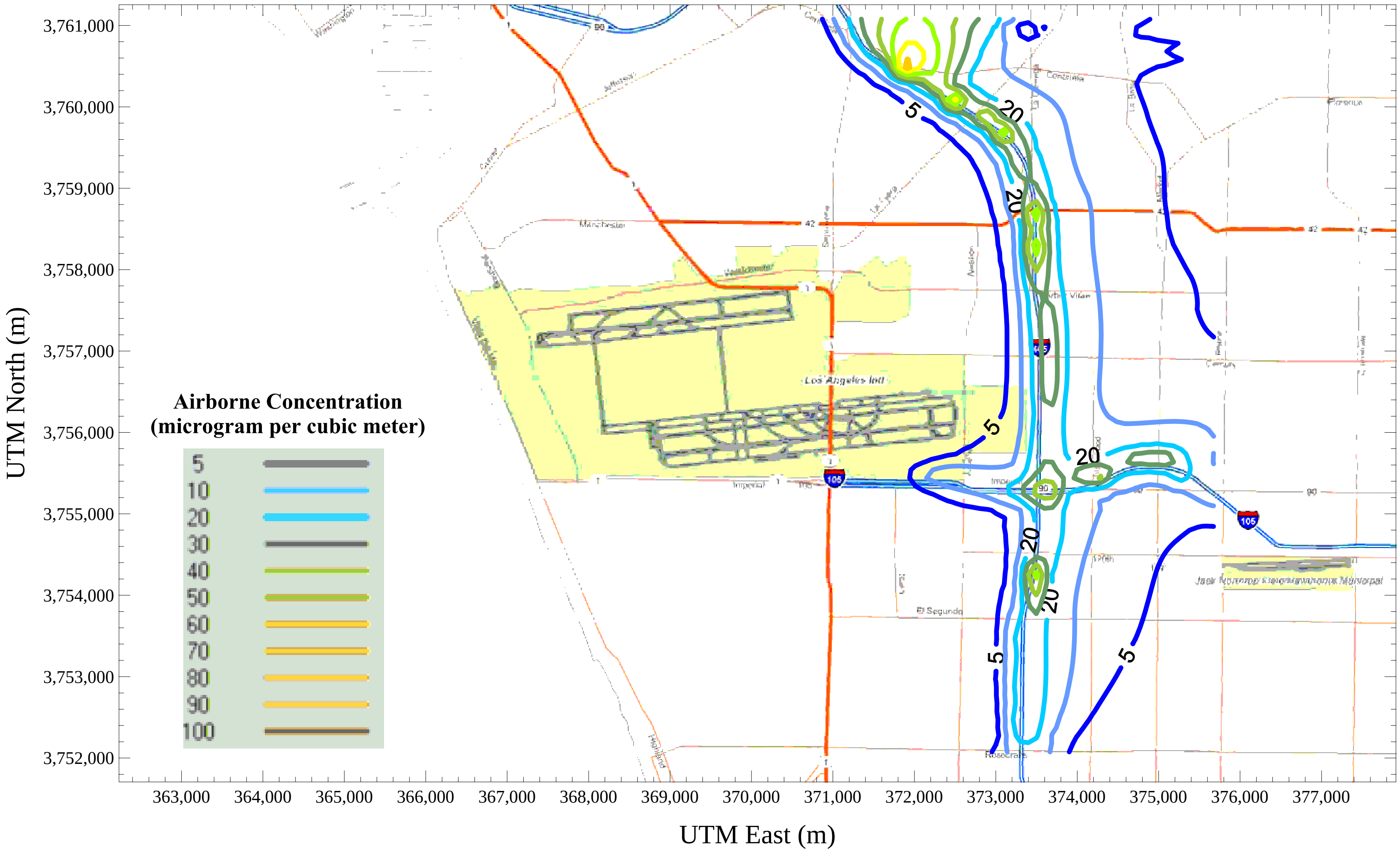
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 32 - 3-month PM10 Concentrations from Chevron Sources - Summer 2007



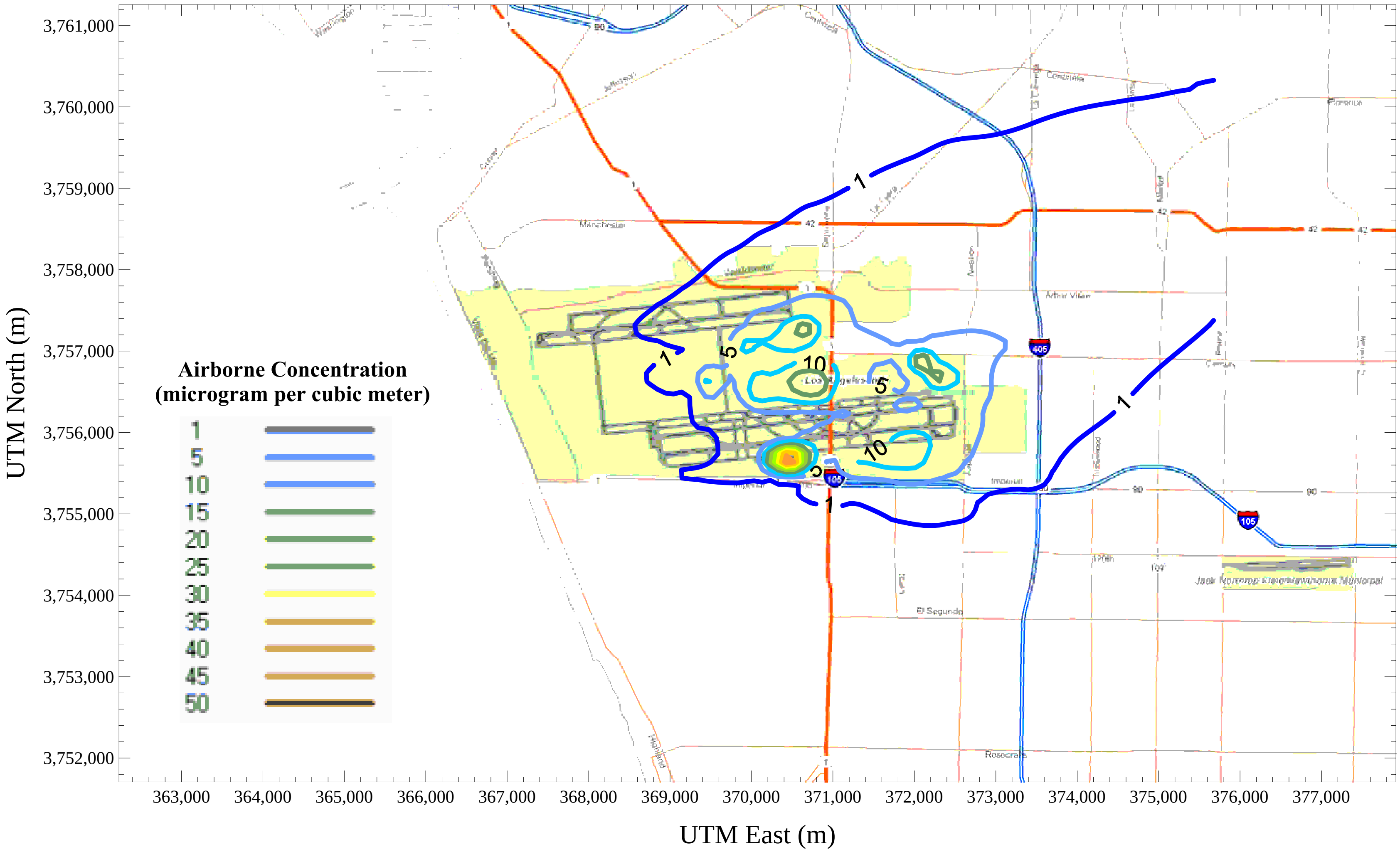
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 33 - 3-month PM10 Concentrations from Off-airport Road Sources - Summer 2007



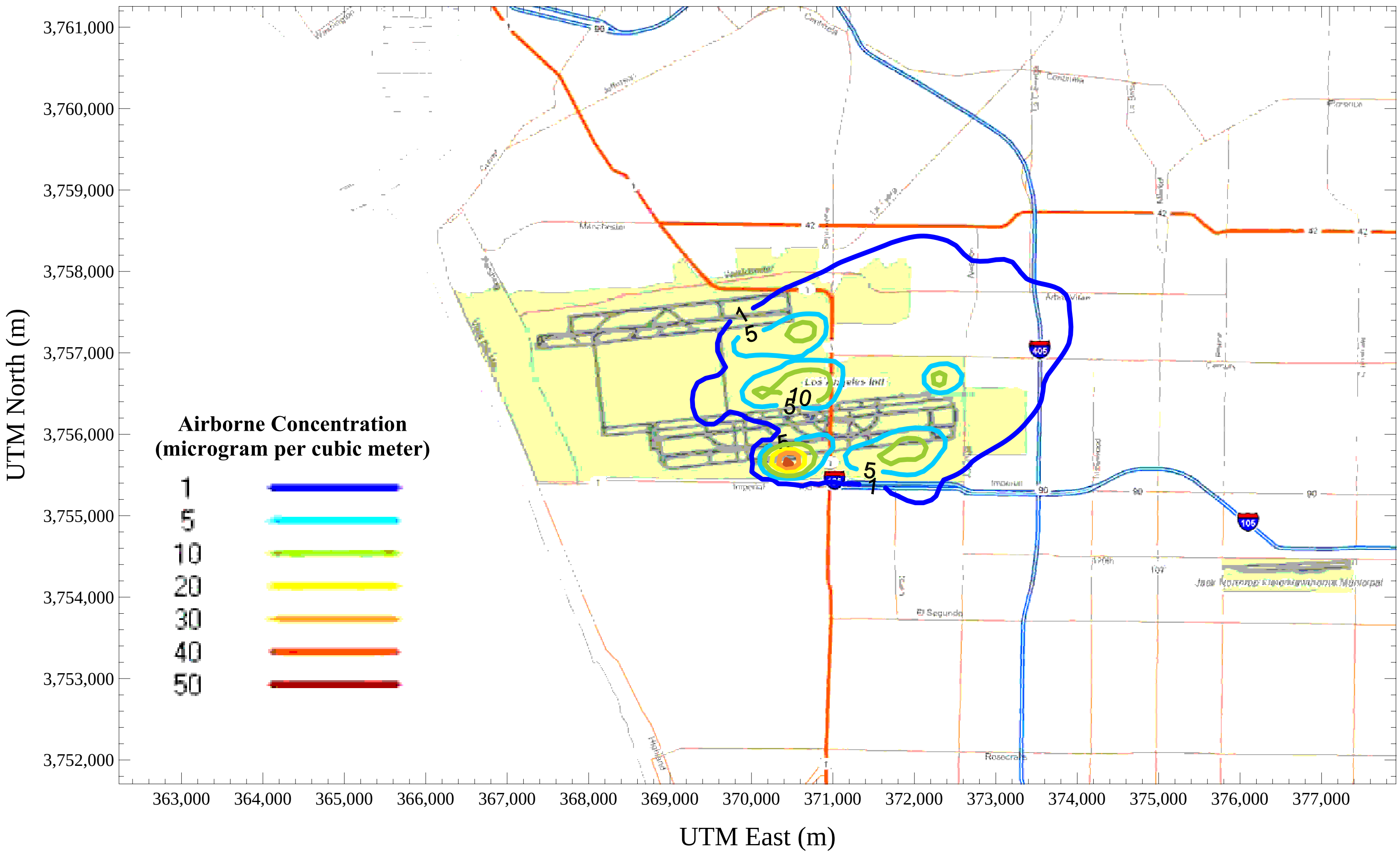
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 34 - 3-month PM10 Concentrations from Airport Sources - Summer 2007



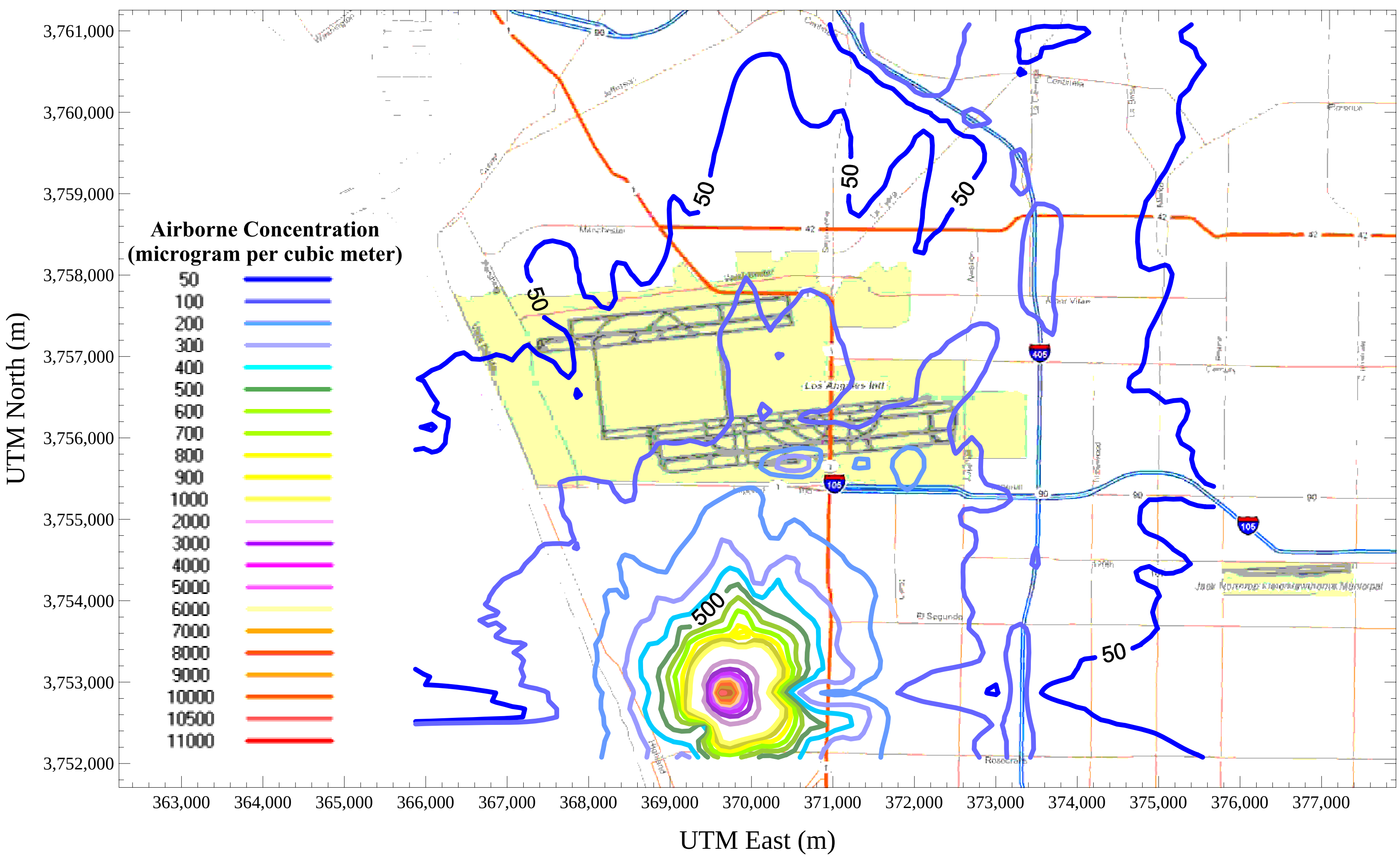
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 35 - 3-month PM10 Concentrations from Gate Sources - Summer 2007



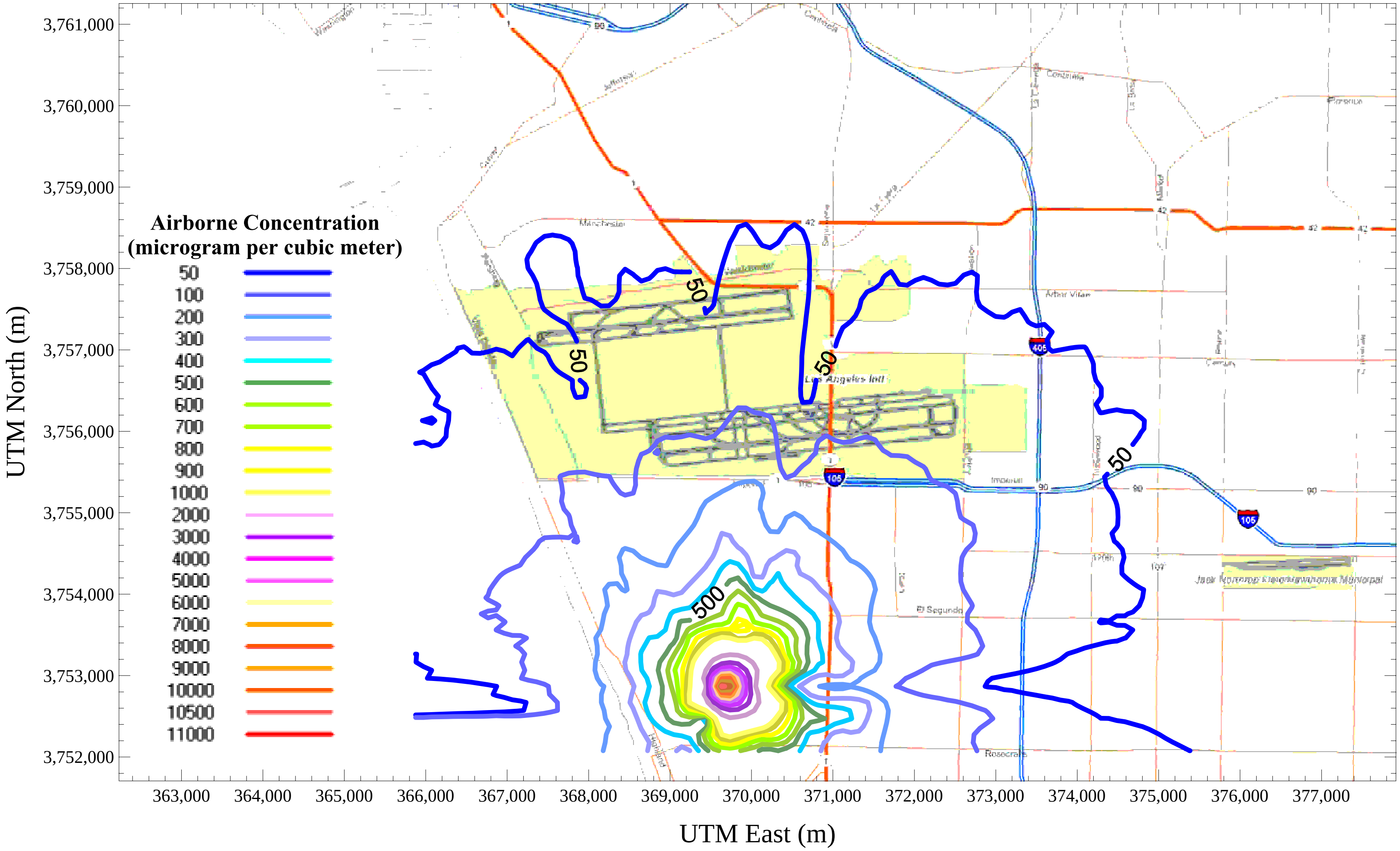
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 36 - Maximum 1-hour PM25 Concentrations from All Sources - Summer 2007



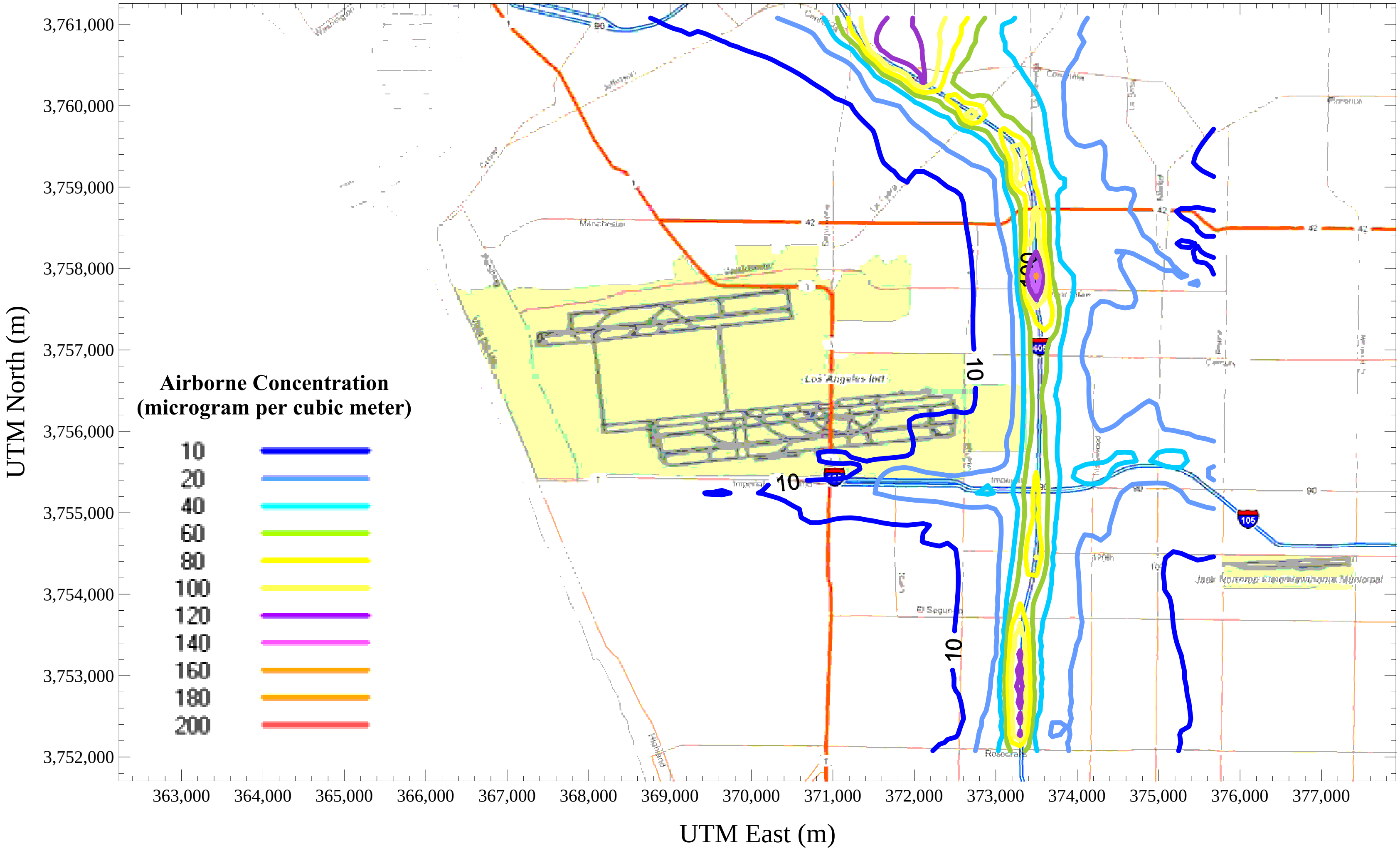
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 37 - Maximum 1-hour PM25 Concentrations from Chevron Sources - Summer 2007



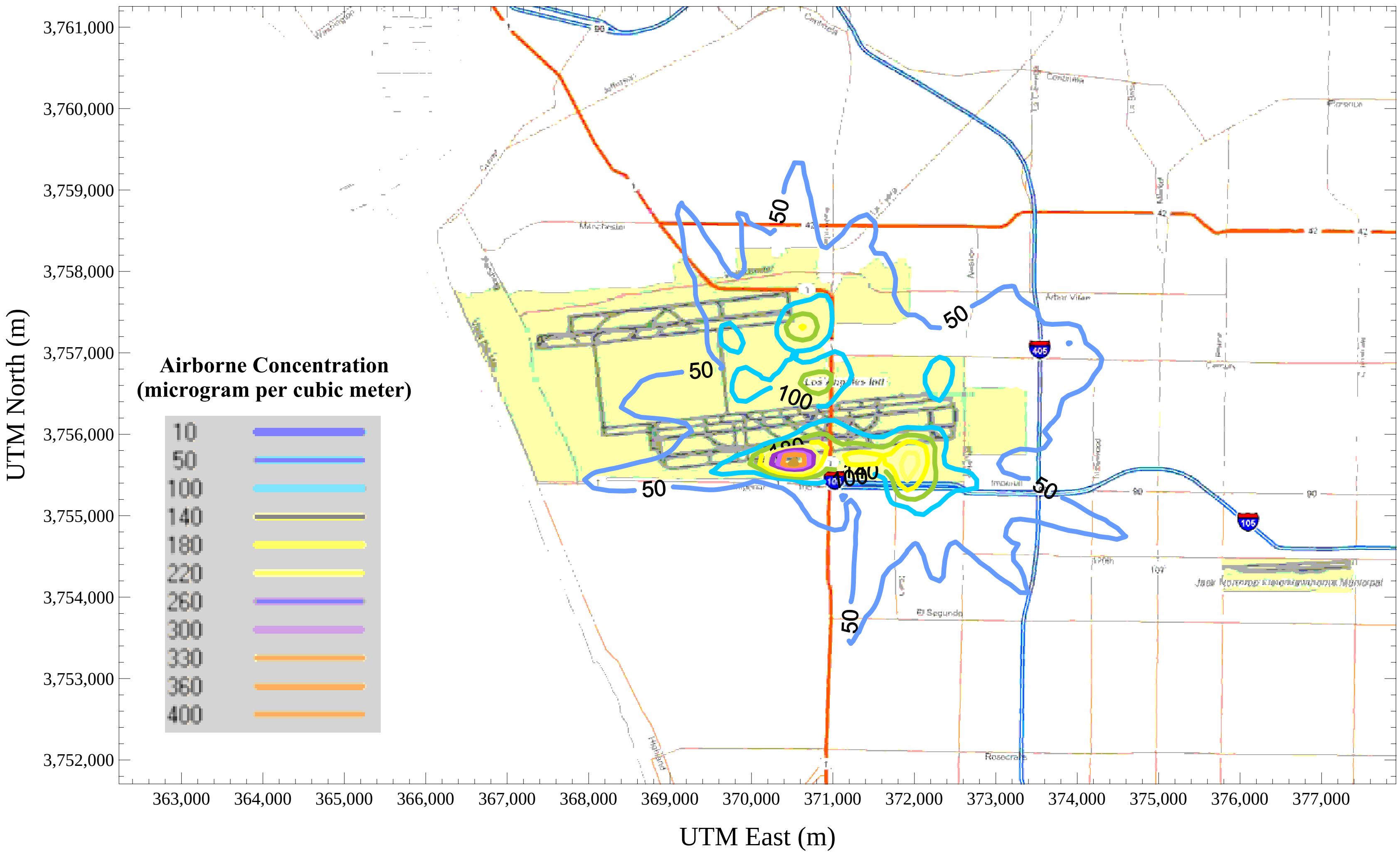
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 38 - Maximum 1-hour PM25 Concentrations from Off-airport Road Sources - Summer 2007



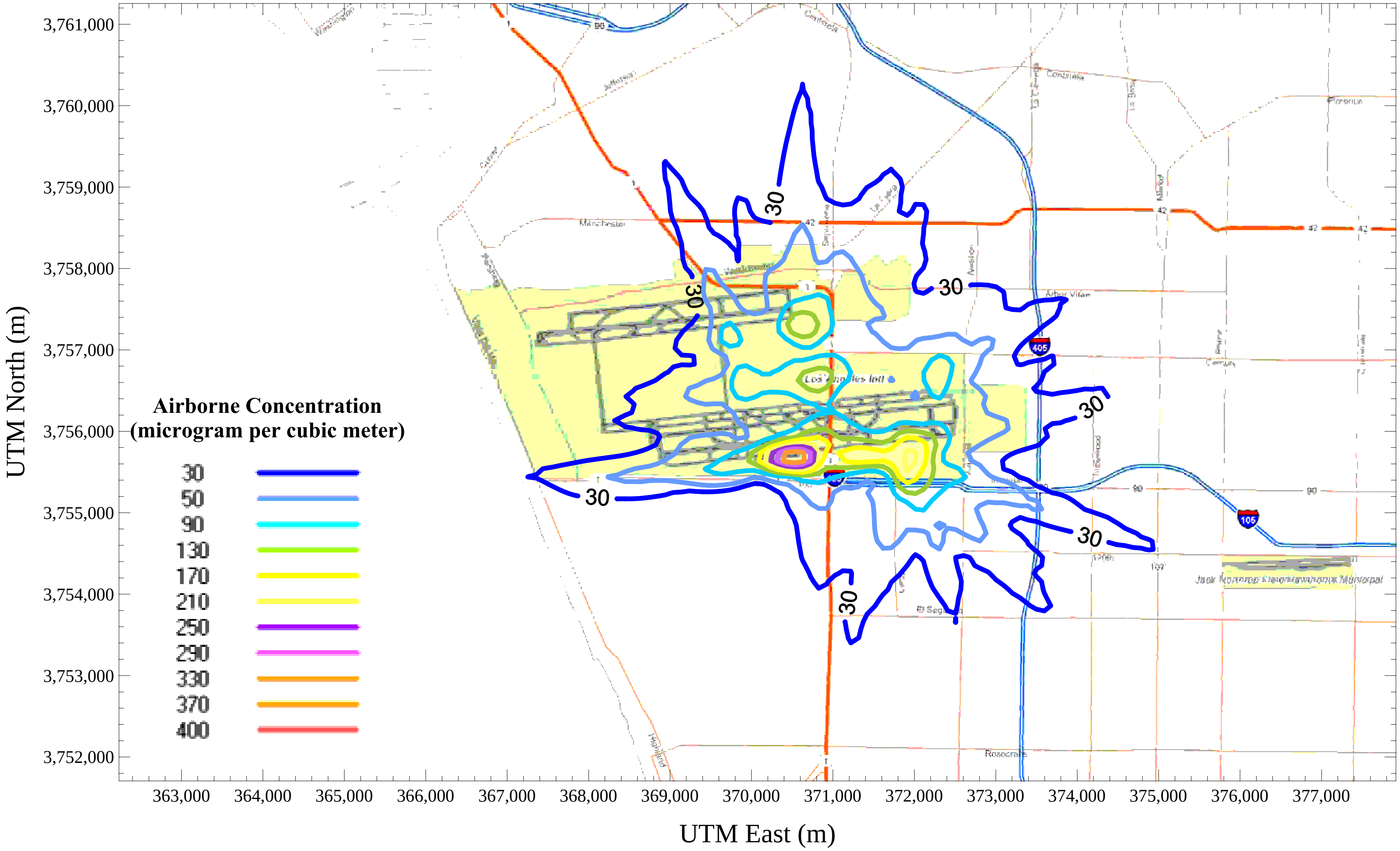
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 39 - Maximum 1-hour PM25 Concentrations from Airport Sources - Summer 2007



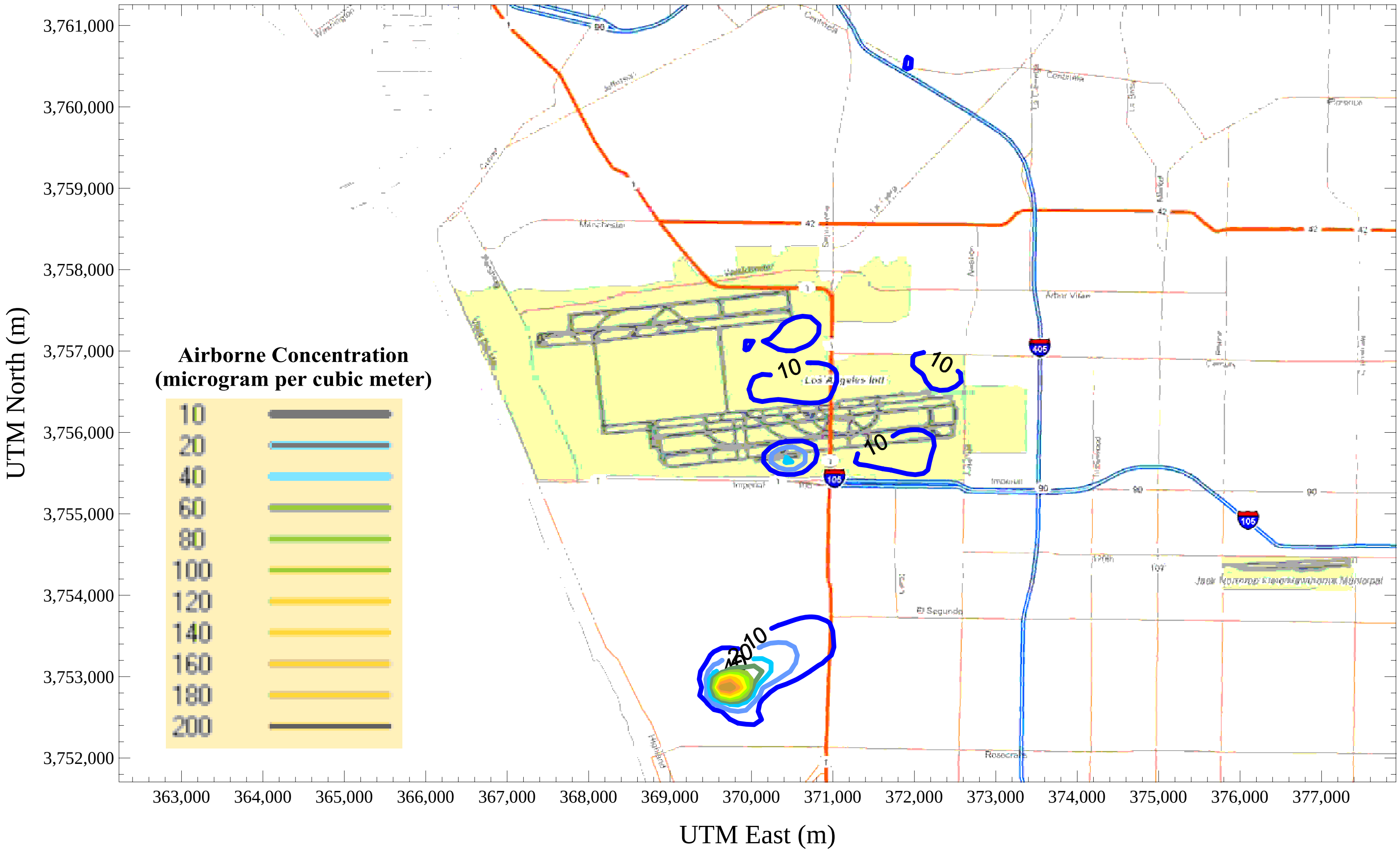
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 40 - Maximum 1-hour PM25 Concentrations from Gate Sources - Summer 2007



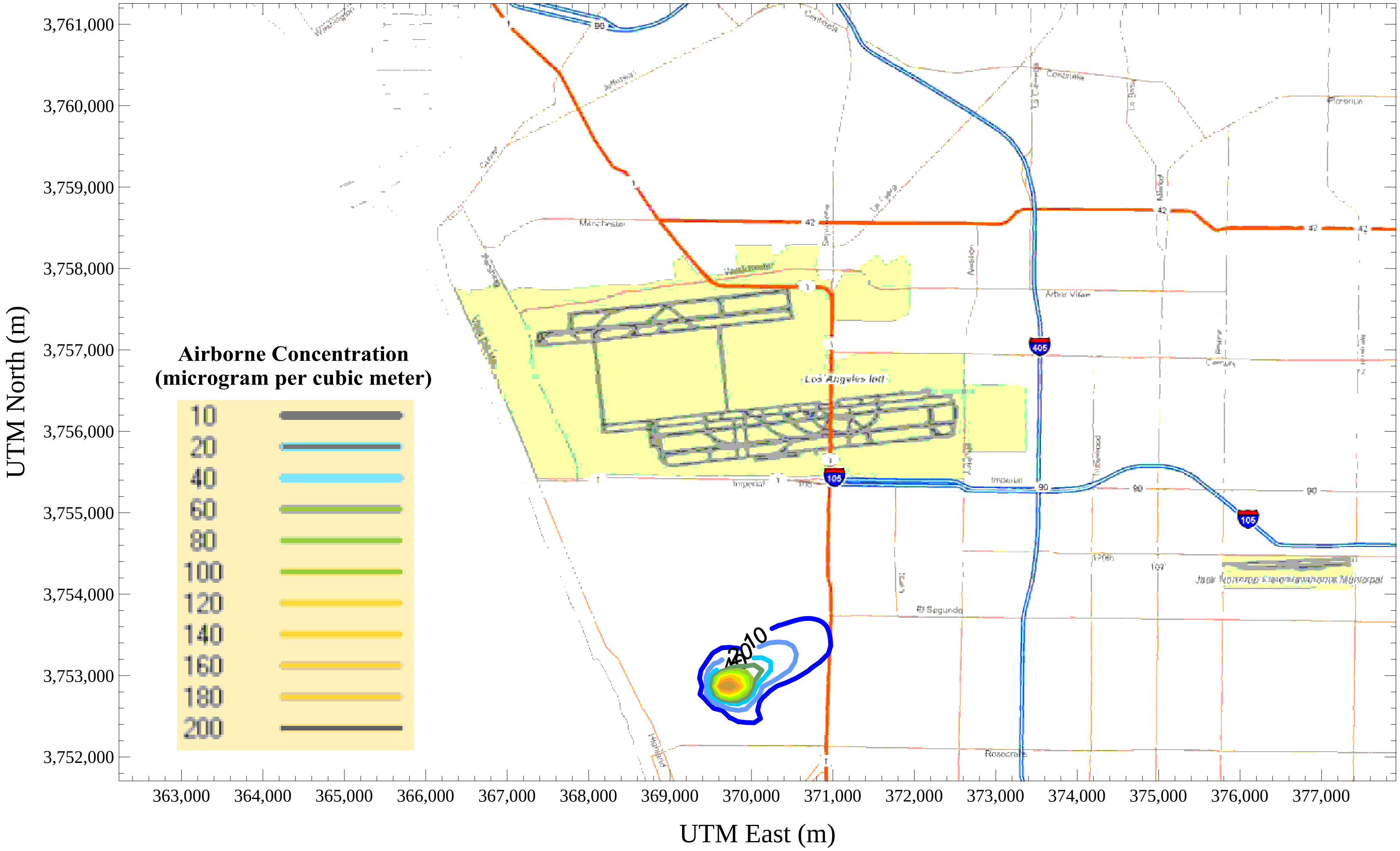
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 41 - 3-month PM25 Concentrations from All Sources - Summer 2007



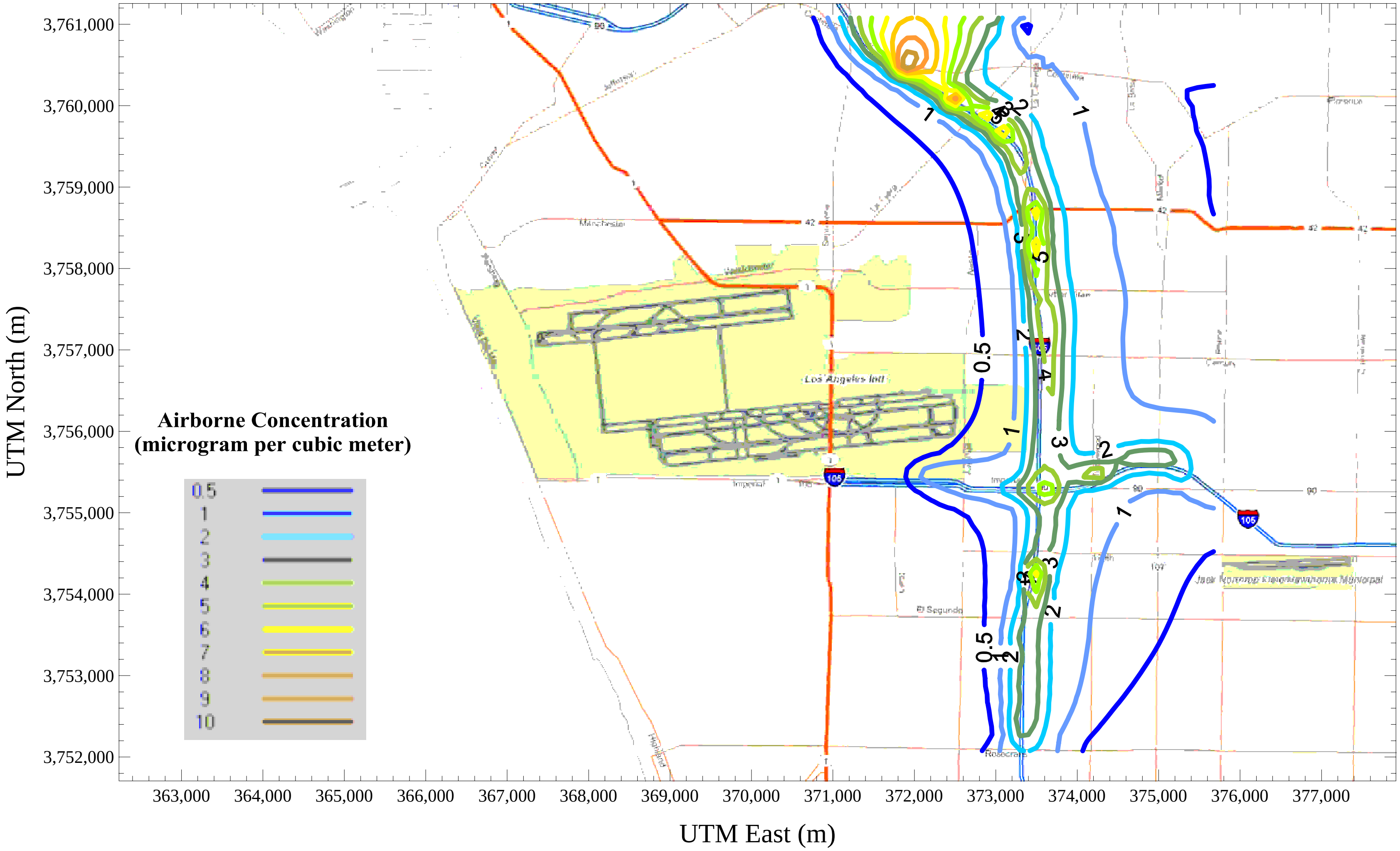
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 42 - 3-month PM25 Concentrations from Chevron Sources - Summer 2007



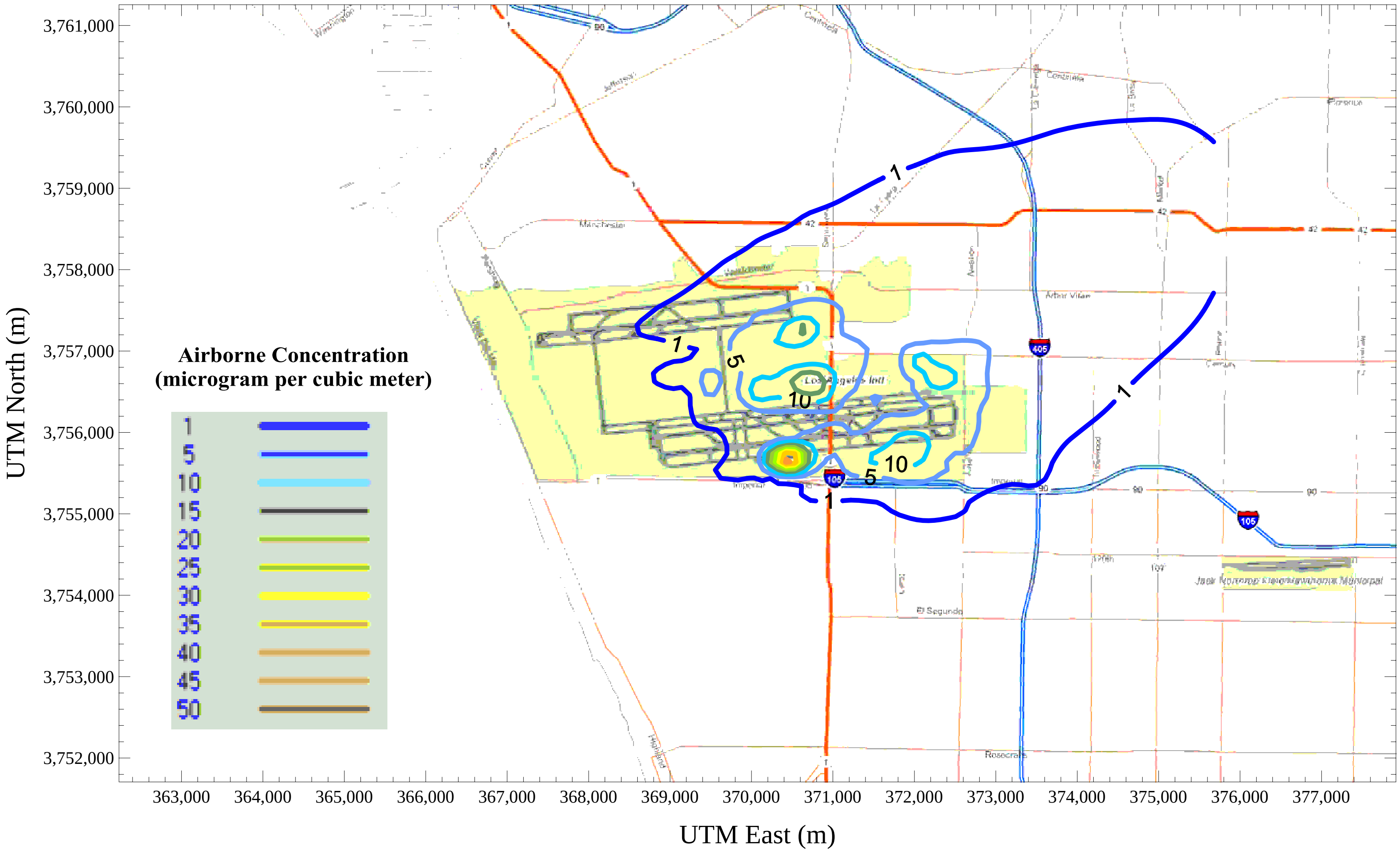
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 43 - 3-month PM25 Concentrations from Off-airport Road Sources - Summer 2007



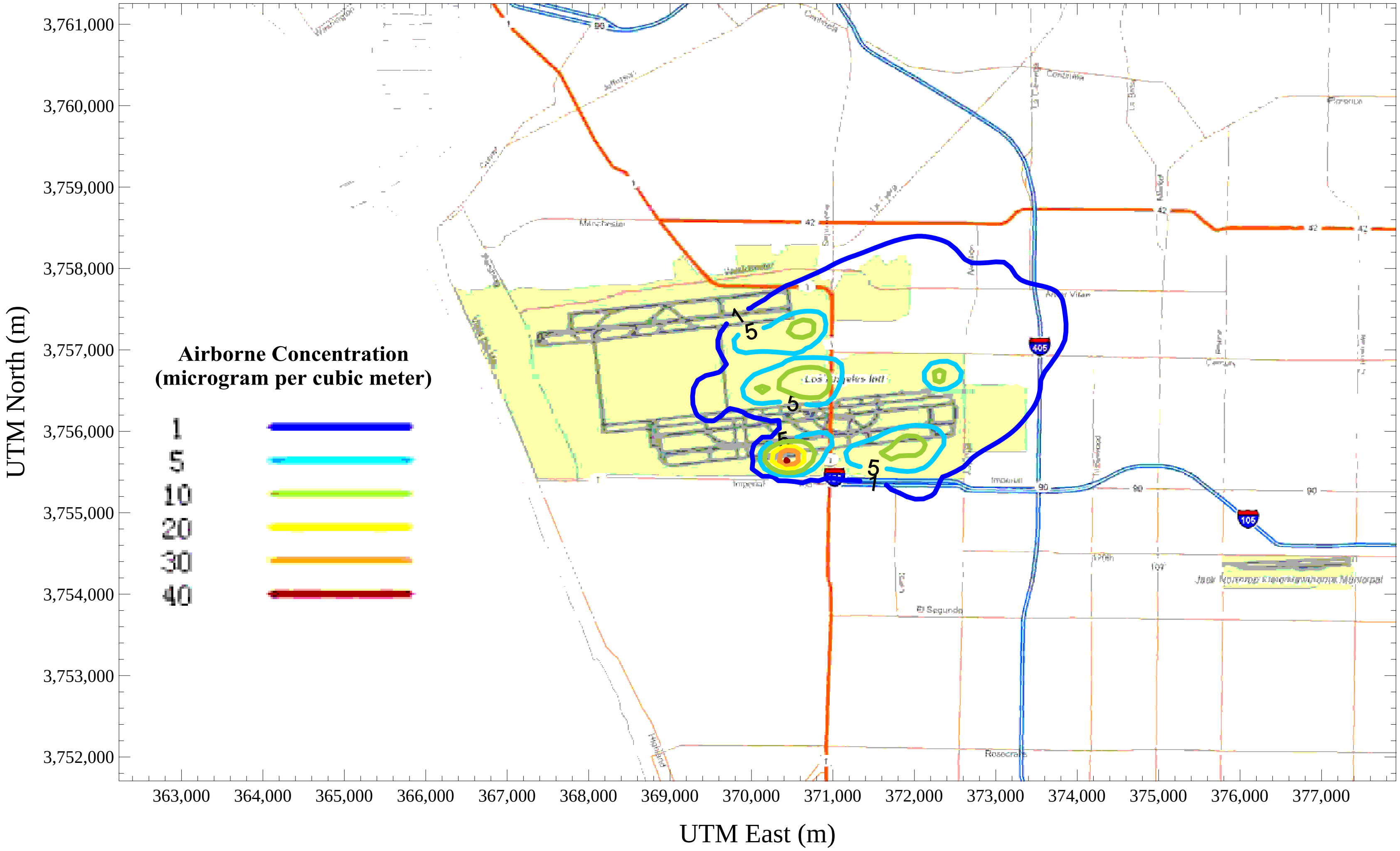
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 44 - 3-month PM25 Concentrations from Airport Sources - Summer 2007



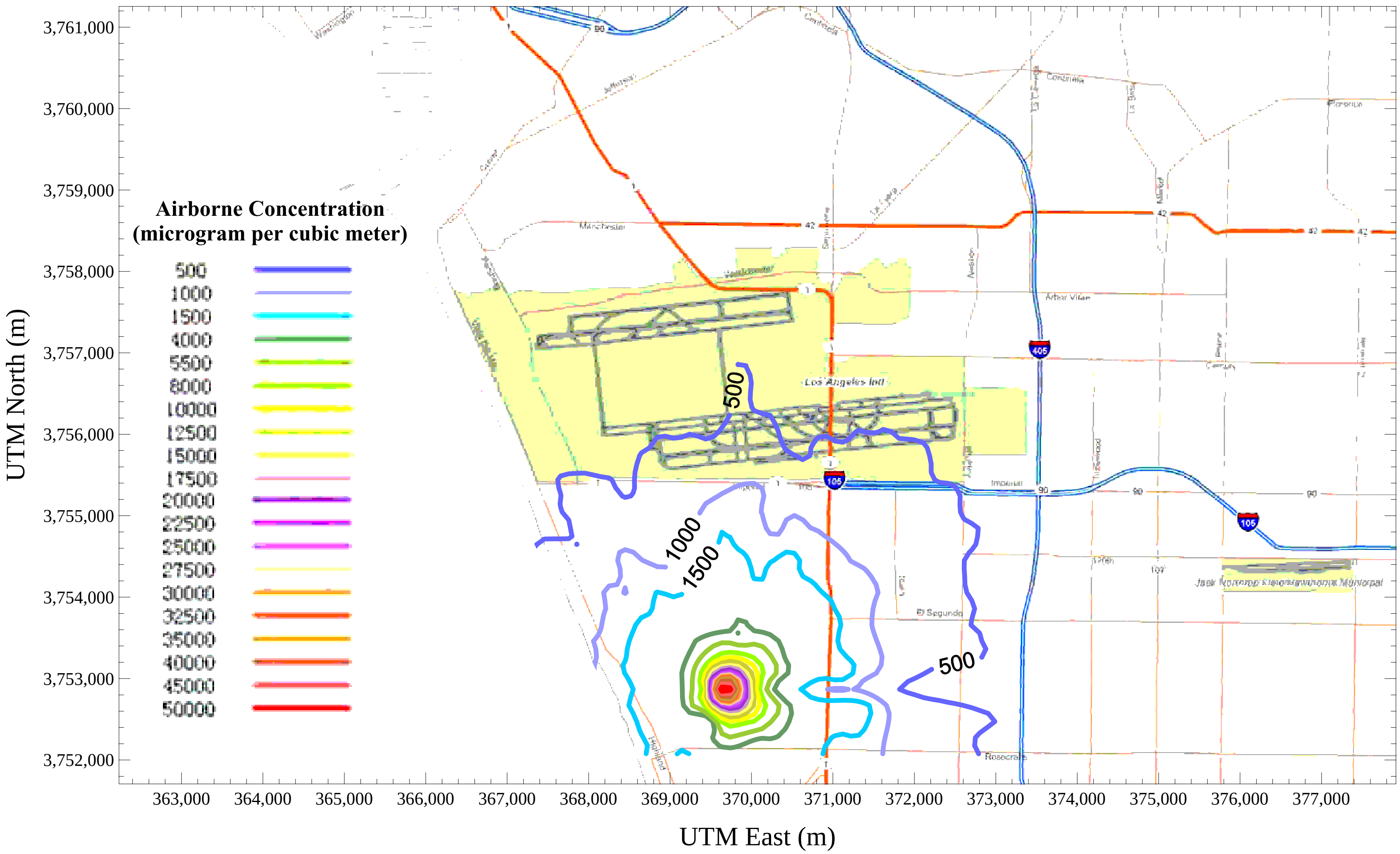
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 45 - 3-month PM25 Concentrations from Gate Sources - Summer 2007



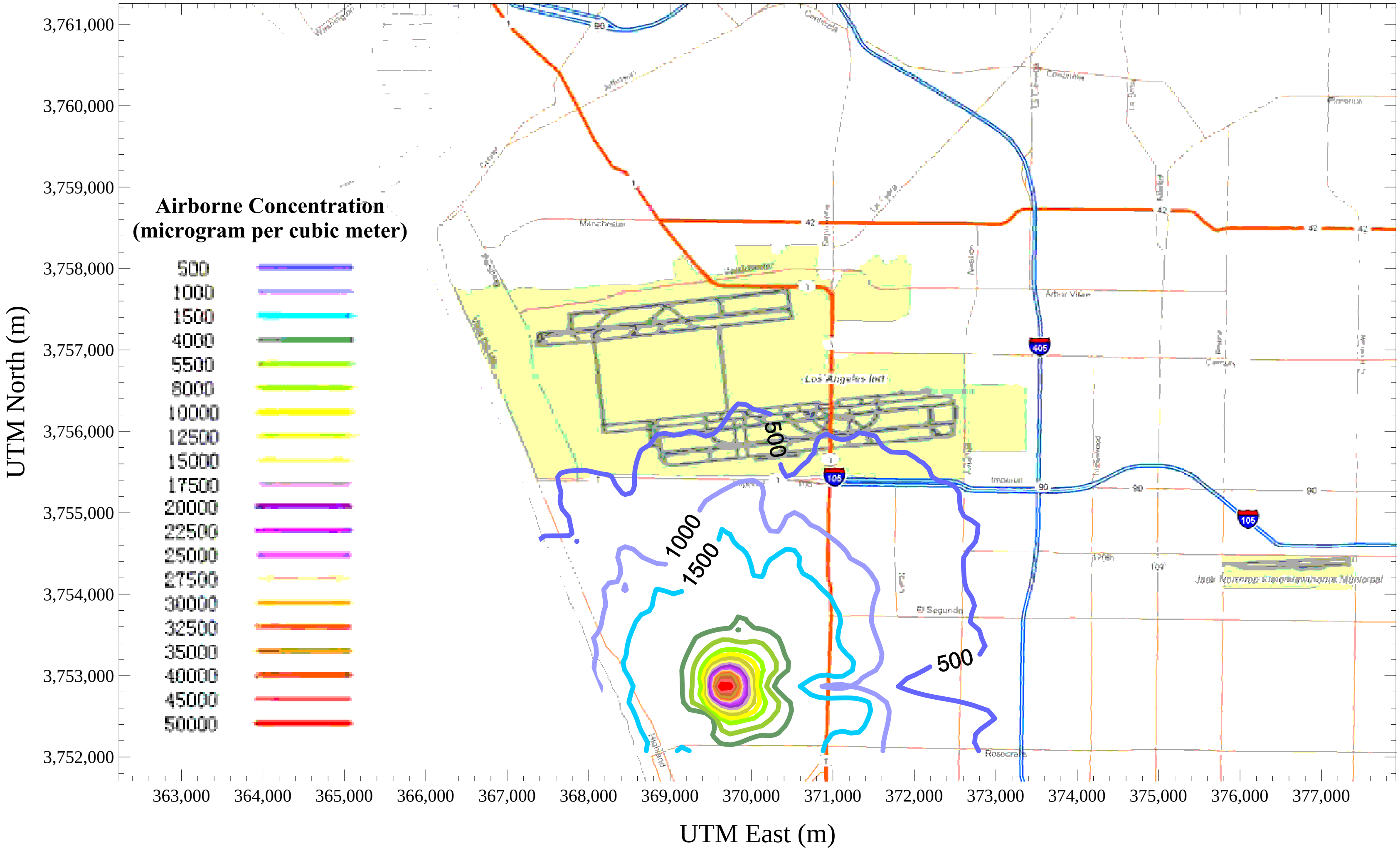
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 46 - Maximum 1-hour SO2 Concentrations from All Sources - Summer 2007



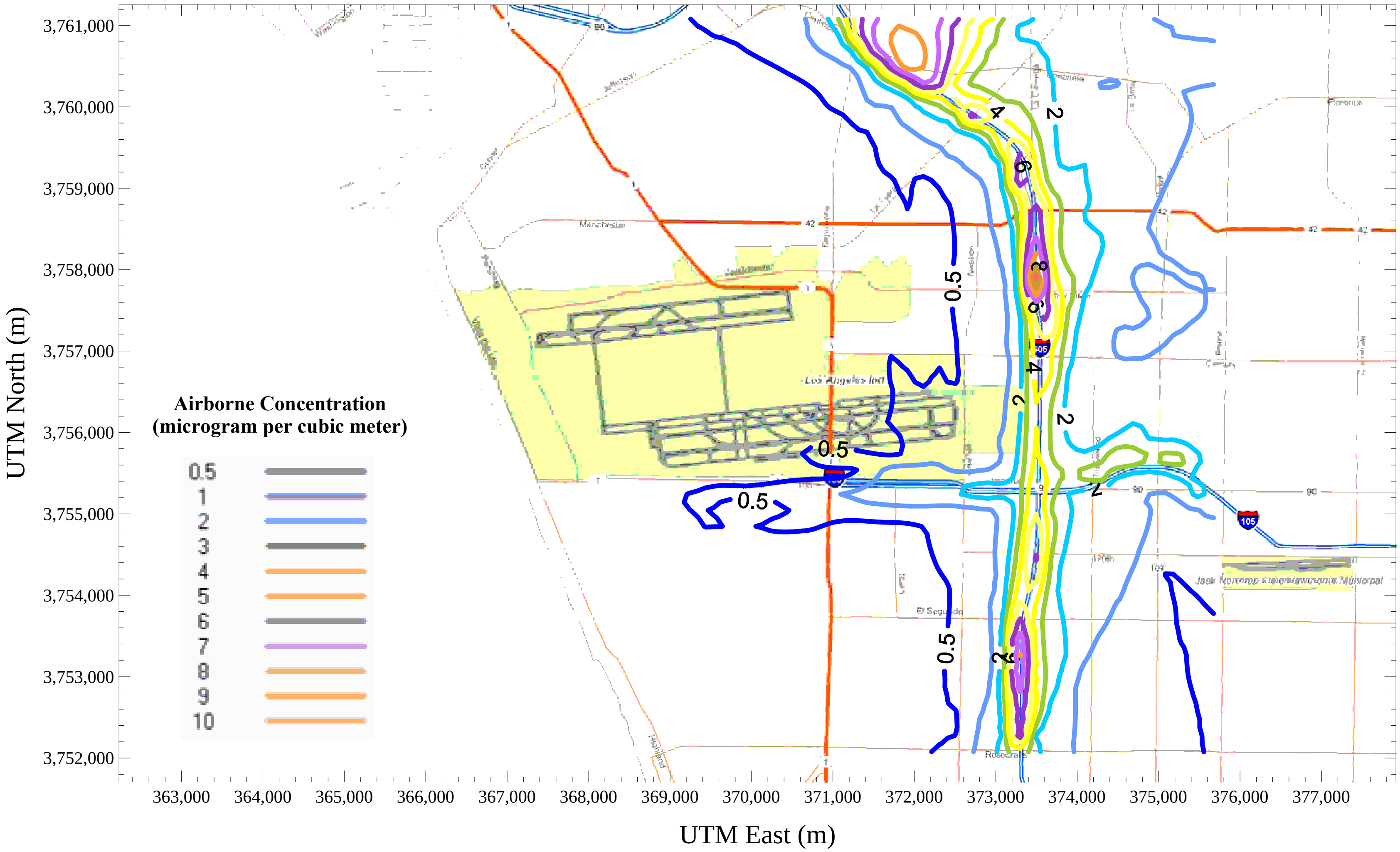
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 47 - Maximum 1-hour SO2 Concentrations from Chevron Sources - Summer 2007



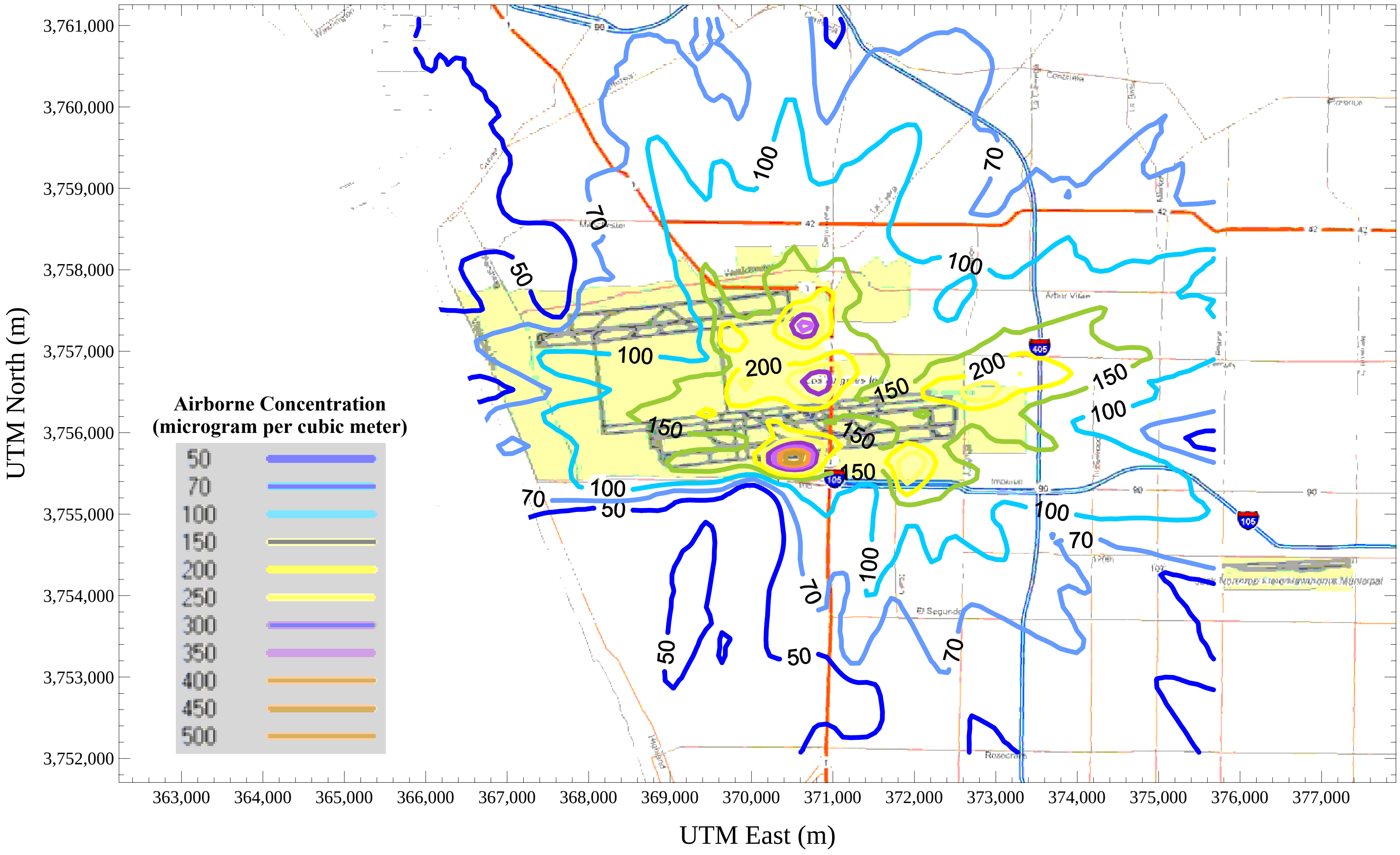
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 48 - Maxmum 1-Hour SO2 Concentrations from Off-airport Road Sources - Summer 2007



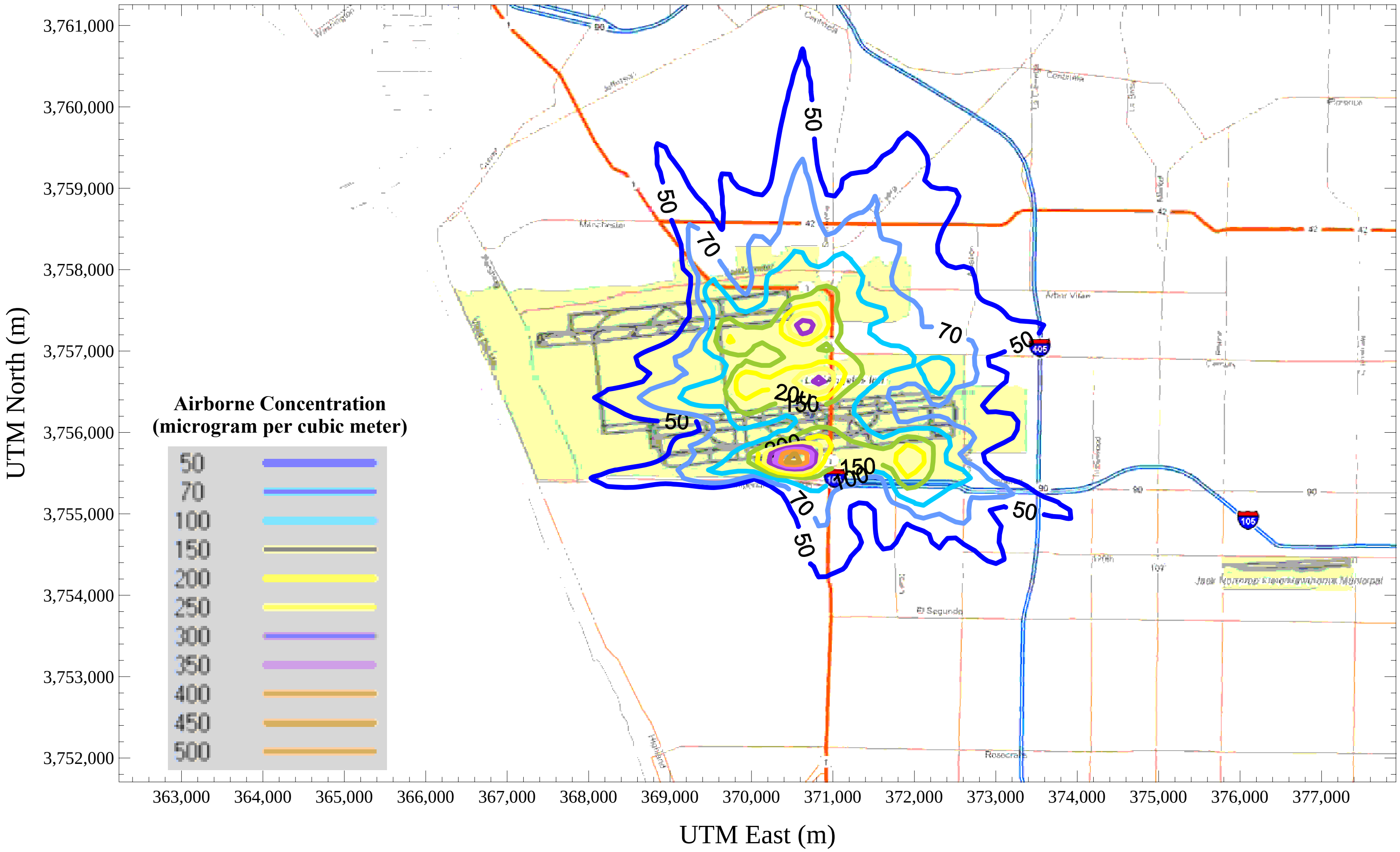
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 49 - Maximum 1-Hour SO2 Concentrations from Airport Sources - Summer 2007



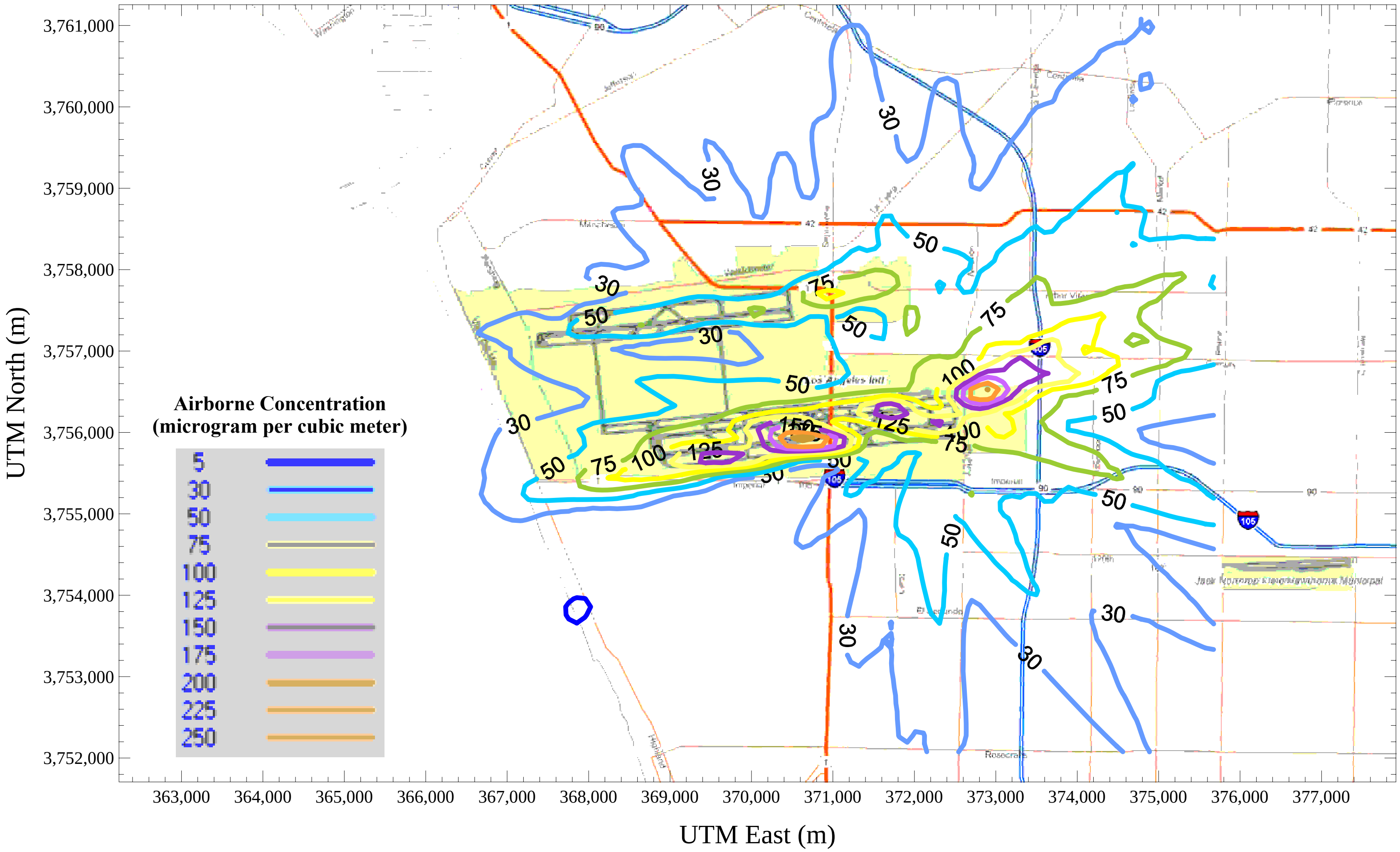
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 50 - Maximum 1-Hour SO2 Concentrations from Gate Sources - Summer 2007



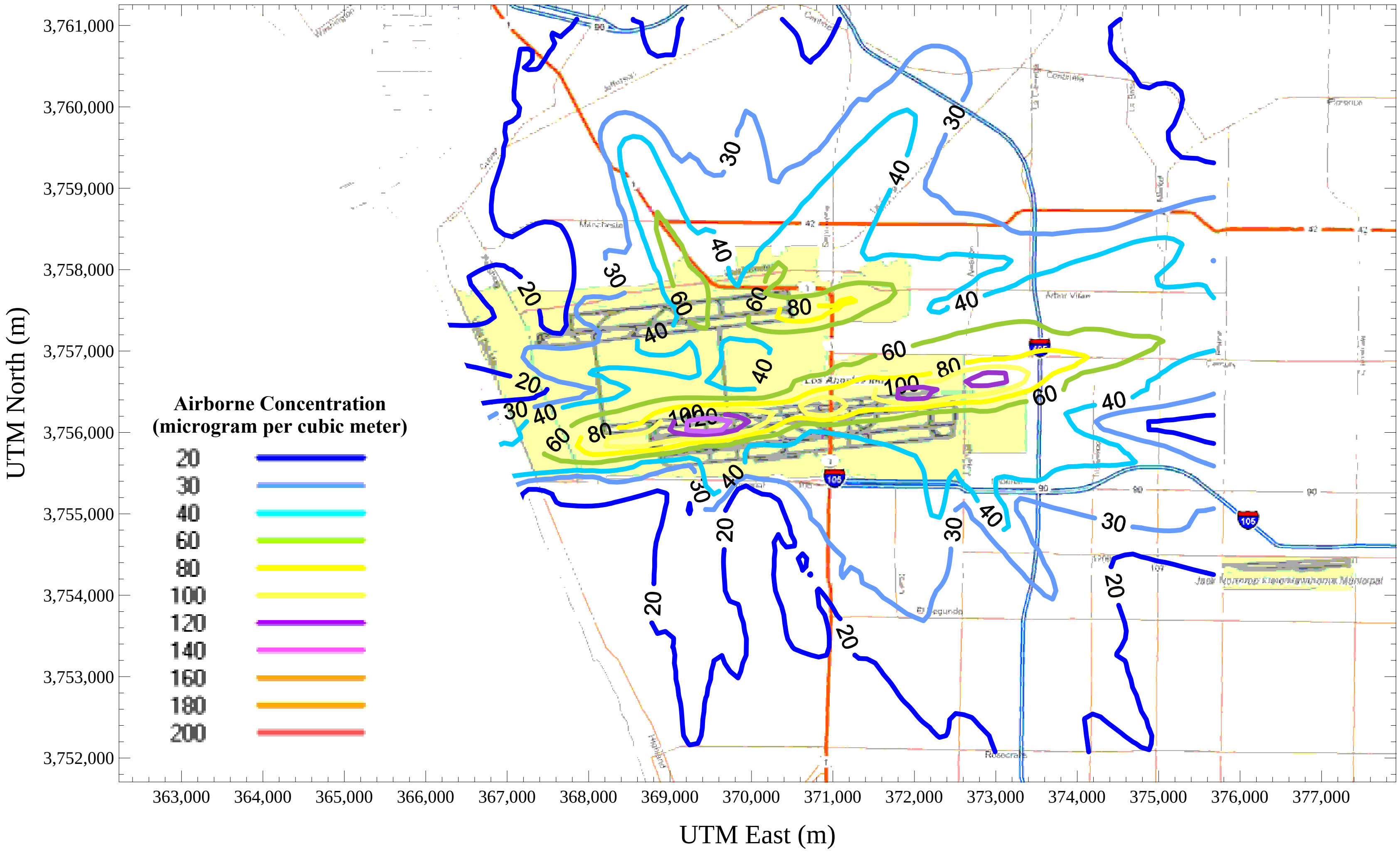
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 51 - Maximum 1-Hour SO2 Concentrations from Runway Sources - Summer 2007



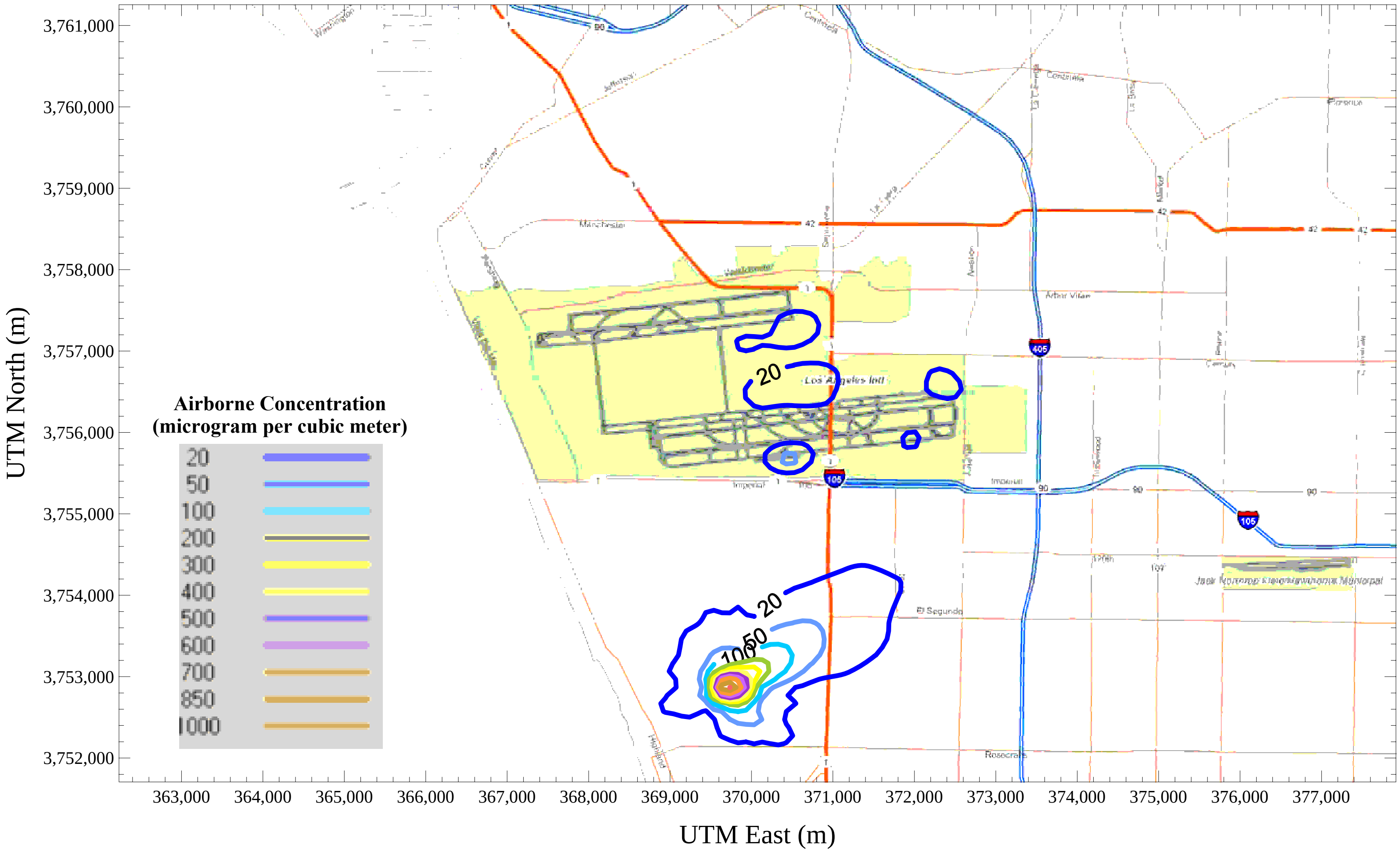
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 52 - Maximum 1-Hour SO2 Concentrations from Taxiway Sources - Summer 2007



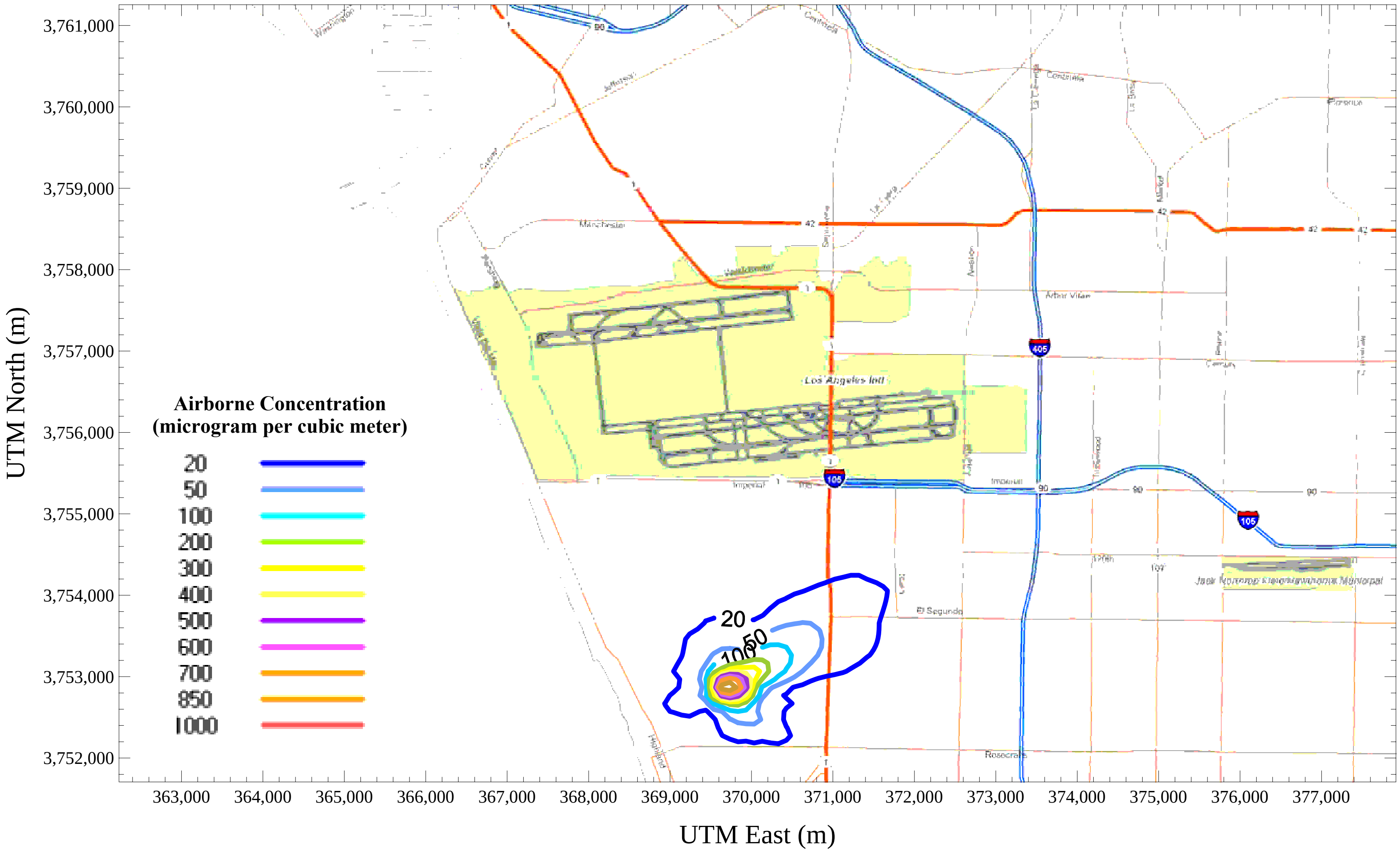
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 53 - 3-month SO2 Concentrations from All Sources - Summer 2007



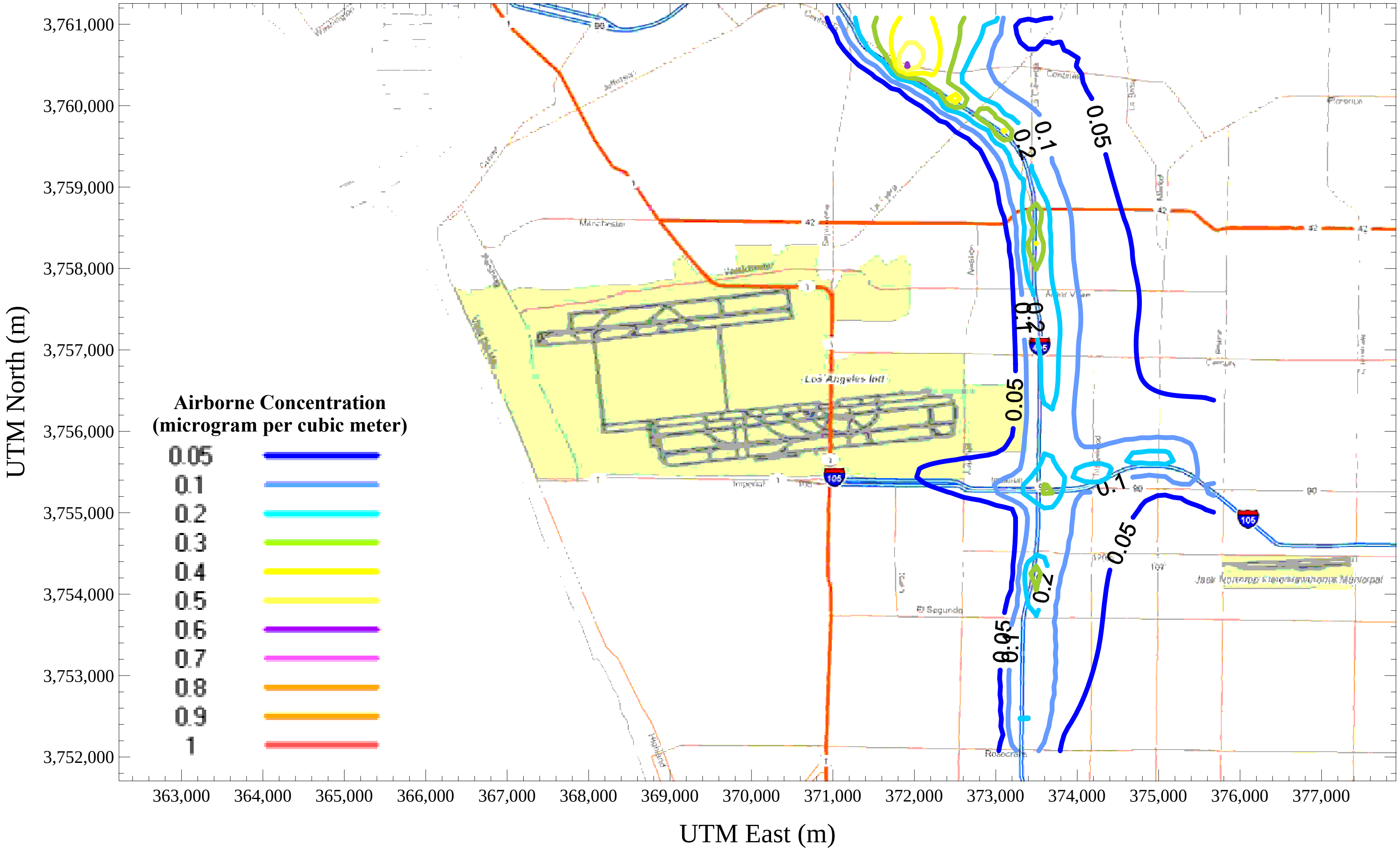
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 54 - 3-month SO2 Concentrations from Chevron Sources - Summer 2007



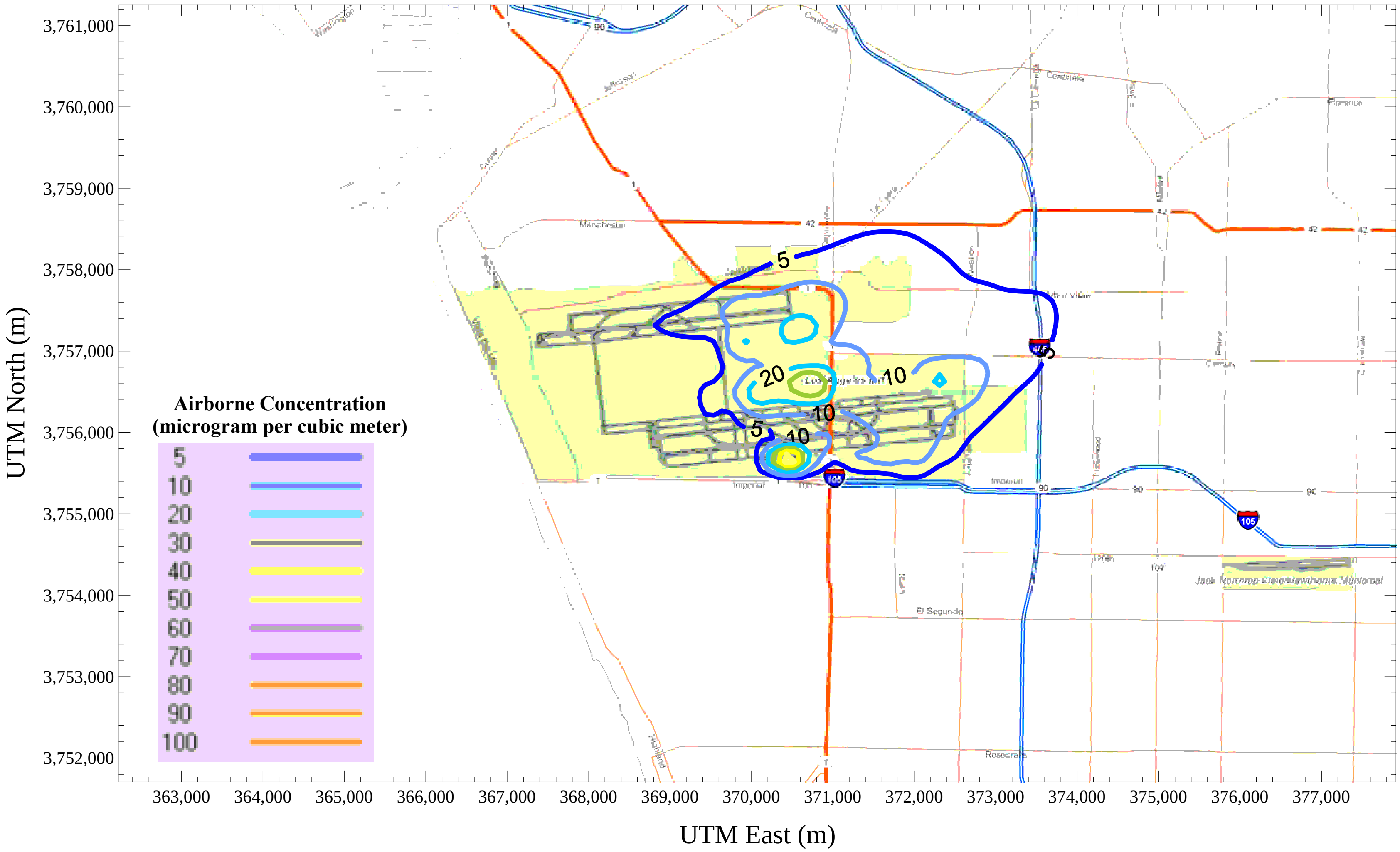
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 55 - 3-month SO2 Concentrations from Off-airport road Sources - Summer 2007



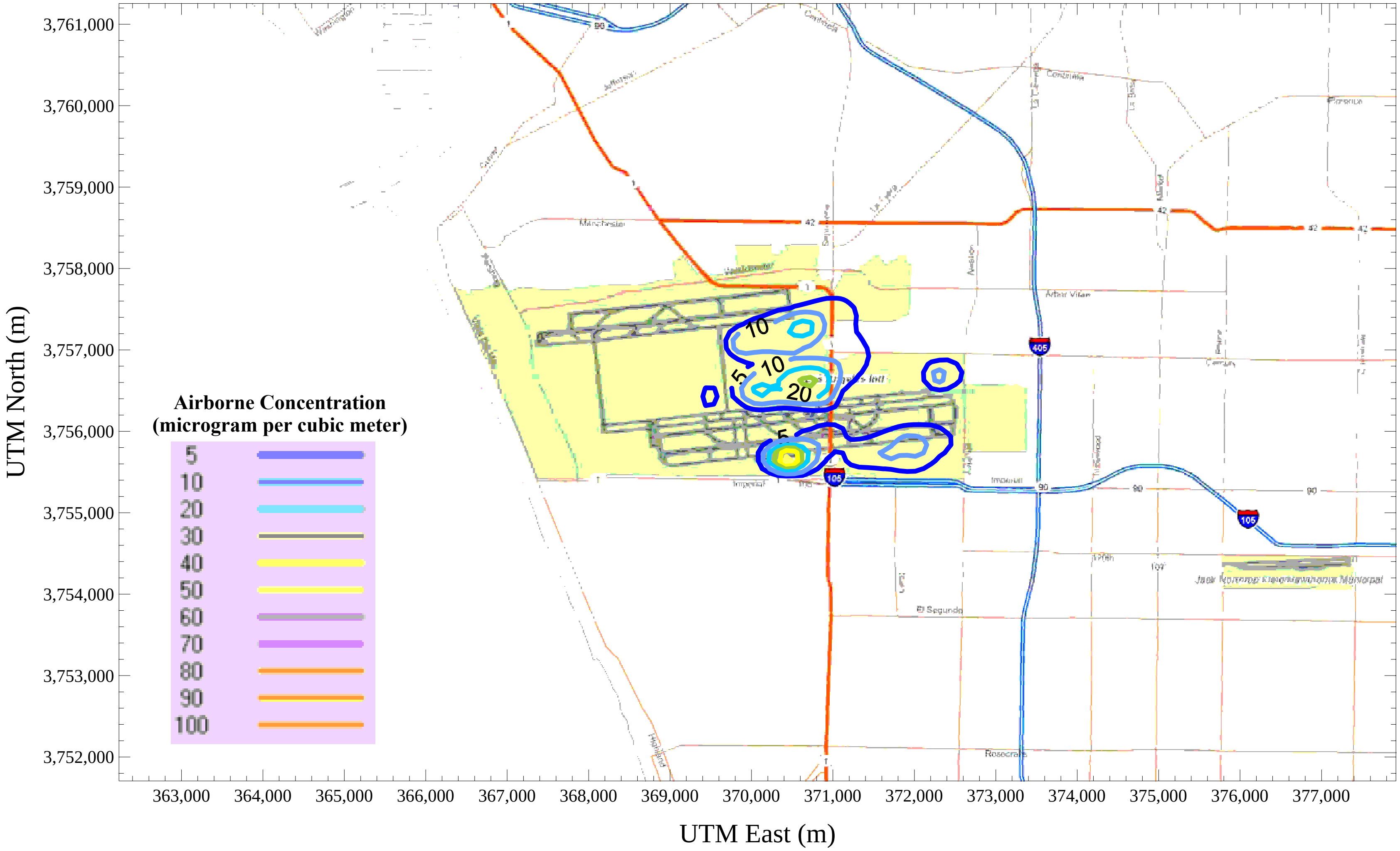
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 56 - 3-month SO2 Concentrations from Airport Sources - Summer 2007



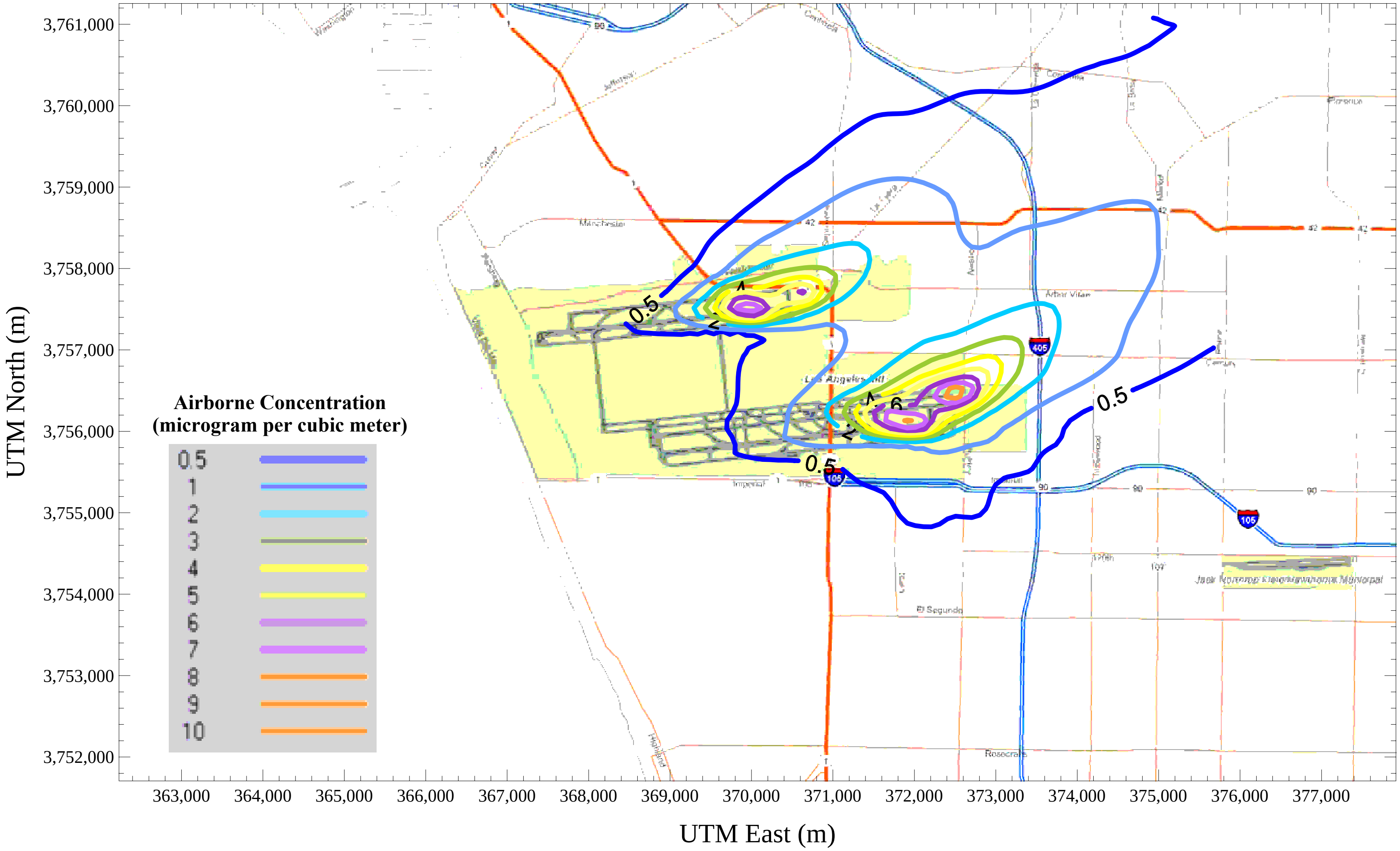
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 57 - 3-month SO2 Concentrations from Gate Sources - Summer 2007



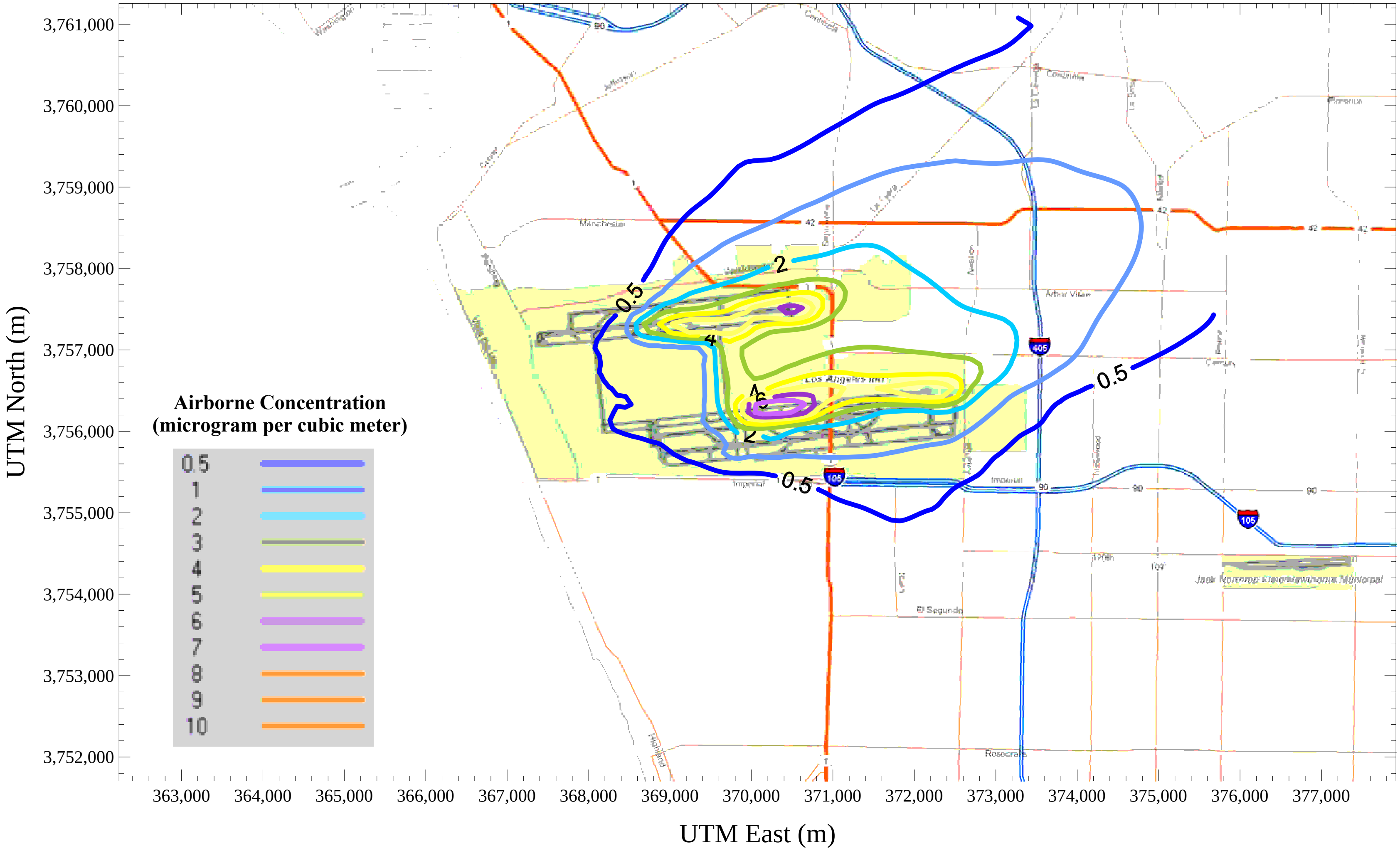
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 58 - 3-month SO2 Concentrations from Runway Sources - Summer 2007



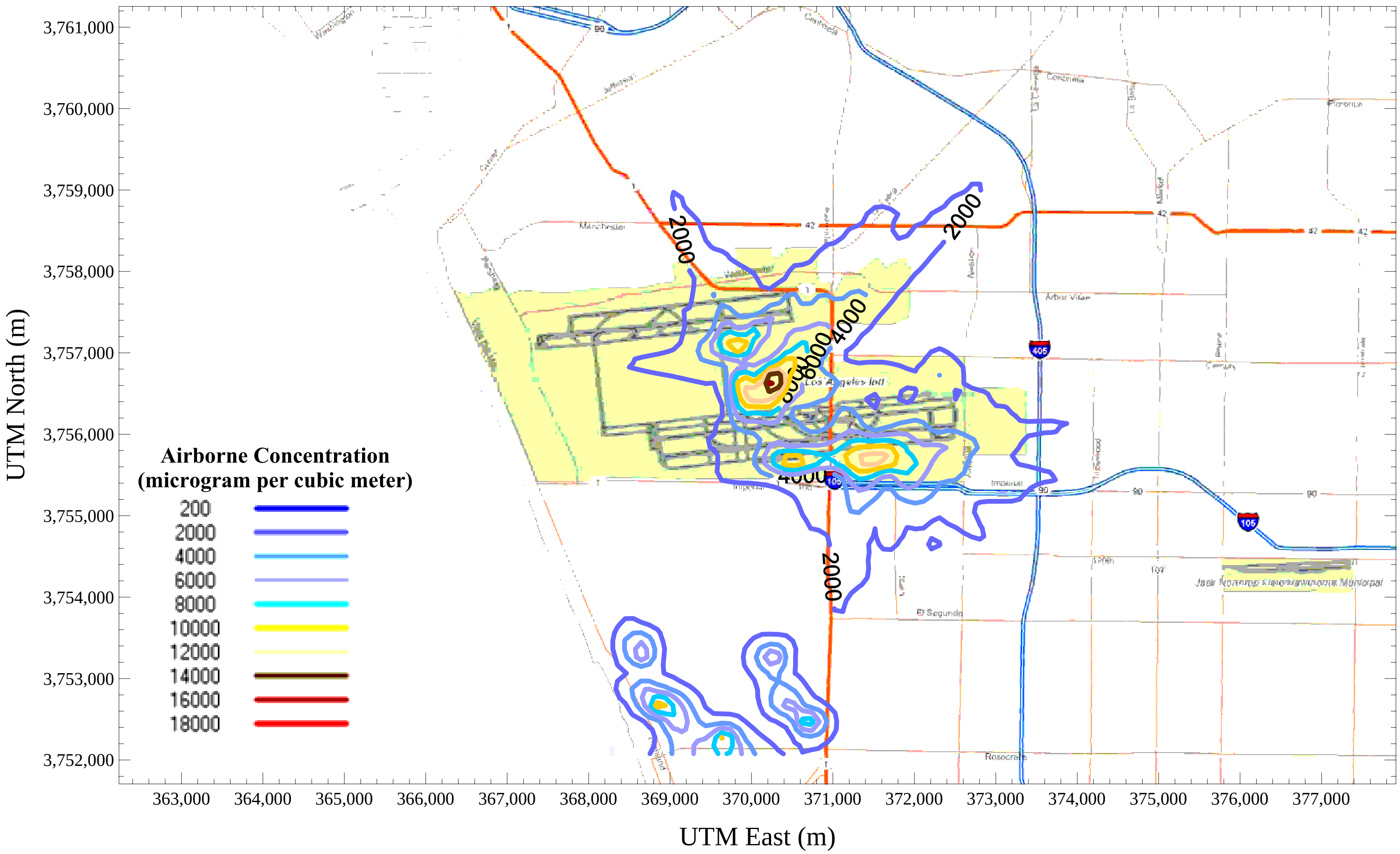
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 59 - 3-month SO2 Concentrations from Taxiway Sources - Summer 2007



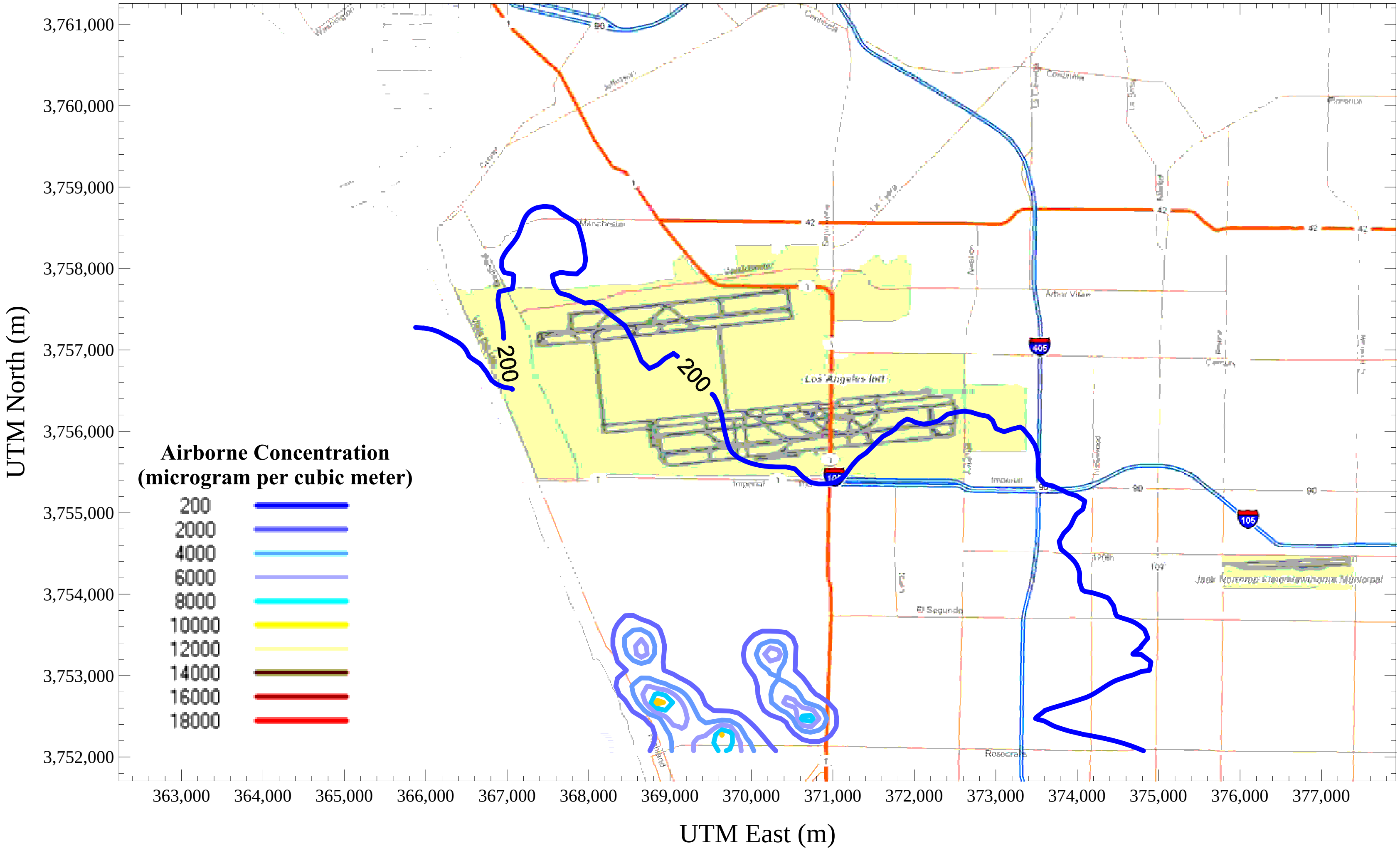
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 60 - Maximum 1-hour VOC Concentrations from All Sources - Summer 2007



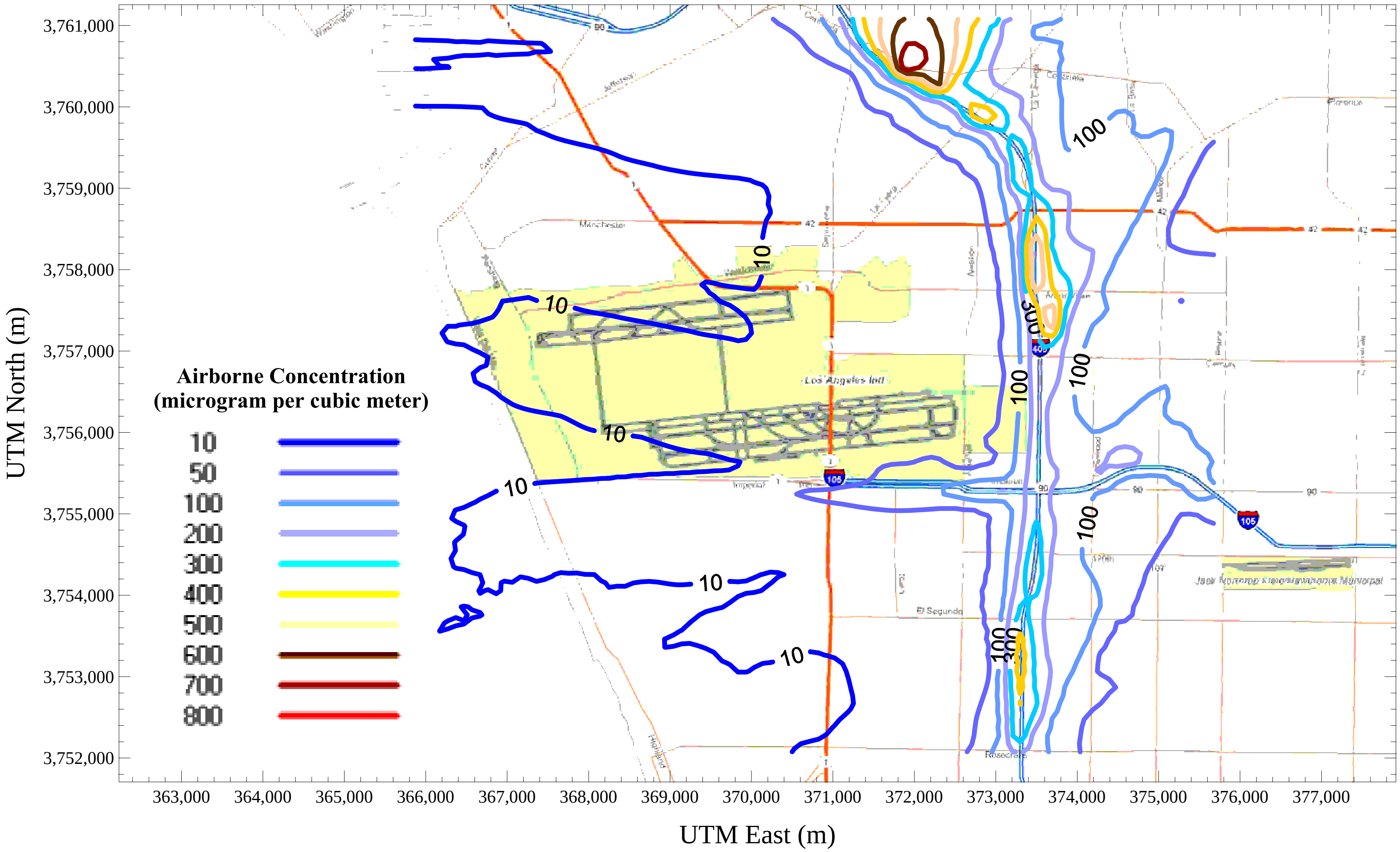
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 61 - Maximum 1-hour VOC Concentrations from Chevron Sources - Summer 2007



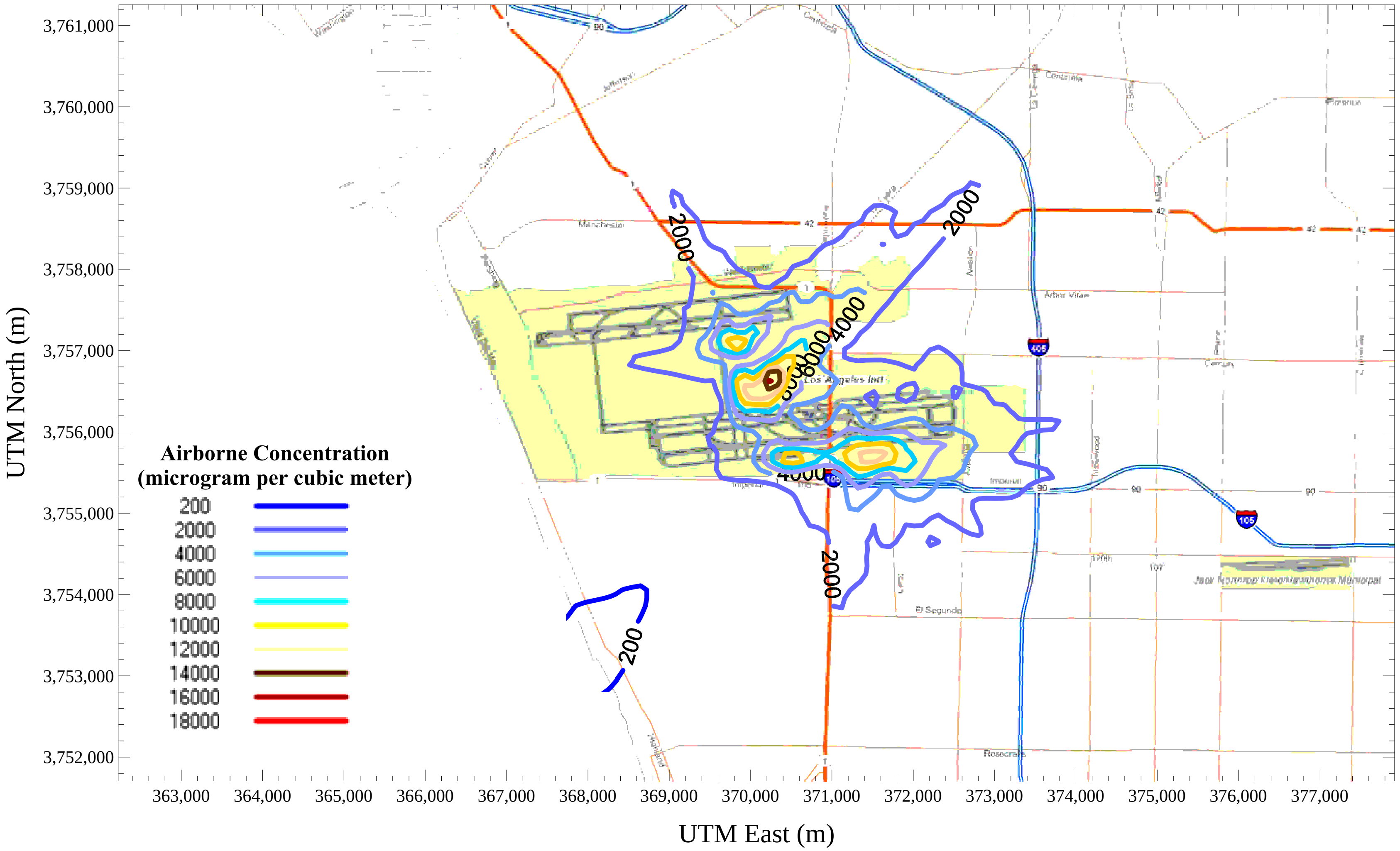
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 62 - Maximum 1-hour VOC Concentrations from Off-airport Road Sources - Summer 2007



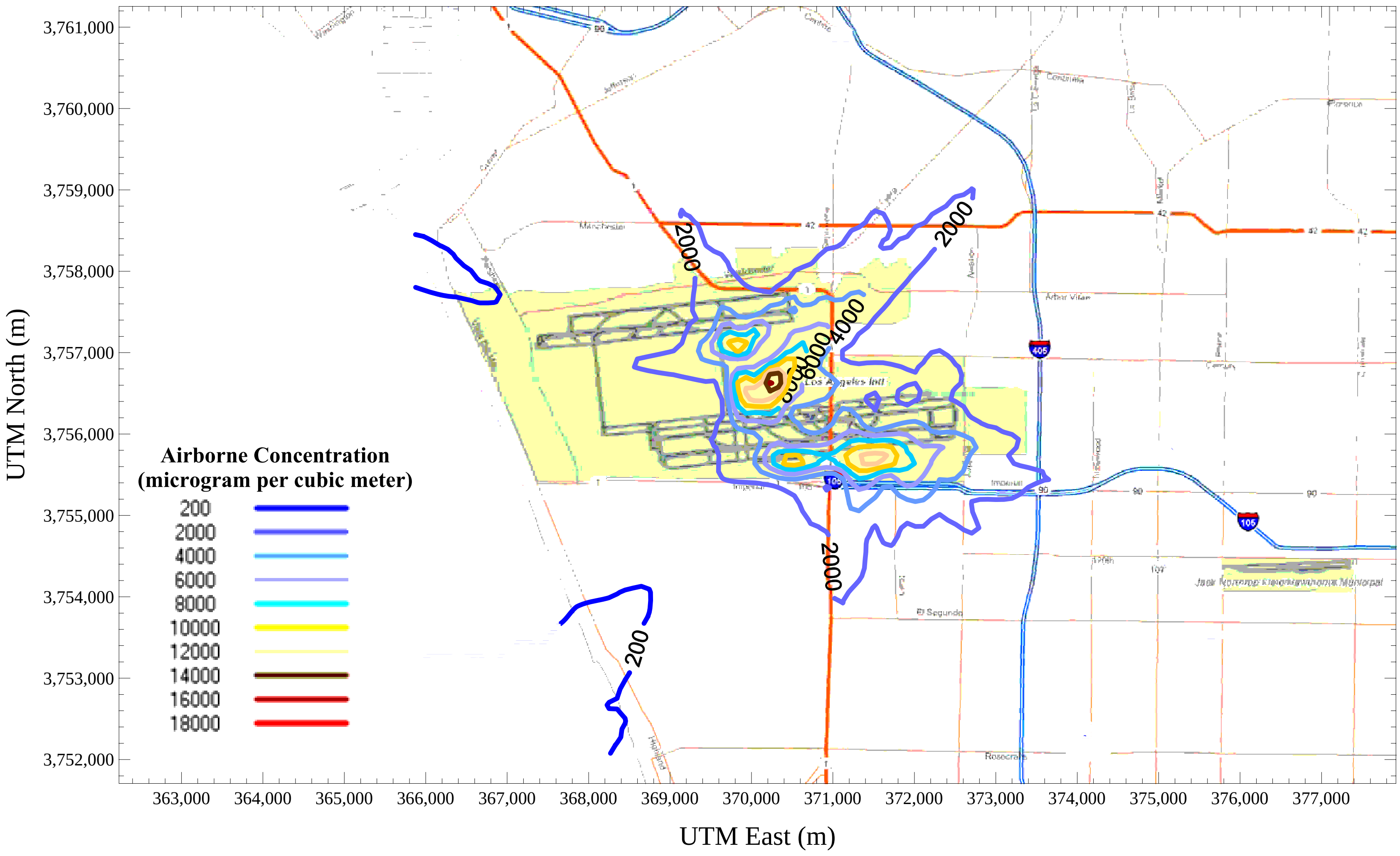
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 63 - Maximum 1-hour VOC Concentrations from Airport Sources - Summer 2007



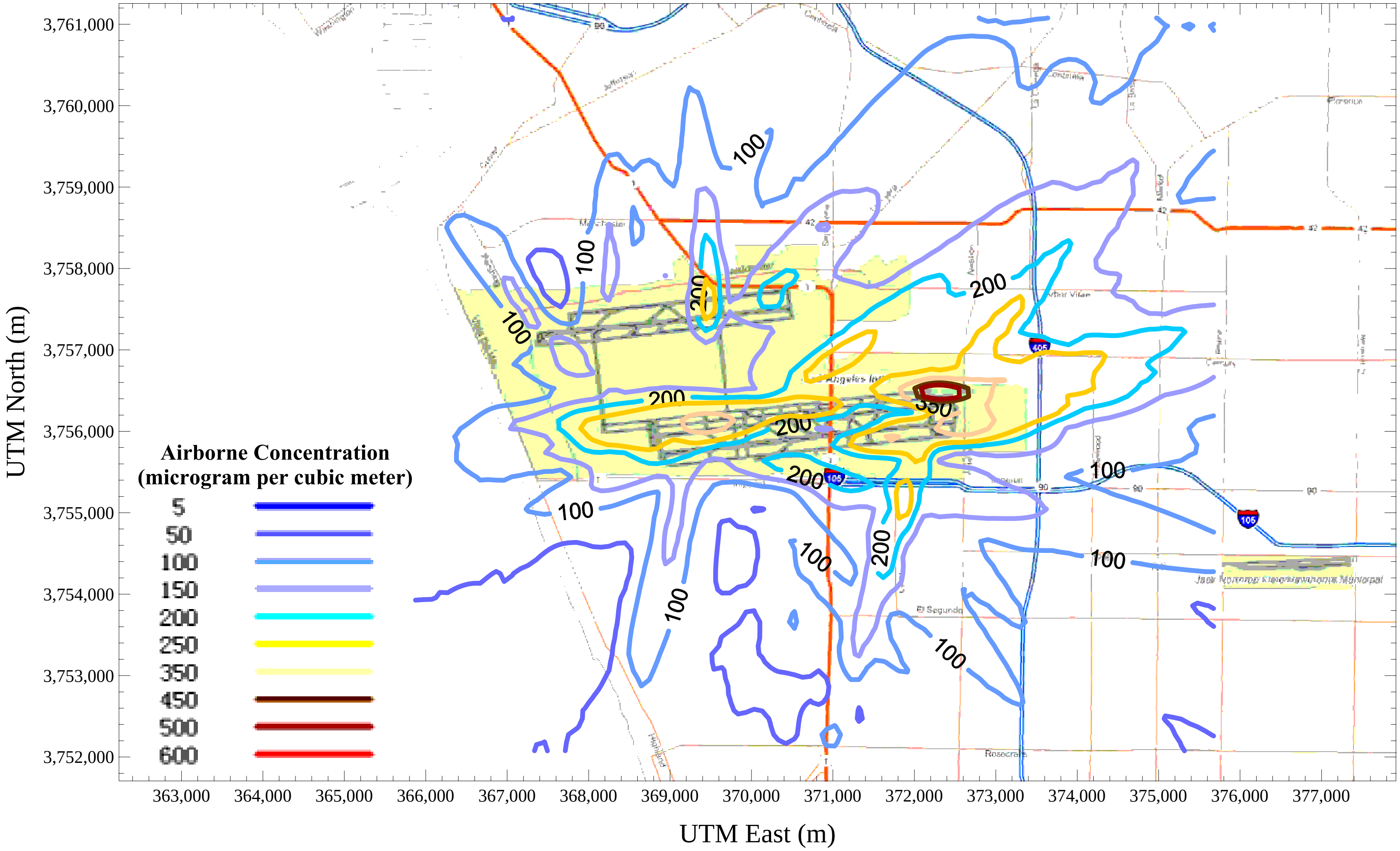
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 64 - Maximum 1-hour VOC Concentrations from Gate Sources - Summer 2007



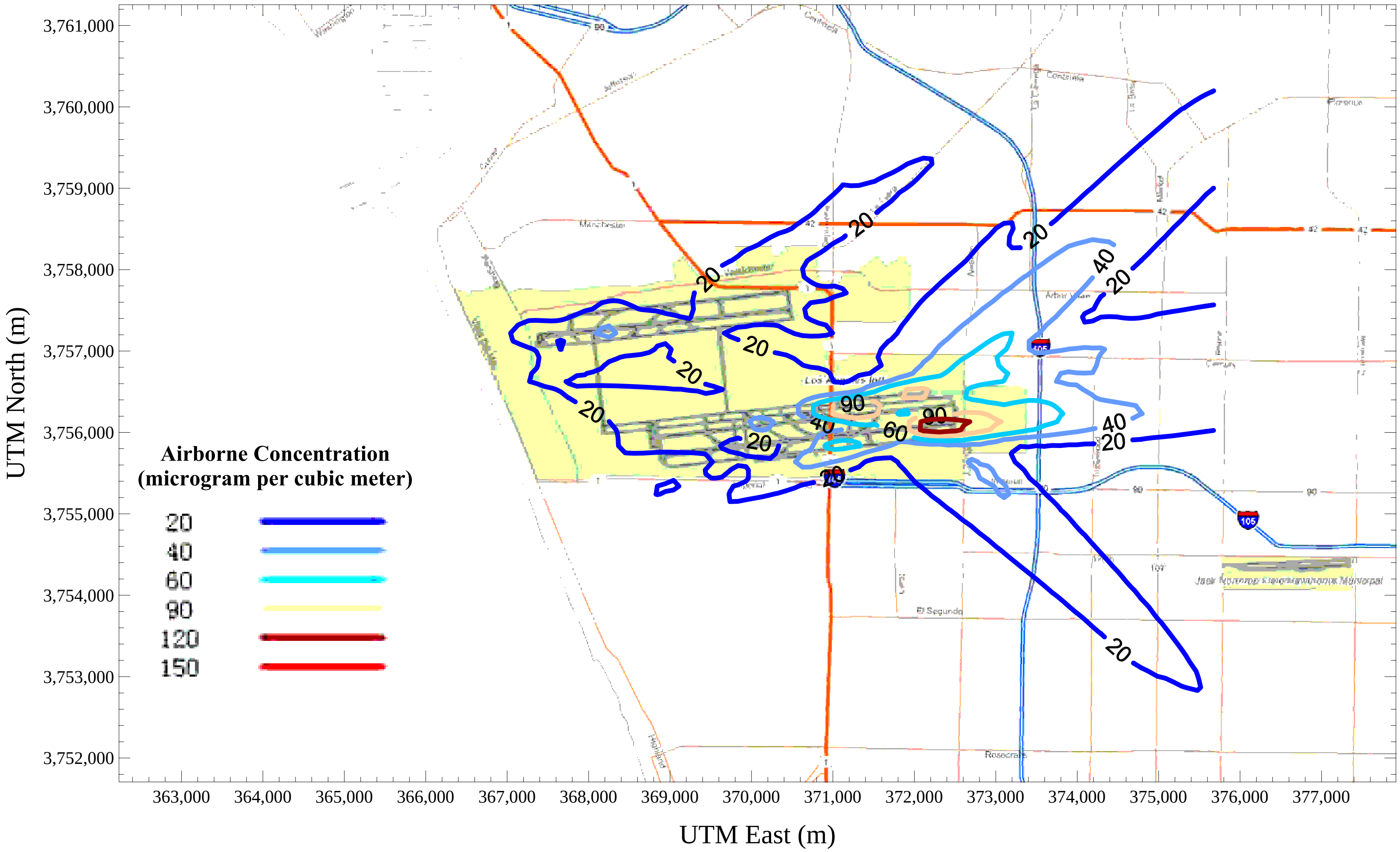
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 65 - Maximum 1-hour VOC Concentrations from Taxiway Sources - Summer 2007



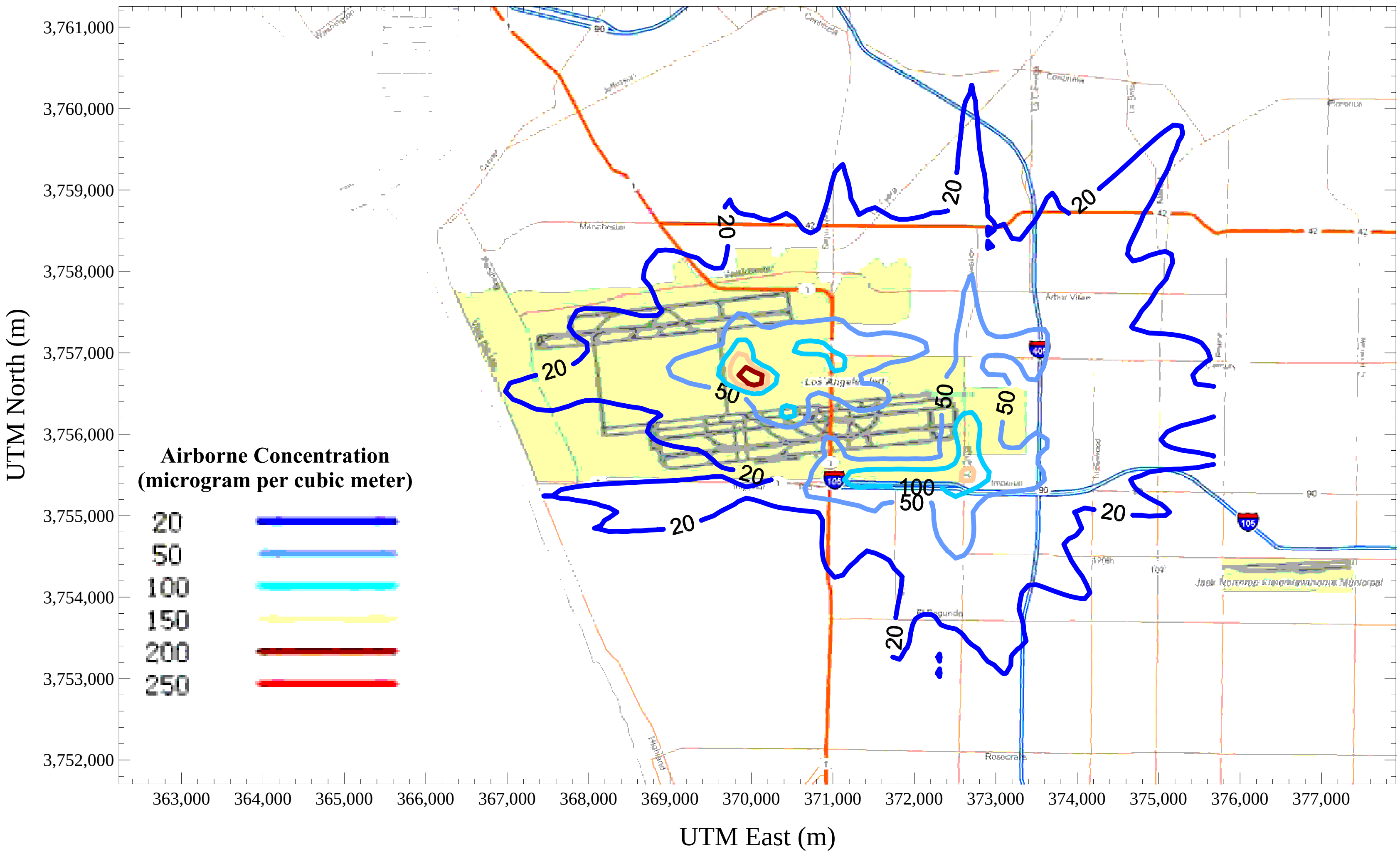
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 66 - Maximum 1-hour VOC Concentrations from Runway Sources - Summer 2007



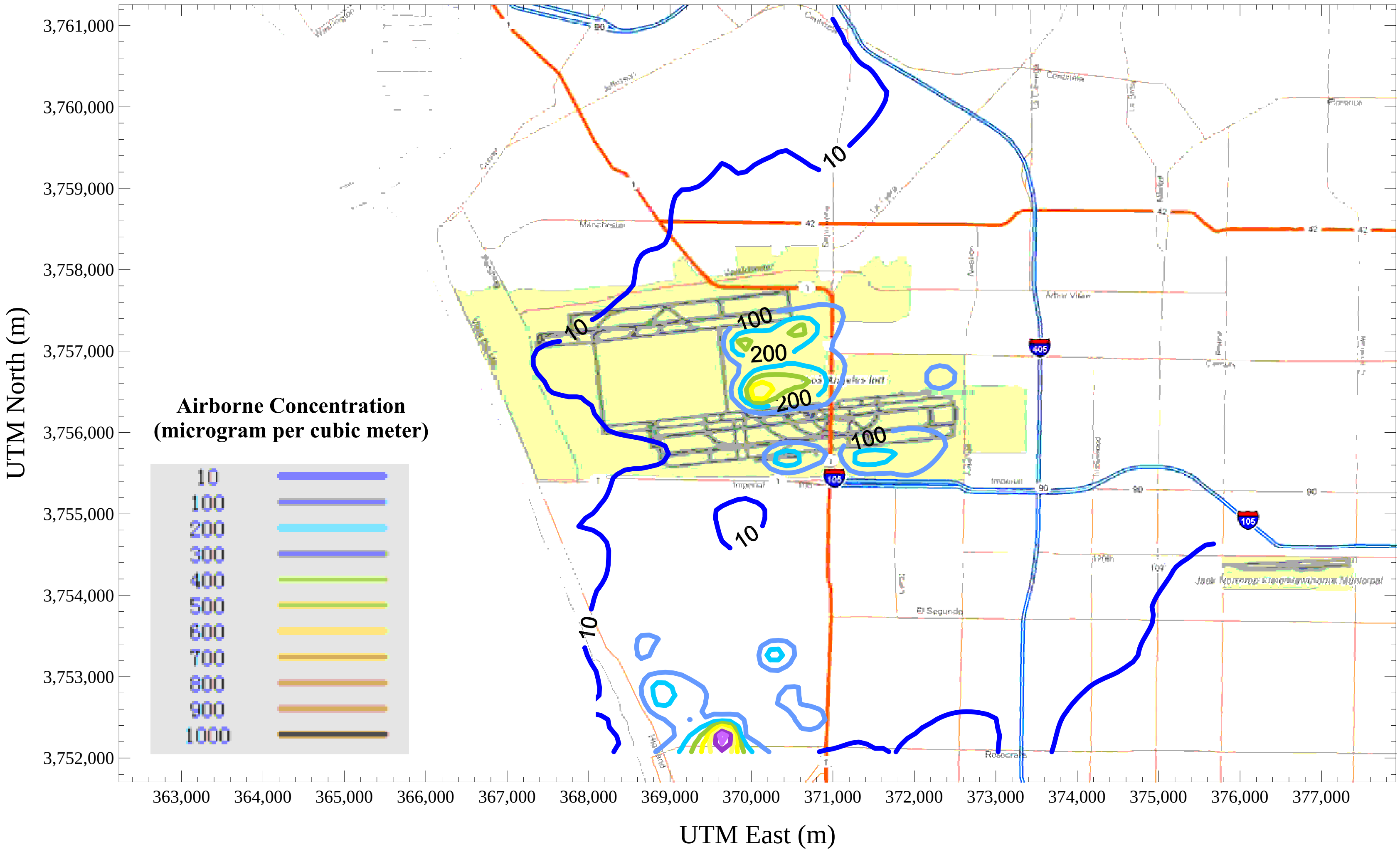
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 67 - Maximum 1-hour VOC Concentrations from Airport Road Sources - Summer 2007



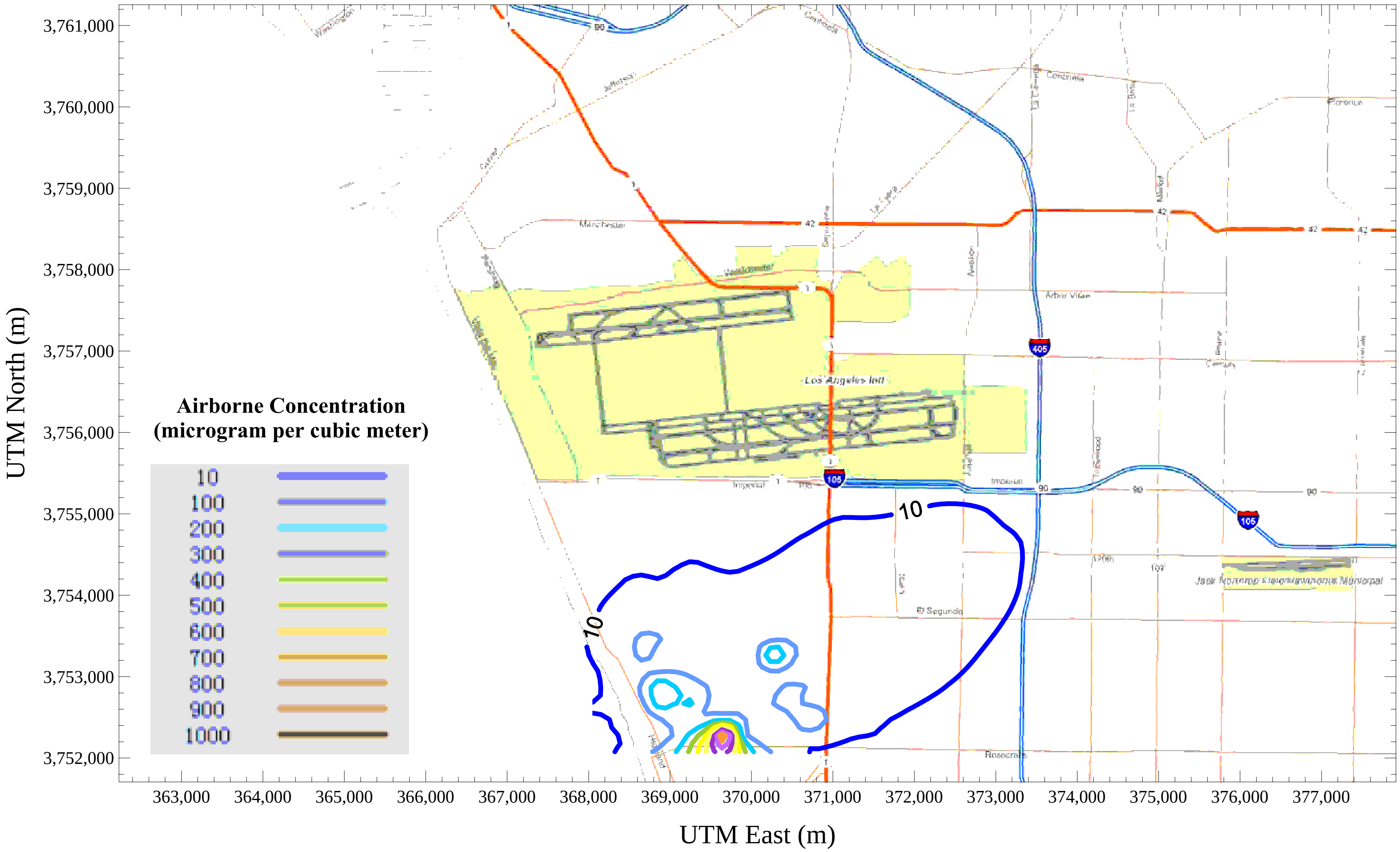
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 68 - 3-month VOC Concentrations from All Sources - Summer 2007



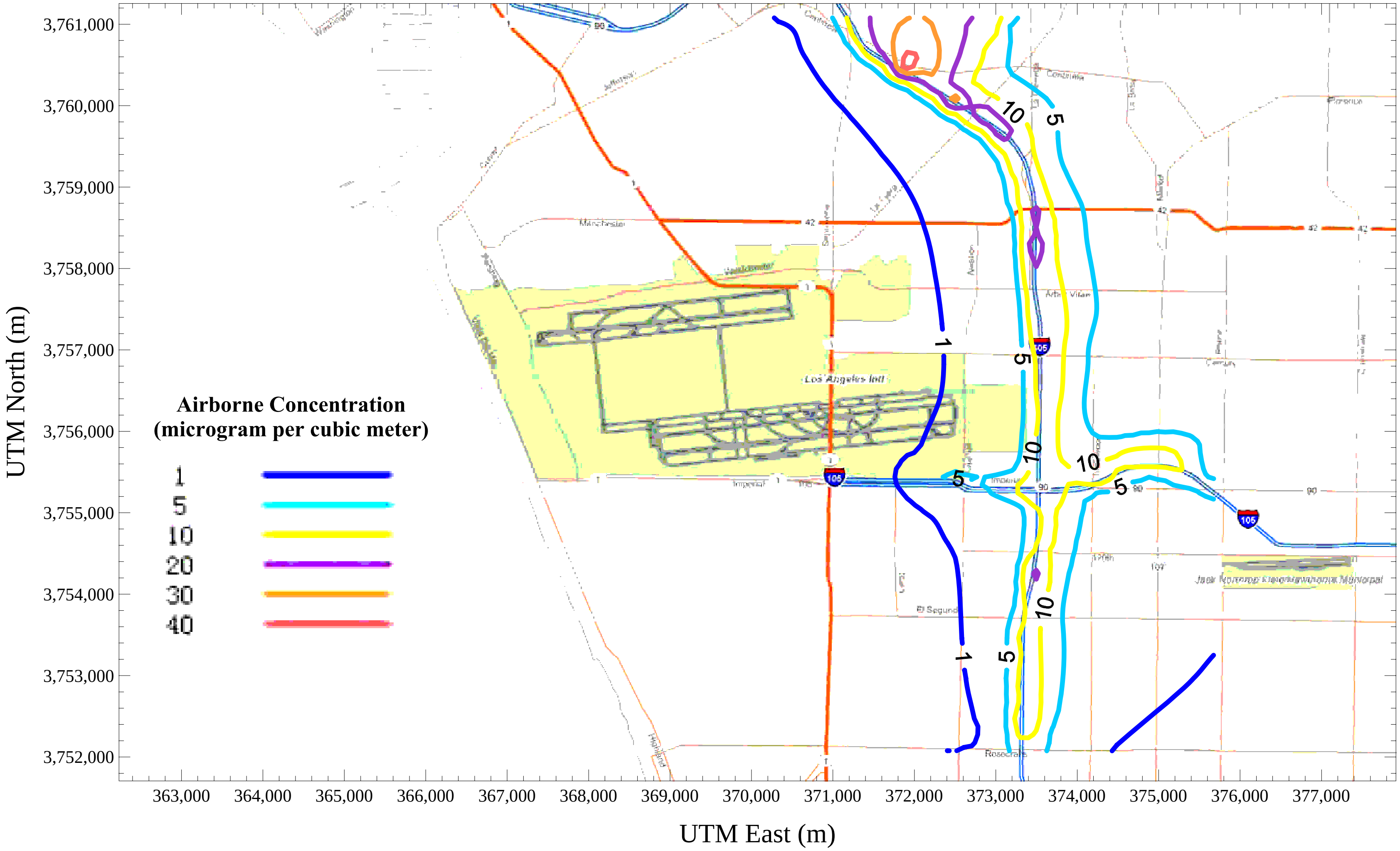
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 69 - 3-month VOC Concentrations from Chevron Sources - Summer 2007



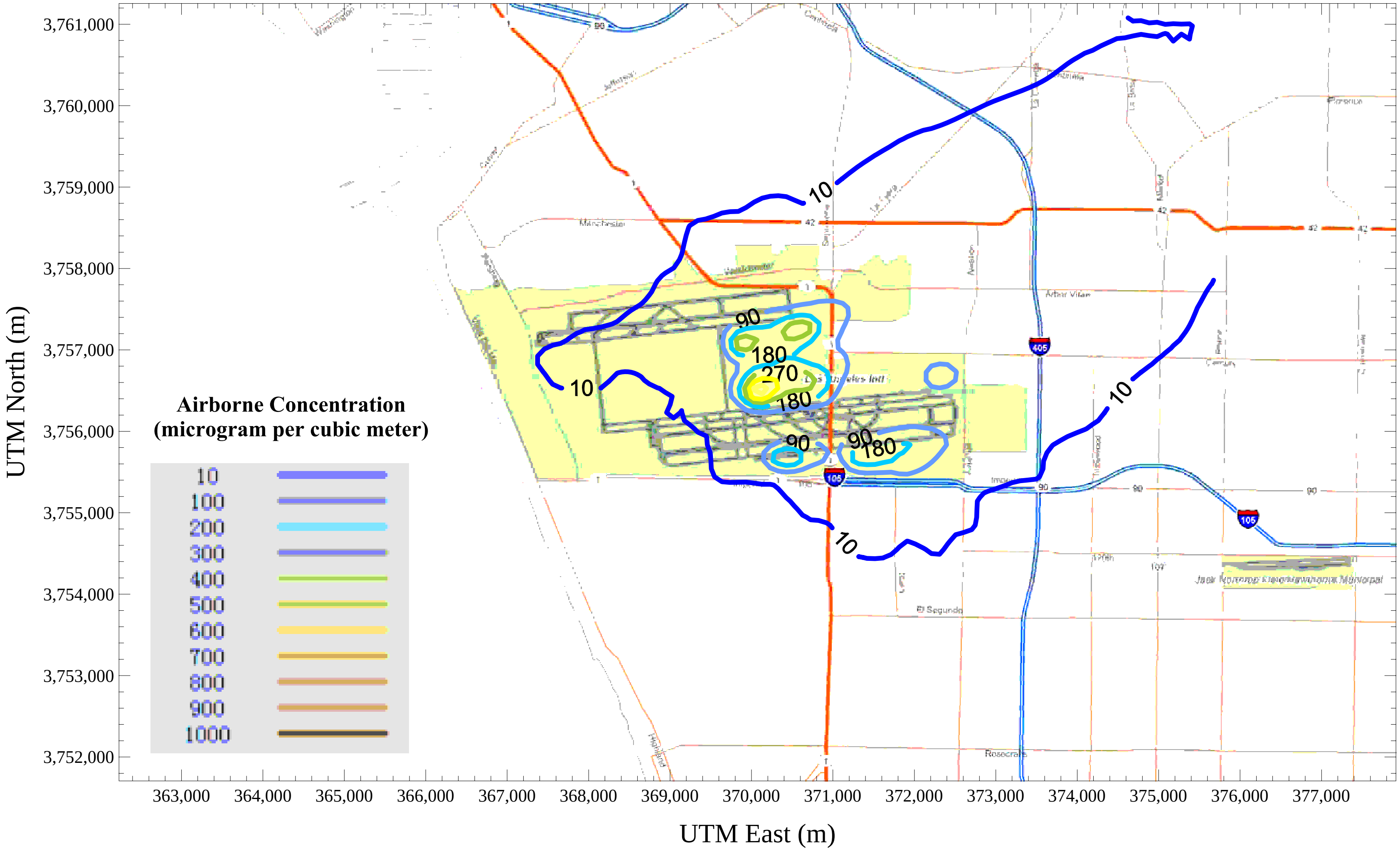
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 70 - 3-month VOC Concentrations from Off-airport Road Sources - Summer 2007



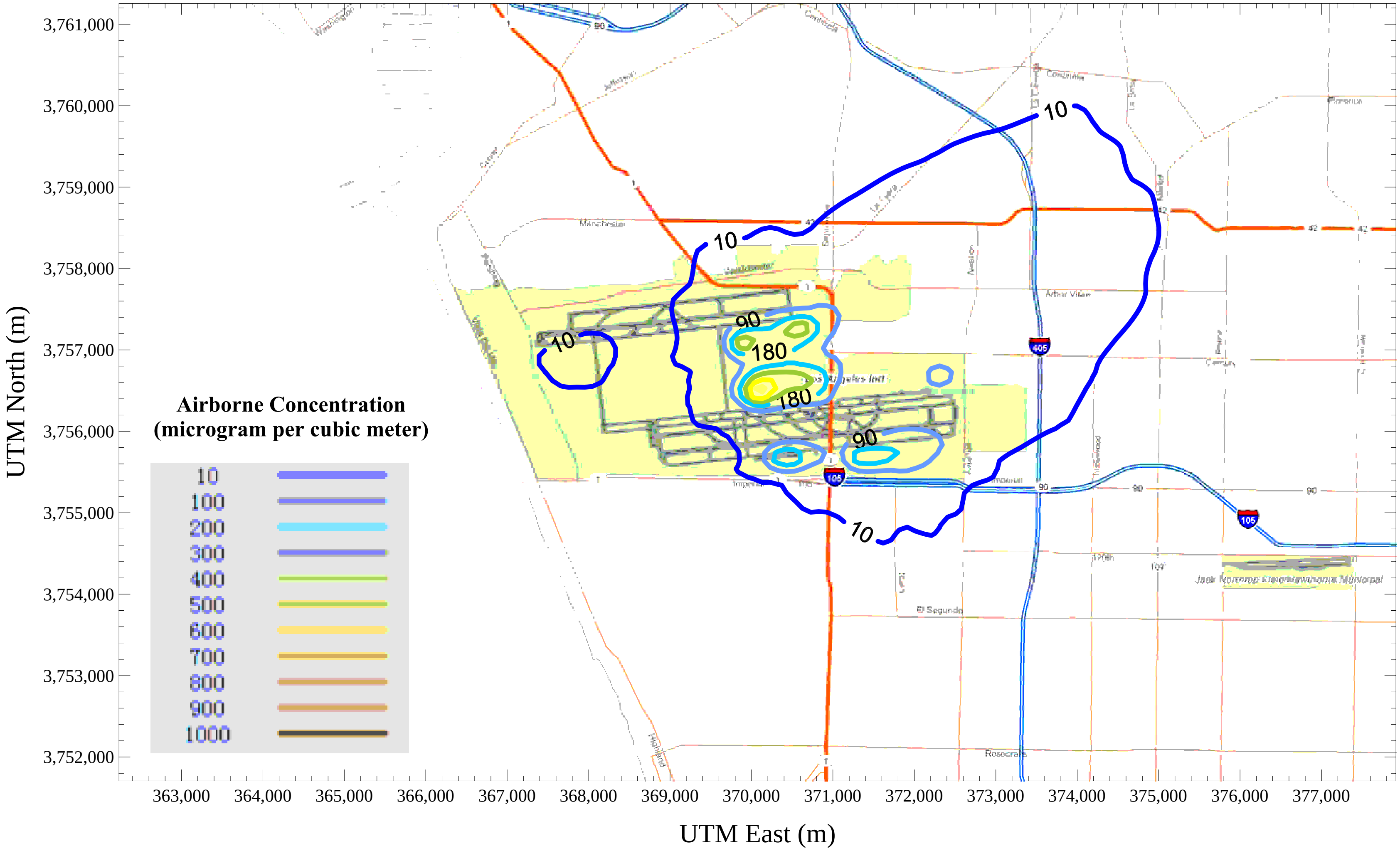
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 71 - 3-month VOC Concentrations from Airport Sources - Summer 2007



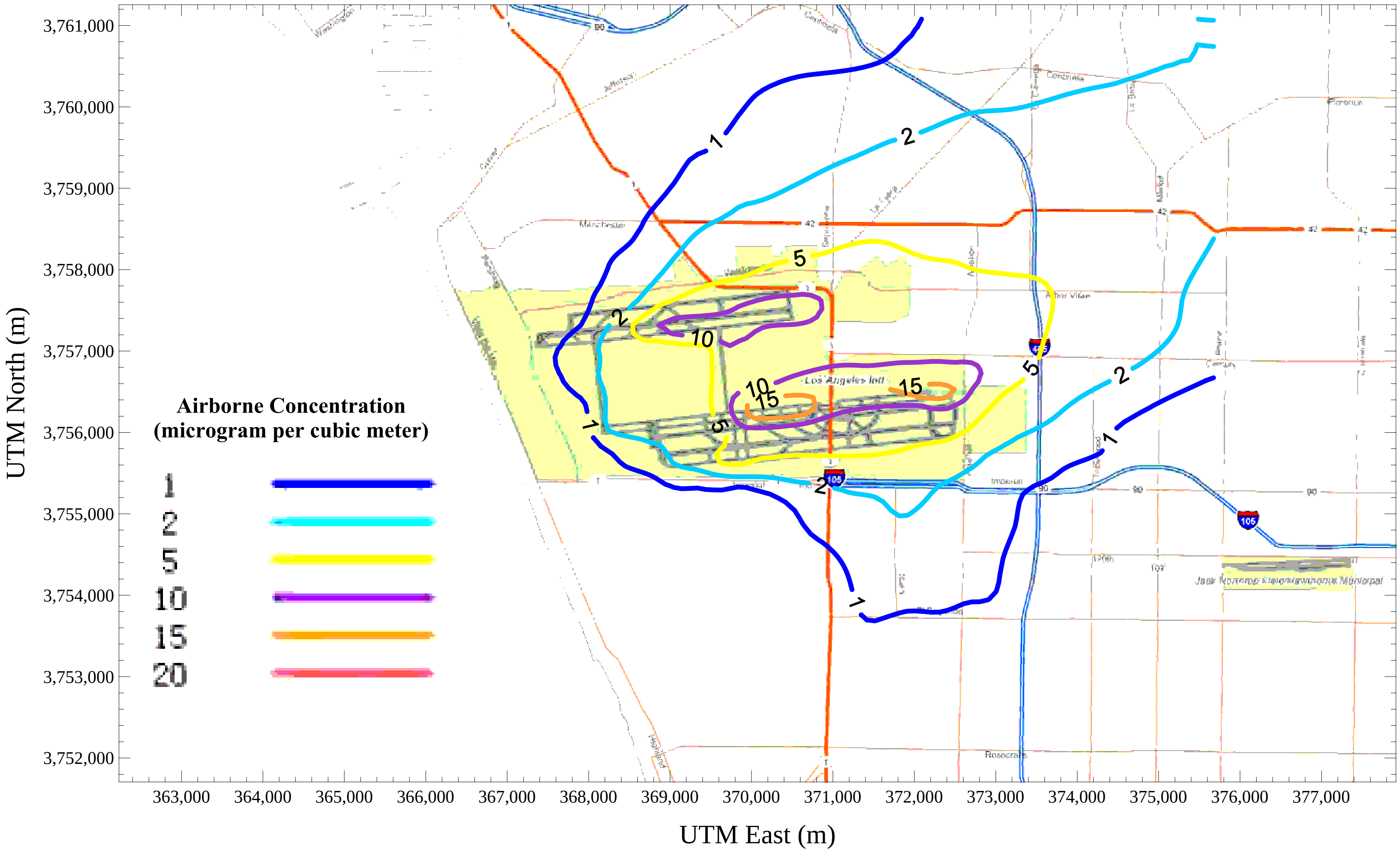
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 72 - 3-month VOC Concentrations from Gate Sources - Summer 2007



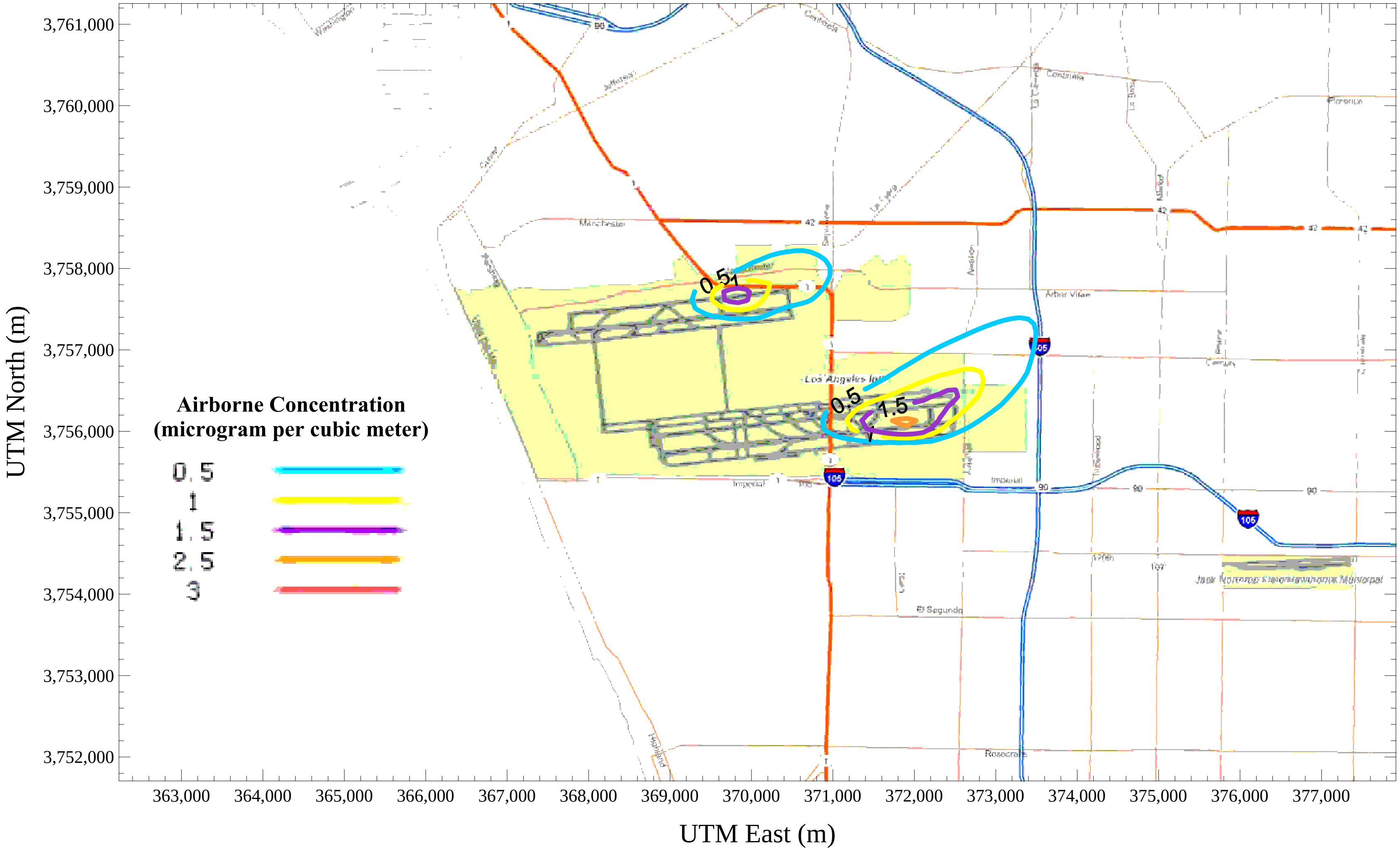
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 73 - 3-month VOC Concentrations from Taxiway Sources - Summer 2007



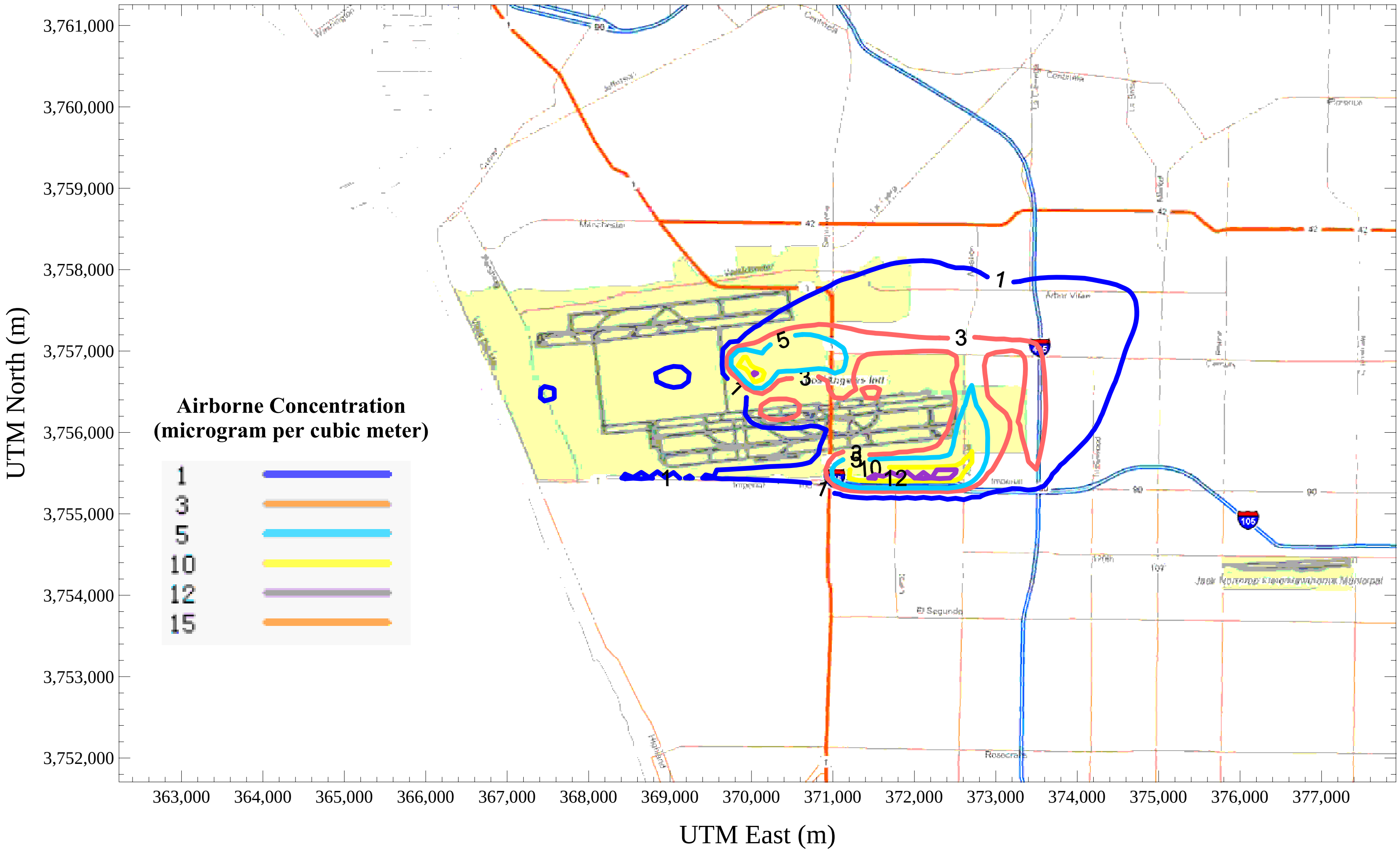
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 74 - 3-month VOC Concentrations from Runway Sources - Summer 2007



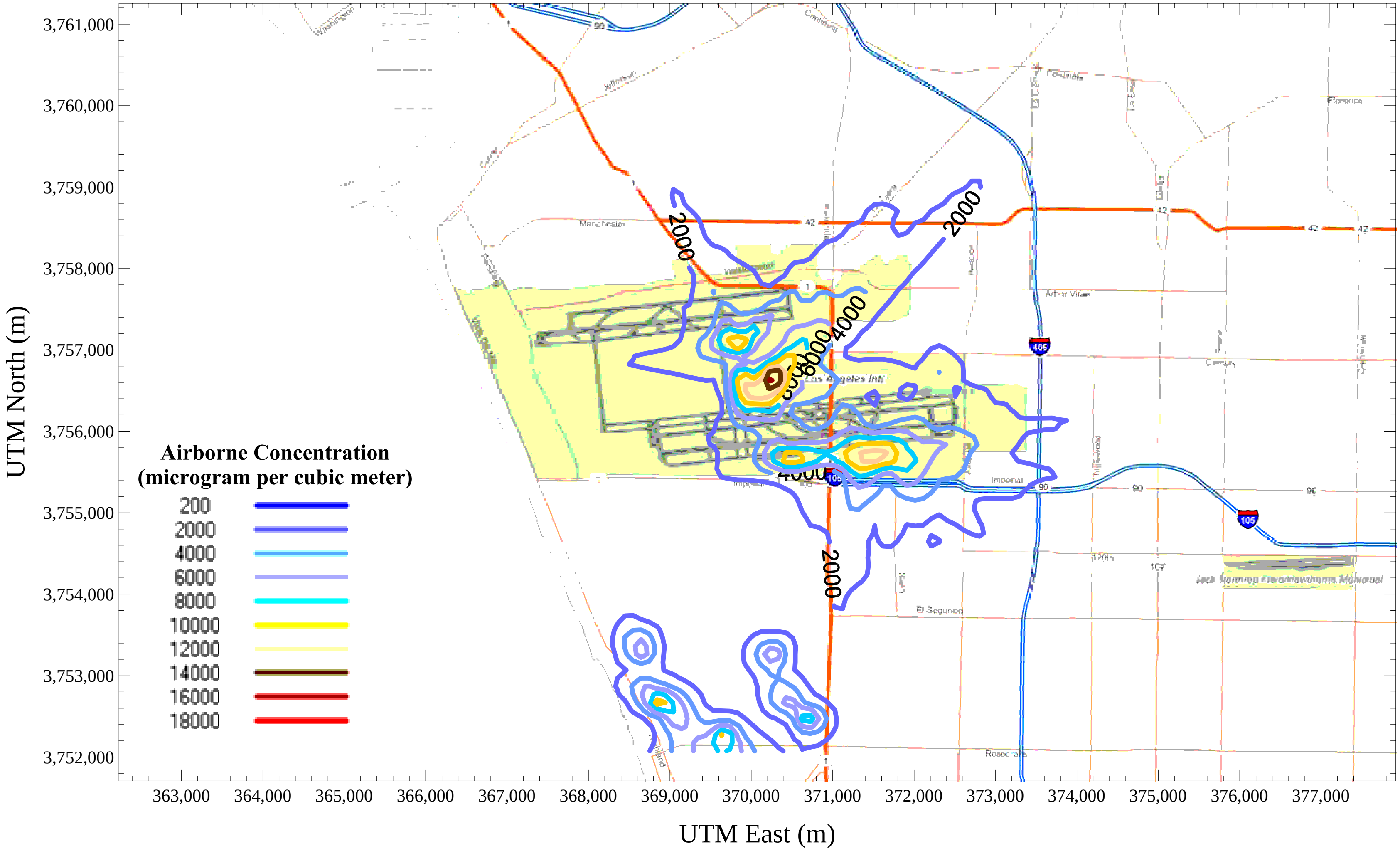
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 75 - 3-month VOC Concentrations from Airport Road Sources - Summer 2007



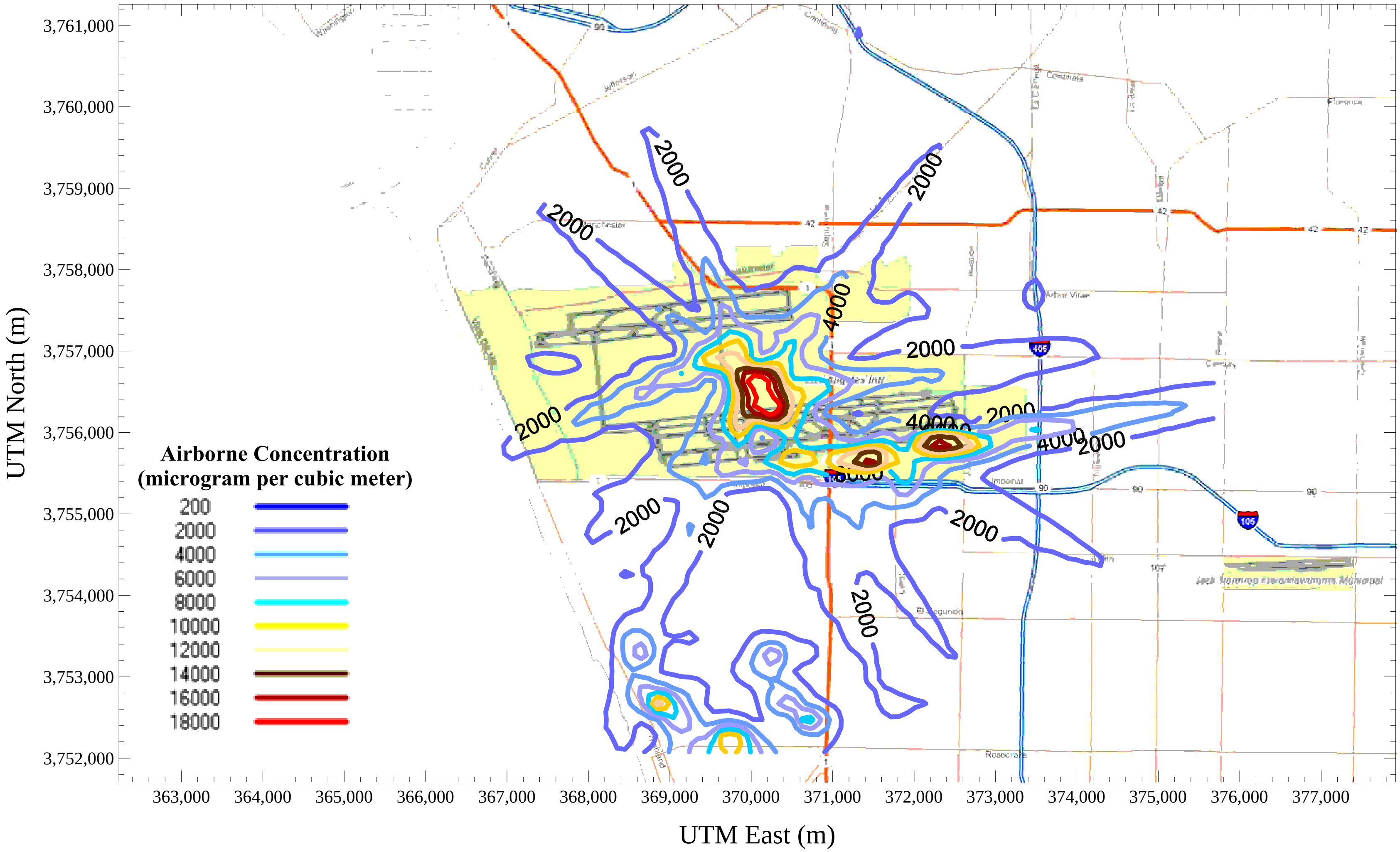
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 76 - Maximum 1-hour VOC Concentrations from All Sources - Summer 2007



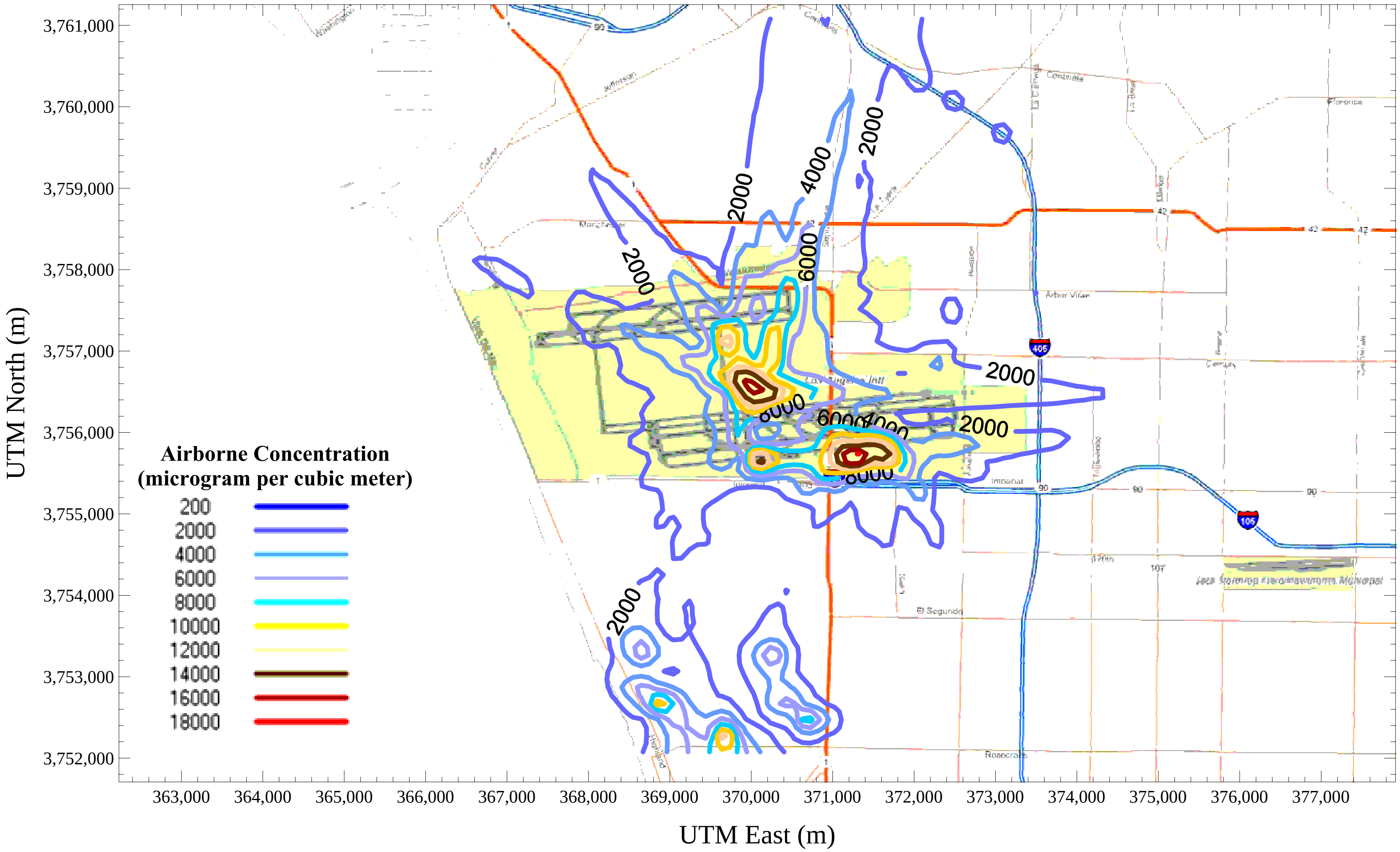
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 77 - Maximum 1-hour VOC Concentrations from All Sources - Fall 2007



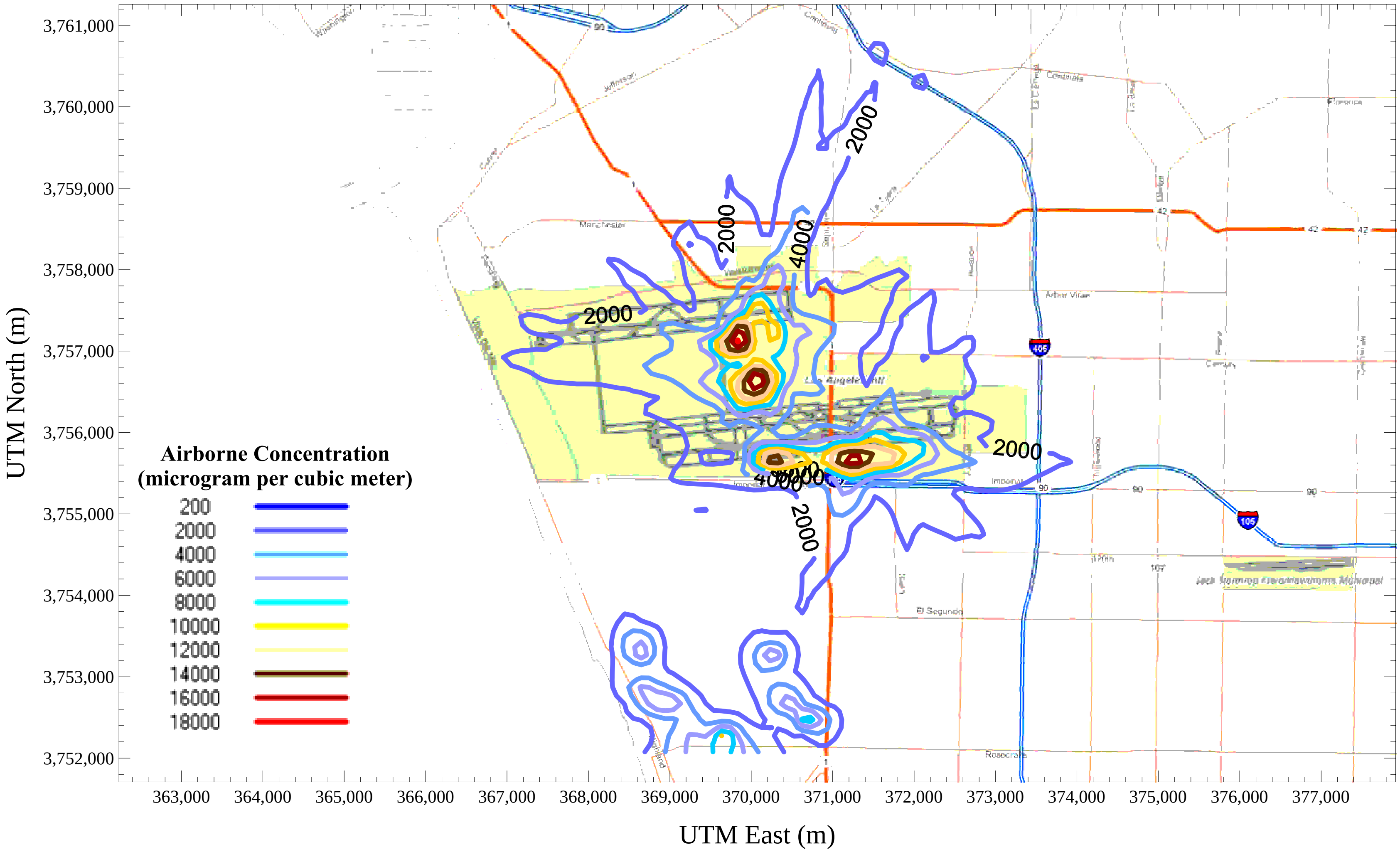
Note: Fall 2007 includes the 3-month period of September, October, and November in 2007.

Figure 78 - Maximum 1-hour VOC Concentrations from All Sources - Winter 2007



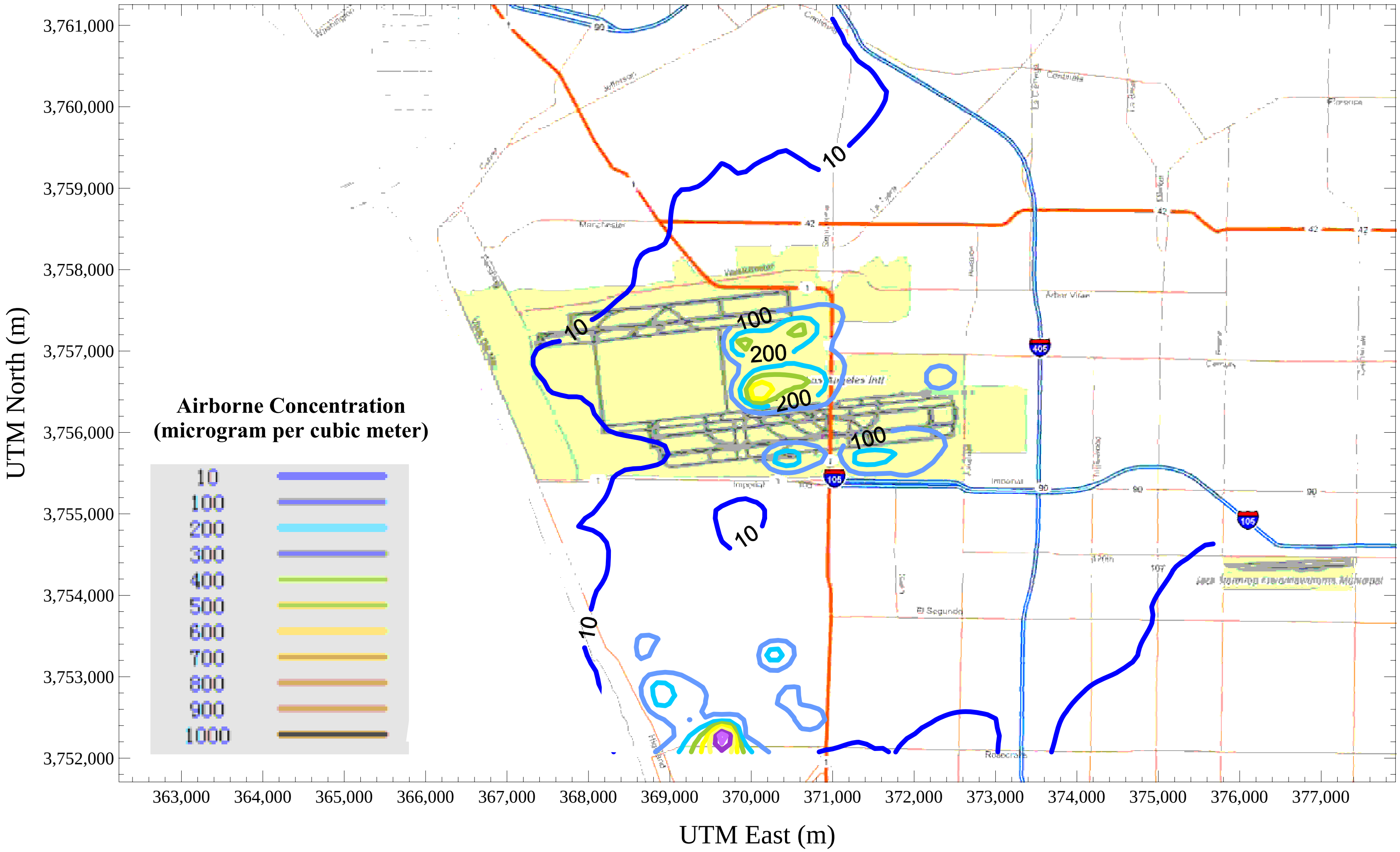
Note: Winter 2007 includes the 3-month period of December, January, and February in 2007.

Figure 79 - Maximum 1-hour VOC Concentrations from All Sources - Spring 2007



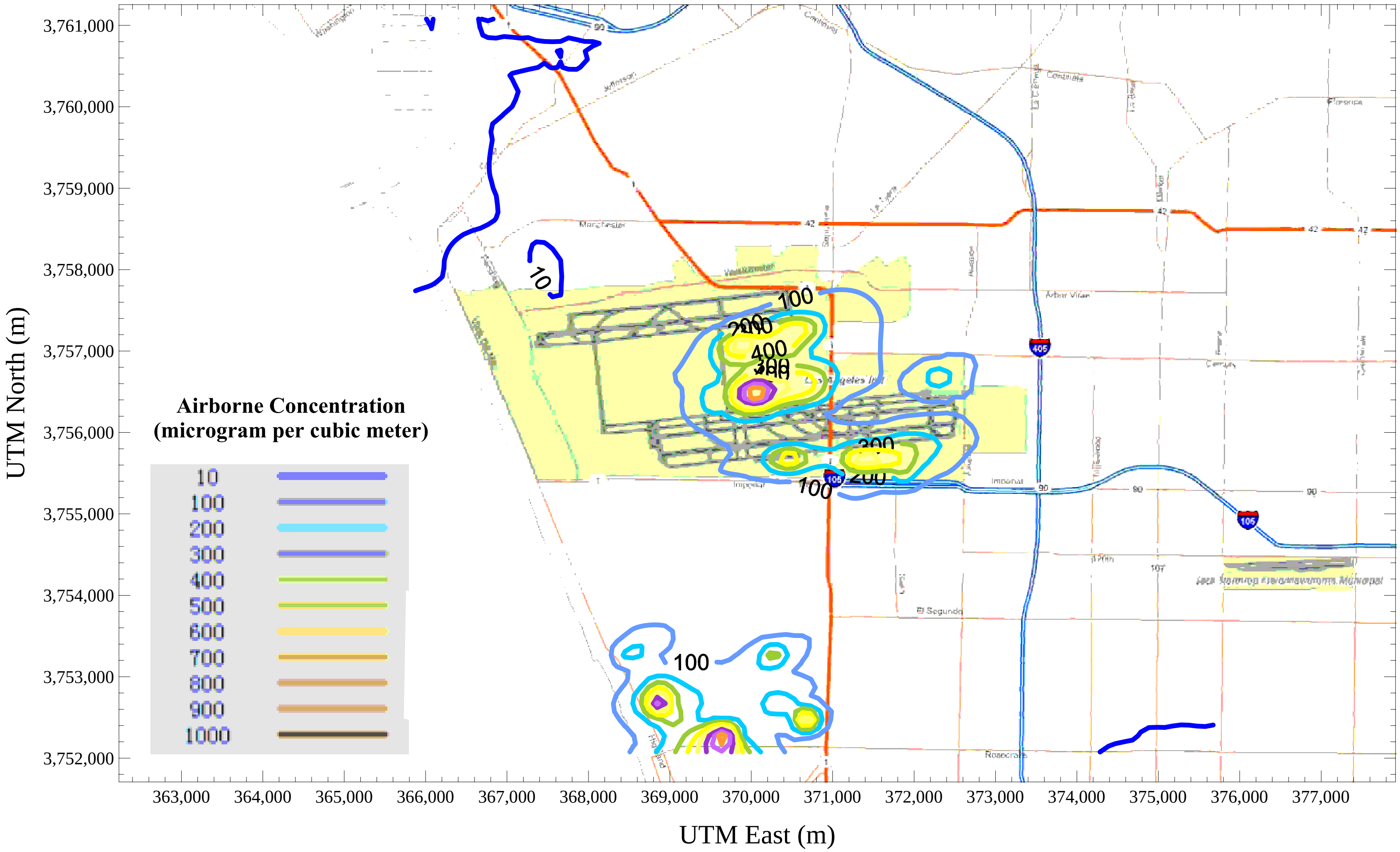
Note: Spring 2007 includes the 3-month period of March, April, and May in 2007.

Figure 80 - 3-month VOC Concentrations from All Sources - Summer 2007



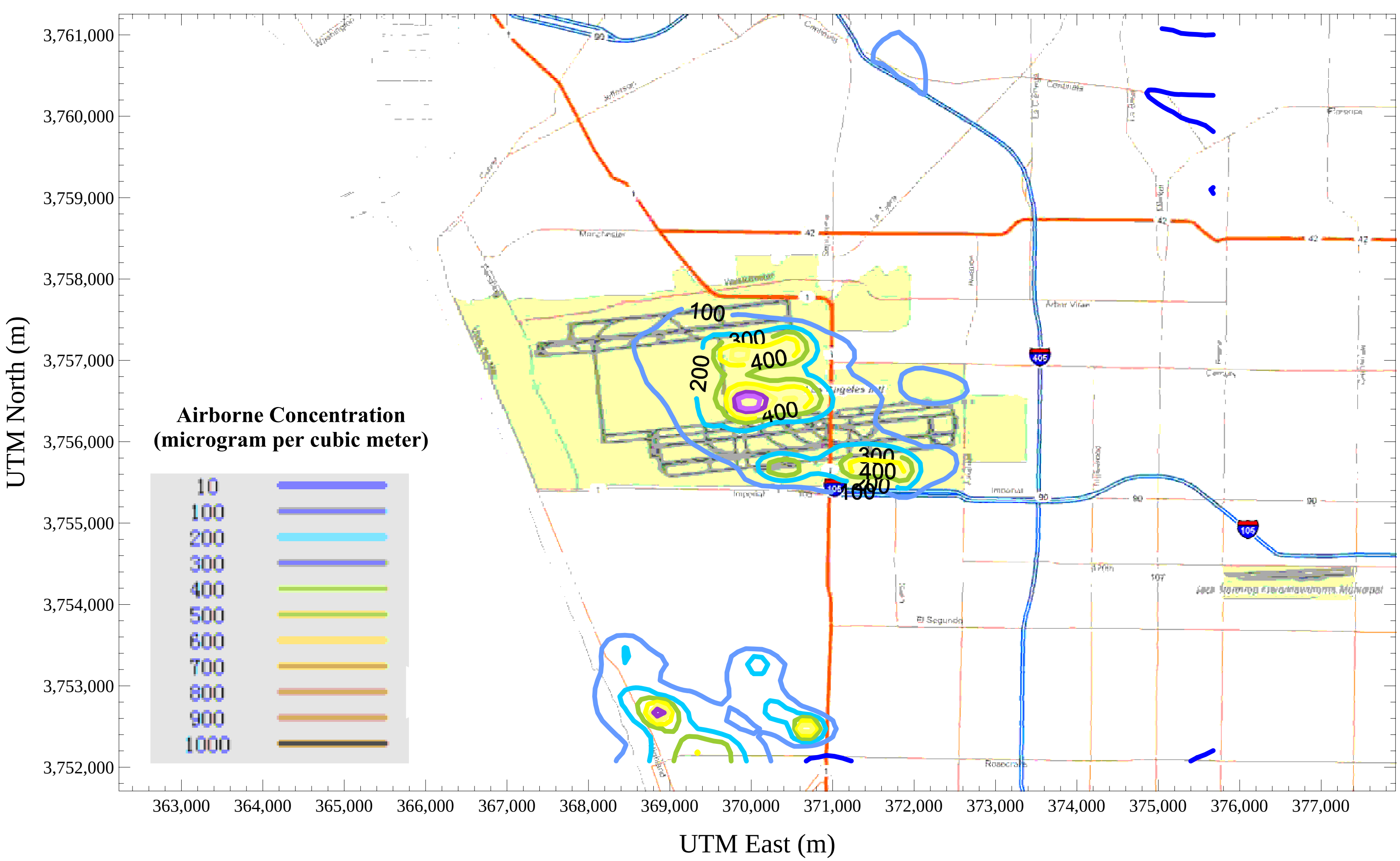
Note: Summer 2007 includes the 3-month period of June, July and August in 2007.

Figure 81 - 3-month VOC Concentrations from All Sources - Fall 2007



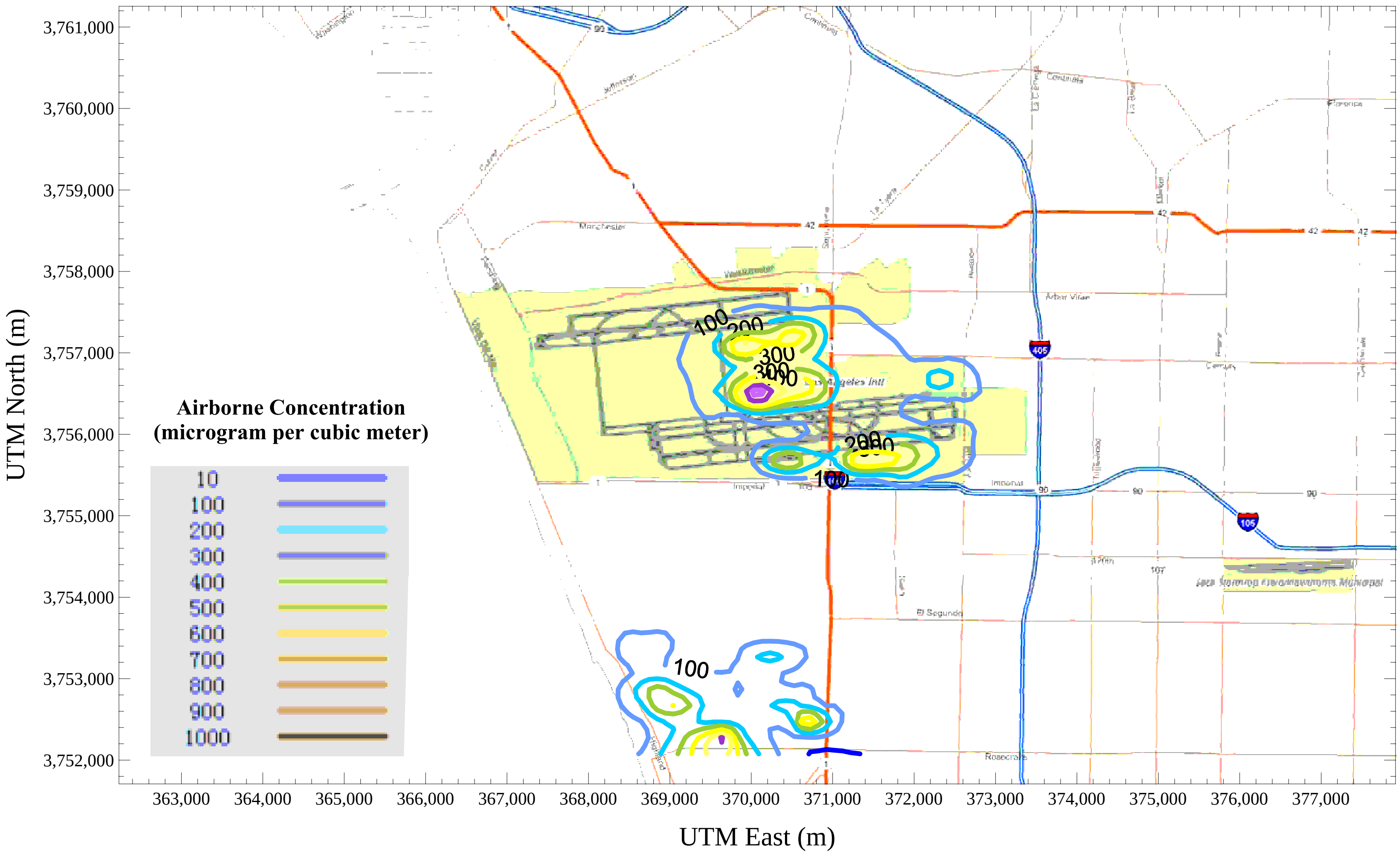
Note: Fall 2007 includes the 3-month period of September, October, and November in 2007.

Figure 82 - 3-month VOC Concentrations from All Sources - Winter 2007



Note: Winter 2007 includes the 3-month period of December, January, and February in 2007.

Figure 83 - 3-month VOC Concentrations from All Sources - Spring 2007

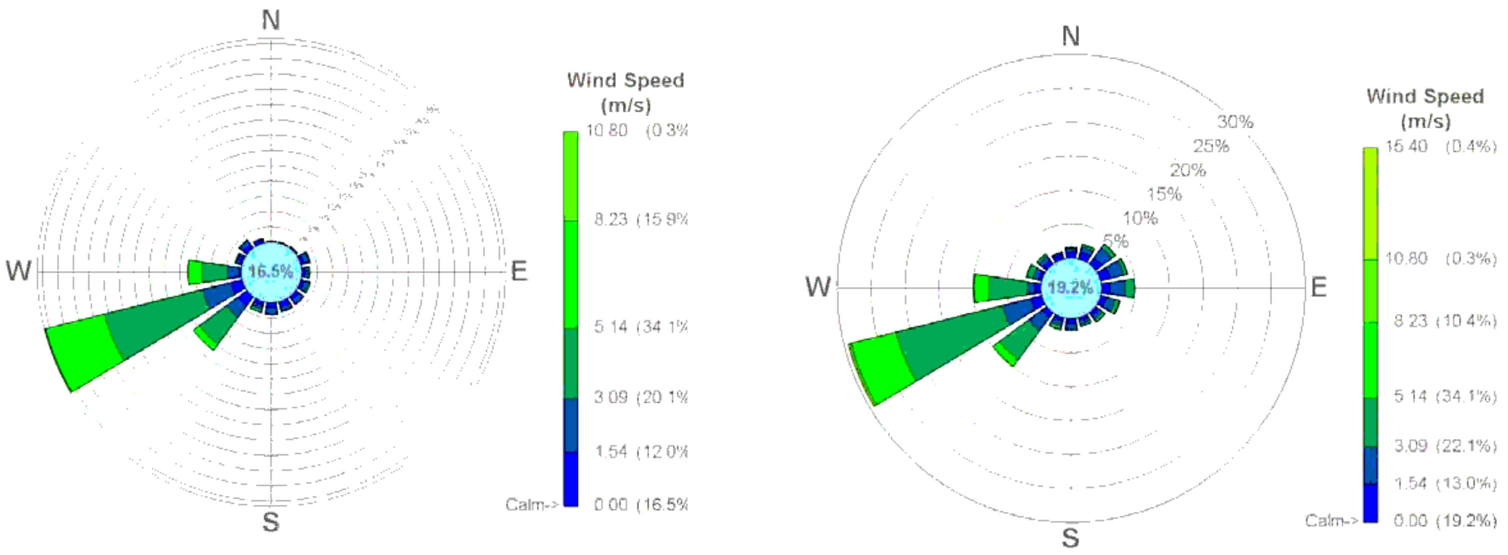


Note: Spring 2007 includes the 3-month period of March, April, and May in 2007.

Figure 84 – Seasonal Wind Rose Plots of 2007

Summer 2007

Fall 2007



Winter 2007

Spring 2007

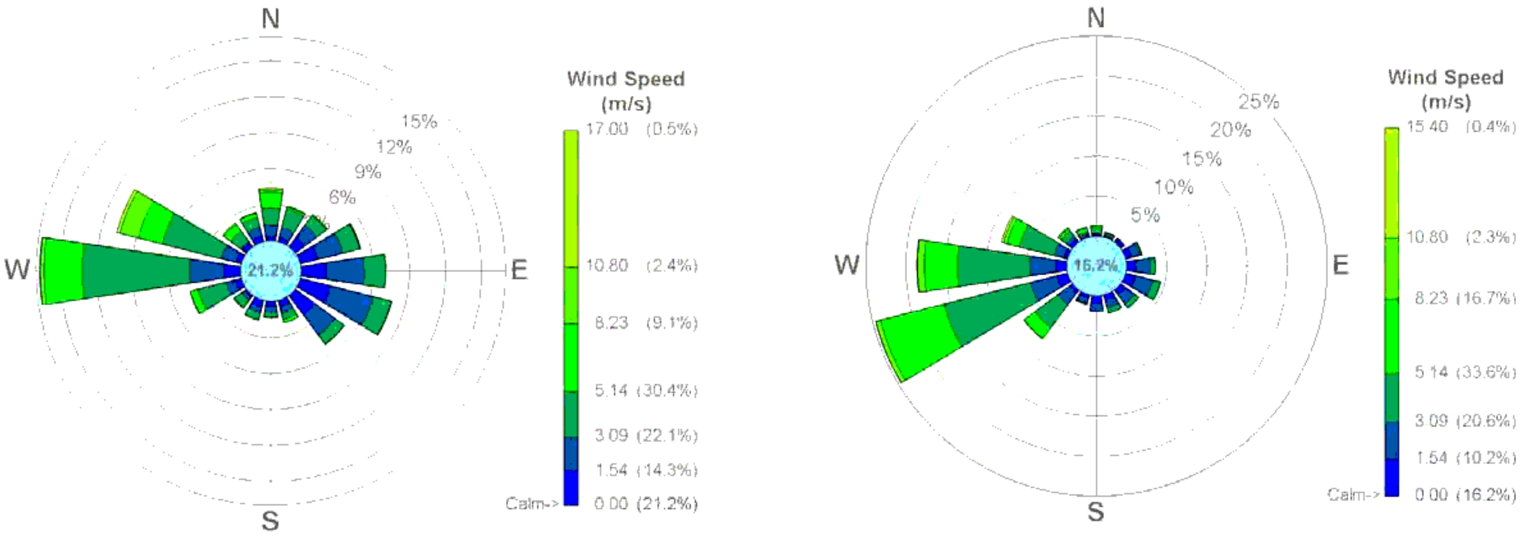
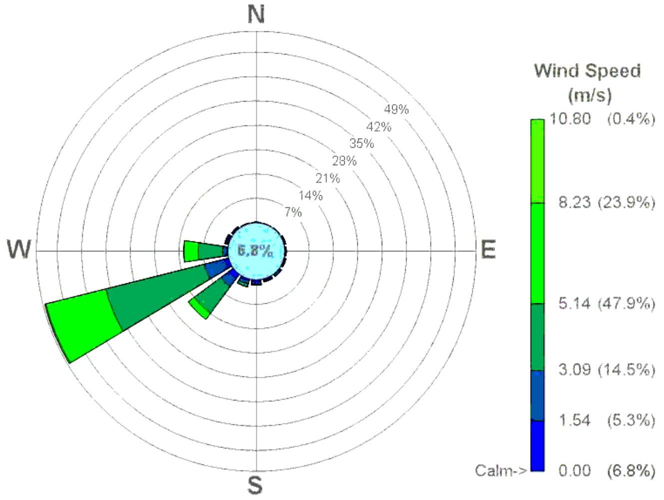
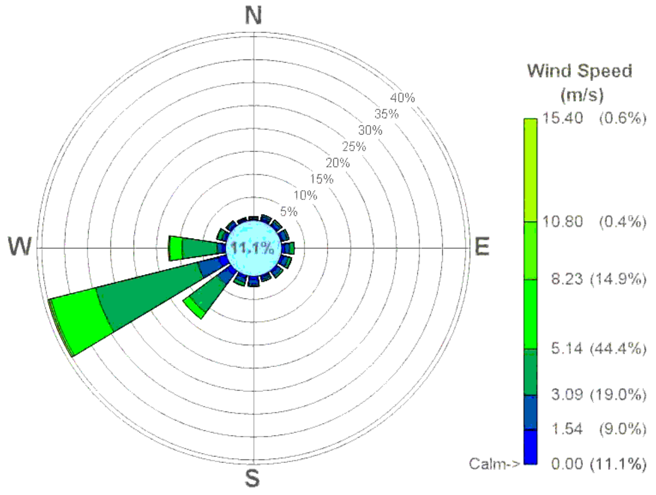


Figure 85 – 2007 Seasonal Wind Rose Plots, 8am-11pm

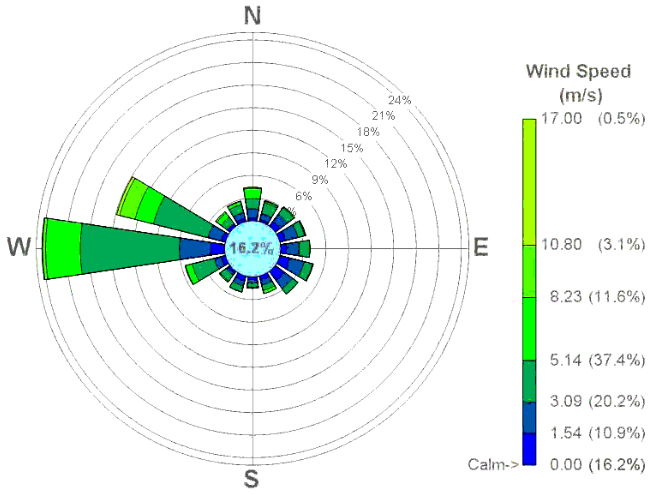
8am-11pm, Summer 2007



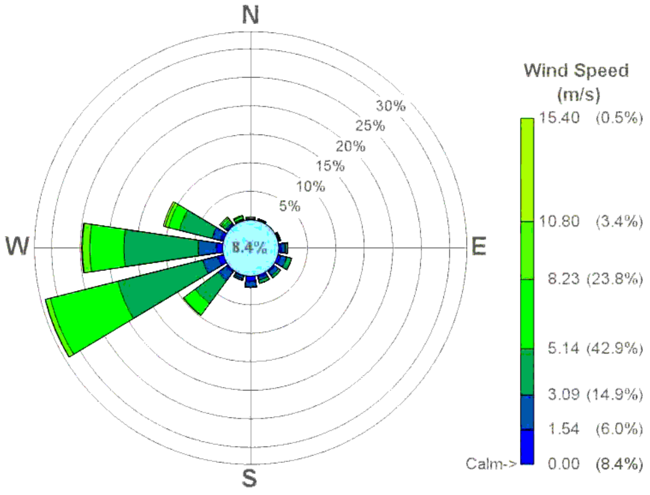
8am-11pm, Fall 2007



8am-11pm, Winter 2007



8am-11pm, Spring 2007



Appendix B

"Source Apportionment Protocol for the Los Angeles World Airports (LAWA) Study"

Source Apportionment Protocol for the Los Angeles World Airports (LAWA) Study

Dr. Weiping Dai and Dr. Maria Zufall, Trinity Consultants
Dr. Ron Henry, University of Southern California

1. INTRODUCTION

This protocol is provided to describe the technical approaches that will be used in the modeling portion (i.e., Task 8 in the Technical Workplan dated May 10, 2007) of the air quality and source apportionment study at the Los Angeles International Airport (LAX) administered by the Los Angeles World Airports (LAWA). The goal of the modeling portion of the pilot study is to:

- Determine significant sources of air pollution and their emissions;
- Estimate the contribution of LAX sources on air pollution levels;
- Provide input to optimize monitor locations; and
- Identify the methods and measurements that will be most successful in determining LAX's air quality impact.

For this project, two types of dispersion modeling will be performed to achieve the stated goals: source-oriented modeling and receptor modeling. Source-oriented air dispersion modeling requires the input of emissions data for sources of air pollution and the release characteristics of those emissions. Also required is the meteorology data and pollutant transport information to estimate downwind pollutant impacts. The U.S. EPA recommends several models for source-oriented dispersion modeling. Of which, AERMOD is recommended for near-field (<50 km) applications.[1] For the first phase of this project, the AERMOD model will be used. The techniques to be used for source-oriented modeling are discussed in Section 2 of this protocol.

Receptor modeling techniques utilize measured concentration data at specific locations (i.e., receptors), along with measured meteorological data (including back-trajectories of wind) and emission source characteristics to estimate the contribution of individual sources to measured pollutant concentrations. Technically, receptor models that use meteorological data are known as hybrid receptor models. This pedantic distinction is not followed here – hybrid models are simply grouped with receptor models. Details on receptor modeling are provided in Section 3 of this protocol.

Note that despite advancements in meteorology, atmospheric science and chemistry, monitoring techniques, and the aforementioned analysis methods, it is very difficult to discreetly characterize the impact of LAX sources on the ambient air. The meteorology, terrain, and emission sources in the Basin create a complex atmosphere. There is no guarantee that the results will isolate airport sources from other local, regional, and international sources in the Basin. Nonetheless, a well-conducted study can advance the understanding of the airshed and estimate possible impacts of LAX air emissions on the surrounding communities.

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[1] 40 CFR Part 51, Appendix W, *Guideline on Air Quality Models*

2. SOURCE-ORIENTED MODELING

MODEL SELECTION AND METHODOLOGY

SELECTION OF MODEL

The latest version (07026) of the AERMOD model will be used to estimate maximum ground-level concentrations. AERMOD is a refined, steady-state, multiple source, Gaussian dispersion model and was promulgated in December 2005 as the preferred model to use for industrial sources for near-field (< 50 km distant) analyses.[2] Although the analysis is not for regulatory purposes, most regulatory default model options will be used and will follow procedures outlined in the *Guideline on Air Quality Models*. Furthermore, even though the AERMOD model has the Plume Rise Modeling Enhancements (PRIME) incorporated in the regulatory version to assess the effects of buildings on air pollutant dispersion, the analyses for this study will not incorporate building downwash. Most of the airport sources will be represented as area or volume sources which are not impacted by downwash. In addition, the impacts will be predicted off-site from the airport, at a distance far enough that the impacts of turbulent wakes would be minimal.

As steady-state dispersion model, AERMOD is scientifically capable of predicting impacts at locations close to the emission sources (i.e., the near-field concept). For example, AERMOD can even predict impacts at locations within area emission sources. Considering the relatively short distances between the emission sources of interest (including both airport and regional sources) and the receptors (e.g., monitoring sites), it would be critical to represent the emission sources properly (e.g., type of emission sources and source characteristics) in the model as well as obtain representative meteorological and source data with sufficient temporal and spatial resolution. These considerations are discussed in more details in the following sections of this document.

TREATMENT OF TERRAIN

Complex terrain is defined as any terrain elevation exceeding stacktop height. Complex terrain is further sub-categorized into intermediate terrain (terrain elevation less than final plume rise height) and true complex terrain (terrain elevation greater than final plume rise height). The AERMOD model simplifies the treatment of terrain, as it does not have different algorithms for varying source-receptor elevation relationships described above. Through the use of the AERMOD terrain preprocessor (AERMAP), AERMOD incorporates not only the receptor heights, but also an effective height (hill height scale) that represents the significant terrain features surrounding a given receptor that could lead to plume recirculation and other terrain interaction.[3]

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[2] *Ibid.*

[3] US EPA, *Users Guide for the AERMOD Terrain Preprocessor (AERMAP)*, EPA-454/B-03-003, Research Triangle Park, NC

Receptor terrain elevations input to the model will be those interpolated from Digital Elevation Model (DEM) data obtained from the U.S. Geological Survey (USGS). DEM data consist of arrays of regularly spaced elevations and correspond to the 1:24,000 scale topographic quadrangle map series. The array elevations are at 30-meter intervals and will be interpolated using Trinity's *BREEZE*®*-AIR* software to determine elevations at the defined receptor intervals. All data obtained from the DEM files will be checked for completeness and spot-checked for accuracy against elevations on corresponding USGS 1:24,000 scale topographical quadrangle maps. Missing or erroneous data from the DEM files will be replaced by direct interpolation from the DEM data.

METEOROLOGICAL DATA

AERMET is the meteorological pre-processor associated with AERMOD. AERMET uses hourly observed surface and upper air meteorological data along with land use characteristics to determine the meteorological inputs (e.g., wind speed, direction, mixing heights, and turbulence) that drive the dispersion model. For example, the mechanical and convective mixing heights are calculated in AERMET for each hour based on the hourly surface and upper air input values (i.e., observed data). Tables 1 through 3 list the variables required as input data to AERMET. Tables 4 and 5 list the variables as output from AERMET and input to AERMOD. Note that the meteorological input data required by AERMET are based on single-station hourly observations. Furthermore, the LAX Airport is located in an urban area whose night-time heat island effect may significantly affect the atmospheric turbulence and thus the dispersion of urban source emissions. According to the U.S. EPA AERMOD implementation guide, in order to avoid double counting the effects of the urban heat island, on-site measured turbulence data should not be used when applying AERMOD's urban option. Therefore, on-site measure turbulence measurement is not necessary for AERMOD modeling. From the perspective of the meteorological data requirements, 3-dimensional wind data is not mandatory. Choosing the option between 3-D sonic and 2-D mechanical anemometers would depend on the quality and accuracy of the required data that can be obtained by each option.

TABLE 1. SURFACE OBSERVATIONAL DATA REQUIREMENT FOR AERMET

Variable	Unit	Mandatory/Optional	Note
Ceiling Height	Hundreds of Feet	Mandatory	
Wind Direction	Tens of Degrees	Mandatory	
Wind Speed	Knots	Mandatory	
Dry Bulb Temperature	Degrees Fahrenheit	Mandatory	
Total Cloud Cover	Tens of Percent	Mandatory	
Precipitation Amount	Millimeter	Optional	Used for wet deposition
Opaque Cloud Cover	Tens of Percent	Optional	Used when Total Cloud Cover not available
Relative Humidity	Tens of Percent	Optional	
Station Pressure	Inch Hg	Optional	Used only to calculate dry air density; default value of 1013.25 mb
Wet Bulb Temperature	Degrees Fahrenheit	Optional	
Dew-Point Temperature	Degrees Fahrenheit	Optional	
Present Weather	No Dimension	Optional	
Horizontal Visibility	Kilometers	Optional	

TABLE 2. UPPER AIR OBSERVATIONAL DATA REQUIREMENT FOR AERMET

Variable	Unit	Mandatory/Optional
Atmospheric Pressure	Millibars	Mandatory
Height Above Ground Level	Meters	Mandatory
Dry Bulb Temperature	Degrees Celsius	Mandatory
Dew-Point Temperature	Degrees Celsius	Mandatory
Wind Direction	Degrees from North	Mandatory
Wind Speed	Meters per Second	Mandatory

TABLE 3. SURFACE CHARACTERISTIC PARAMETERS FOR AERMET

Parameter Name	Unit	Mandatory/Optional
Bowen Ratio	No Dimension	Mandatory
Albedo	No Dimension	Mandatory
Surface Roughness Length	Meters	Mandatory

TABLE 4. AERMET SURFACE OUTPUT DATA

Parameter Name	Unit
Sensible Heat Flux	Watt per Square Meter
Surface Friction Velocity	Meters per Second
Convective Velocity Scale	Meters per Second
Vertical Potential Temperature Gradient Above PBL	Meters
Height of Convectively-generated Boundary Layer	Meters
Height of Mechanically-generated Boundary Layer	Meters
Monin-Obukhov Length	Meters
Surface Roughness Length	Meters
Bowen Ratio	No Dimension
Albedo	No Dimension
Wind Speed	Meters per Second
Wind Direction	Degrees
Reference Height for Wind Speed and Wind Direction	Meters
Temperature	Kelvin Degrees
Reference Height for Temperature	Meters
Precipitation Code	No Dimension
Precipitation Rate	Millimeter per Hour
Relative Humidity	Percent
Station Pressure	Millibar
Cloud Cover	Tens of Percent

TABLE 5. AERMET PROFILE OUTPUT DATA

Parameter Name	Unit
Height Above Ground Level	Meters
Temperature	Degrees Celsius
Wind Direction	Degrees from North
Wind Speed	Meters per Second

The measurement portion of this study will be collecting on-site meteorological data at two locations at LAX. These data will contain all of the necessary parameters (i.e., wind speed, direction, temperature, cloud cover) to represent surface meteorological stations for use in AERMET. Measured data will be quality assured and may be filled, as appropriate.

Trinity will utilize nearby upper air locations to obtain the upper air parameters necessary for processing of AERMOD. Based on a preliminary review of data quality, availability, and representativeness, it is proposed that the San Diego airport upper air station will be used for upper air data. Trinity will contact SCAQMD to determine if the profiler data from LAX would provide appropriate data that could be used instead. The land use parameters used in AERMET will be developed in accordance with U.S. EPA's recent guidance on the use of AERSURFACE.[4]

Model runs will be conducted using both sets of collected meteorological data for the study period (June – August 2008). The initial modeling for monitor review will utilize National Weather Service LAX data for June – August 2007.

RECEPTOR GRIDS

Ground-level concentrations will be calculated within receptors located within the 70 km^2 study area. Receptors will be evenly spaced at 200 m within three km of LAX and 1,000 m beyond three km. In addition, receptors will be located at the ambient monitor locations and possibly at sensitive receptors, such as schools, hospitals, or child-care facilities.

FORMATION OF SECONDARY AIR POLLUTANTS

As an objective for the long-term study, consideration of secondary air pollutants formation (e.g., secondary $PM_{2.5}$, sulfate, and nitrate) is important for understanding the impacts of these pollutants. However, from a technical perspective, secondary air pollutants are typically formed as a regional scaled rather than a short-distance local scaled phenomenon. Considering that the receptors of interest (e.g., nearby community) are located just outside the LAX Airport boundary, within such a short-distance, the formation of secondary air pollutants due to the airport emissions is expected to be limited. Moreover, it is believed that a regional model (e.g., CMAQ) designed to simulate regional and long-range transport air quality phenomena would not provide the resolution to resolve the local-scaled (e.g., hundreds of meters) dispersion and chemical transformation.

In this pilot study, the impacts of the LAX airport emissions will be assessed based on the primary emissions of criteria pollutants. It is believed that this approach would be sufficient to characterize the potential impacts and hot spots due to the airport emissions. The selected dispersion model (i.e., AERMOD) for this pilot study is capable of modeling dispersion of the primary emissions with the consideration of effects due to various atmospheric boundary layer phenomena including complex terrain, building downwash, plume rise. In addition, deposition can also be modeled with AERMOD if required.

REPRESENTATION OF EMISSION SOURCES

LAX EMISSION SOURCES

An emissions inventory will be developed for airport-related sources using the Federal Aviation Administration's (FAA) Emissions and Dispersion Modeling System (EDMS). EDMS is the

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[4] AERSURFACE User's Guide, U.S. EPA, EPA-454/B-08-001, January 16, 2008.

required air pollution model for FAA applications.[5] EDMS develops time- and location-varying emissions from aircraft, ground support equipment, mobile sources related to airport activity and other airport related emissions sources. EDMS incorporates specific details on types of airplanes and typical aircraft schedules for taxi and take-off to develop robust temporal and spatial representation of airport emissions. Although the EDMS can incorporate the emissions data to run AERMOD directly, Trinity will take the emissions data and set up additional details in the AERMOD runs. Trinity will evaluate the emission data for opportunities to simplify the data (to improve model run time), while maintaining the fidelity of the model results. For example, Trinity will evaluate the conversion of area sources to volume sources.

In addition to the emissions developed by the EDMS, emissions from the support combustion equipment will be developed. These emission units consist of boilers used to provide comfort heating and cooling and generators for emergency purposes. Emissions from these units will be based on LAX emissions inventories which incorporate actual fuel usage and U.S. EPA-developed emission factors.

REGIONAL EMISSIONS INVENTORY

In addition to the sources at the airport, a regional inventory of sources will be incorporated into the model. This will allow the model results to be compared directly against ambient measurements. The regional inventory will be based on data collected by the South Coast Air Quality Management District (SCAQMD). These emission sources may include the shipping and port emissions as well as emissions from nearby stationary sources (e.g., power plant and refinery).

COORDINATE SYSTEM

In all modeling analyses input and output files, the location of emission sources, structures, and receptors will be represented in the Universal Transverse Mercator (UTM) coordinate system. The UTM grid divides the world into coordinates that are measured in north meters (measured from the equator) and east meters (measured from the central meridian of a particular zone, which is set at 500 km). The LAX location is approximately 369,877 m East and 3756,673 m North in Zone 11S (NAD 83).

SOURCE TYPES

The AERMOD dispersion model allows for emissions units to be represented as point, area, or volume sources. For point sources with unobstructed vertical releases, it is appropriate to use actual stack parameters (i.e., height, diameter, exhaust gas temperature, and gas exit velocity) in the modeling analyses. Units such as the boilers and generators units will be modeled as point sources using actual stack parameters. Roadway sources and aircraft mobile sources (e.g., taxing, queuing, take-off, and landing) are represented in EDMS as area sources, although Trinity will look at converting these to volume sources. Gate activities will be represented as volume sources.

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[5] Federal Register, Volume 63, No. 70, April 13, 2998.

MODELED POLLUTANTS

In the initial modeling scenarios, the model runs will be performed for the following “criteria” pollutants: nitrogen dioxide (NO_2), carbon monoxide (CO), sulfur dioxide (SO_2), volatile organic compounds (VOC), and particulate matter (PM). Note that ozone is formed from a photochemical reaction between NO_X and VOC and requires the use of a photochemical model to appropriately estimate impacts. Therefore, ozone will not be addressed as part of this study. Additional pollutants of interest, such as individual organic compounds, will be modeled as VOC initially and may be identified during the study process. Dispersion modeling may also be conducted for these pollutants.

Predicted ambient air impacts will be predicted for the above pollutants at each receptor location over several averaging periods, ranging from 1-hour to annually. The impacts will be separated by LAX airplane and airport sources and the regional inventory sources.

3. RECEPTOR MODELING

METHODOLOGY

The receptor modeling methodology described below is considered to be the most likely receptor modeling approach to provide results that shed light on the study goal with the study constraints. The receptor modeling method to be applied to the Pilot Study data will be Nonparametric Trajectory Analysis (NTA). An overview of the proposed method is described below. Details from an example analysis are provided at the end of this section and additional information can be found in the peer-reviewed paper (Henry, 2007).[6]

NONPARAMETRIC TRAJECTORY ANALYSIS WITH MINUTE DATA [7]

The NTA receptor modeling method utilized in the pilot study uses back trajectories along with kernel smoothing methods to locate and quantify the sources of emissions on a local scale using short-term data. Wind speed and wind direction data from all the monitoring sites will be used to calculate back trajectories. The concentration of the pollutant at the time of arrival at the monitor is associated with the points along the corresponding trajectory. For a suitably spaced grid of points, the expected value of the concentration associated with trajectories passing near the grid points is calculated by a nonparametric regression analysis method or kernel smoothing. The kernel function is usually Gaussian and the smoothing results from a moving average using weights derived from the kernel. The result is a contour map with the average value of the concentration at the monitor given that the air passes over of near that part of the map. The only adjustable parameter in the analysis is the kernel smoothing parameter. If it is too small the results will be very lumpy and clearly under-smoothed, while if it is too large the result will be

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[6] Henry, R. C. 2007. Locating and Quantifying the Impact of Local Sources of Air Pollution. *Atmospheric Environment* 42, 358-363.

[7] Refers to data taken on a 1-5 minute frequency.

very broad regions with little variability and clearly over-smoothed. Generally, an appropriate smoothing parameter is chosen by trial and error, fortunately the results are not sensitive to small changes in the smoothing parameter.

NTA will be applied to minute data from each site for PM_{10}, $PM_{2.5}$, SO_2, NO, NO_2, NO_X, CO, and black carbon. The back trajectories will be calculated by inverse distance weighted averages of all available minute data. NTA will identify the regions associated with high concentrations of each species at the monitors. The average amount of selected pollutants coming from appropriate wind direction sectors will be calculated with uncertainties. The NTA results will be interpreted in terms of the impact of airport operations and other sources on each species. The location of the monitoring sites will also be evaluated in light of the NTA results.

REVIEW OF ADDITIONAL RECEPTOR MODELS WITH PARTICULATE COMPOSITION DATA

The possible use of other receptor models that use observations of particulate composition will be evaluated. These models will be restricted to EPA-approved versions of Chemical Mass Balance (CMB) and the multivariate model Unmix. The likelihood that the full study would produce data of sufficient quantity and quality for the application of these models will be addressed. Specifically, the existence of compositional “fingerprints” for sources of interest will be evaluated in light of available particulate composition data. Possible technical difficulties due to near multicollinearity of sources with similar composition will be considered. The possibility of using particulate lead as a tracer for aviation gasoline is an example of the possibilities that will be considered.

EXAMPLE OF NONPARAMETRIC TRAJECTORY ANALYSIS

The result of the method is a map of showing the average concentration of a pollutant at the monitor if the air has passed over a point on the map. The following example is for 1-minute concentrations of sulfur dioxide gas measured at the north Long Beach site by the South Coast Air Quality Management district (SCAQMD). The result in Figure 1 was obtained using only data from the north Long Beach site from the three-month period January, February, and March 2005. The monitor is located at (0, 0) on the map, which is superimposed on an aerial photo of the Los Angeles – Long Beach port area. The contour lines are sulfur dioxide concentrations in parts per billion. The highest contours are for 5.5 parts per billion of sulfur dioxide; these are shown in deep red. The area encompassed by the red contours is centered on the facilities of the Valero refinery, indicating that this is the source of much of the sulfur dioxide gas impacting the north Long Beach monitor. The area also includes parts of another refinery, Long Beach Generating Station, and part of the facilities of the Port of Los Angeles. These sources are also contributing to the burden of sulfur dioxide at the monitor. Applying the method to data from another nearby monitor would help to distinguish the contributions of these sources.

The method starts by calculating back-trajectories using the wind speed and direction data from one or more sites. Figure 2 is an example of three back trajectories calculated for the north Long Beach site. The trajectories trace the path of the air for the previous two hours. The red dots on the trajectories are placed at 30-minute intervals. Back trajectories are calculated covering the entire time period of interest. In the example in Figure 1, this is three winter months. Once the trajectories have be calculated, the concentration of the pollutant at the time of arrival at the monitor is associated with each point on the trajectory. For a suitably spaced grid of points, the expected value of the concentration associated with trajectories passing near the grid points is calculated by a method know as nonparametric regression or kernel smoothing. The result is a contour map as shown in Figure 1. The values of the contours give the average value of the concentration at the monitor given that the air passed over of near that part of the map. The areas associated with the highest values are the location of the major sources contributing to concentrations of the pollutant at the monitor. In this way the major sources of pollution are identified and the impact of them on the monitor quantified.

MATHEMATICAL DETAILS

Back Trajectory Calculation

If there is only one site with meteorological data, calculate the trajectories as follows from wind speed and azimuth data.

As shown in Figure 3, the wind azimuth is the direction the wind is coming *from* measured clockwise from north. To calculate the x (east-west) and y (north-south) coordinates of the direction the wind is coming from, the azimuth angle must be converted to the usual mathematical definition of angle, i.e., measured counterclockwise from the x-axis. If the azimuth angle is Z, and the mathematical angle is θ, then
$\theta = 90 - Z$, for $0 \le Z \le 90$, and
$\theta = 450 - Z$, for Z otherwise,
As defined above, θ is between 0 and 360.

If the wind speed is u, the x and y coordinates of the wind velocity at time t_k are then

$$v_x(t_k) = u(t_k)\cos(\theta(t_k))$$

$$v_y(t_k) = u(t_k)\sin(\theta(t_k))$$

Then the x and y coordinates of the points on the back trajectory starting at time t_j are

$$x_k(t_j) = \sum_{i=0}^{k} v_x(t_{j-i})\Delta t$$

$$y_k(t_j) = \sum_{i=0}^{k} v_y(t_{j-i})\Delta t$$

$$k = 1,\cdots,N$$

where Δt is the time step, that is the time between measurements and N is how many steps backward in time are taken. More complex schemes to calculate back trajectories using wind and other meteorological data from additional can also be used. Each point on the trajectory is associated with c_j the concentration at time t_j when the air arrives at the receptor. Finally, all the points from the set of all the trajectories of interest starting at all possible times along with the associated concentrations are assembled in a set of ordered triples (x_i,y_i,c_i), where the index i ranges over all the points of all the trajectories.

Smoothing

Next, kernel smoothing is used to estimate the average concentration at the monitor if the air passes over a point on the map from the set of trajectory points and concentrations *(x_i,y_i,c_i)* as calculated above. Any type of smoothing may be used but to demonstrate the method, smoothing with the Epanechnikov kernel *K(x)* is chosen. By definition,

$$K(x) = 0.75(1 - x^2) \quad -1 \leq x \leq 1.$$

Define some equally-spaced set of *x* and *y* coordinates given by *(X_i,Y_j)*. Then the average concentration at the receptor of air that has passed over point *(X_i,Y_j)* is given by

$$\overline{C}(X_i, Y_j) = \frac{\sum_k K\left(\frac{(X_j - x_k)}{h}\right) K\left(\frac{(Y_j - y_k)}{h}\right) c_k}{\sum_k K\left(\frac{(X_j - x_k)}{h}\right) K\left(\frac{(Y_j - y_k)}{h}\right)}$$

where *h* is the smoothing parameter defined by

$$h = \frac{FWHM}{\sqrt{2}}$$

and *FWHM* is an adjustable parameter giving the full width at half maximum of the smoothing function. The variance of this estimate is given by

$$\mathrm{Var}(\overline{C}(X_i, Y_j)) = \|K\|^4 \frac{\sum_k K\left(\frac{(X_i - x_k)}{h}\right) K\left(\frac{(Y_j - y_k)}{h}\right) (c_k - \overline{C}(X_i, Y_j))^2}{\left[\sum_k K\left(\frac{(X_i - x_k)}{h}\right) K\left(\frac{(Y_j - y_k)}{h}\right)\right]^2}$$

where,

$\|K\|^2 = \int_{-\infty}^{\infty} K^2(x)dx = 0.6,$ for the Epanechnikov kernel.

EXTENSIONS OF THE METHOD

Forward Trajectories

The same methodology as outlined above can be applied to forward trajectories instead of back trajectories. An example is shown in Fig. 4. In this case the Long Beach 1-minute sulfur dioxide data from the summer months of 2005 (May, June, July) was used. The figure shows the average value of sulfur dioxide at the monitoring site for air that has passed over the monitoring site. Since the sources of sulfur dioxide are southwest of the monitoring site, the impact of sulfur dioxide at the site will be to the northwest. The forward trajectory method is valuable in defining a “region of influence” for a pollutant.

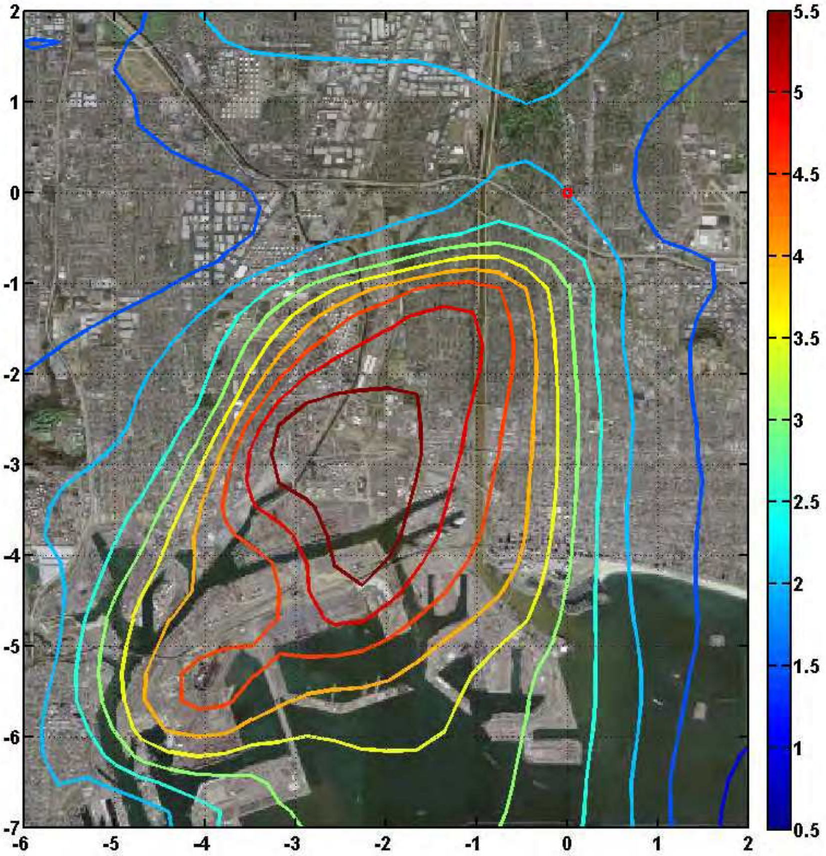

Figure 1. Average concentration of sulfur dioxide measured at the north Long Beach site if the air passes over a point on the map. The monitor is located at the red point at (0,0) on the grid; the units of the grid are miles.

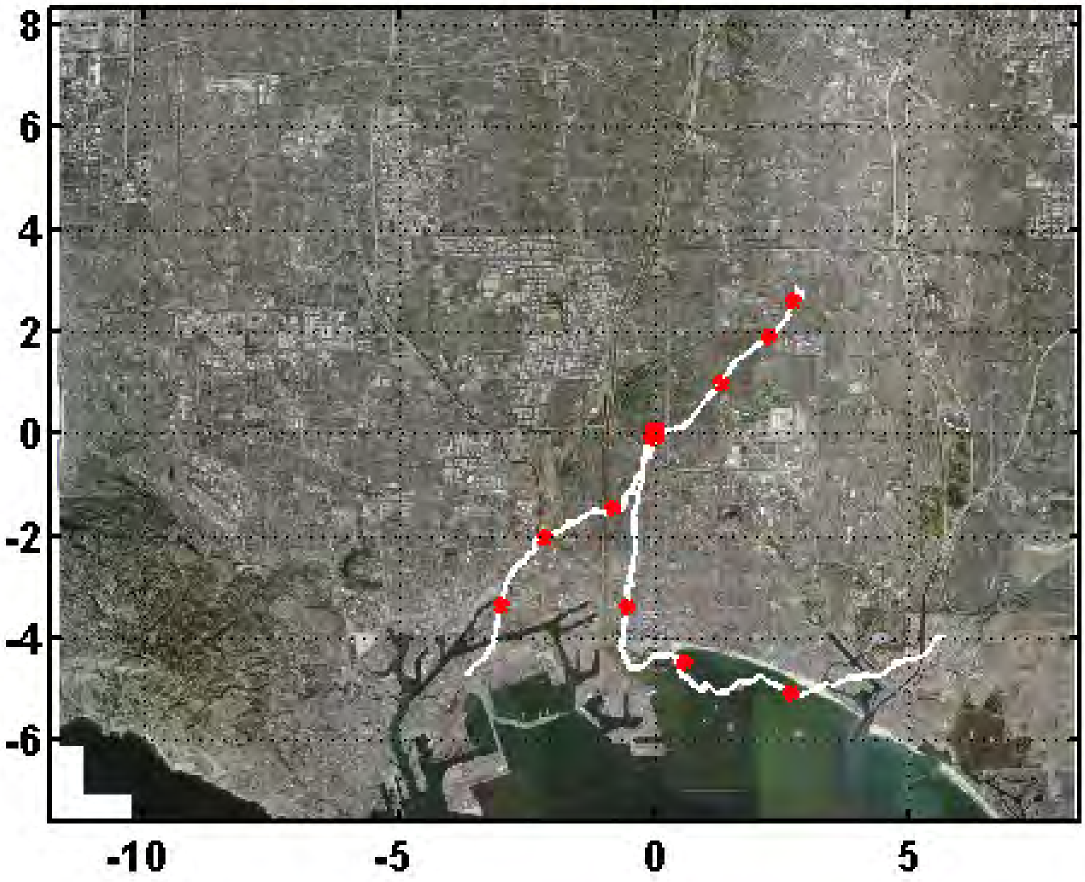

Figure 2. Three typical back trajectories calculated from 1-minute wind speed and direction observed at the SCAQMD north Long Beach monitoring site. The trajectories trace the path of the air back two hours. The red '+' marks are placed at 30 minute intervals.

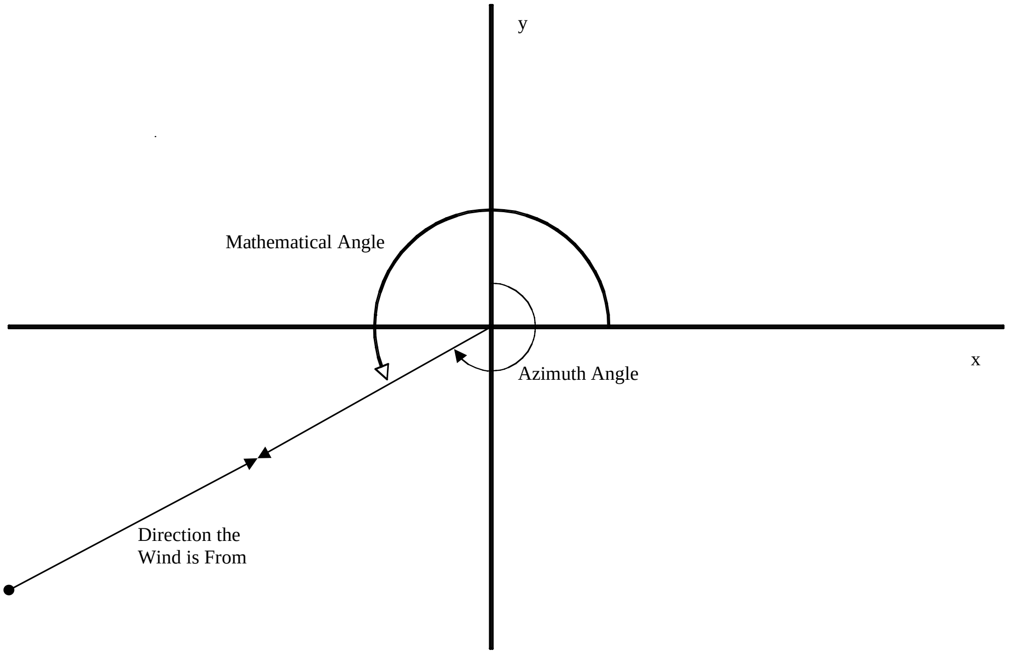

Figure 3. Definition of angles used for trajectory calculations.

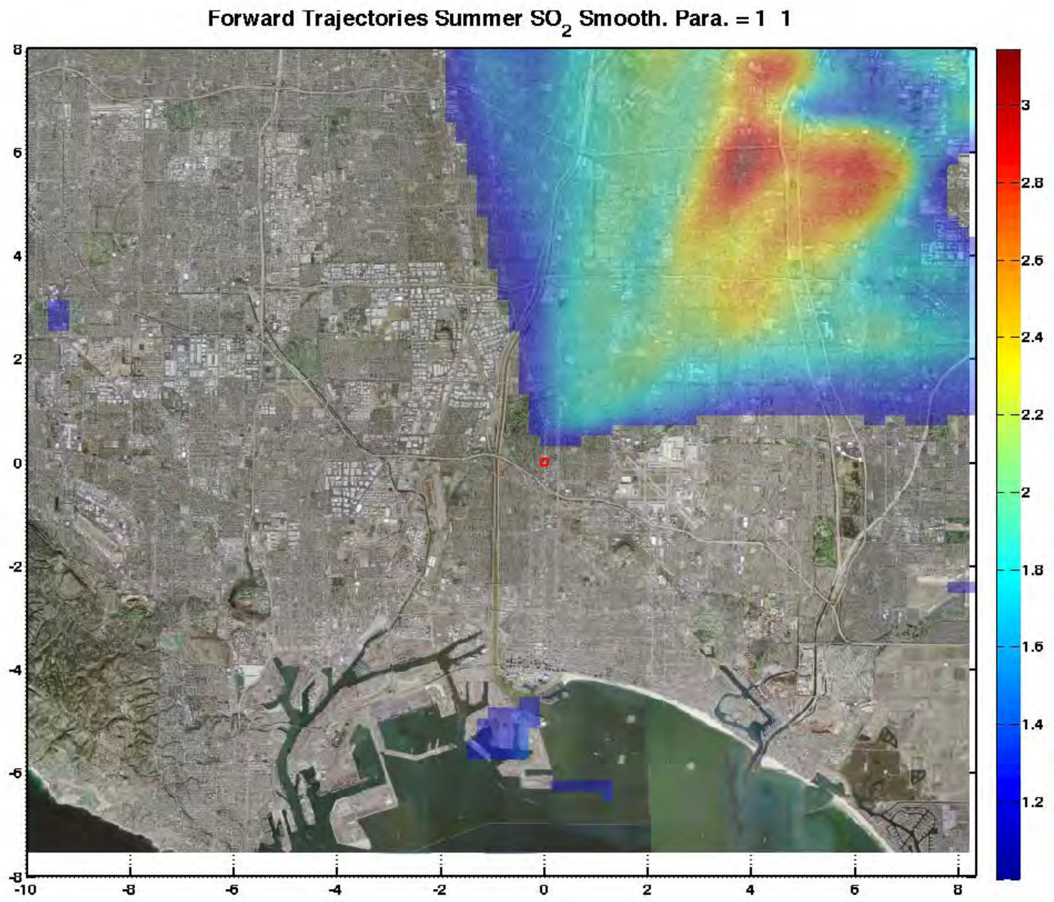

Figure 4. Forward trajectory analysis of sulfur dioxide for the summer months of 2005. The color scale is dimensionless, 1 represents the average value and 3 is 3 times the average value. Values below the mean are not shown.

4. STUDY IMPLICATIONS AND INTEGRATION

The source-oriented modeling will provide predicted impacts of air pollutant concentration at areas surrounding the airport. Preliminary model results using the methods described above will be developed using LAX emissions sources only to provide feedback on measurement station location. Additional model runs will be conducted that incorporate not only LAX sources, but the surrounding regional inventory. Results from the inventory analyses will be used to assess the relative importance of LAX to the regional air pollutant concentrations. Impacts from LAX sources will be reviewed by source type and compared to impacts from the regional inventory. The comparisons will review spatial and temporal variability and will be compared to both the measured data and the receptor modeling.

Using the methods detailed above, receptor modeling will be completed using selected pilot study data and aims to resolve source-specific details on LAX emissions sources and their air quality impact. The receptor modeling will also identify areas of improvement for future studies to better resolve the LAX source.

Source-oriented and receptor modeling use disparate techniques and typically predict results over different temporal and spatial scales. Nonetheless, specific periods will be identified for comparison. In this study, SO_2 and $PM_{2.5}$ results will be compared. SO_2 is chosen due to the expected signature of airplanes using higher sulfur fuel and $PM_{2.5}$ is of interest due to health risks. The team will evaluate substituting the $PM_{2.5}$ results with those of another species in the case it is determined that secondary compounds creating $PM_{2.5}$ are affecting the results.

The model review and comparisons will provide insight to the influence of LAX on air quality in the surrounding area. In addition, the analyses will provide valuable information on improving future studies of both measurements and modeling. All of the analyses and recommendations will be provided to LAWA in a final report.

Module K — Receptor Modeling

Receptor Modeling Report

(Task 8)

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SECTION 1

INTRODUCTION

1.1 Overview

A primary objective of the Los Angeles International Airport (LAX or "the Airport") Air Quality and Source Apportionment Study (AQSAS) is to apportion the pollutant concentrations found in the community surrounding LAX, i.e., what pollutants are Airport-related versus what pollutants are not Airport-related. The first component of the recently-completed AQSAS was a Technology and Feasibility Demonstration Project (Demonstration Project) designed to show the feasibility of comprehensive source apportionment. The second component of the AQSAS will be a Long Term Study that will carry out source apportionment for all pollutants over a 12-month period. The Modeling and Data Analysis—Receptor Modeling Task (Task 8) of the Demonstration Project was intended to determine the feasibility of using Receptor Modeling as a tool to accomplish the complete source apportionment.

Since the inception of the AQSAS, the scientific approach has been to employ equipment and methods for comprehensive source apportionment that go beyond the established source apportionment tools currently used by the air quality community. This Receptor Modeling Report of the Demonstration Project reviews the feasibility of completing comprehensive source apportionment using a combination of time-tested source apportionment techniques in conjunction with recently developed tools that make use of extremely detailed air quality data. This report will show that traditional receptor modeling tools such as Chemical Mass Balance, as well as cutting-edge techniques such as Nonparametric Trajectory Analysis, play a critical role in the accurate apportionment of the Airport's contribution to air pollution in the community surrounding LAX. This report seeks only to provide the reader with a sense that the AQSAS primary goal of source apportionment is feasible and attainable. This comprehensive source apportionment will be a process that will include use of all methods that have been discussed in this report (e.g. CMB and NTA), and methodologies that have not been discussed in detail in this report (e.g. Spatial Gradient Analysis and Multivariate Modeling). With the use of all models, tools, methods, and weather and pollutant data available it is apparent that source apportionment is feasible if an appropriate data collection and analytical programs are implemented.

1.2 Introduction to Receptor Modeling

Air quality receptor models are mathematical models and data analysis tools that estimate the contribution of sources or source categories to air quality based on measured concentrations from one or more monitoring stations (or "sites"). The Technical Work Plan recommended the use of one traditional receptor model, Chemical Mass Balance (CMB); and two data analysis methods, Spatial Gradient Analysis, and Time Series Analysis.

Both Spatial Gradient Analysis and Time Series Analysis require simultaneous measurement of pollutants at multiple locations, which was not an established objective of the Demonstration Project. As a result, only the feasibility of using CMB to apportion the emissions in the Study Area can be determined in this Demonstration Project.

Although CMB was referenced in the TWP, it is one model within a category that shall be referred to here as Chemical Composition Models. Chemical Composition Models refer to both CMB and multivariate modeling ("Unmix" is a specific multivariate model that is expected to be used for this study). These models are capable of apportionment using particulate matter and/or VOC measurements. In the case of CMB, the model assumes that the number and composition of emission sources in the area are known (or assumed). In the case of multivariate modeling the model requires upwards of 100 samples taken in order to determine the chemical composition of sources. Therefore multivariate modeling cannot be assessed directly in the Demonstration Project, but will play a role in apportioning the emissions in the Long Term Study.

It is believed that all major sources in the AQSAS Study Area are known (e.g. LAX, marine vessels, the Chevron El Segundo Refinery, Scattergood Power Plant, and roadway sources such as Sepulveda Boulevard and Interstate 405). Therefore, use of CMB for the apportionment of LAX sources requires only distinct sets of pollutant indicators (also referred to as a "signature" or a "fingerprint") that are conservative and can be detected within the Study Area. Literature on this subject documents a set of indicators that allow the separation of diesel- and gasoline-powered emissions sources (see Section 5.1). This report also evaluates whether fingerprints exist that allows for the separation of the emissions of particles and gasses from aircraft from those of other emission sources in the Study Area. The investigation of possible fingerprints is discussed in Section 3.

In addition to the previously mentioned receptor models, a new hybrid model has been developed for use in situations where there is insufficient data for compositional receptor models. This model, Nonparametric Trajectory Analysis (Henry, 2007) can be used to spatially locate emissions sources by using wind speed and direction, together with the measured air quality data, to trace the path a measured pollutant has taken to the monitors. This model is still in its preliminary testing stages but appears capable of clarifying source locations and the contributions of sources of individual pollutants. The ability to locate and determine contributions of sources increases the possibility of apportionment using receptor modeling by allowing the use of source information in pollutants such as SO_2 and NO_x even though these are not unique indicators of any one source. For example, this method will provide an unprecedented ability to separate SO_2 measured at any one site into multiple sources in the Study Area.

As a result of the limited data collected in the Demonstration Project, it is premature to assess the feasibility of using Time Series Analysis, Spatial Gradient Analysis, and Multivariate Models. Thus, only Chemical Mass Balance and Nonparametric Trajectory Analysis are discussed in detail in this report. All analyses in this report were performed using data from the Demonstration Project that was available as of November 9, 2008.[1]

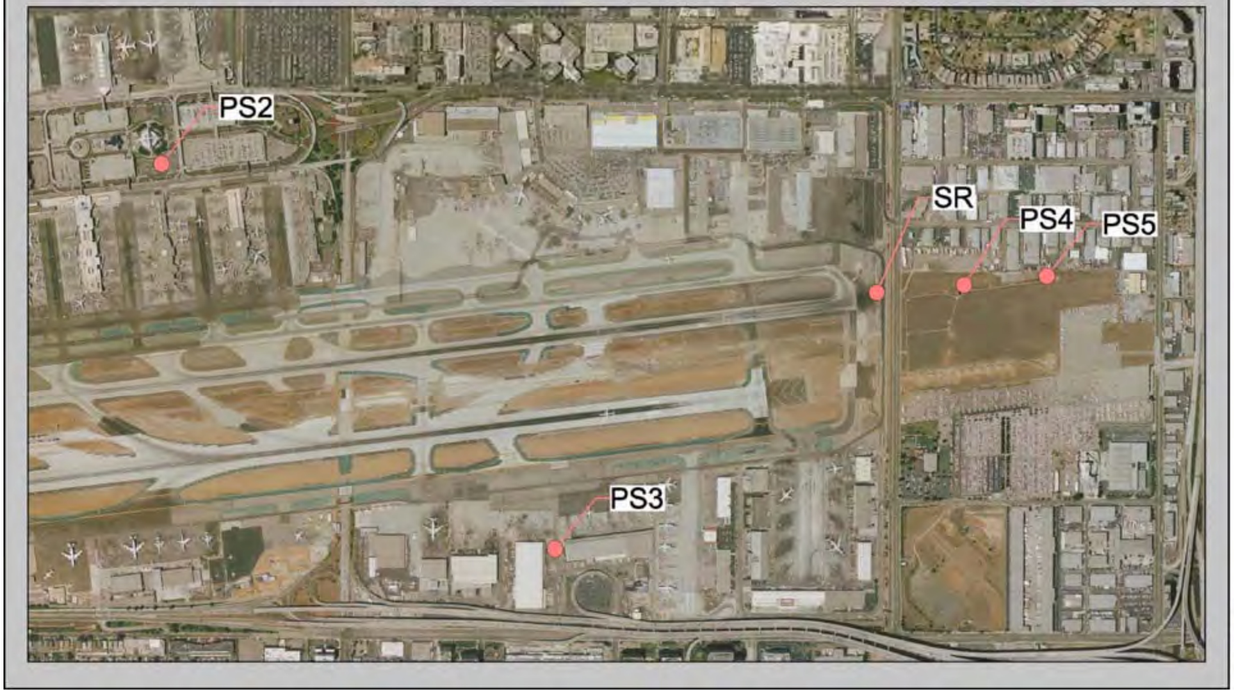
1.3 Data

Figure 1 shows the monitoring locations in the Demonstration Project. These sites were used for both continuous monitoring and discrete sampling, although different monitoring and sampling methods were used at each location. The location for the South Runway (SR) site was chosen specifically to provide a source-dominated site, located directly behind jets taking off from the LAX's longest runway (Runway 25R). The locations for Portable Site 4 (PS4) and Portable Site 5 (PS5) were chosen specifically to provide two typically downwind sites. These sites were uniformly spaced 255 meters and 510 meters to the east of the SR site along the extended centerline of Runway 25R. Portable Site 2 (PS2) was located in the Central Terminal Area (south of the east end of the north runways, and north of the center point of the south runways). Portable Site 3 (PS3) was located in the Southeast Cargo Complex, which is located south of Runway 25L

Figure 1

MONITORING LOCATIONS

AQSAS—Demonstration Project
Los Angeles International Airport



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[1] The list of missing data can be found in the Task 6 -- Monitoring and Sampling Report (Weston, 2008).

All of the monitoring was performed sequentially (i.e. monitoring and sampling for one site was performed, then the monitoring apparatus was moved to the next site). This pattern resulted in collection of 42 days of data at five sites in 50 calendar days.

1.3.1 Continuous Monitoring

Continuous monitoring of the concentration of oxides of nitrogen (NO_x), nitrous oxide (NO), sulfur dioxide (SO_2), carbon monoxide (CO), carbon dioxide (CO_2), ozone (O_3), black carbon (BC), methane (CH_4), non-methane hydrocarbons (NMHC), Polycyclic Aromatic Hydrocarbons (PAH), particulate matter with an aerodynamic diameter of 10 micrometers or less (PM_{10}), particulate matter with an aerodynamic diameter of 2.5 micrometers or less ($PM_{2.5}$), and the size and number of ultra-fine particles (UFP) were performed at either one or all of the monitoring sites for the Demonstration Project. Continuous measurements were reported in 1-minute increments for all pollutants except for PM_{10} and $PM_{2.5}$. These measurements were reported in 1-hour averages and therefore were not detailed enough for use in Nonparametric Trajectory Analysis and were not used in this analysis. However, this report gives special attention to continuous measurements of SO_2, UFP, PAH, and BC. SO_2, UFP, PAH species were monitored in 1-minute increments at all 5 sites and BC was measured every 5 minutes and interpolated to 1-minute concentrations. Of special interest are SO_2 and UFP as they are species that are associated with aircraft emissions. BC and PAH are studied in detail since they are typically associated with emissions from diesel engine such as those found powering Ground Support Equipment (GSE) and heavy-duty trucks.

1.3.2 Discrete Sampling

Numerous sampling methods were used in the Demonstration Project including Summa Canisters, filters, denuder tubes, and deposition plates, and were variously analyzed for carbonyls, VOCs, $PM_{2.5}$ speciation for elemental composition and for organic and elemental carbon, PAH compounds, Hopanes, and Steranes.[2] Sample methods, duration of data collection, and location details from the Demonstration Project can be found in the Task 6—Monitoring and Sampling Report (Weston, 2008). Analyses of the sampling results are discussed in Section 3—Chemical Composition Receptor Modeling.

1.3.3 Meteorological data

The meteorological data used in this study was reported by the Automated Surface Observation System (ASOS) sites at LAX, Santa Monica Municipal Airport (SMO) and Hawthorne Airport (HHR). These wind data are two-minute vector averages reported every minute. This data was subjected to QA/QC procedures at the local, regional, and national level by the National Oceanic and Atmospheric Administration (NOAA).

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[2] PAH compound, Hopane, and Sterane analyses were not complete at the time this report was initially prepared.

SECTION 2

TIME SERIES AND SOURCE CHARACTERIZATION

2.1 Introduction

An initial step in determining the feasibility of using receptor modeling to apportion pollutants is to show that certain pollutants track well with aircraft activities and/or each other.

Figure 2 shows the locations and dates that the continuous monitoring data used in these analyses were collected. Most importantly this figure also shows what pollutants were measured contemporaneously, indicating where correlations between the pollutants (or lack thereof) are indicative of potential source signatures.

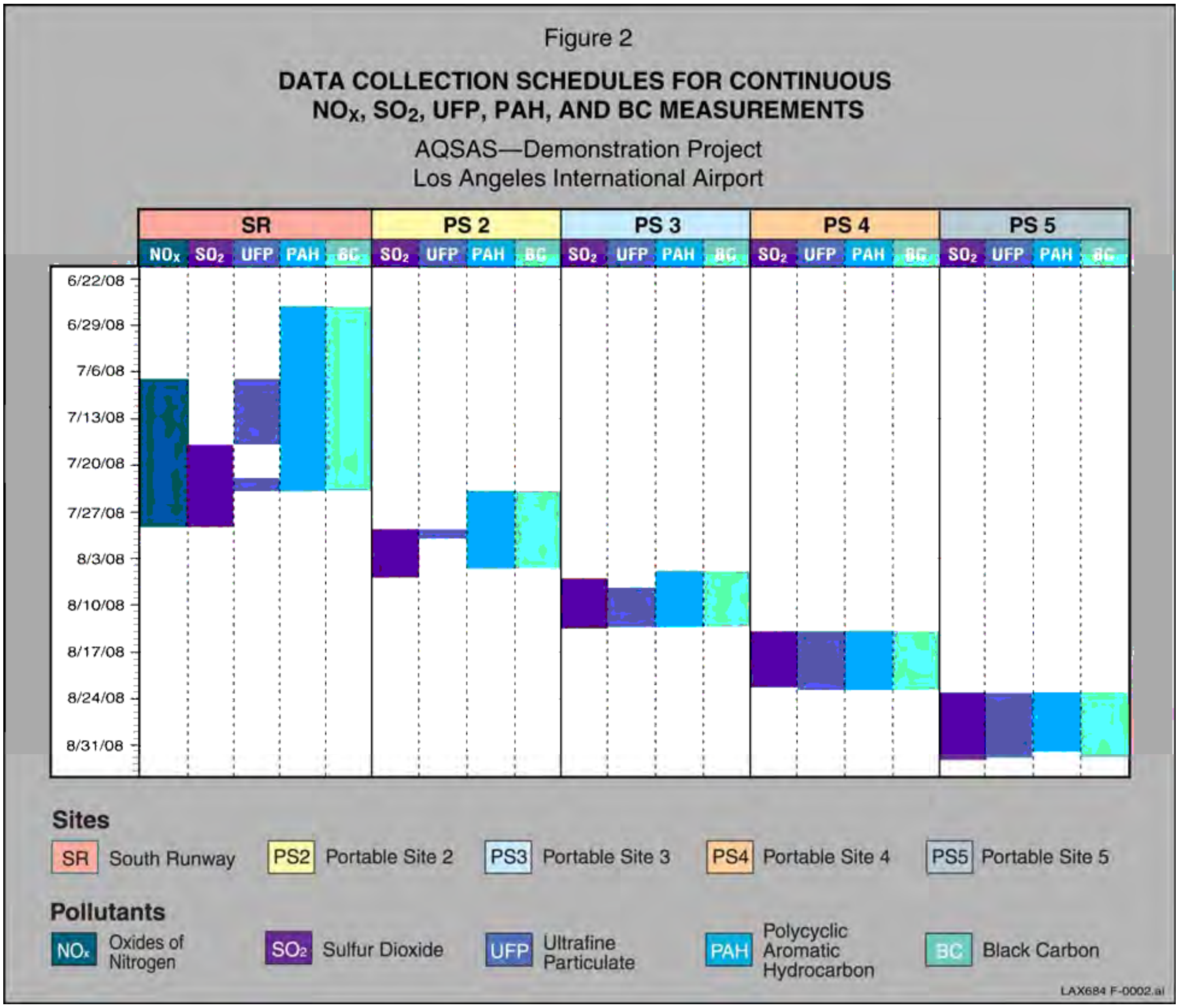

Figure 2

DATA COLLECTION SCHEDULES FOR CONTINUOUS NO_X, SO_2, UFP, PAH, AND BC MEASUREMENTS

AQSAS—Demonstration Project
Los Angeles International Airport

2.2 Characteristic Sources of Pollutants Evaluated

The individual pollutants measured by the continuous monitors can often be associated with a dominant source category (e.g. aircraft, diesel vehicles, gasoline vehicles, marine, etc.). That does not mean other sources don't emit that pollutant, but a preponderance of the measured concentration of that pollutant is likely to be associated with a source. The following describes whether source categories can be typically associated with the monitored pollutants.

The generation of NO_x and NO is typically associated with any combustion source in the study area. For most combustion sources, the emission will be more than 90% NO, which oxidizes quite slowly to NO_2. NO_2, however, may have an atmospheric lifetime of only minutes: under strong sunlight it is rapidly converted back to NO. The chemical reactivity of NO_x makes it important, but usually of limited usefulness for receptor modeling.

The State of California has implemented a law requiring all diesel fuel to be Ultra Low Sulfur. The only significant Airport-related emissions sources that emit SO_2 are aircraft. This potentially provides an excellent fingerprint of aircraft sources if there are no other major sources of SO_2 affecting the Study Area. However, both the El Segundo Chevron Refinery (Chevron) and ships located offshore, and several less significant stationary sources, have been shown to be sources of SO_2 that will certainly hinder the use of SO_2 as an aircraft emissions fingerprint[3].

The production of CO and CO_2 are generally associated with any combustion source in the Study Area. CO_2 measurements in this study were adjusted by subtracting 380 ppb, the global background CO_2 concentration, to increase emphasis on emissions in the vicinity of the monitors.

There are no significant sources of ozone emissions in the study area. Ozone is generally formed by a photochemical reaction of precursor pollutants, reactive organic gases and NO_x.

Diesel vehicles are likely the major source of BC and PAH emissions in the Study Area. The mass emissions of these pollutants from aircraft are likely substantially less than from diesel vehicles.

Emissions of CH_4 and NMHC can be associated with any of the combustion sources in the Study Area.

2.3 Time Series

Figure 3 is a time series plot of the 1-minute data for NO, SO_2, and total UFP particle count at the SR site for the 2-hour period from 15:00 to 17:00 PST on Monday, July 21, 2008. Because the concentrations of these species have very different scales, each has

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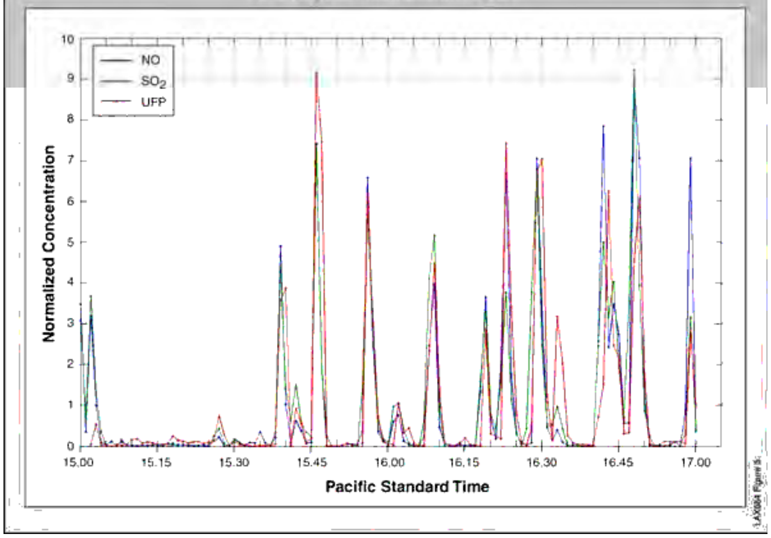
[3] See Task 3 Report, Identify Other Potentially Significant Emission Sources in the Study Area (Aspen, 2008)

been normalized to its mean value during the period (i.e. a value of 5 in the plot means 5 times the average for that species). The NO and SO_2 are dominated by aircraft takeoffs and are very highly correlated to each other (a correlation coefficient of 0.91). The total UFP particle count is also dominated by aircraft emissions but its correlation with NO (a correlation coefficient of 0.78) is less than the correlation of SO_2 to NO.

Figure 3

TWO-HOUR SNAPSHOT OF CONTINUOUS MONITORING FOR NO, SO_2, AND UFP ON MONDAY, JULY 21, 2008

AQSAS—Demonstration Project
Los Angeles International Airport



The timing of aircraft takeoffs (as seen in a video taken at the end of Runway 25R) was compared to all "peaks" in the figure (i.e. data values that rise above zero and return to zero within 3 minutes). The "larger peaks" (i.e. any peaks above two) are perfectly correlated with aircraft takeoffs from the end of Runway 25R. However, the video shows there are times when aircraft do not take off from the end of the runway (the primary takeoff position) but instead depart from the intersection of Runway 25R with Taxiway F (a secondary takeoff position). These takeoff positions are shown in Figure 4. When aircraft takeoff from this secondary takeoff position, there are no large peaks associated with these takeoffs. This shows that the peak concentration at the monitors is notably less when the departures point is moved 970 ft further from the monitors (alternate vs. standard take-off location). This decrease in peak concentration is also consistent with the decreasing peak concentrations between SR, PS4 and PS5 sites. An example of this measured difference based on departure location is shown during the period 15:05 to 15:37 in Figure 3 the video showed 13 takeoffs from the secondary position and the figure shows no large peaks during this time.

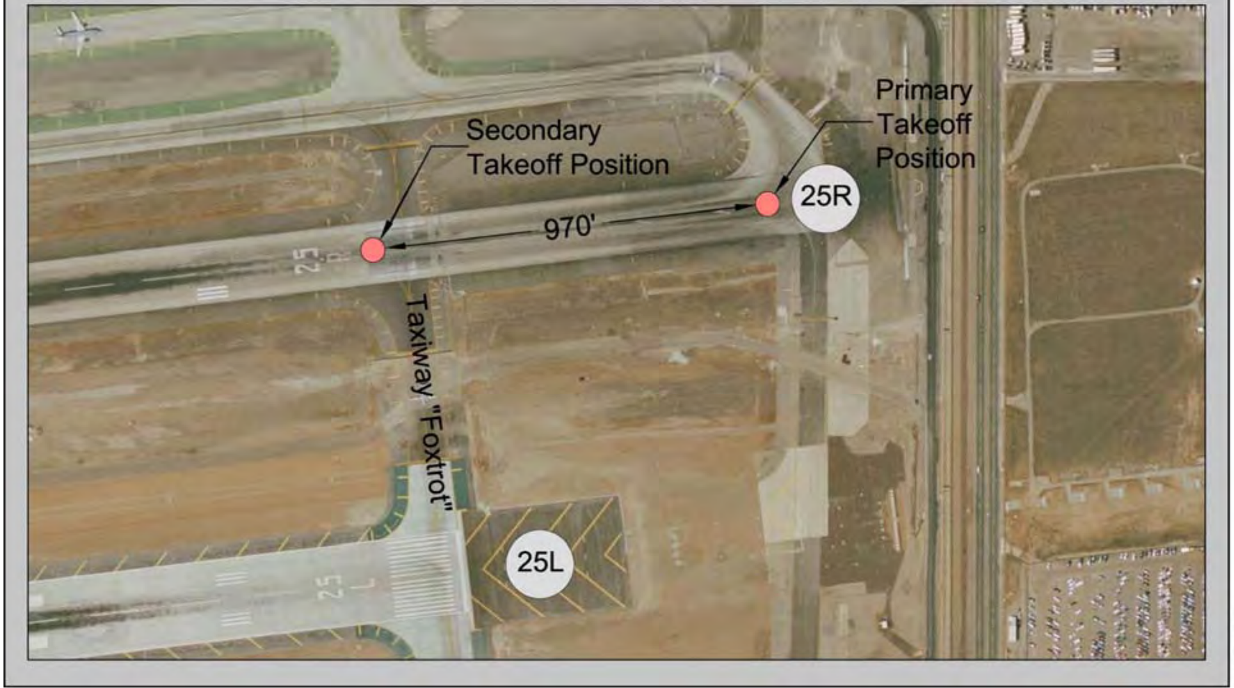
2.4 Ultra Fine Particulate Matter

When UFP is characterized at the exhaust nozzle of typical commercial aircraft gas-turbine engines the UFP is found to be predominantly refractory, non-volatile and carbonaceous with diameters ranging from ~20 to 100nm. The particles are products of combustion in the gas-turbine engine and are found to have typical number concentrations on the order of 10^6 particles cm^{-3}. Non-aircraft UFP drawn into the engine with ambient air is also present at the exhaust nozzle. Its number concentrations are orders of magnitude lower than those of the carbonaceous UFP, typically $\leq 10^4$ cm^{-3}, with diameters that tend to cover a broad size range extending up to hundreds of nanometers, well beyond the size range of the engine generated PM. The thermodynamic conditions at the exhaust nozzle preclude the formation of condensable PM at this location.

Figure 4

LOCATIONS OF TAKEOFF POSITIONS FOR RUNWAY 25R

AQSAS—Demonstration Project
Los Angeles International Airport



Downstream of the nozzle as the exhaust plume expands and mixes with the atmosphere, certain combustion-generated gases in the exhaust flow condense on some of the existing particles causing small shifts in their mean diameters, and undergo gas-to-particle conversion forming new particles. The new volatile UFP are much smaller in size with mean diameters on the order of 10nm. Typical number concentrations of these volatile UFP exceed those of the carbonaceous UFP by factors of 10 to 100. Therefore in the expanding exhaust plume both non-volatile and volatile engine-generated UFP are present. The fate of the volatile species is found to depend strongly on the ambient air meteorology whereas the size and mass of the carbonaceous UFP remain largely unchanged. (Whitefield, 2008)

Based on these general properties of aircraft UFP, it is reasonable for modeling purposes to examine the UFP measurements in three specific ranges:

- **Condensable particulate matter (UFP1—the smallest size range)**—UFP which includes particulates less than 29.4 nm in size
- **Carbonaceous aircraft particulate matter (UFP2—the middle size range)**—UFP which includes particles greater than 45.3 nm and less than 107.5 nm in size

- **Non-aircraft particulate matter (UFP3—the largest size range)**—UFP which includes particles greater than 191.1 nm and less than 523.3.0 nm in size

The specificity in these ranges is a function of the size categories measured by the monitoring equipment. These size categories output by the monitoring equipment are the nearest sizes corresponding to 30 nm, 50 nm, 100nm, 200nm, and 500 nm. It also is noted that Total UFP includes all sizes, not just these three ranges.

A paper published in 2002 (Yifang, 2002) shows that UFP size distribution near freeways in Los Angeles (i.e. diesel-related) has two peaks--one at about 12 nm and the other centered at about 30 nm, with most particles ranging from 20 to 40 nm. UFP from diesel vehicles are a potential interfering factor at community sites that are closer to major roadways than the airport runways.

2.5 Correlation of Species Measurement

In the AQSAS's recent report on Analysis of Air Quality Emissions Data a comparison of pollutant measurements was made with aviation activity and a demonstrated strong relationship between aircraft activity and pollutant measurements. It is also important to consider the relationship of multiple pollutants. This section looks at the relationship in the variation of four monitored pollutants. When evaluated at each of the monitoring locations, this reveals information about the nature of the pollutant sources. The following analysis is preliminary; a more complete analysis using advanced statistical methods such as Principal Component Analysis would be valuable.

Table 1 provides a summary of the statistical relationship of the UFP measurements with three monitored pollutants; Nitrous Oxide, Sulfur Dioxide, and Polycyclic Aromatic Hydrocarbons. The values in the table reflect the minute-by-minute correlation of the data for each of the monitored pollutants with that of each category of UFP. A value of 1.00 indicates that the two pollutants vary uniformly, while a value of zero indicates there is no relationship in the variation of the two pollutants being considered. The values shown in the table represent all of the collected data and have not been corrected for wind direction or differing numbers of observations.

Table 1

CORRELATIONS OF UFP SIZE CATEGORIES

AQSAS - Demonstration Project
Los Angeles International Airport

Nitrous Oxide (NO)

	SR	PS4	PS5
UFP1	0.605		
UFP2	0.469		
UFP3	0.060		
UFP Total	0.611		

Sulfur Dioxide (SO_2)

	SR	PS4	PS5
UFP1	0.756	0.836	0.601
UFP2	0.535	0.670	0.666
UFP3	-0.045	0.028	0.220
UFP Total	0.761	0.846	0.629

Polycyclic Aromatic Hydrocarbons (PAH)

	SR	PS4	PS5
UFP1	0.345	0.465	0.435
UFP2	0.495	0.798	0.667
UFP3	0.011	-0.022	0.080
UFP Total	0.358	0.488	0.468

Note: SO_2 correlation at SR are based on approximately 2 days of data collection
NO and PAH correlations at SR are based on approximately 10 and 12 days of data collection, respectively
PS4 correlations are based on approximately 10 days of data
PS5 are based on approximately 8 days of data

The pollutants were selected because they each can generally be associated with an emission source (i.e. supporting apportionment), as described in Section 2.1. The UFP is most likely to be generated by aircraft or diesel-powered vehicles. The NO is associated with fuel combustion near an emission source (further downwind it is converted to NO_2) and thus is most likely to be generated by aircraft or diesel-powered vehicles. The SO_2 is most likely generated by aircraft, but significant sources in the area include the Chevron refinery and the Marine Terminal. Finally, the PAHs are most likely to be emitted by diesel-powered vehicles such as GSE and on-road trucks.

From Table 1 it is noticed that UFP1, UFP2, and UFP Total have much stronger correlation to the measured pollutants than UFP3. There are two conclusions from this observation:

1. UFP3 is comprised primarily of non-aircraft sources and should only show strong correlation when pollutant measurements are not dominated by aircraft—thus SO_2 measurements are likely aircraft-dominated

2. UFP measurements are of particle count and thus UFP Total is dominated by UFP1 and UFP2 (mass emissions of UFP Total may not show this trend).

UFP1, UFP2, and Total UFP are well correlated with both SO_2 and NO in all of the comparisons indicating that the main source of UFP1, UFP2, SO_2, and NO in these measurements is jet exhaust. The data also demonstrates that this correlation (indicative of aircraft exhaust) is seen at the most distant monitoring site, PS5. Thus, while the particle counts for UFP1 and UFP2 may be affected during the time taken to travel to PS5, it is clear that both the UFP and SO_2 measurements at these sites are dominated by aircraft exhaust.

UFP1 and Total UFP are not well correlated with PAH indicating that these pollutants are associated with different emission sources. Since the comparison with SO_2 and NO indicated that UFP has a strong association with aircraft exhaust, PAH in these measurements is likely associated with diesel vehicles and not aircraft. The diesel vehicles most likely emitting the PAH are either GSE or on-road trucks. This conclusion is corroborated by separate analysis of this data set that showed PAH and BC are very closely correlated at all sites.

UFP2 has a weaker statistical correlation with SO_2 than UFP1, although there still is a strong relationship. This is indicative of additional sources of UFP2 being part of the UFP2 measurements. It is also noted that UFP2 has a stronger correlation with PAH than SO_2 at PS4. Diesel equipment is thought to be the most likely source of UFP2 emissions that contain minimal SO_2 but substantial PAH. This indicates that some of the measured UFP2 could be generated from GSE at the SR site and from trucks traveling on Aviation Boulevard at the PS4 and PS5 sites. It is also noted that emissions from the diesel generators used at PS4 and PS5 could be affecting this correlation during periods with atypical wind patterns (i.e. nighttime winds from the east). Regardless, this correlation suggests further examination of whether diesel UFP emissions are a significant component of the measurements in the UFP2 size range

Figures 5 and 6 graphically represent a small fraction of the data that is summarized by Table 1. These figures demonstrate the rapid fluctuations in the data and the importance of 1-minute data. It can also be surmised that the presence of a strong statistical correlation for the minute-by-minute time series of air quality data provides information about the pollutant sources. It is also clear UFP size data contains helpful information.

The data shown on Figures 5 and 6 was collected at the PS4 site on August 20 and 21, 2008. In both figures, the concentrations have been normalized by the average values, so 3 means three times the average.

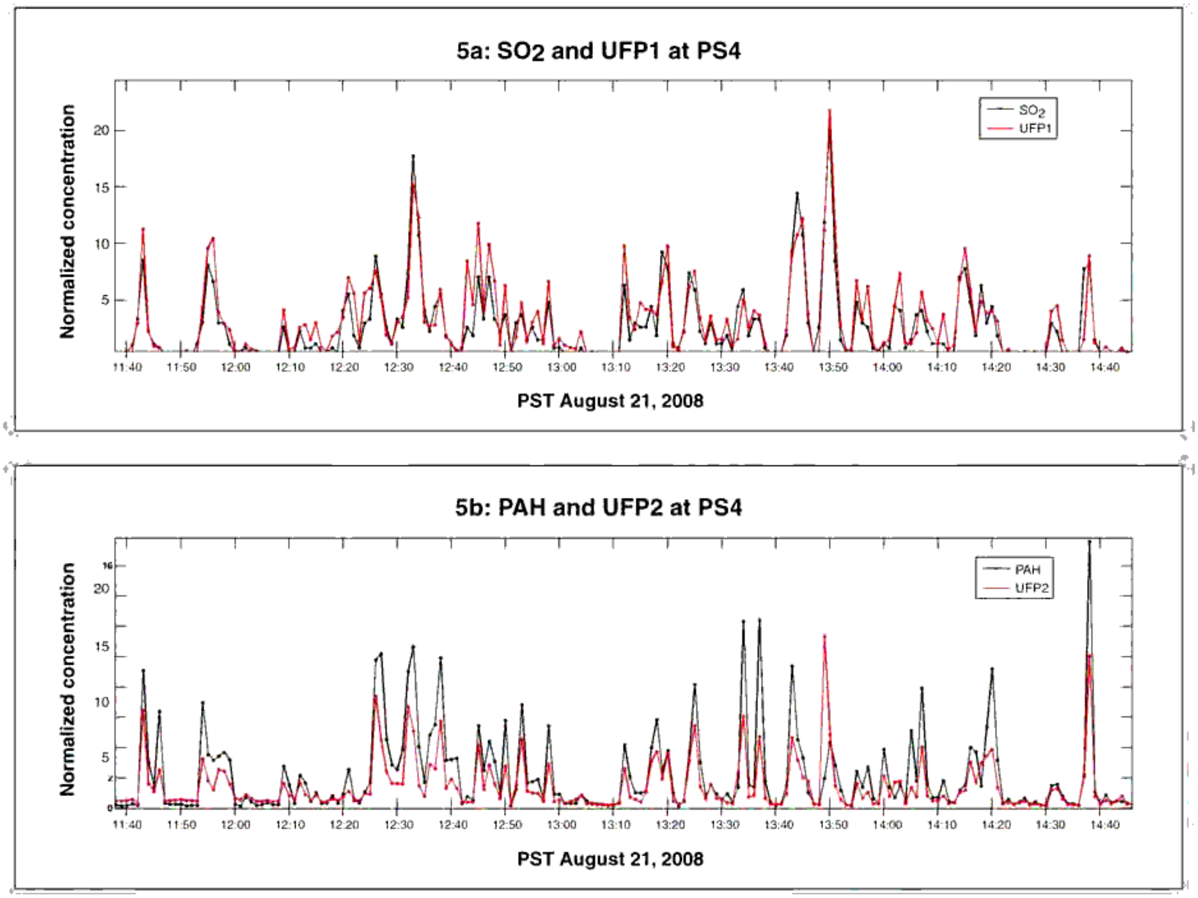
Figure 5a is a plot of the SO_2 and UFP1 data for the middle of the day on August 21. Figure 5b is the time series of PAH and UFP2 for the same period. The figures show a remarkable minute-by-minute relationship between SO_2 and UFP1 and PAH and UFP2. As can be seen by comparing Figure 5a and 5b, there is much less relationship between the measurements contained on the two charts. At the time this data was collected, the wind was blowing directly from the south runways toward the PS4 site. The SO_2 can be assumed to be almost entirely from jet exhaust, and thus the UFP1 is also likely to be coming predominately from jet exhaust. This indicates that different emission sources contribute to the PAH and UFP2 measurements than contributed to the SO_2 and UFP1 measurements at PS4 during this period. The likely sources of PAH are diesel vehicles on nearby Aviation Boulevard and the Airport service road that runs parallel to it. The similar trends between PAH and UFP2 corroborates the conclusion that the PAH and UFP2 in this time series at this monitor are dominated by diesel exhaust. Further, it supports the observation on the correlations in Table 1 that UFP2 measurements may be influenced by diesel emissions.

Different sources begin to impact the PS4 site when the wind direction changes. This is shown in Figure 6 which contains two plots similar to Figure 5, but for the time period 21:00 on August 20 to 12:00 on August 21. During this period, the winds veered from the typical daytime pattern of a westerly sea breeze to coming out of the north, east, and south. The winds finally return to a westerly flow at 10:00. Thus, during the period before 10:00 Airport emissions do not directly impact the monitoring site. This is indicated by the lack of similarity between SO_2 and UFP1 as seen in Figure 6a and by the lack of sharp peaks that characterize the discrete pollutant events resulting from aircraft takeoffs. Figure 6b also shows a breakdown of the similarity between UFP2 and PAH, indicating that the pollutant measurements are dominated by different emission sources than those depicted in Figure 5.

Figure 5

EXAMPLE OF POLLUTANT CORRELATION DURING DAYTIME PREVALING WIND PATTERNS

AQSAS—Demonstration Project
Los Angeles International Airport



5a: SO_2 and UFP1 at PS4

5b: PAH and UFP2 at PS4

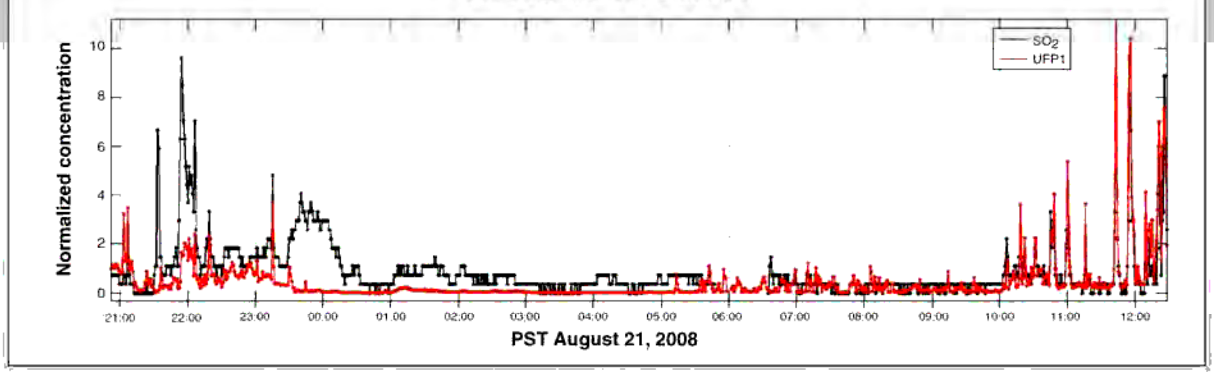
LAX684 Figure 5

Figure 6

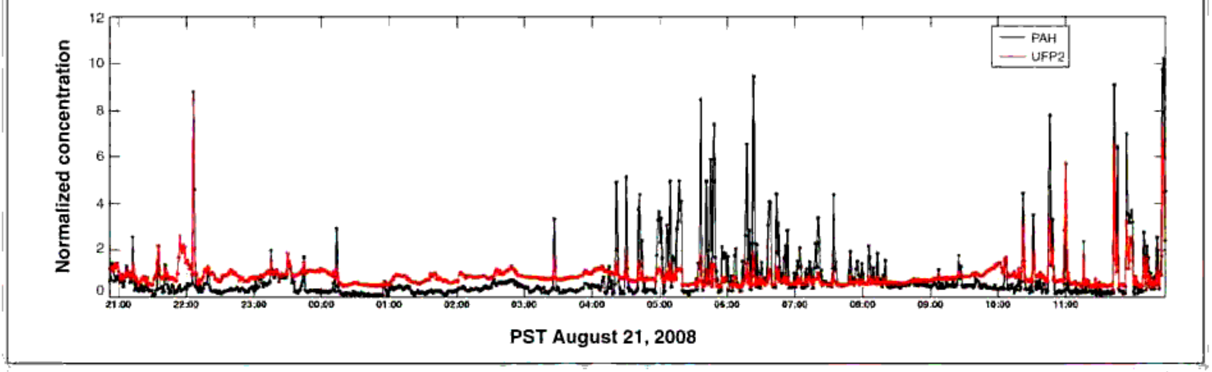
EXAMPLE OF POLLUTANT CORRELATION DURING NIGHTTIME PREVALING WIND PATTERNS

AQSAS—Demonstration Project
Los Angeles International Airport

6a: SO_2 and UFP1 at PS4



6b: PAH and UFP2 at PS4



LAX684 Figure 6

SECTION 3

CHEMICAL COMPOSTION EVALUATION FOR RECEPTOR MODELING

3.1 Introduction

Chemical Composition Receptor Models seek to quantitatively distinguish several emission sources based on a mass balance of several chemical components (i.e., particulate matter and volatile organic gases). Thus, these receptor models cannot distinguish a source of pollutants that is similar to another source of pollutants, or a source of a single measured pollutant (e.g. sulfur dioxide, or carbon monoxide) since these have no markers to distinguish between the emissions from one source or another.

Chemical Composition Receptor Models refer to a specific type of receptor model that uses the chemical composition as an input to the model. In this category of receptor models there are two specific models that will be utilized in the AQSAS, CMB and Multivariate. CMB requires information about the number of sources and their chemical compositions or fingerprints, and Multivariate (MVR) which uses multivariate models to derive the number and composition of sources. CMB is discussed further in the following paragraphs.

MVR does not require a known fingerprint. As long as there are over 100 samples, MVR may produce a fingerprint and an apportionment. Note: if there is no distinct fingerprint that can be measured--known or unknown--that separates aircraft and diesel emissions, MVR will combine the two sources. MVR was not used in the Demonstration Project but is likely to be used in the Long Term Study.

Successful application of CMB requires that each of the sources have distinct chemical composition signatures or "fingerprints". To evaluate the applicability of CMB as an apportionment technique, this section examines the use of SO_2, UFP, PAH, BC, VOCs, PM and the analysis of fuel samples as fingerprints of sources.

Table 2 contains summary data of the measurements of SO_2, UFP, PAH and BC at each of the monitoring sites. The locations of monitoring sites SR, PS4 and PS5 (shown in Figure 1, Section 1) are on the extended centerline of Runway 25R, purposely located downwind of departing aircraft during prevailing wind patterns. The SR site is closest to aircraft as they take off, PS4 is downwind of the SR site (during the prevailing winds) by 255 m, and PS5 is downwind by a further 255 m (510 m total). Thus, as expected, the aircraft-related pollutant concentrations are highest at the SR site and the concentrations decrease with the distance from the source.

As seen in Table 2, the average concentrations for SO_2 and UFP at the PS4 and PS5 sites are about a fifth to a tenth of the concentrations at the SR site. This decreased concentration is consistent with the dispersion of pollutants when moving away from a single source. The average concentrations of PAH and BC decrease more slowly with distance, indicating a more complicated geometric configuration of emission sources relative to the monitoring locations. The ratio of concentrations for both PAH and BC at

PS4 and PS5 are approximately 3.7 and 5.7, respectively. The cause for this is likely the presence of significant sources of PAH and BC from a location other than the runway threshold. This could be indicative of sources of PAH and BC either upstream or downwind of the SR site. However, since the difference in values between PS4 and PS5 is nearly a doubling, this indicates a significant portion of the PAH and BC measured at PS4 and PS5 comes from a source downwind of the SR site. Indeed, there is significant diesel vehicle traffic on Aviation Boulevard, a north-south roadway between the SR site and the PS4 and PS5 sites. Thus Aviation Boulevard is downwind of the SR site but upwind of PS4 and PS5 sites during the prevailing daytime winds. This diesel vehicle traffic is the likely source of the additional PAH and BC at PS4 and PS5. In the following section on receptor modeling, a species is considered to be dominated by aircraft emissions if the ratio of its mean at PS4 and PS5 to the SR mean is in the range of 5 to 10.

3.2 Ambient Air VOC Composition Data

This section presents the analysis and discussion of VOC composition data. It is important to note that the discussion is formulated on seven summa canister samples per site. There are a number of species that are detected in fewer than half of these seven samples. This limited data is sufficient only to provide cursory observations that can inform the Year Long Study. Detailed conclusions can not be based on such a small data set.

As seen in Table 2, gaseous species dominated by aircraft emissions, such as SO_2, are 5 to 10 times higher at the SR site as compared to the PS4 and PS5 sites. This ratio is consistent with the decrease in concentration predicted by dispersion modeling when moving about 250 m away from a single source (i.e. runway threshold aircraft emissions). Table 3 shows the observed PAMS VOC concentrations for all sites during the study. No two monitoring locations were collecting data at the same time, yet still no species are clearly 5 to 10 times higher at the SR site that could be the basis for a distinct aircraft signature. A possible exception is styrene (which could be related to aircraft exhaust) as it is the only species that is seen in all seven samples at the SR site but is not seen at the PS5 site and only reported once at the PS4 site. However, the levels of styrene measured at the SR site are in the range that is commonly observed in the Los Angeles area.

Table 2

BASIC STATISTICS OF SELECT SPECIES

AQSAS - Demonstration Project
Los Angeles International Airport

Site	Number of Data Points	Min	Max	Median	Mean	Std. Dev.	Ratio of mean at SR to Mean
Sulfur Dioxide (ppb)							
SR	16,945	0	175	5	12.510	19.010	1.000
PS4	11,752	0	62	1	2.701	4.694	4.632
PS5	14,188	0	401	0	1.284	10.180	9.743
PS2	10,815	0	33	2	2.312	2.328	5.411
PS3	10,470	0	26	2	1.881	1.743	6.651
Ultra Fine Particles (Total Number)							
SR	17,033	2,070	11,500,000	182,000	868,900	1,356,000	1.000
PS4	12,292	2,150	2,890,000	49,900	140,100	250,100	6.202
PS5	14,340	2,760	962,000	46,700	71,510	78,310	12.151
PS2	2,151	4,540	674,000	44,100	64,240	64,040	13.526
PS3	8,678	3,750	1,810,000	16,150	34,260	82,200	25.362
Polyaromatic Hydrocarbons (ppb)							
SR	39,417	0.900	1654.000	15.600	64.070	117.900	1.000
PS4	12,180	0.900	565.500	7.800	17.080	30.900	3.751
PS5	12,959	0.900	272.200	7.400	11.260	12.860	5.690
PS2	16,440	0.900	243.300	15.200	20.550	17.400	3.118
PS3	11,940	0.900	559.500	4.200	10.770	29.730	5.949
Black Carbon (µg m^{-3}) *(a)*							
SR	32,810	0	85,190	5,630	8,614	8,708	1.000
PS4	11,570	0	24,630	1,514	2,252	2,256	3.825
PS5	13,806	0	24,280	1,212	1,463	1,105	5.888
PS2	15,525	0	8,273	1,779	1,965	1,130	4.384
PS3	10,380	0	20,610	747	1,219	1,843	7.066

(a) BC numbers are 1-minute averages interpolated from 5-minute observations, so these do not contain actual 1-minute variability

Source: Jacobs Consultancy, November 2008.

Table 3

PAMS VOC CONCENTRATIONS
AQSAS - Demonstration Project
Los Angeles International Airport

	SR		PS2		PS3		PS4		PS5	
VOC Species	Number *(a)*	Conc. *(b)*	Number *(a)*	Conc. *(b)*	Number *(a)*	Conc. *(b)*	Number *(a)*	Conc. *(b)*	Number *(a)*	Conc. *(b)*
Ethylene	7	9.36	7	6.71	7	4.27	6	6.25	7	5.13
Propane	7	7.34	7	11.44	7	19.87	5	7.00	7	11.31
1,2,4-trimethylbenzene	1	6.10	2	2.60	3	2.57	1	7.00	-	-
Toluene	7	5.53	7	5.49	7	5.00	7	8.13	7	5.01
Styrene	7	5.26	1	9.30	-	-	1	4.90	-	-
Propylene	7	5.19	7	4.26	7	2.89	6	3.80	6	3.57
3-Methylhexane	4	5.15	6	5.60	3	6.20	1	1.80	2	4.40
2-Methylpentane	7	5.03	7	2.43	6	2.82	3	2.17	4	2.50
Ethane	7	4.97	7	7.47	7	3.61	5	4.40	7	6.20
Isopentane	6	3.98	7	5.97	7	5.80	5	3.90	7	5.00
Acetylene	7	3.41	5	2.02	4	2.05	1	1.60	5	1.92
N-Butane	4	3.28	6	5.43	6	2.18	5	3.24	7	4.31
Methylcyclopentane	6	3.13	7	2.74	6	2.77	4	4.58	6	2.37
M/P-Xylenes	5	3.02	5	3.14	6	2.53	1	1.70	4	1.80
N-Pentane	4	2.95	7	3.49	7	2.39	4	2.40	5	3.40
N-Hexane	7	2.64	7	3.33	7	2.34	7	11.31	6	2.57
Isobutane	3	2.30	6	5.07	5	2.12	5	3.70	5	4.16
2-Methylhexane	4	2.28	3	3.17	6	2.58	1	1.50	3	1.70
Benzene	5	2.22	3	1.73	-	-	-	-	1	1.50
2,2,4-Trimethylpentane	5	1.96	5	2.04	5	1.72	3	1.63	3	1.57
3-Methylpentane	1	1.70	2	1.85	4	2.18	2	6.90	4	1.60
O-Xylene	1	1.60	-	-	2	1.45	-	-	1	1.40
Methylcyclohexane	2	1.50	1	1.40	2	1.85	-	-	-	-
Ethylbenzene	1	1.40	-	-	-	-	-	-	-	-
M-Ethyltoluene	1	1.40	-	-	1	1.70	-	-	-	-
N-Heptane	1	1.40	-	-	2	1.65	-	-	1	2.80
1-Butene	-	-	-	-			-	-	1	1.70
2,3-Dimethylpentane	-	-	-	-	2	1.50	-	-	-	-
2-Methylheptane	-	-	-	-	1	1.60	-	-	-	-
Cyclohexane	-	-	-	-	1	1.70	-	-	-	-
N-Dodecane	-	-	-	-			1	2.10	-	-
N-Nonane	-	-	-	-	1	2.00	-	-	-	-

(a) Number of samples that detected species.
(b) Average concentration in samples detected in ppbC.

The TO-15 compounds listed in Table 4, similar to the PAMS compounds, did not measure concentrations at the SR site that were substantially greater than measured at the other sites. The implication is that none of these compounds are dominated by aircraft emissions and thus cannot be basis for a distinct signature for aircraft.

Table 4

TO-15 VOC CONCENTRATIONS
AQSAS - Demonstration Project
Los Angeles International Airport

VOC Species	PS2		PS3		PS4		PS5		SR	
	Number *(a)*	Conc. *(b)*	Number *(a)*	Conc. *(b)*	Number *(a)*	Conc. *(b)*	Number *(a)*	Conc. *(b)*	Number *(a)*	Conc. *(b)*
2-Butanone	2	8.45	4	6.90	-	-	3	5.40	4	6.18
Acetone	7	36.93	7	43.44	7	68.94	7	35.31	7	54.06
Carbon Disulfide	1	3.20	1	2.30	1	3.20	2	3.00	1	3.00
Ethanol	5	7.40	6	7.20			5	11.36	3	9.97
Methanol	4	20.93	6	15.13	4	12.00	2	14.10	4	11.78
Methylene Chloride	-	-	-	-	2	24.75	-	-	-	-
N-Hexane	-	-	-	-	2	12.45	-	-	-	-
Propylene	3	3.47	6	3.77	-	-	3	3.17	5	3.36
Toluene	1	2.80	2	2.80	-	-	1	2.70	1	3.10
Vinyl Acetate	1	4.60	1	5.00	-	-	1	5.90	1	4.70

(a) Number of samples that detected species.
(b) Average concentration in samples detected in µg m^{3}.

Finally, Table 5 shows a summary of the concentrations of the TO-11 suite of VOCs. Only data from the SR site are available, so no comparison to other sites is possible. However, published concentrations show the levels of these compounds measured at the SR site are typical of those seen in southern California (Sawant, et al. 2004). Thus, none of these species are likely to be dominated by aircraft emissions.

Table 5

TO-11 VOC CONCENTRATIONS
AQSAS - Demonstration Project
Los Angeles International Airport

	SR	
VOC Species (µg/m^3)	Number *(a)*	Conc. *(b)*
Acetaldehyde	14	3.46
Acrolein	4	0.168
Benzaldehyde	14	0.344
Butyraldehyde	7	0.433
Crotonaldehyde	11	0.284
Formaldehyde	14	3.195
Hexaldehyde	10	0.584
Methacrolein	13	0.34
Methyl Ethyl Ketone	11	0.566
M-Tolualdehyde	1	0.09
Propionaldehyde	14	0.516
Valeraldehyde	12	0.148

(a) Number of samples that detected species.
(b) Average concentration in samples detected.

3.3 *Fuel Analysis (VOC Composition)*

Samples of Jet-A, unleaded gasoline, and diesel fuel used by construction equipment and diesel fuel used by ground support equipment were subjected to several types of analysis. For this analysis, the working hypothesis is that the compounds seen in the fuel are characteristic of what is seen in the unburned hydrocarbon component of exhaust. In some instances this can be observed in gasoline and diesel engines, and it is hypothesized to be possible for aircraft turbine engines. Thus, species that could comprise a distinct aircraft signature will have much higher concentrations in Jet-A fuel than diesel or unleaded gasoline.

Samples of Jet-A, unleaded gasoline, and diesel fuel used by construction equipment and diesel fuel used by GSE were subjected to several types of analysis.[4]

Table 6 shows the results of one of the fuel analyses methods (EPA Reference Method 8260). The concentrations of the trimethylbenzenes and xylenes are much higher in Jet-A than in diesel, and could potentially delineate jet aircraft emissions from diesel

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[4] A complete list of analyses and results can be found in the Task 4 -- Sample and Characterize Mobile Source Fuels Used On and Around the Airport (AAC, 2008).

emissions. However, gasoline also has very high concentrations of these species. The most reliable source apportionment requires species that are dominated by Jet-A and allow for differentiation of gasoline and diesel fuel, i.e., species that have much higher concentrations in Jet-A and diesel than gasoline.

Table 6

8260 VOC FUEL CONCENTRATION
AQSAS - Demonstration Project
Los Angeles International Airport

Analyte	Jet-A Wt %	DIESEL (1) Wt %	Jet-A/ Diesel (1)	DIESEL (2) Wt %	Jet-A/ Diesel (2)	Unleaded Gasoline Wt %
Benzene	0.00160	0.00176	0.9	0.00366	0.4	0.80000
n-Butylbenzene	0.04820	0.00100	48.2	0.00100	48.2	0.00400
sec-Butylbenzene	0.02420	0.00424	5.7	0.00300	8.1	0.01380
Ethylbenzene	0.05220	0.01060	4.9	0.01250	4.2	1.18000
Isopropylbenzene	0.02130	0.00252	8.5	0.00206	10.3	0.06900
p-Isopropyltoluene	0.03080	0.00273	11.3	0.00213	14.5	0.00410
Naphthalene	0.03840	0.00153	25.1	0.00161	23.9	0.03850
n-Propylbenzene	0.06020	0.00760	7.9	0.00540	11.1	0.24400
Toluene (Methyl benzene)	0.04500	0.01920	2.3	0.04600	1.0	6.60000
1,2,4-Trimethylbenzene	0.41000	0.06480	6.3	0.04840	8.5	2.55000
1,3,5-Trimethylbenzene	0.09600	0.01560	6.2	0.01210	7.9	0.48300
o-Xylene	0.11500	0.01890	6.1	0.02300	5.0	2.20000
m,p-Xylenes	0.19000	0.03920	4.8	0.05440	3.5	5.94000

Note: Number of significant digits is not indicative of analytical certainties.
Two samples of diesel fuel were taken on the day of fuel sampling.

The fuel samples were also analyzed by gas chromatograph / mass spectrometry (GC/MS), maximizing the number of chemical species that can be uniquely identified and measured. The major and minor VOC species and classes of VOCs (concentrations > 1%) in Jet-A fuel are seen in Table 7. The high carbon number species, dodecane and above (10 or more carbons) are seen to be very low in gasoline, but not in Jet-A or diesel fuel and if present in the emissions, can be used in receptor modeling of VOCs to separate gasoline from Jet-A and diesel fuel. It is important to note that these results come from a single sample at each of the four locations and do not reflect or quantify variability in the fuel compositions.

In order to support CMB modeling, species that are high in Jet-A compared to diesel must be identified and quantified. The ratio of Jet-A to diesel species is shown in Table 7, and a number of species have much higher concentrations in Jet-A than diesel.

Note that there are three dimethyl- 2, 3-dihydro-1H-indenes that have concentrations of about 1 percent in Jet-A that are very low in diesel fuel. These explain most of the total indene concentration in Jet-A of about 3.1 percent. Total indenes in the diesel fuels are 0.7 and 1.5 percent. The two largest indene species in diesel A and B are also shown in Table 7. These are quite different from the Jet-A indene species; thus, emission measurements of dimethyl-2,3-dihydro-1H-indenes are potentially dominated by jet aircraft VOC emissions and could be a part of a jet aircraft signature.

No speciated data for the organic constituents in the particulate samples was available and thus the possibility of chemical composition receptor modeling for particulate matter was not considered.

3.4 Particulate Matter Composition

This section presents the analysis and discussion of particulate matter composition data. It is important to note that the discussion is formulated on filter samples taken at all 5 monitoring sites. Twenty-four samples were taken at the SR site and 14 samples were taken at each additional site. There are a number of species that are detected in fewer than half of these samples. This limited data is sufficient only to provide cursory observations that can inform the Year Long Study. Detailed conclusions can not be based on such a small data set.

$PM_{2.5}$ samples were collected with sequential samplers at all five monitoring sites. In addition, MiniVol samplers were used at the SR site only. The MiniVol data is duplicative but was collected to provide information that would aid in evaluating technology for the Long Term Study. The $PM_{2.5}$ samples were analyzed for elemental species using the x-ray fluorescence (XRF) method. $PM_{2.5}$ samples were also analyzed for elemental carbon (soot) and organic carbon by a method used in the Interagency Monitoring of Protected Visual Environments (IMPROVE) network of air monitoring sites. The results of both the XRF and the IMPROVE methods are discussed in the following paragraphs.

3.4.1 X-ray Fluorescence (XRF) Elemental Data

The average measured concentration for each species analyzed using the XRF method are shown in Table 8. Samples that did not detect the species are excluded from the average. To identify species that can support establishing a chemical fingerprint for jet exhaust, a species should have concentrations substantially higher at the SR site than at the PS4 and PS5 sites. The concentration of such a species should decrease as it travels progressively downwind. Table 8 shows that nickel, chromium, and copper are higher at the SR site than the other sites. However, examination of the data shows that the nickel and chromium have just one extremely high value at the SR site; if this one value is discounted, then nickel and chromium are not unusually high at this site. This leaves copper as the only species that is consistently and significantly higher at the SR site.

Table 7

GC/MS FUEL COMPOSITION
AQSAS - Demonstration Project
Los Angeles International Airport

Analyte	Jet-A Wt. %	Diesel (A)		Diesel (B)		UNL. GAS. Wt. %
		Wt. %	Ratio with Jet-A	Wt. %	Ratio with Jet-A	
Cyclic Paraffins (Naphthenics)	27.4	34.6	0.8	34.4	0.8	7.08
Isoparaffins	27.1	35.6	0.8	36.3	0.7	41.91
Mono-Aromatics	15.6	1.4	11.1	1.5	10.4	0
Di-Aromatics	14.2	6.7	2.1	6.9	2.1	0
Total Aromatics	29.8	8.1	3.7	8.4	3.5	31.69
Paraffins	11	14.4	0.8	14.5	0.8	7.32
Indenes	3.1	0.7	4.4	1.5	2.1	0.02
Aldehydes	1.2	1.8	0.7	2.5	0.5	0
Dodecane	2.01	1.02	2	1.15	1.7	0.05
Undecane	1.97	0.67	2.9	0.69	2.9	0.11
Tridecane	1.6	1.22	1.3	1.24	1.3	0.02
Undecane, 2,6-Dimethyl-	1.51	0.57	2.6	0.54	2.8	0
Trans-Anti-1-Methyl-Decahydrona…	1.33	0.5	2.7	0.51	2.6	0
Naphthalene, DECAHYDRO-2-METHYL-	1.21	0.01	121	0.66	1.8	0
Cyclohexane, 2-Butyl-1, 1, 3-Trim…	1.2	0.01	120	0.17	7.1	0
Tetradecane	1.19	1.49	0.8	1.45	0.8	0
Decane	1.1	0.26	4.2	0.28	3.9	0.11
Naphthalene, 1,2,3,4-Tetrahydro…	1.16	0.47	2.5	0.81	1.4	0
1h-Indene, 2,3-Dihydro-1,6-Dime…	1.06	0.01	106	0.01	106	0
1h-Indene, 2,3-Dihydro-1,3-Dime…	1	0.01	100	0.01	100	0
1h-Indene, 2,3-Dihydro-4-Methyl-	0.85	0.01	85	0.01	85	0
Additional indene related species:						
1H-Indene, 2, 3-dihydro-4, 7-dime…				0.48		
1H-Indene, 2,3-dihydro-4,5,7-tr…				0.33		
1H-Indene, 2,3-Dihydro-1,1,3-TR…		0.32				
1H-Indene, 2,3-Dihydro-1,1,5-TR…		0.16				

Table 8

ELEMENTAL DATA – X-RAY FLUORESCENCE METHOD

AQSAS - Demonstration Project
Los Angeles International Airport

	SR		PS2		PS3		PS4		PS5	
Element	Number *(a)*	Conc. *(b)*	Number *(a)*	Conc. *(b)*	Number *(a)*	Conc. *(b)*	Number *(a)*	Conc. *(b)*	Number *(a)*	Conc. *(b)*
Aluminum	10	0.035	8	0.065	5	0.036	12	0.037	12	0.033
Antimony	-	-	-	-	1	0.079	-	-	-	-
Bromine	20	0.008	14	0.009	13	0.006	11	0.005	13	0.007
Calcium	20	0.045	14	0.08	14	0.058	14	0.037	14	0.049
Chlorine	20	0.1	14	0.174	14	0.39	14	0.043	14	0.115
Chromium	1	0.149	1	0.005	-	-	1	0.003		
Cobalt	5	0.003	3	0.003	-	-	1	0.002	2	0.002
Copper	20	0.024	10	0.004	-	-	13	0.007	11	0.004
Indium	-	-	-	-	-	-	1	0.036	-	-
Iron	20	0.075	14	0.085	14	0.041	14	0.058	14	0.053
Lanthanum	-	-	-	-	1	0.012	1	0.013	-	-
Lead	-	-	1	0.01	-	-	-	-	-	-
Magnesium	19	0.06	14	0.115	14	0.1	10	0.042	14	0.069
Nickel	18	0.038	8	0.004	7	0.005	9	0.002	9	0.003
Potassium	20	0.067	14	0.073	14	0.053	14	0.033	14	0.05
Selenium	-	-			1	0.003	-	-	-	-
Silicon	20	0.089	14	0.098	12	0.058	14	0.069	13	0.07
Silver	-	-			-	-			1	0.028
Sodium	20	0.614	14	1.049	14	1.018	14	0.353	14	0.744
Strontium	-	-			1	0.003			1	0.005
Sulfur	20	2.151	14	3.649	14	1.833	14	1.937	14	2.278
Tin	-	-	-	-	1	0.065	-	-	-	-
Titanium	2	0.007	-	-	-	-	-	-	-	-
Vanadium	11	0.006	8	0.014	11	0.013	7	0.01	11	0.009
Zinc	7	0.006	7	0.011	1	0.01	3	0.007	7	0.008
Zirconium	-	-	1	0.021	2	0.01	1	0.009	1	0.013

(a) Number of samples that detected species.
(b) Average concentration in samples detected, in µg/m³.

3.4.2 IMPROVE Elemental and Organic Carbon Data

The IMPROVE method measures the organic particulates in four ranges (O1 – O4) according to the temperature at which the particulate sublimates when it is heated. Three different ranges of elemental carbon (E1 – E3) are also quantified by the IMPROVE method. Table 9 shows the IMPROVE measurements of elemental and organic carbon for the samples collected during the Demonstration Project. It is clear from Table 9 that there is an increased concentration of particulates at the SR site compared to the other sites, comprised of elevated levels of both organic and elemental carbon. This would suggest that organic and elemental carbon are both important components of jet exhaust and is consistent with the observations in the APEX series of experiments. Still unknown is if the ratios of the various ranges of organic carbon and elemental carbon in jet exhaust constitute a distinct fingerprint (compared to other sources). The presence of a fingerprint is possible, but more information is needed on the values of the organic and elemental carbon ranges for diesel, gasoline, and other sources in the Study Area.

In the Long Term Study, with data from many samples, an MVR receptor model may be able to discern fingerprints from these species for various sources, including jet exhaust. However, it is a concern that the organic/elemental carbon fingerprints for jet exhaust and diesel exhaust may not be unique.

Table 9

ELEMENTAL DATA AND ORGANIC DATA – IMPROVE METHOD

AQSAS - Demonstration Project
Los Angeles International Airport

	SR		PS2		PS3		PS4		PS5	
Species	Number *(a)*	Conc. *(b)*	Number *(a)*	Conc. *(b)*	Number *(a)*	Conc. *(b)*	Number *(a)*	Conc. *(b)*	Number *(a)*	Conc. *(b)*
Improve_A - E1	18	4.54	6	2.63	1	2.46	1	1.3	4	1.77
Improve_A - E2	19	2.96	-	-	-	-	2	0.92	2	1.07
Improve_A - E3	-	-	-	-	-	-	-	-	-	-
Improve_A - O1	18	2.96	12	1.86	12	1.91	10	1.08	11	1.14
Improve_A - O2	20	3.3	14	2.62	12	2.24	14	1.48	14	1.57
Improve_A - O3	20	2.43	7	2.11	8	1.64	4	1.83	3	1.54
Improve_A - O4	-	-	-	-	-	-	-		-	-

(a) Number of samples that detected species.
(b) Average concentration in samples detected, in μg/m^3.

SECTION 4

NONPARAMETRIC TRAJECTORY ANALYSIS

4.1 Introduction

Nonparametric Trajectory Analysis (NTA) is a receptor modeling method developed by Dr. Ronald Henry that is able to use 1-minute data from continuous air quality monitors and meteorological stations. However, only 1-hour average concentration and meteorological data is generally reported. The use of 1-hour data makes it difficult to separate out the influence of sources that are less than 1–hour travel time from a monitor.

NTA allows for determining the location of nearby sources of specific pollutants in the area surrounding an air quality monitor based on 1-minute observations of the pollutants and wind speed/direction. The data needed for this analysis includes monitor data for the specific pollutant and meteorological data (including wind speed/direction), all in 1-minute increments. This method can be performed using data from one monitoring site and one meteorological site, but more robust information about local sources can be garnered with additional monitoring and meteorological sites.

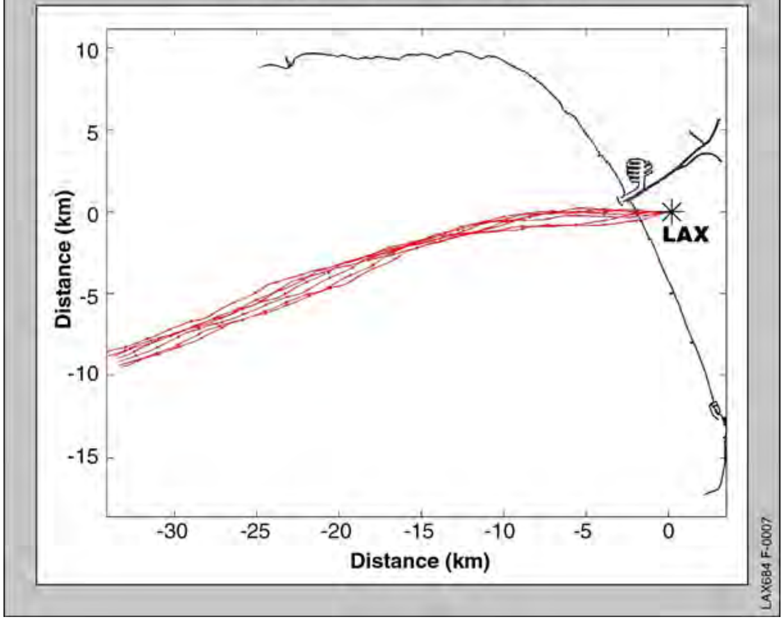
NTA uses wind speed and direction to calculate the trajectories (or paths) from which monitored pollutants have come (these are referred to as "back-trajectories"). When wind passes over a pollutant source it carries the pollutants in the direction of the wind, creating a plume. Ultimately, the pollutants in a plume can be measured by air quality monitors. The NTA back-trajectories are used to determine the source of the pollutants that have been detected by monitors by tracing the path of the plume. For illustrative purposes seven back-trajectories are shown on Figure 7. NTA creates a back-trajectory for every minute of monitor data. The NTA methodology is described completely in the peer-reviewed paper (Henry, R. C. 2007).

Figure 7

EXAMPLE BACK-TRAJECTORY

AQSAS—Demonstration Project

Los Angeles International Airport



In the Demonstration Project, the NTA method is applied to the monitored data for SO_2, UFP, BC, and PAH from all sites that had data available except the SR site. Concentrations and meteorological conditions at the SR monitor are dominated by aircraft jet blast, overwhelming pollutant and meteorological information from nearby locations. The result of NTA is a contour map, centered around the monitor, showing the cumulative pollutant contributions from locations near the monitor. The model develops this contour by assigning the monitored pollutant concentration to every point in a back trajectory. This is repeated for each monitor reading (every 1-minute data point) and if multiple back trajectories fall on the same point, the model sums the values assigned to that point. This array of summed values are then normalized, which results in the highest values corresponding to locations that are likely important pollutant sources contributing to the concentrations measured at the monitor.

4.1.2 Introduction of SCAQMD Data

As described in the TWP, the Study Team collected species monitoring data from the South Coast Air Quality Management District (SCAQMD). This monitoring data included NO_X and SO_2 measurements, in 1-minute increments, for the months of June and July, 2008. The data was provided before being subjected to SCAQMD's rigorous quality assurance/quality control (QA/QC) protocols. Therefore, the Study Team performed QA/QC checks on the data internally[5].

This data, collected by an external team of air quality monitoring experts, is a critical component in assessing the feasibility of Nonparametric Trajectory Analysis modeling for the Long Term Study. The SCAQMD monitoring site provided the only monitoring data from a site located off Airport property, and therefore provided data that was taken some distance away from Airport emission sources. NTA was developed to be used at such a distance from sources and the Long Term Study expects to apply this model only for sites that are remote from emission sources.

As seen on Figure 8, the site is located northwest of LAX. Given the prevailing wind pattern in the Study Area, the SCAQMD site is most often upwind of LAX.

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[5] The SCAQMD monitoring equipment was checked by the Study Team's independent QA/QC contractor. See QA/QC Report, Task 6 (T&B Systems, 2008)

Figure 8

LOCATION OF SCAQMD AIR QUALITY SITE

AQSAS—Demonstration Project
Los Angeles International Airport

4.2 NTA Analysis of Demonstration Project Data

Similar to the constraints of CMB, in order to apportion the emissions in the AQSAS Study Area to sources that affect the AQSAS Study Area, it is important to find a specific pollutant or combination of pollutants (i.e., a fingerprint) that can be used to track emissions sources in the AQSAS Study Area. However, fingerprints to separate sources may not exist. If a fingerprint can not be identified, separating sources based on geographical location may be feasible and NTA is one of the only techniques to provide that geographic delineation. Airport emissions sources include aircraft, GSE, parking facilities, stationary sources (such as boilers, generators, and cooling towers), roadways that are exclusively used for Airport-related traffic, and the portions of traffic on public roadways that is Airport-related. These Airport emission sources almost entirely run on gasoline, diesel fuel, or Jet-A fuel.

4.3 Nonparametric Trajectory Analysis Results

DISCLAIMER

THE NTA RESULTS ARE DISCUSSED NEXT. BEFORE READING AHEAD THE READER IS STRONGLY ADVISED THAT THIS METHOD IS STILL UNDER DEVELOPMENT AND ITS APPLICATION HERE IS EXPERIMENTAL. THE READER IS ESPECIALLY CAUTIONED IN THIS CASE SINCE THE METHOD WAS ORIGINALLY DESIGNED TO WORK WITH THREE MONTHS OF 1-MINUTE DATA FROM MONITORING STATIONS THAT ARE NOT WITHIN ONE KILOMETER OF MAJOR SOURCES. IN THIS DEMONSTRATION PROJECT, THERE ARE ONLY A FEW DAYS OF DATA AT EACH SITE AND THERE ARE SOURCES WITHIN HUNDREDS OF METERS OF THE MONITORS. THE RELATIVELY SMALL AMOUNT OF DATA MAKES IT IMPORTANT NOT TO INTERPRET EVERY HIGH POINT OR PEAK IN THE PLOTS; THESE COULD BE THE RESULT OF WORKING WITH TOO FEW DAYS OF DATA OR JUST THE EFFECT OF A FEW ERRANT DATA POINTS.

4.3.1 Contour Maps

The NTA-derived contour maps are shown in Appendix A, Exhibits 1 through 12, and are superimposed on a base map of the area showing the coastline, the major freeways, the north and south runways, and the El Segundo Marine Terminal. The areas without color were either not covered by the 2-hour back trajectories calculated in this analysis, or the NTA value at that grid point was not significantly different from zero. These zero values in the NTA results at specific grid points are usually caused by too few data points where the detected air at the monitoring station had passed over the specific grid point (i.e. too few back-trajectories cross the specific grid point). The NTA results for each grid point are indicated by the colors in the figures.

The NTA values (i.e., color indicators in the figures) represent the average pollutant concentration measured at the monitor for air samples whose back-trajectory included that grid point. High values (shown in orange and red on the figures) are expected to be associated with pollutant sources, but the high values on the NTA map may extend past the source area itself if wind patterns consistently result in the same trajectory between the source and the monitor.

Some small isolated high values may be due to insufficient data. The Demonstration Project collected data for ten or fewer days at each site except the SR site. The presence of abnormal values is understandable since NTA relies on larger data sets to reduce incorrect placement of sources.

4.3.2 Discussion of Contours

Exhibit 1 shows the NTA results at PS4 for SO_2, UFP, PAH and BC. At PS4 for each pollutant, there is a plume of elevated values extending from the site down the south runways and out into the ocean. Also, in all cases there are small peaks to the south of the runways. These small isolated high results may not be significant because of the limited data set. A complete statistical analysis could establish the significance of the high results; however this was not necessary to meet the objective of this task – determining the efficacy of NTA for apportionment.

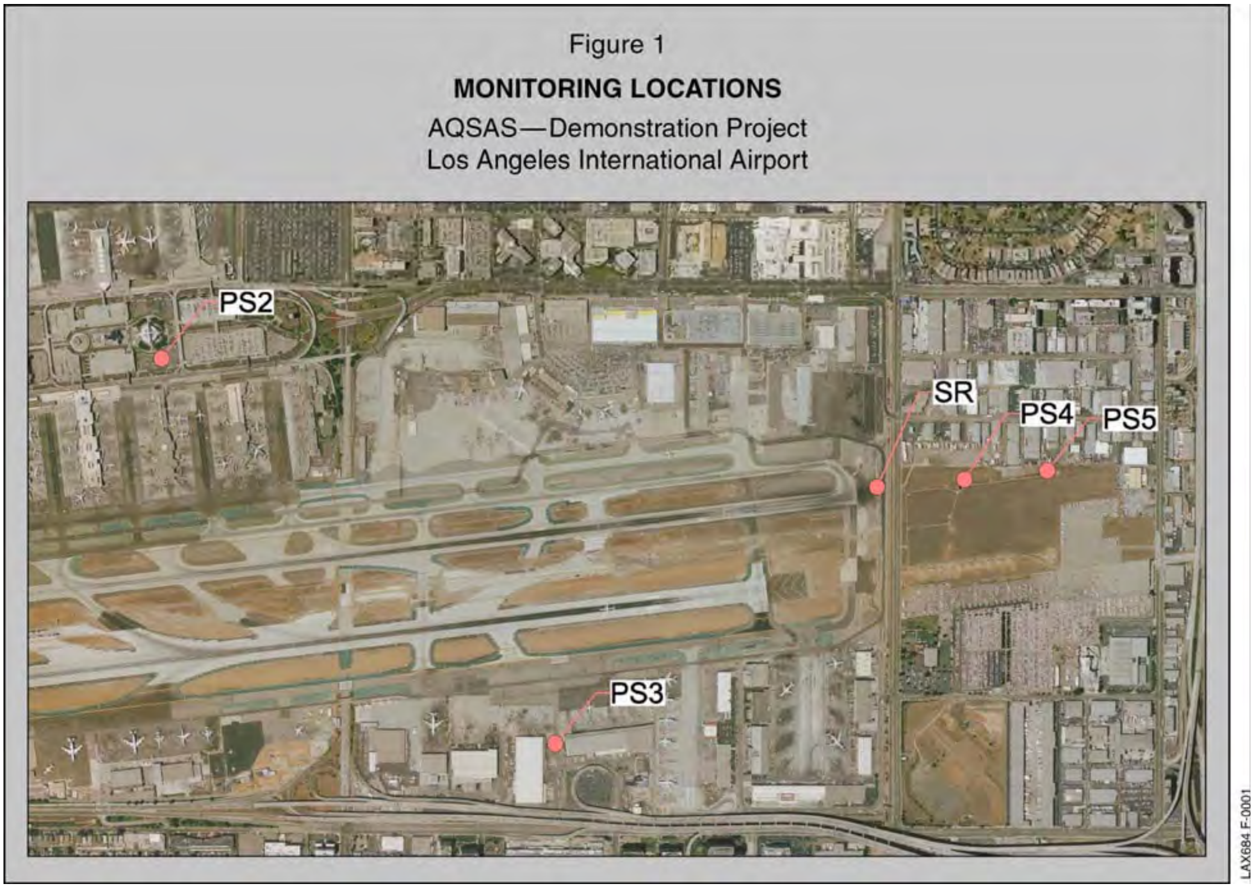

Figure 1

MONITORING LOCATIONS

AQSAS—Demonstration Project
Los Angeles International Airport

As shown on Figure 1 (shown above for convenience), the PS4 and PS5 sites are located on the extended centerline of Runway 25R at approximately 255m and 510 m respectively from the SR site. As expected, the NTA results show the most obvious impact of aircraft departures at the PS4 site, the closer of the two sites. The NTA results at the PS5 site (shown in Exhibit 2) are similar to the PS4 site for UFP. Exhibit 2 shows that at the PS5 site there are very high values of UFP associated with air coming from the direction of the runway. SO_2, PAH, and BC also show high values associated with air traveling from Runway 25R, however the highest values in the SO_2, PAH, and BC analyses are to the southeast. No explanation for this is given at this time as this will be further explored in the Long Term Study. A possibility is that the emissions could be coming from the diesel generator that powered the monitoring stations, which was located in that direction. However, this theory does not explain why the high results seen in the PS5 site results are not seen in the PS4 site results, even though the PS4 site was powered by the same generator with a similar geographic configuration.

The NTA results for the PS2 site are shown in Exhibit 3. This site is located in the middle of the central terminal area, and therefore between the middle of the south runways and the east end of the north runways. The NTA results for UFP at this monitoring site have limited applicability since there was only one and a half days data for this pollutant. SO_2, PAH, and BC all show high values at PS2 associated with areas primarily (but not exclusively) to the south.

The NTA results for the PS3 site are located in Exhibit 4. This site is located in the South Cargo Complex as shown in Figure 1, and therefore was located south of almost all airport-related sources. By comparing these results with the results for the PS2 site (Exhibit 3), the high values at PS3 are mostly associated with trajectories from areas to the north. Since these two sites are separated by only 1.5 km, the marked difference in the two NTA results is most likely due to the activity on the south runways and the activity at the terminal areas which are both located between the monitoring sites.

Exhibits 5 through 8 shows a compilation of the NTA results contained in Exhibits 1 through 4, however, Exhibits 5 through 8 show results combined by pollutant rather than by site. This rearrangement allows the reader to see that all the pollutant results are similar for PS4 and PS5 (which are on the extended centerline of Runway 25R) and quite different for PS2 and PS3 that are separated by Runways 25L and 25R. This supports the conclusion that airport activity on or near the southern airfield is the dominant source of all four species at the four monitoring sites where NTA was applied. This does not quantify or diminish potential impacts from more distant sources. The existence of these potential distant sources is demonstrated by NTA results of SO_2 and nitrogen oxides (NO_X) measured at the SCAQMD site that is not downwind of Airport-related emissions.

4.4 South Coast Air Quality Management District – NTA Results

All relevant data from the SCAQMD site during the 61 days of the Demonstration Project for NO_X and SO_2 were analyzed using NTA. This generous amount of data made it possible to study diurnal patterns in the NTA. The diurnal differences at this location provide the ability to see individual emission sources since the site is very near the coastline and subject to sea breezes (primarily during the late morning and into the early evening, strong winds blow from the sea inland) and land breezes (late evening and early morning the winds reverse and flow more weakly from the land to the sea). This reversal of wind direction has a major influence on which emission sources impact the air quality measurements. During a sea breeze in the daytime hours the sources identified by NTA are offshore. Conversely, during a land breeze, typically at night, the sources discovered by NTA are inland, and were found to be east and north of the site.

The locations of possible sources, including LAX and others, were studied using an NTA model of the 1-minute SCAQMD monitoring data. The results of this analysis for both NO_x and SO_2 are shown in two video files that have been made available as appendices to this report. These movie files were produced by combining the back-trajectories for a 1-hour period in 10 minute increments for all 61 days in the analysis period (i.e. there are 144 frames in the video, 6 frames per hour for 24 hours). Thus, all back-trajectories for the period between 06:00 and 07:00 for all 61 days in the analysis were combined into one frame of the video. The next frame of the movie is based on all trajectories for all days between 06:10 and 07:10, and so on.

The main features of the SO_2 video are shown in the four frames shown in Exhibits 9 through 12. Exhibit 9 shows that at 06:00 high concentrations of SO_2 are associated with air from all directions, including LAX, but primarily air coming from the north. Exhibit 10 shows that at 10:00 the sea breeze is becoming dominant (reflected in the lack of data from the east) and the possible influence of the El Segundo Marine Terminal can be seen to the southwest. Exhibit 11 shows that at 12:30 the sea breeze is fully established and what appears to be the influence of aircraft taking off from the north runways can be seen. Finally, Exhibit 12 shows that at 23:00 the shift to a land breeze from a sea breeze is seen, showing on and offshore sources. For the most part, very similar patterns are seen in the NO_x video.

4.5 NTA Conclusions and Recommendations

Nonparametric Trajectory Analysis is an effective method of determining the existence and locations of emission sources in the Study Area. NTA captures the spatial complexity and temporal dynamics of sources better than other receptor models. More work is needed to fully utilize the information in NTA when applied to sites on Airport property and monitoring locations proximate to a dominant source of emissions.

Analyzing SO_2 data provides the best hope for separating aircraft exhaust impacts from heavy-duty diesel emissions, but only if NTA can be used to separate aircraft SO_2 emission from the SO_2 generated by offshore sources and the refineries. Monitors should be located upwind and downwind of Airport sources to determine the differential pollutant contributions of LAX. These upwind sites (or "background" sites) should be placed near the coast and refinery for daytime background estimates, and inland for nighttime background estimates. These are needed to identify and eliminate the impact of refineries and off-shore sources.

The relative conservation of SO_2 compared to resident time in the atmosphere needs to be fully documented. This is important if SO_2 is to be used for quantitative source apportionment. SO_2 can generally be treated as a conservative species over short time periods (about 1 hour). However, SO_2 can react rapidly in fog droplets with ozone and hydrogen peroxide. This will have to be taken into consideration in the Long Term Study.

Because wind speed and direction are so important for application of NTA and interpretation of many of the receptor modeling results, additional wind data that is geographically spread across the Study Area is needed. An offshore meteorological station at the El Segundo Marine Terminal would be particularly useful, since the possible significant impact of marine sources on the community is demonstrated by the NTA analysis of the SCAQMD site SO_2 and NO_X data. An offshore station would help understand the complex wind patterns associated with the land-sea interface. Dr. Henry is exploring the use of data from NOAA's Meteorological Assimilation Data Ingest System (MADIS) that has several mesonet monitors in the area that would help with the Long Term Study. Historical data from these sites would be of use in putting the meteorology of the Long Term Study in historical perspective.

SECTION 5

CONCLUSIONS

5.1 Assessment of Modeling Viability

It is important to understand that not all questions can be answered in the Demonstration Project. This report seeks only to provide the reader with a sense that the AQSAS primary goal of source apportionment is feasible and attainable. This comprehensive source apportionment will be a process that will include use of all methods that have been discussed in this report (e.g., CMB and NTA), and methodologies that have not been discussed in detail in this report (e.g., Spatial Gradient Analysis and Multivariate Modeling). With the use of all models, tools, methods, and weather and pollutant data available it is apparent that source apportionment is feasible if an appropriate data collection program is implemented.

Dispersion modeling will also play an important role in source apportionment for the AQSAS, though its role is not the topic of this report. However, it is important to mention that there are aspects of a comprehensive source apportionment that receptor modeling cannot address (e.g., apportionment of pollutants from Airport-related and non-Airport related roadway traffic) that will be addressed by a comprehensive dispersion model. Dispersion modeling is also expected to provide some understanding of the geographic boundaries of the pollutant impacts resulting from key sources.

Although the efficacy of using Spatial Gradient Analysis, Time Series Analysis, and Multivariate Receptor Modeling for source apportionment could not be assessed in the Demonstration Project, it is expected that these models and tools will be of great use in the Long Term Study. Spatial Gradient Analysis and Time Series Analysis will likely play a large role in scrutinizing and presenting data and results; and multivariate modeling will be used in apportioning pollutants to sources, although the apportionment of aircraft is still in question at this time.

It is important to note that results of the Demonstration Project have shown that collecting 1-minute pollutant data wherever possible and reducing sample collection times to the shortest possibly increments is imperative to the success of the Long Term Study. Also noteworthy will be an effort to gain greater understanding of the UFP size distribution for source categories. Analyzing the UFP2 data for inter-pollutant correlations (time series), NTA modeling, and CMB indicate that there may be more overlap in UFP size distribution of the aircraft and diesel sources than recognized in current literature. Resolving this understanding of UFP size categories will play a predominant role in source apportionment and therefore equipment that collects this data in 1-minute increments or less should be used as extensively as possible in the Long Term Study. It was also found that 1-minute meteorological data and a detailed video record of aircraft, GSE and airfield roadways will play key roles in the Long Term Study.

5.2 Time Series and Source Characterization

In addition to understanding the association of pollutants and sources, as was investigated in the pollutant profile comparisons of the Analysis of Air Quality Emissions Data (Jacobs Consultancy, 2008) it is also important to understand the relationships among pollutants themselves. This report chronicles the analysis of many such relationships. It has been determined that within close proximity to the Airport, SO_2, NO, and UFP1 are all very highly correlated with each other, and that the source of those pollutants is aircraft. It has also been determined that the source of BC and PAH is likely diesel-powered vehicles. Contradictory evidence has been found that the source of UFP2 within close proximity to the Airport may be dominated by aircraft and may be dominated by diesel vehicles. The dominant source of UFP2 and its utility in source apportionment will have to be investigated further. The overwhelming evidence is that UFP3 does not correspond to aircraft.

It is important to recognize that the analysis shown in this report has indicated that it is possible to see aircraft exhaust (during prevailing wind patterns) even as the monitoring stations get farther away from the source and these pollutants cross over a major source of diesel vehicles (e.g., GSE use and Aviation Boulevard) and that it is also possible to discern pollutants from this roadway.

This analysis has shown unequivocally that wind direction must be considered when doing any analysis on pollutant data for the Long Term Study. For the Demonstration Project this was an unnecessary step for determining feasibility, however a method to partition the data based on wind direction for use during a quantitative source apportionment must be defined.

5.3 Chemical Mass Balance

It is a requirement for both Chemical Composition Receptor Models (Chemical Mass Balance and Multivariate Receptor Modeling) that aircraft have a distinct signature in order for either model to provide a quantitative source apportionment of aircraft. This is because for CMB the modeler must know the distinct signature, and for MVR if there is no distinct signature the aircraft will be combined with diesel sources in the apportionment.

Table 10 summarizes the results of the search for distinct indicators of Airport-related sources (e.g. aircraft, gasoline, and diesel). This investigation has identified a number of pollutants that are potential indicators. These pollutants are in essence “rated” with green indicating strong applicability documented in this report, yellow indicating further investigation needed but still good potential for use in the Long Term Study, and red indicating these potential indicators will not be key components used in the Long Term Study.

Table 10

POTENTIAL INDICATOR POLLUTANTS FOR APPORTIONMENT

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Potential Indicators	Characteristic Source	Applicability for Apportionment	
Black Carbon	Diesel	Direct relationship to diesel	Candidate for Apportionment
SO_2	Aircraft / Marine / Chevron	NTA can geographically separate these competing sources	
UFP3	Diesel	Direct relationship to diesel	
Dodecane and above (10 or more carbons)	Possibly Aircraft / Possibly Diesel	Useful in isolating gasoline	
PAMS plus high m.w. Carbons	Gasoline / Diesel	Delineate gasoline and diesel	
Nickel	Marine	Delineates PM from heavy fuel oil combustion from ships	
Chromium	Marine	Delineates PM from heavy fuel oil combustion from ships	
NO	Combustion	Only conservative near the source	Possible species for apportionment, but further study required
Total UFP	Diesel / Aircraft	Dominated by low mass, high count small UFP	
UFP1	Diesel / Aircraft	Not conservative over longer distance	
UFP2	Aircraft / Shoulder of diesel	Correlation to PAH indicated may not be unique to Aircraft	
Styrene	Possibly Aircraft	Styrene is the only PAMS species that is consistently detected at the SR site but not any other, therefore indicating that it is aircraft dominated	
Trimethylbenzenes	Possibly Aircraft / Possibly gasoline	Trimethylbenzenes were found to be higher in Jet-A than diesel fuel. However, gasoline has very high concentrations of these species and therefore these species are not likely to be unique to Jet-A	
Dimethyl- 2,3-dihydro-1H-indenes	Possibly Aircraft	Further field measurements required	
Organics and Elemental carbon in particulates	Gasoline/ Diesel / Possibly Aircraft	Further field measurements required	
PAH (Continuous)	Diesel / Gasoline / (Aircraft small)	Not unique to any source	Not candidate for apportionment
NO_x	Combustion	Not unique to any source	
CO	Combustion	Not unique to any source	
CO_2	Combustion	Not unique to any source	
NMHC	Combustion	Not unique to any source	
Xylenes	Gasoline / Possibly Aircraft	Xylenes were found to be higher in Jet-A than diesel fuel. However, gasoline has very high concentrations of these species and therefore these species are not likely to be unique to Jet-A	
Copper		Not likely to produce a fingerprint	
PAH (Samples)	Diesel / Aircraft	No information available at time of report	No data available
Hopanes and Steranes	Diesel	No information available at time of report	

5.4 Nonparametric Trajectory Analysis

The Nonparametric Trajectory Analysis model is a new method still in development for use in the Long Term Study. The use of this model for the Demonstration Project was solely to present its capabilities and not to deduce any information about the location of sources in the communities surrounding LAX, nor to provide any source apportionment.

This report has shown NTA's value as a tool in source apportionment and in particular its applicability in geographically separate pollutants that are not unique to one source. NTA can also provide invaluable information on any unidentified sources in the Study Area. NTA captures the spatial complexity and temporal dynamics of sources better than other receptor models, but more work is needed to fully utilize the information in NTA when applied to sites on Airport property and monitoring locations proximate to a dominant source of emissions.

For NTA to be best utilized in the Long Term Study monitors should be located upwind and downwind of Airport sources to determine the differential pollutant contributions of LAX. These upwind sites (or "background" sites) should be placed near the coast and refinery for daytime background estimates, and inland for nighttime background estimates. These are needed to identify and measure the pollutant concentrations resulting from local sources.

The quantity and location of additional meteorological sites (specifically, wind speed and direction) are of the utmost importance to the quality of results that can be attained from NTA and all other receptor models. The Long Term Study should include meteorological stations geographically spread across the study area (approximately every 2 km is recommended). An offshore meteorological station would also be particularly useful, (e.g. the El Segundo Marine Terminal), and would help to understand the complex wind patterns associated with the land-sea interface.

5.5 Evaluation of Opportunities for Quantitative Apportionment

This section summarizes the analysis of the collected data to evaluate the opportunities and likely limitations for quantitative apportionment of pollutants in the communities surrounding LAX. CMB and MVR require sources to have a distinct emission profile in order to quantitatively apportion emissions. The collected data from the Demonstration Project is encouraging and indicates opportunities for apportionment of the three key airport related emission source categories as described in the following sections.

5.5.1 Apportionment of Aircraft (Jet-A).

Analyzing SO_2 data provides the best hope for separating aircraft engine impacts from heavy-duty diesel emissions, but only if NTA is used to separate out the impact of offshore sources and refineries. Based purely on the chemical makeup of SO_2, it is impossible to distinguish between multiple SO_2 sources. Thus NTA becomes an important tool in the ultimate goal of source apportionment. NTA has the ability to geographically locate the sources of SO_2 that are being detected at a monitor and therefore apportion SO_2 to more than one source. SO_2 can generally be treated as a conservative species over short time periods (about 1 hour). However, SO_2 can react rapidly in fog droplets with ozone and hydrogen peroxide. This will have to be taken into account in the Long Term Study. If NTA is to be used in this manner, background sites near the coast for the daytime data and inland for nighttime data are needed to help identify and eliminate the impact of refineries and off-shore sources.

Aircraft are a dominant source of UFP at the monitoring sites in the Demonstration Project and their size distribution is different than UFP from diesel sources. Complete delineation between these sources is limited by overlap in the smallest particle sizes and the proximity of the peaks associated with the slightly larger particles. One of the peak particle sizes for diesel PM is about 30 nm, while a peak particle size for aircraft is about 70 nm. This proximity results in the “tails” of each size distribution curve overlapping slightly.

The size distribution curve for aircraft-generated UFP has a very narrow Gaussian distribution of particle size, potentially allowing for separation of aircraft emissions from diesel sources or ships. However, scientifically understanding the fate and transport of those particles is essential to using UFP measurements for apportionment, either qualitatively or quantitatively. UFP are inherently unstable in the atmosphere and are destroyed through interactions with surfaces. An understanding of the relative conservation of UFP compared to resident time in the atmosphere is essential if UFP are to be used for quantitative source apportionment.

The mass emission index of UFP contained in aircraft exhaust has been determined to be stable over distances of less than 1,000 meters during the APEX experiments (Whitefield, 2008). However particle counts were not stable in this period. Since UFP mass index is not unique to aircraft, measurement of UFP mass emissions will not quantitatively apportion aircraft emissions.

Thus, for very short travel times UFP counts can likely be used for quantitative apportionment of jet aircraft. But since UFP counts are not conserved, they will only be useful as qualitative indicators of aircraft impact, and will not likely be the basis of a quantitative source apportionment.

5.5.2 Apportionment of Motor Vehicles (Diesel v. Gasoline)

Most of the PM_{10} and $PM_{2.5}$ from aircraft, gasoline vehicles, and diesel vehicles is organic. Source apportionment of organic aerosol was determined by Chow et al. (2007) to allow for separation of diesel and gasoline vehicle contributions using high molecular hydrocarbons such as coronene along with the usual suite of elemental analysis, sulfates, nitrates, and elemental and organic carbon. Fujita et al. (2007) found similar results for organic particulate from southern California. Thus, given existing measurement and receptor modeling technology, organic material from diesel vehicles and gasoline vehicles can be apportioned.

At present, this methodology has not contemplated separating organic particulate matter generated by aircraft from that generated by diesel equipment. As a result aircraft contributions are likely to be considered a part of the diesel contributions. This could change if aircraft particulate matter were found to be high in certain high molecular weight organics. Samples were taken for this analysis during the Demonstration Study but the results are not available at the writing of this report.

Thus, it is evident that through measurements of gaseous VOCs, separation of diesel and gasoline contributions by receptor modeling is possible. This requires the VOC measurements to extend beyond the standard PAMS list of VOCs to include higher molecular weight VOCs (e.g., up to C_{12}, C_{13}, or C_{14}). Collecting this robust sample allows gasoline vehicles to be identified by vehicle exhaust, gasoline vapor, and whole gasoline (Lewis et al., 1997). There is the possibility of separating aircraft VOCs from vehicle VOCs but further data is required to establish the existence of distinct profiles necessary for this delineation.

SECTION 6

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Appendix A

Exhibit 1

NTA ANALYSIS OF SITE P4

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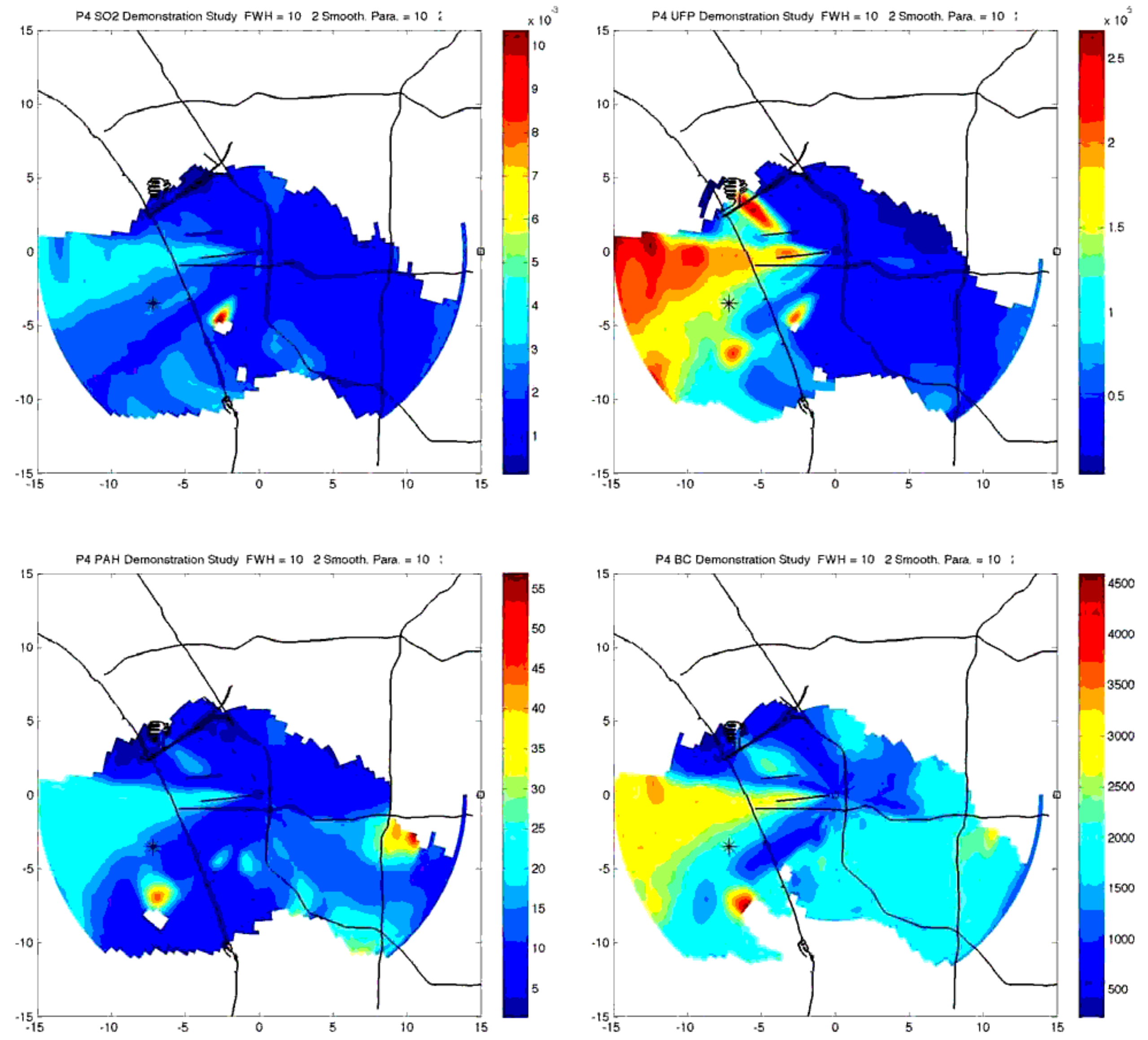
Los Angeles International Airport



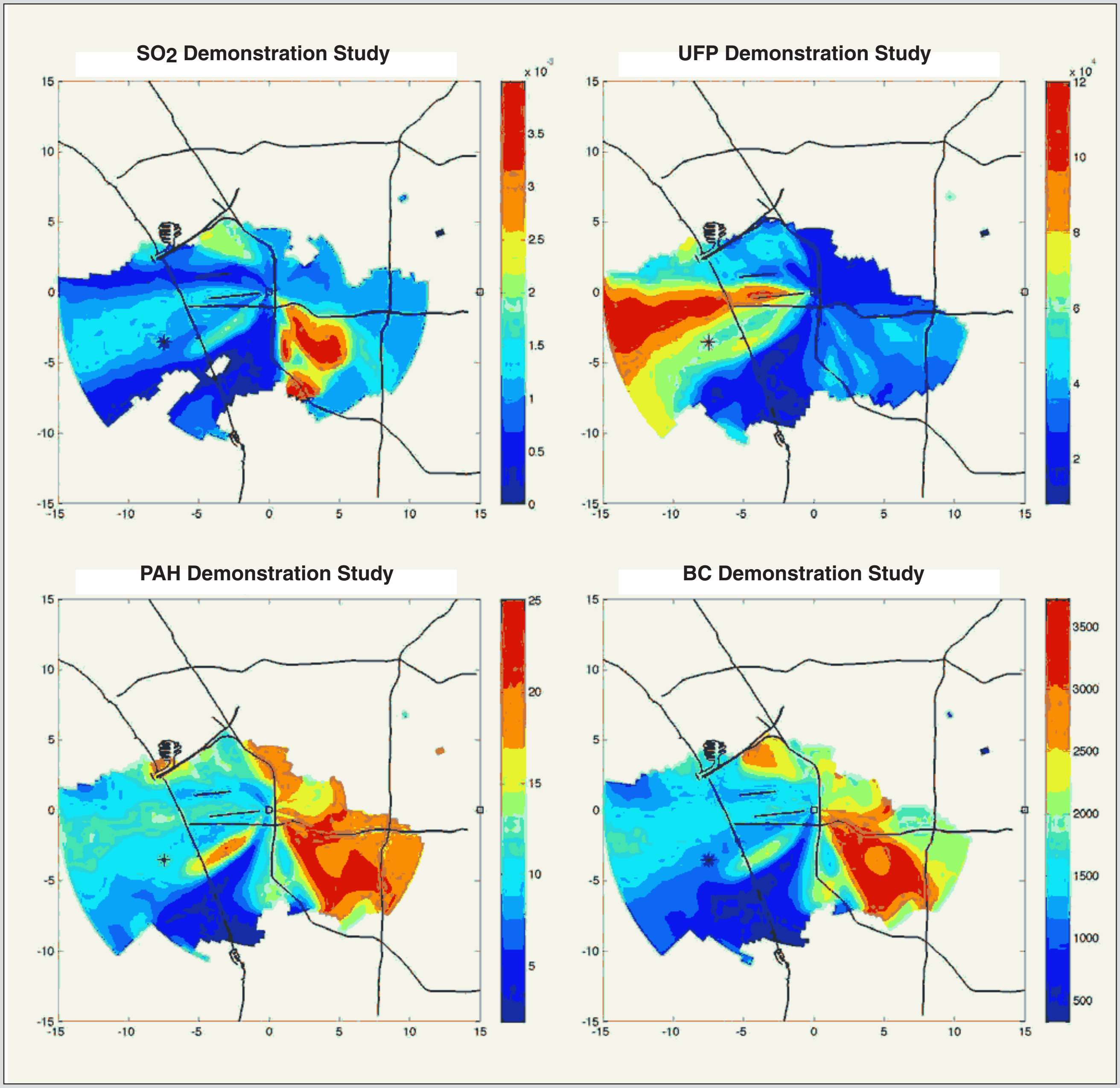
✳ Signifies the location of the El Segundo Terminal.

Note: Black lines are the coastline, major freeways, and the north and south runways.

Exhibit 2

NTA ANALYSIS OF SITE P5

AQSAS—Demonstration Project
Los Angeles International Airport



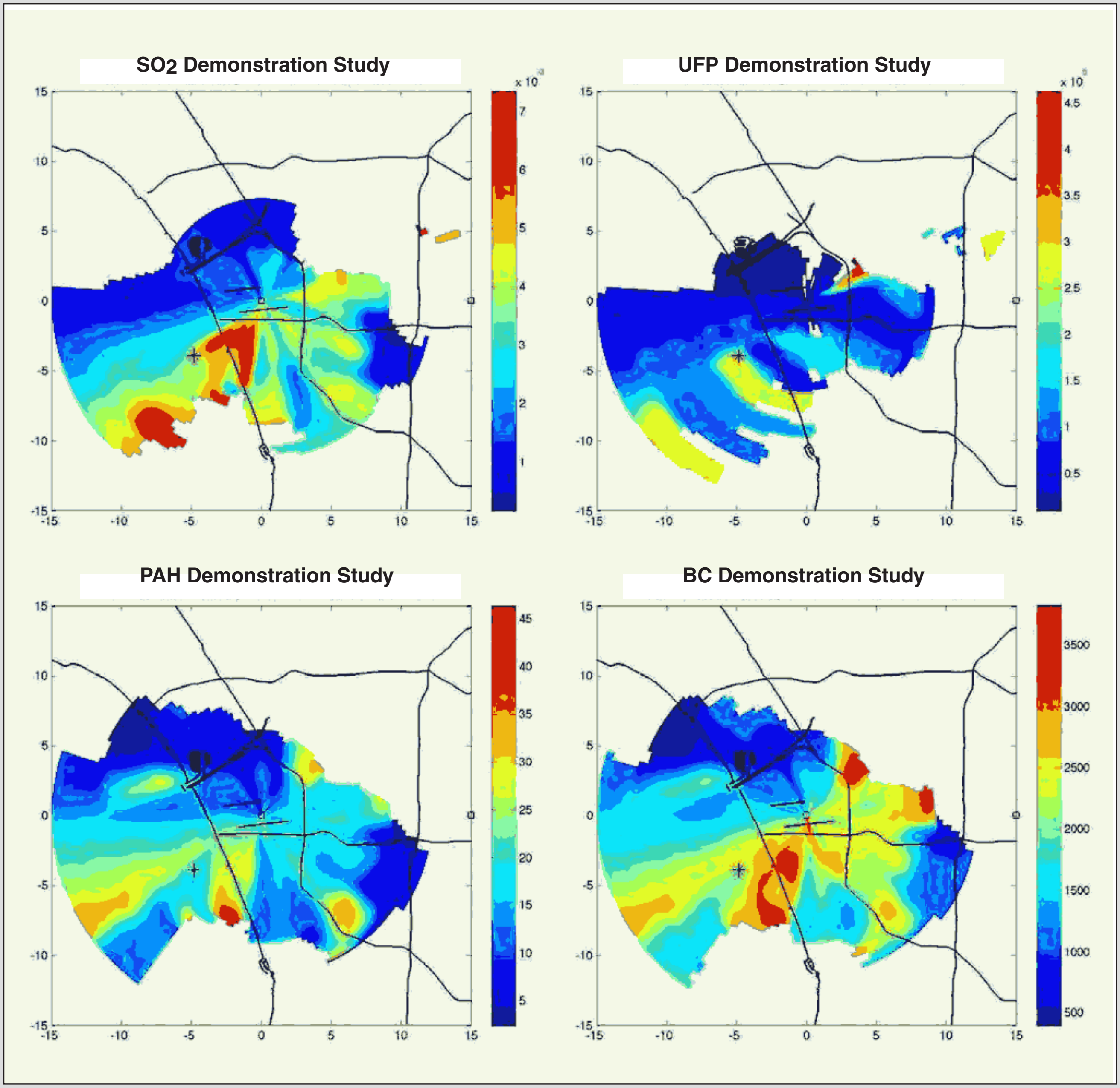
✳ Signifies the location of the El Segundo Terminal.

Note: Black lines are the coastline, major freeways, and the north and south runways.

Exhibit 3

NTA ANALYSIS OF SITE P2

AQSAS—Demonstration Project
Los Angeles International Airport



✳ Signifies the location of the El Segundo Terminal.

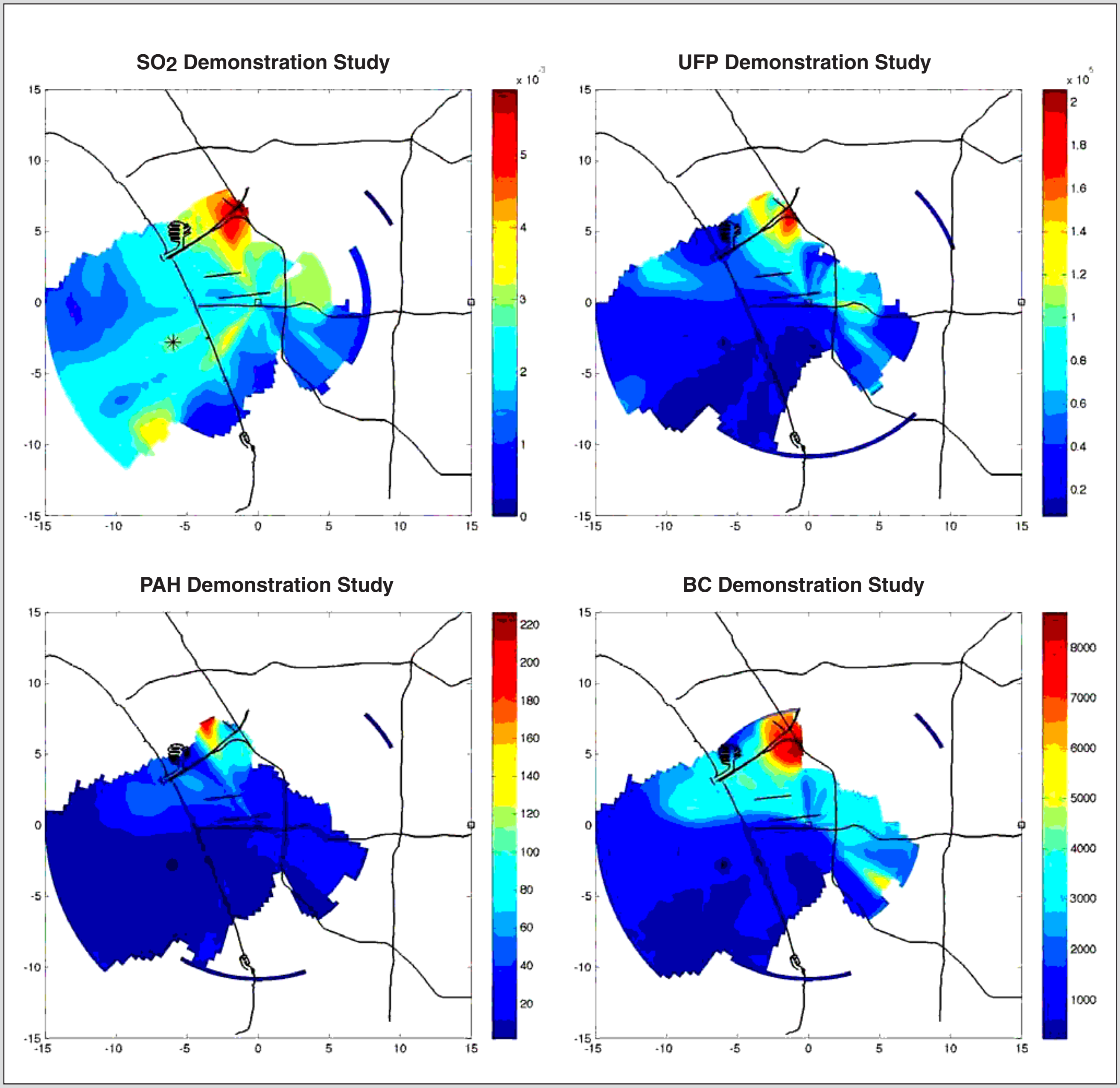
Note: Black lines are the coastline, major freeways, and the north and south runways.

LAX684 Exhibit 3

Exhibit 4

NTA ANALYSIS OF SITE P3

AQSAS—Demonstration Project
Los Angeles International Airport



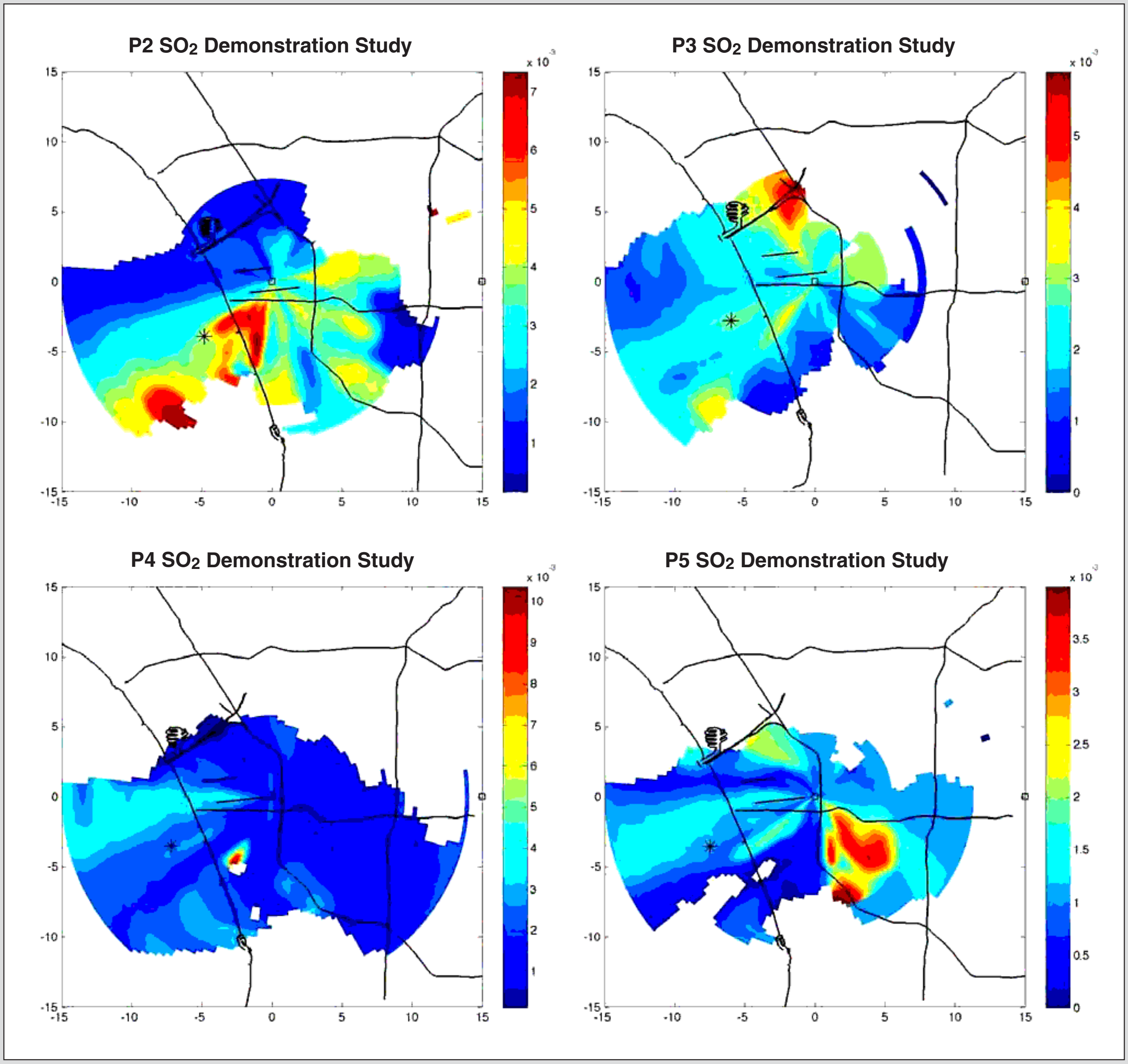
✳ Signifies the location of the El Segundo Terminal.

Note: Black lines are the coastline, major freeways, and the north and south runways.

Exhibit 5

NTA ANALYSIS OF SO_2 FOR ALL SITES OTHER THAN SR

AQSAS—Demonstration Project
Los Angeles International Airport



✳ Signifies the location of the El Segundo Terminal.

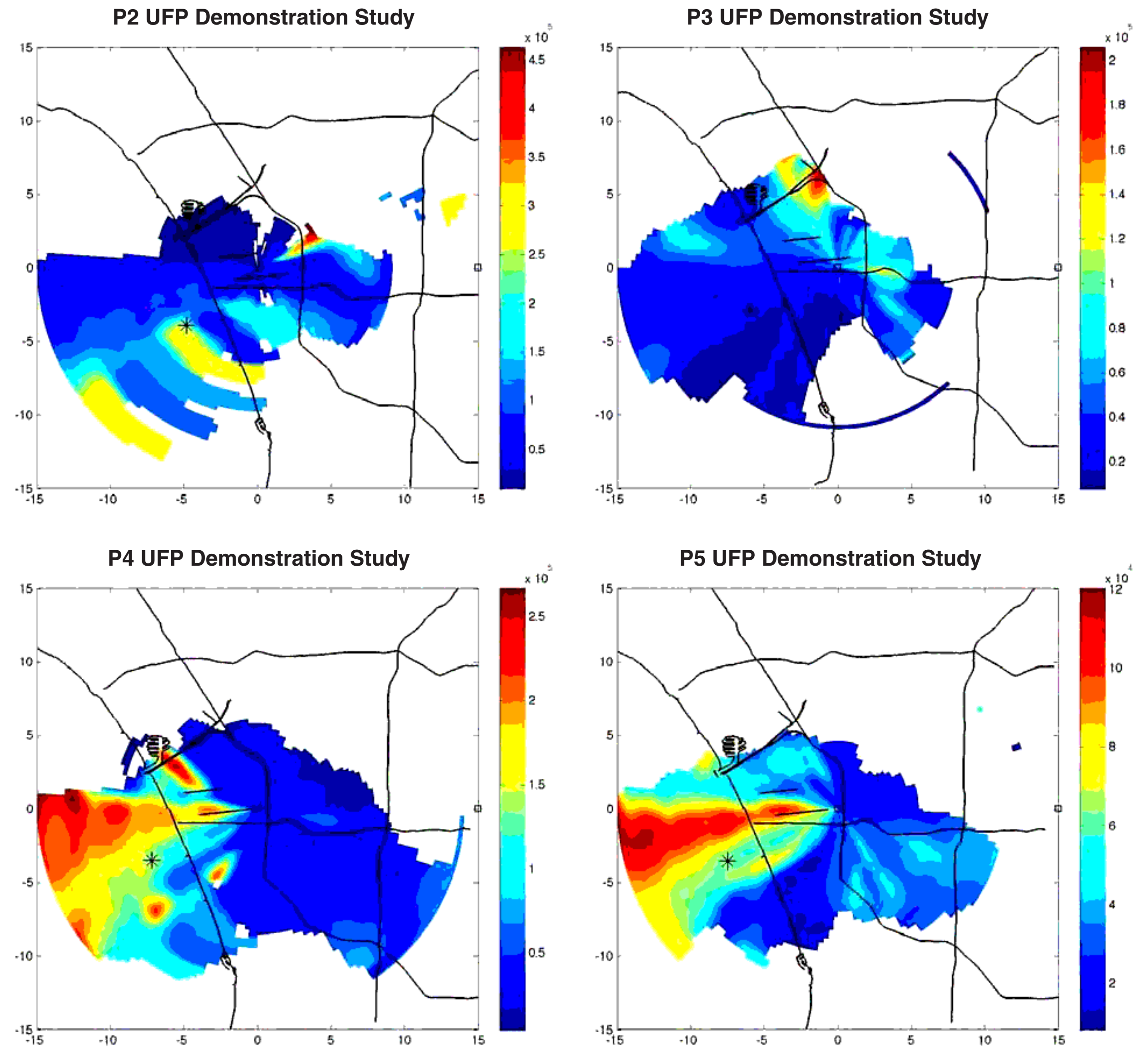
Note: Black lines are the coastline, major freeways, and the north and south runways.

LAX684 Exhibit 5

Exhibit 6

NTA ANALYSIS OF UFP FOR ALL SITES OTHER THAN SR

AQSAS—Demonstration Project
Los Angeles International Airport



✳ Signifies the location of the El Segundo Terminal.

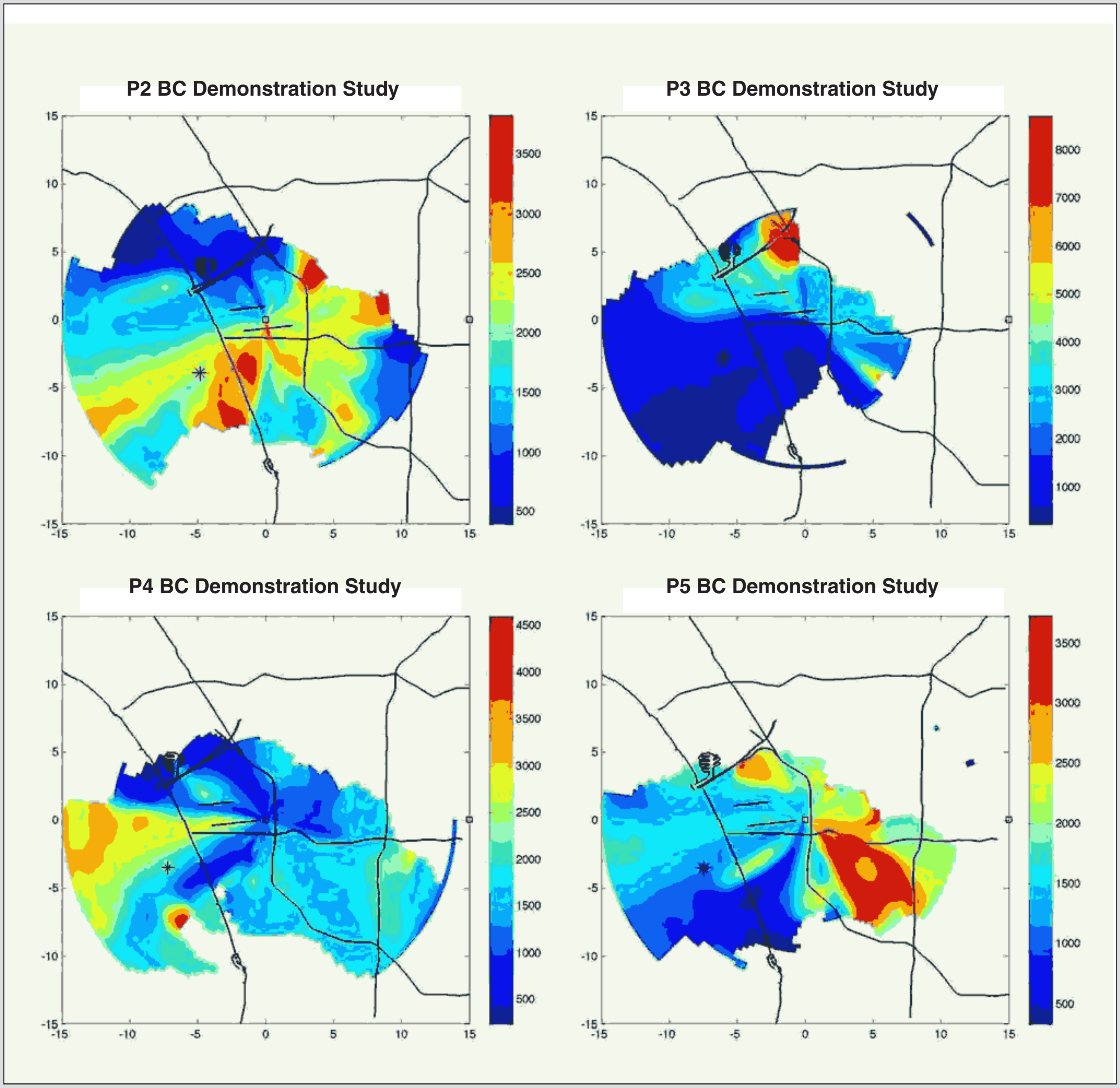
Note: Black lines are the coastline, major freeways, and the north and south runways.

LAX684 Exhibit 6

Exhibit 7

NTA ANALYSIS OF BC FOR ALL SITES OTHER THAN SR

AQSAS—Demonstration Project
Los Angeles International Airport



✳ Signifies the location of the El Segundo Terminal.

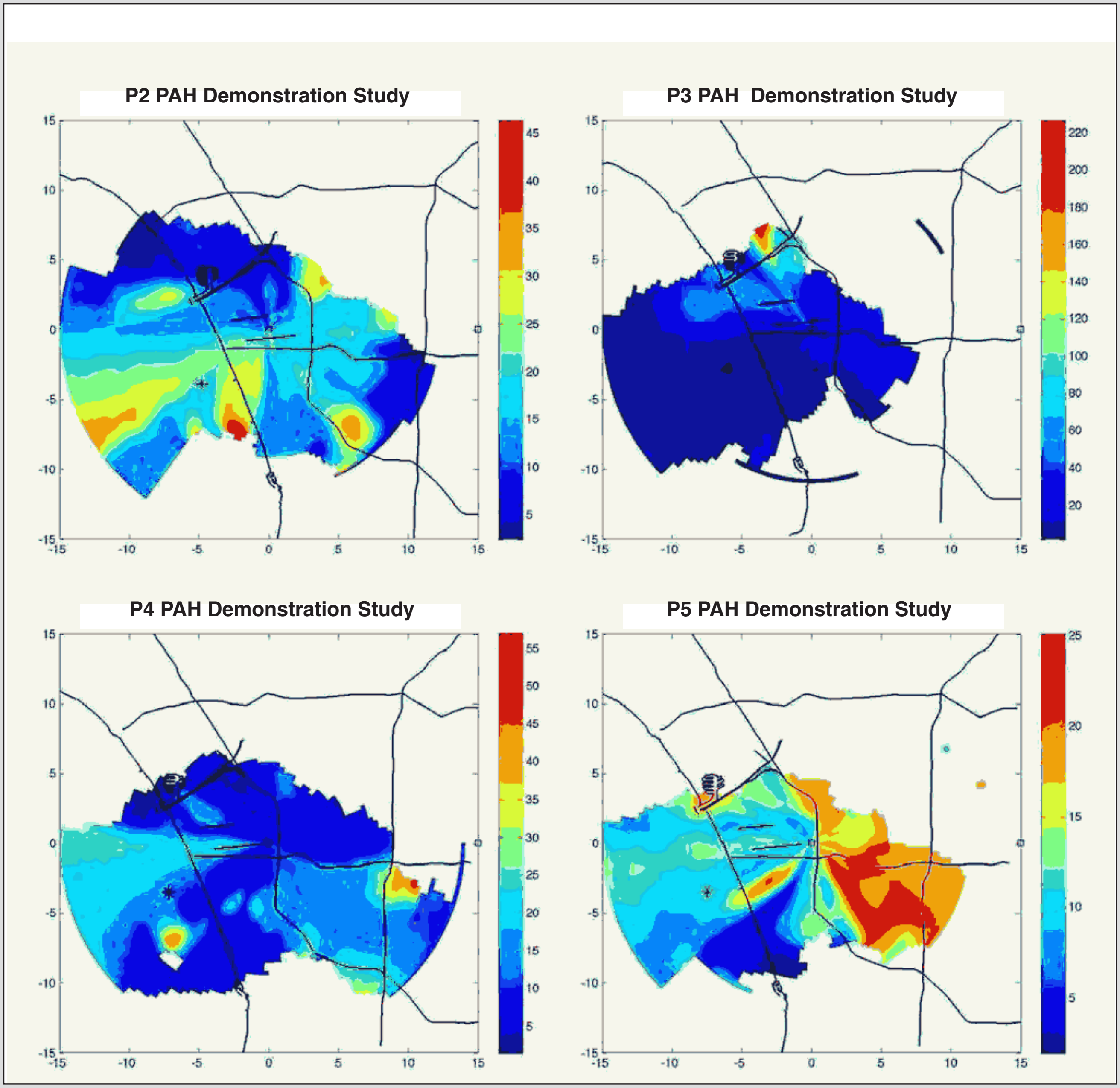
Note: Black lines are the coastline, major freeways, and the north and south runways.

LAX684 Exhibit 7

Exhibit 8

NTA ANALYSIS OF PAH FOR ALL SITES OTHER THAN SR

AQSAS—Demonstration Project
Los Angeles International Airport



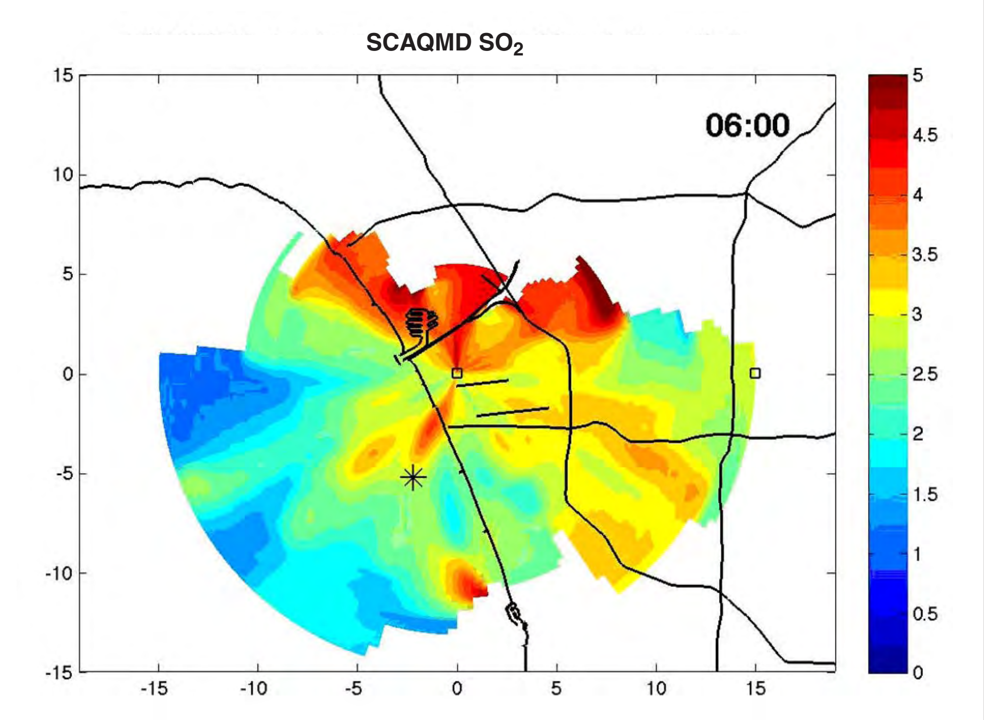
✳ Signifies the location of the El Segundo Terminal.

Note: Black lines are the coastline, major freeways, and the north and south runways.

Exhibit 9

NTA ANALYSIS OF SO_2 FOR SCAQMD SITE FOR ALL ONE-HOUR PERIODS IN JUNE AND JULY 2008 STARTING AT 6:00

AQSAS—Demonstration Project
Los Angeles International Airport



✳ Signifies the location of the El Segundo Terminal.

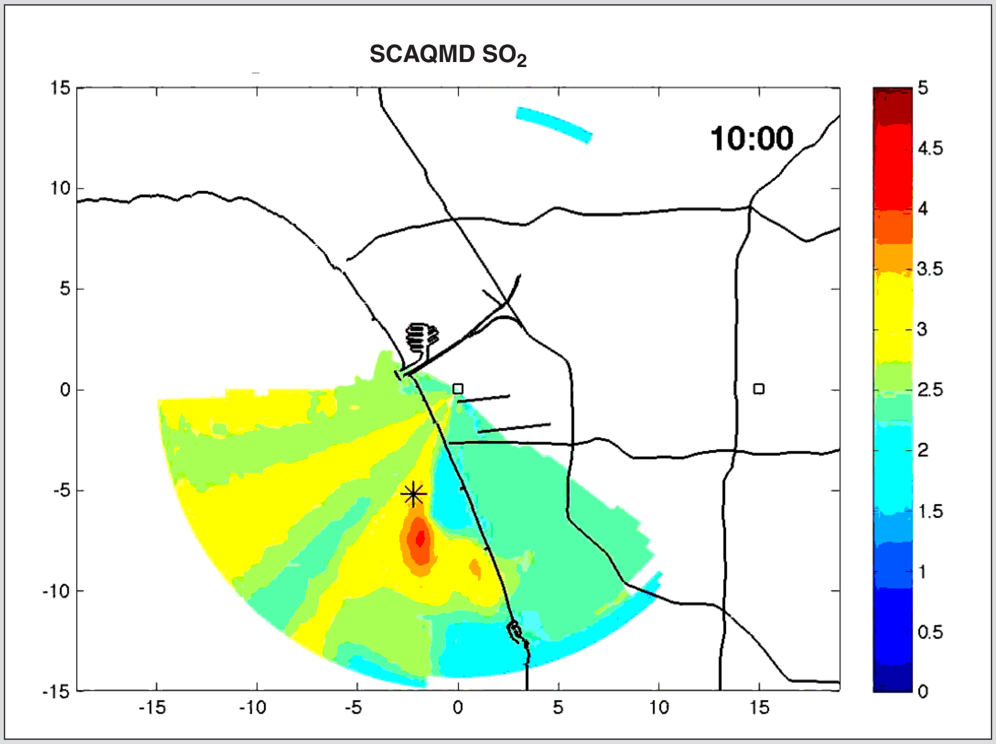
Note: Black lines are the coastline, major freeways, and the north and south runways.

LAX684 Exhibit 9

Exhibit 10

NTA ANALYSIS OF SO_2 FOR SCAQMD SITE FOR ALL ONE-HOUR PERIODS IN JUNE AND JULY 2008 STARTING AT 10:00

AQSAS—Demonstration Project
Los Angeles International Airport



✳ Signifies the location of the El Segundo Terminal.

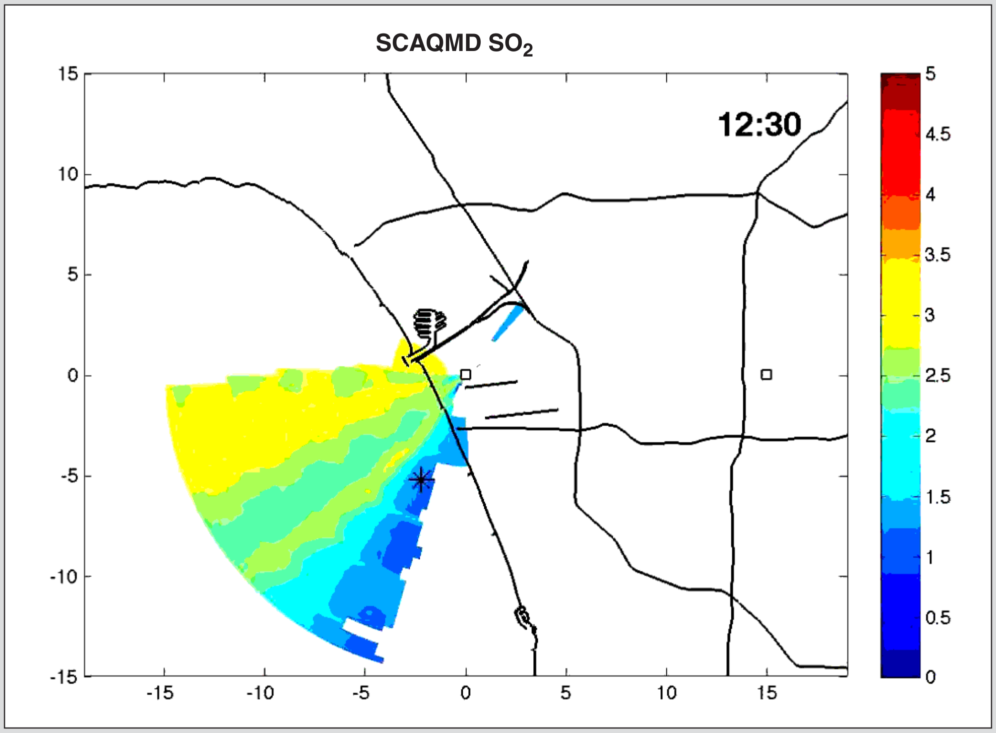
Note: Black lines are the coastline, major freeways, and the north and south runways.

LAX684 Exhibit 10

Exhibit 11

NTA ANALYSIS OF SO_2 FOR SCAQMD SITE FOR ALL ONE-HOUR PERIODS IN JUNE AND JULY 2008 STARTING AT 10:30

AQSAS—Demonstration Project
Los Angeles International Airport



✳ Signifies the location of the El Segundo Terminal.

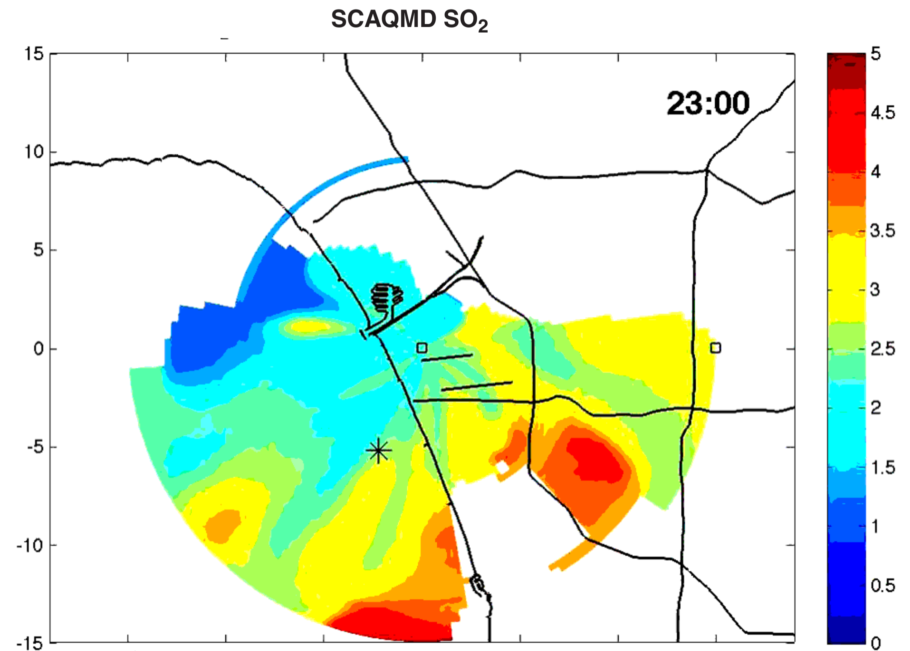
Note: Black lines are the coastline, major freeways, and the north and south runways.

LAX684 Exhibit 11

Exhibit 12

NTA ANALYSIS OF SO_2 FOR SCAQMD SITE FOR ALL ONE-HOUR PERIODS IN JUNE AND JULY 2008 STARTING AT 23:00

AQSAS—Demonstration Project
Los Angeles International Airport



✳ Signifies the location of the El Segundo Terminal.

Note: Black lines are the coastline, major freeways, and the north and south runways.

Module L

Gas Chromatograph/Mass Spectrometer Analysis

(Task 6)

Overview

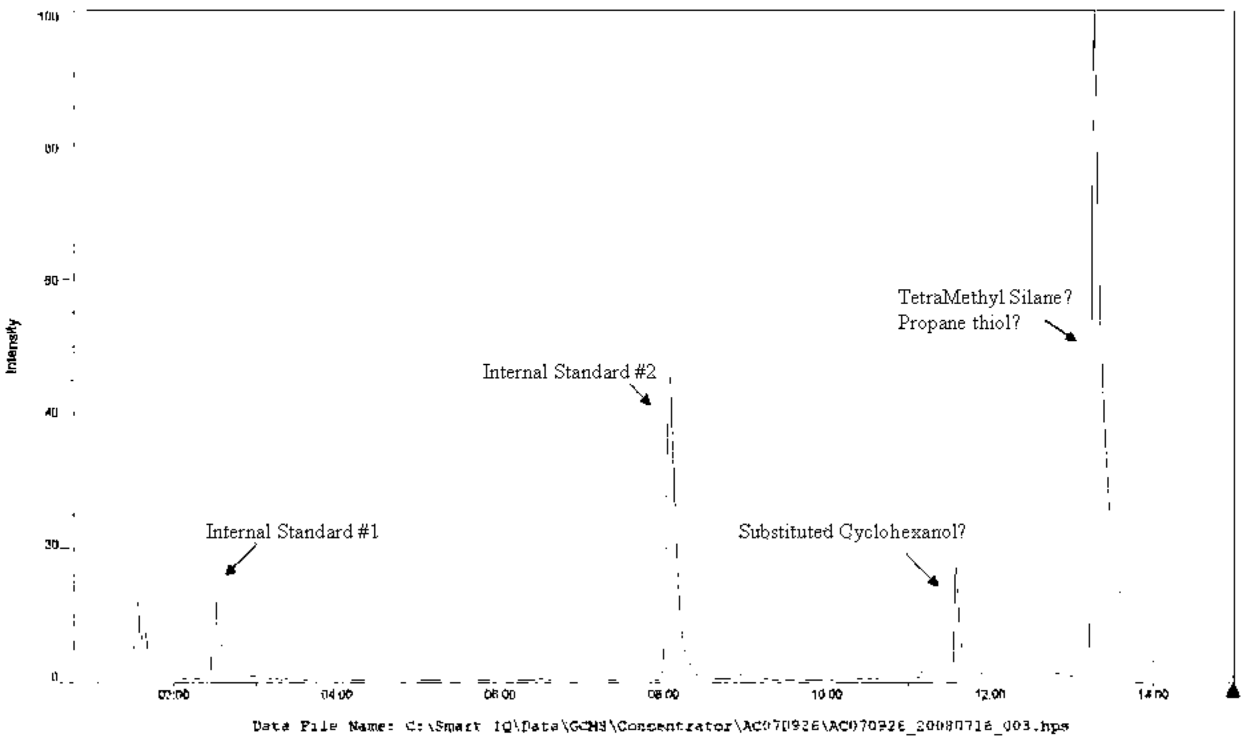
This report serves as documentation of the procedures and general conclusions of the gas chromatograph / mass spectrometer (GC/MS) feasibility test performed at and around the Los Angeles International Airport (LAX) southern-most runway that occurred during the LAX Source Apportionment Study Demonstration Project. The following sections describe the details from the GC/MS operator's field notes and the onsite analysis / observations.

Purpose

Weston was tasked with operating the Inficon™ portable GC/MS to acquire data near the south runway blast fence and outlying locations. The data collected was to determine the feasibility of using the Inficon device to measure ambient air pollutants that may be useful in tracing aircraft-related emissions and determine whether the Inficon GC/MS had sufficient sensitivity to detect and measure volatile organic compounds (VOCs) in ambient air. This would in turn help determine whether any fingerprint or indicator compounds could be identified to differentiate aircraft exhaust from other combustion sources, such as auto and diesel exhaust. This study evaluated instrument performance. Identification of specific aircraft signature compounds was beyond the scope of this study. Collecting comprehensive time-series data for use in the Demonstration Study was also beyond the scope of this study.

Chronology and Example Results

This feasibility study was performed 14 July through 26 July 2008. Monday and Tuesday, 14 and 15 July, were used for training and familiarization with the equipment at the AQMD facility in Diamond Bar, CA. Brad Parrack of AQMD facilitated the Weston GC/MS operator's orientation and equipment loan checkout. Wednesday, 16 July, was spent completing the LAX security badge process and transferring the equipment to the Jacobs project office on Avion Boulevard. Weston performed several ambient air blanks offsite at the hotel room and had limited success with these blanks, as some compounds were present in significant quantities, shown in the example figure below. It was difficult to determine whether the compounds detected were actually present in ambient air, artifacts of the GC/MS system, artifacts of the charcoal tubes used as pre-filters, or some other unknown factors.



Ambient Air Blank – At Motel Window Rosecrans & Aviation

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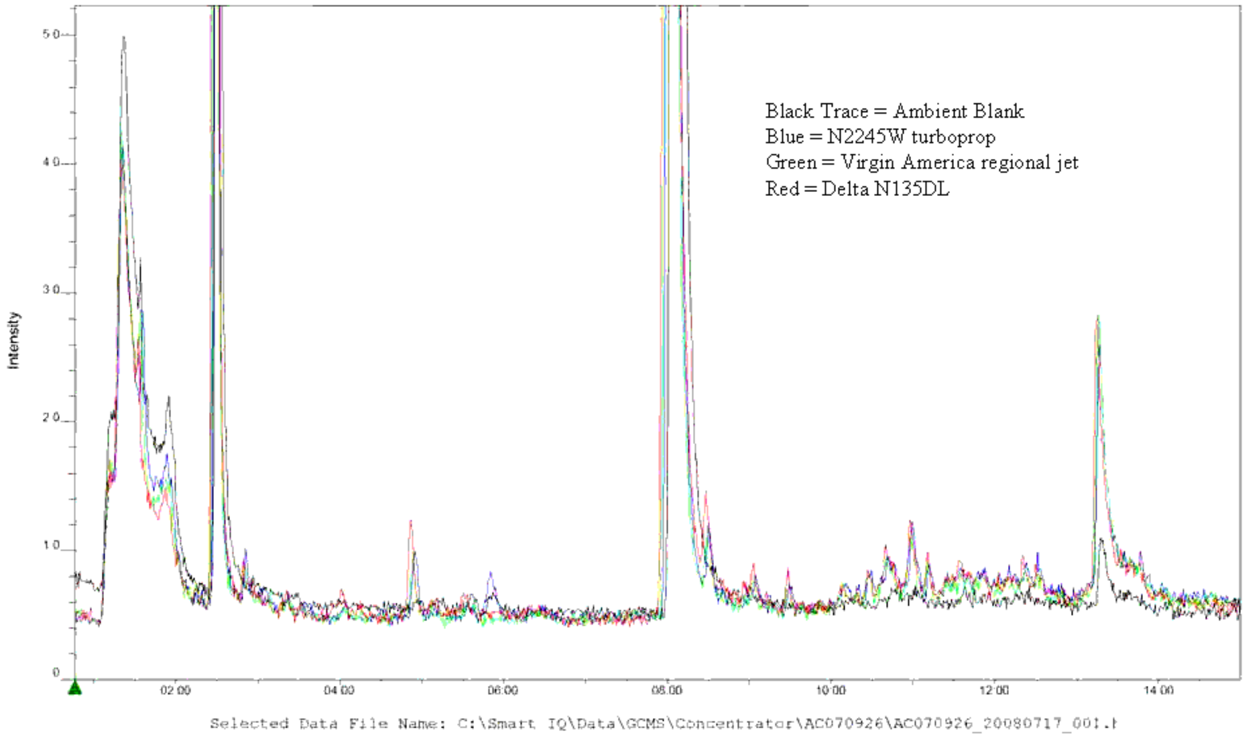
On Thursday, 17 July, Weston acquired data for nine take-offs using the “AC070926” program AQMD provided. The program was renamed as LAXPROJ to make the source of data files obvious, but did not change any parameters in this program at this time. The one minute concentration signals were barely discernable from background noise, and temperature programs were not sufficiently hot or of sufficient duration to prevent carry-over from run to run. A few small peaks could be identified with rather low match probabilities. However, data could not be differentiated between aircraft exhaust or ambient air at the project office versus the blast fence during take-off. (see comparison figure below)

Ambient Blank and 3 Take-offs Overlaid

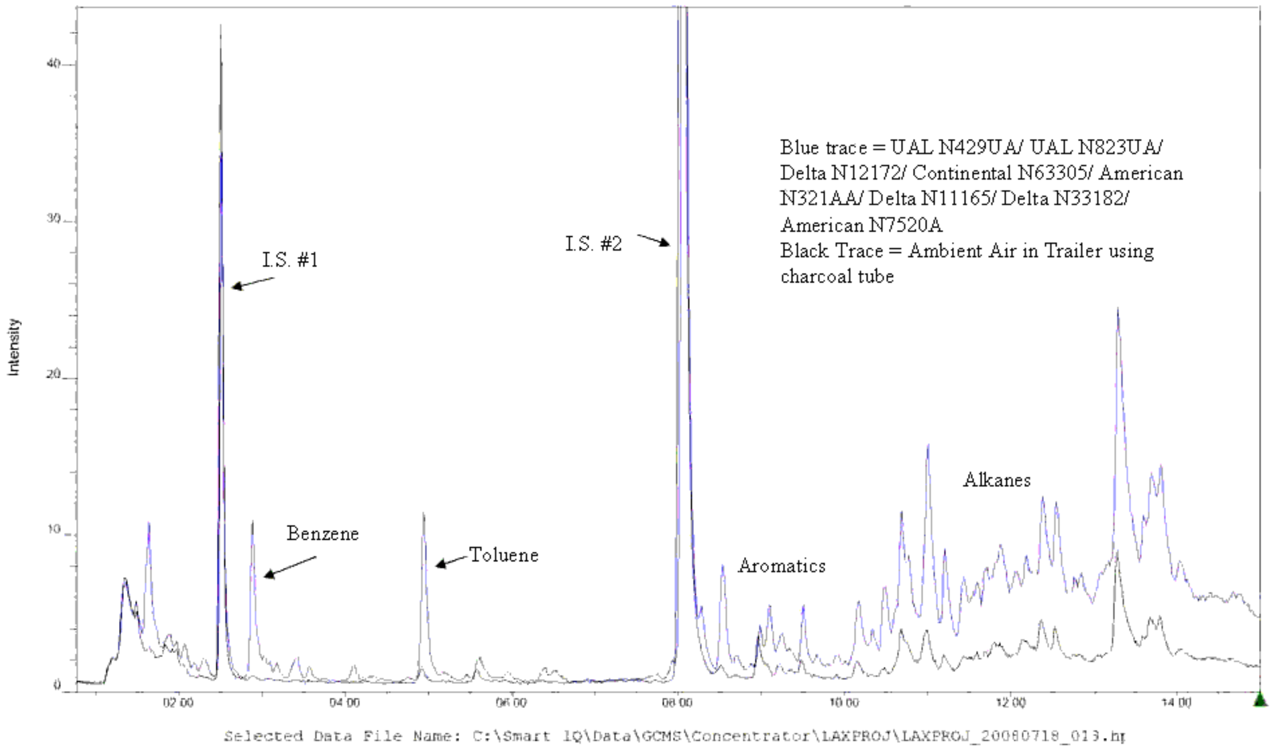


The initial take-off results shown above yielded similar chromatograms (colored traces), that all have features distinct from the blank (black trace). However, signals are so small that spectral identifications were not possible, even with averaging across peaks and baseline spectra subtraction. Scale and peak size were relative to internal standards.

The next figure illustrates six additional take-off samples, compared with two ambient blank samples. Again, features for take-off exhaust are similar for all aircraft.

Friday morning, 18 July, after performing an ambient air blank, the line purge flow rate was determined using a BIOS Drycal and found to be 170 mL/min. Assuming five feet of quarter-inch Teflon sample line from probe to Inficon unit, transfer line void time was determined to be about 15 seconds. The line purge time was changed from one minute to fifteen seconds in the GC/MS program to allow easier timing and “capture” of the aircraft take-off events. After capturing a three take-off event that morning, Weston modified the program for a 30-second concentrator fill. Three additional take-offs were captured using 15-second line purge and 30-second concentrator fill. Sensitivity was not sufficient enough with these parameters, so at mid-morning the concentrator fill time was increased to ten minutes. This was done to determine whether the increased sensitivity expected from the ten-fold longer concentration period provided more useful data. After acquiring data for four take-off and eight take-off sets ending at about 11:03 am, there were still issues with significant levels of detected VOC's in blanks. The following figure shows the eight take-off set compared with a blank using a charcoal tube pre-filter.

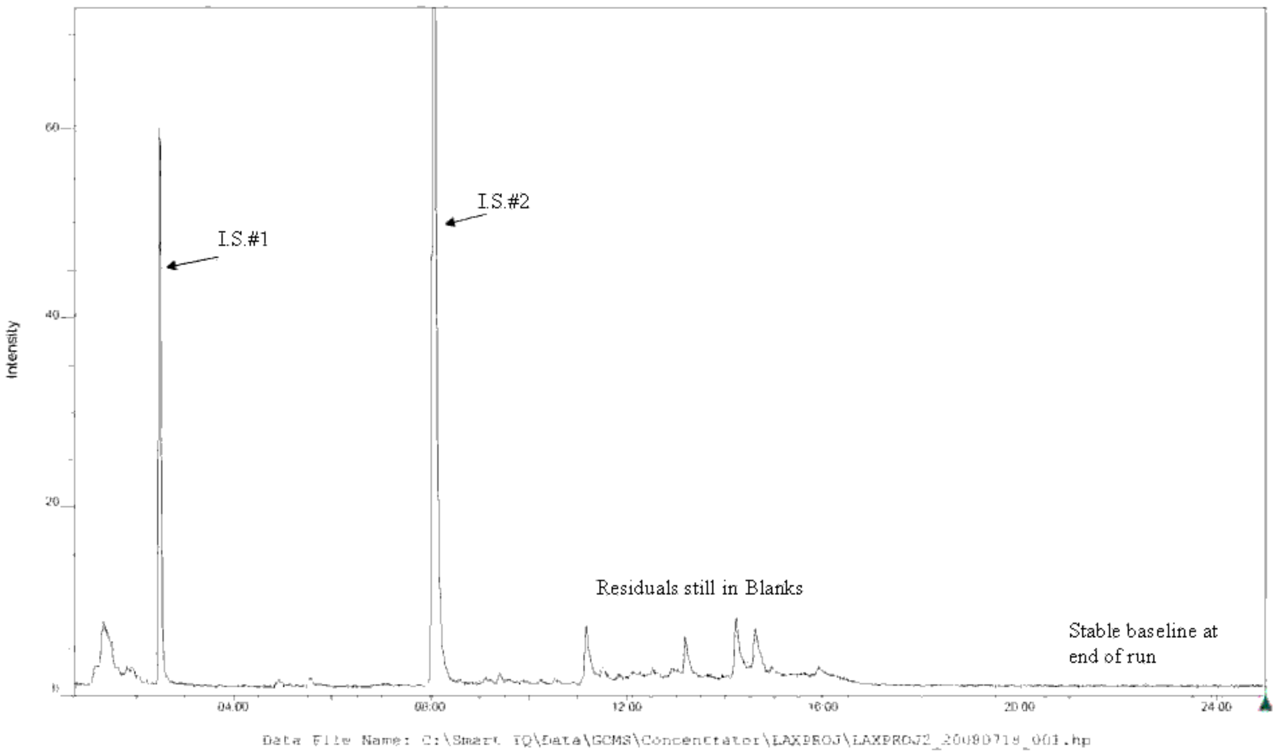
Eight Take-offs During 10 Minute Concentrator Fill - Overlaid With Ambient Blank Using Charcoal Tube "Filter"



The sensitivity did improve using ten-minute concentrator fill, as expected. Individual compounds gave better mass spectra ID's with the use of a ten minute concentrator fill. However, there was carry-over to the blank, and baseline did not return to a starting point due to the oven ramp not being hot enough for the large alkanes in the samples.

The unit was baked out and the final temperature in the GC program was changed to 200° C. At this point, the oven ramp program was changed to a single ramp at 15° C per minute to 200° C with a hold for 8:40 to give 25 minutes total time. The method file was renamed LAXPROJ2 at this point. Also, MS dwell time was decreased to 300 microseconds and the mass range was increased to 300 AMU. After bake-outs and blanks, the oven initial start temp to 50° C was decreased and the hold time decreased to eight minutes to maintain a 25 minute total run time. Weston also increased the probe transfer line temperature, and injection valve temperature, to 80° C and 90° C respectively.

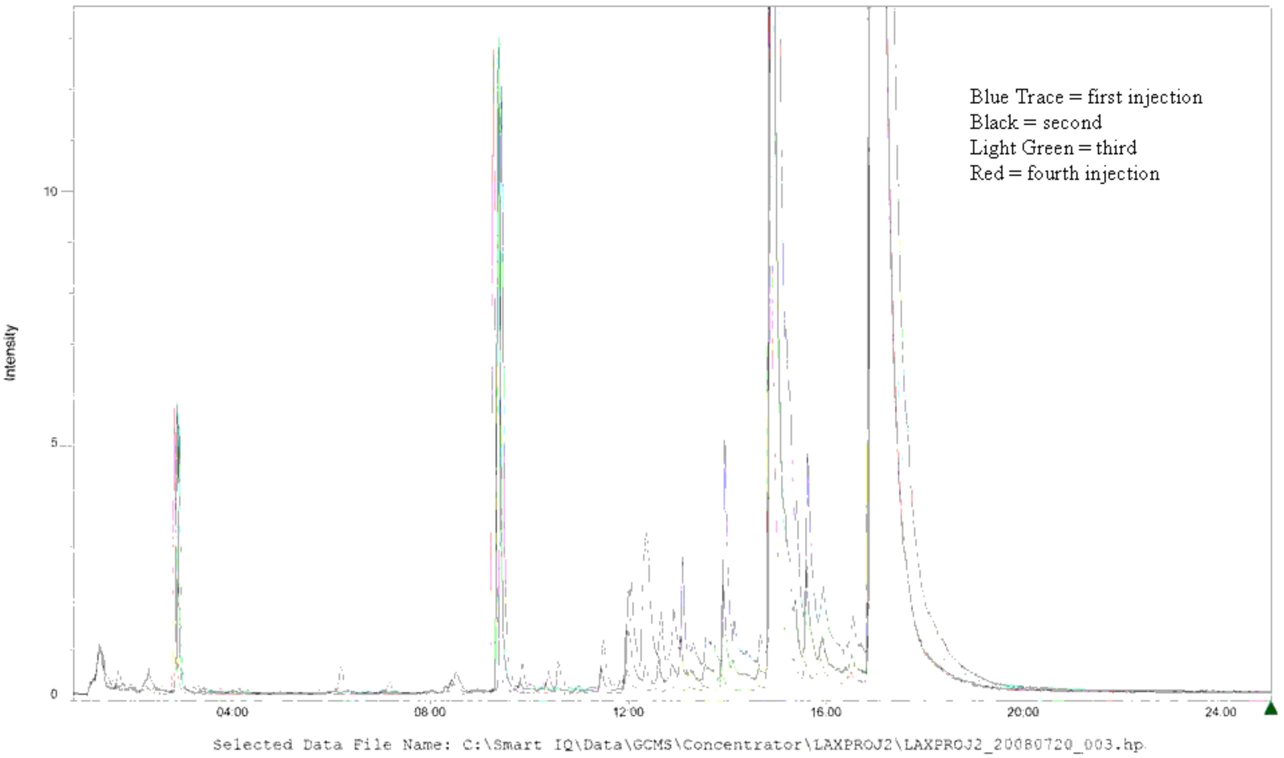
Ambient Air Blank through Charcoal tube "Filter" – Note baseline return after alkanes elute and compound still present from 9 to 16 minutes This is new LAXPROJ2 program used for remainder of study



Saturday, 19 July, Weston was still experimenting with blank issues and finalizing GC program details. A new concentrator trap was installed. The probe line was purged for 60 minutes and more blanks were performed with charcoal tube at probe tip. The Runways were being serviced on Saturday and Sunday, and the south runway was closed to take-offs, so we could not acquired on those days.

Sunday, 20 July, GC parameter adjustments continued and more blanks were performed. The valve oven was changed to 85° C, probe transfer line to 75° C, line purge time to 20 seconds and concentrator fill time to 5 minutes. The probe line was purged for 30 minutes. However, there continued to be background problems with blanks. At this point, the south runway was closed again for maintenance and/or repair and Weston could not test take-offs.

Five Ambient Air Blanks with Charcoal Tube “Filters”

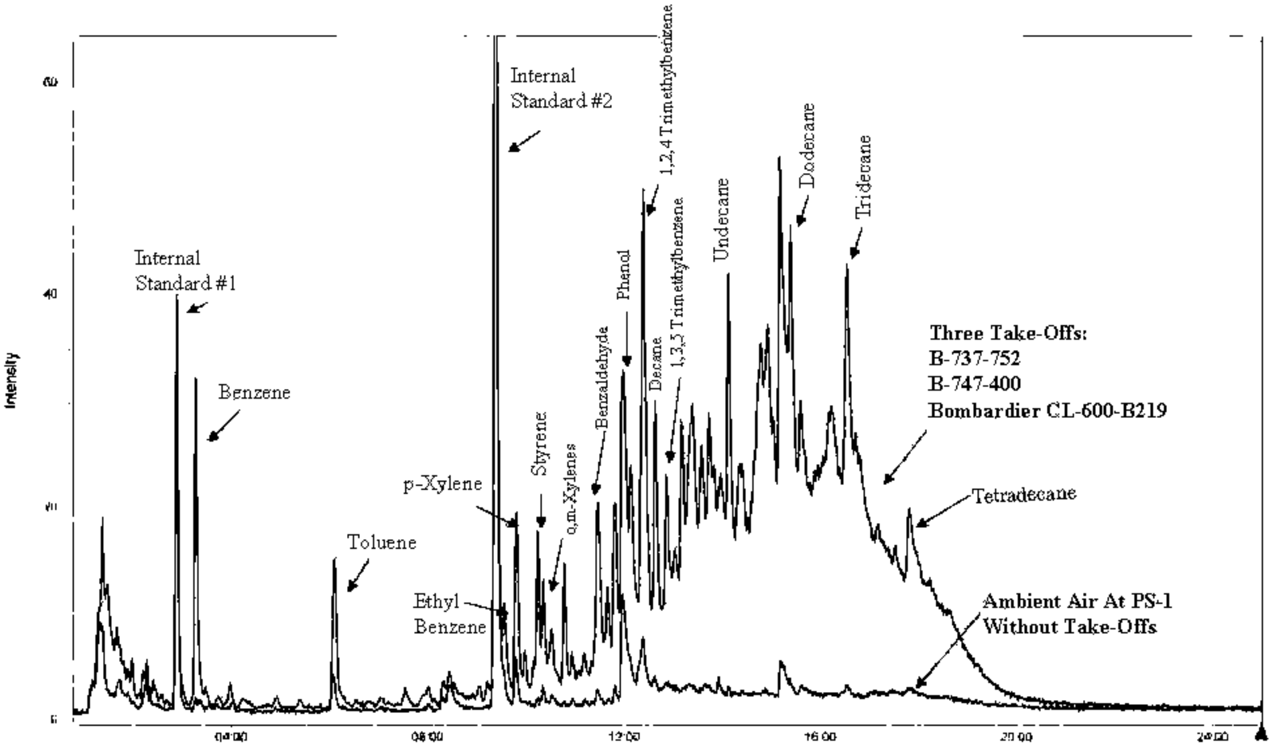


The blanks were still posing difficulties. There were residual hydrocarbons and the same two system artifacts seen previously. The scale and amount of material in blanks were determined to be relative to aircraft exhaust data. It was suspected that some extended probe transfer line purging and heated zone temperature increases liberated compounds from past use.

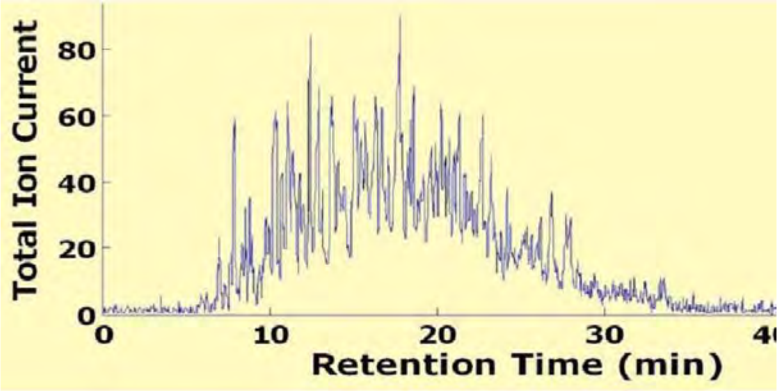
Monday, 21 July, the oven maximum temperature was changed to 190° C and the hold time to 8:40 to maintain a 20 minute run. The heated zones were adjusted down slightly to reduce power consumption and speed cool-down cycle after each run. Ambient data was collected at blast fence during periods of time with no take-offs.

There were five take-off events collected, with two or three take-offs during each concentrator fill. Ambient air during jet blast was clearly discernable from air at fence without any takeoffs, as shown in the figure below.

Comparison of Aircraft Exhaust vs Ambient Air at Blast Fence

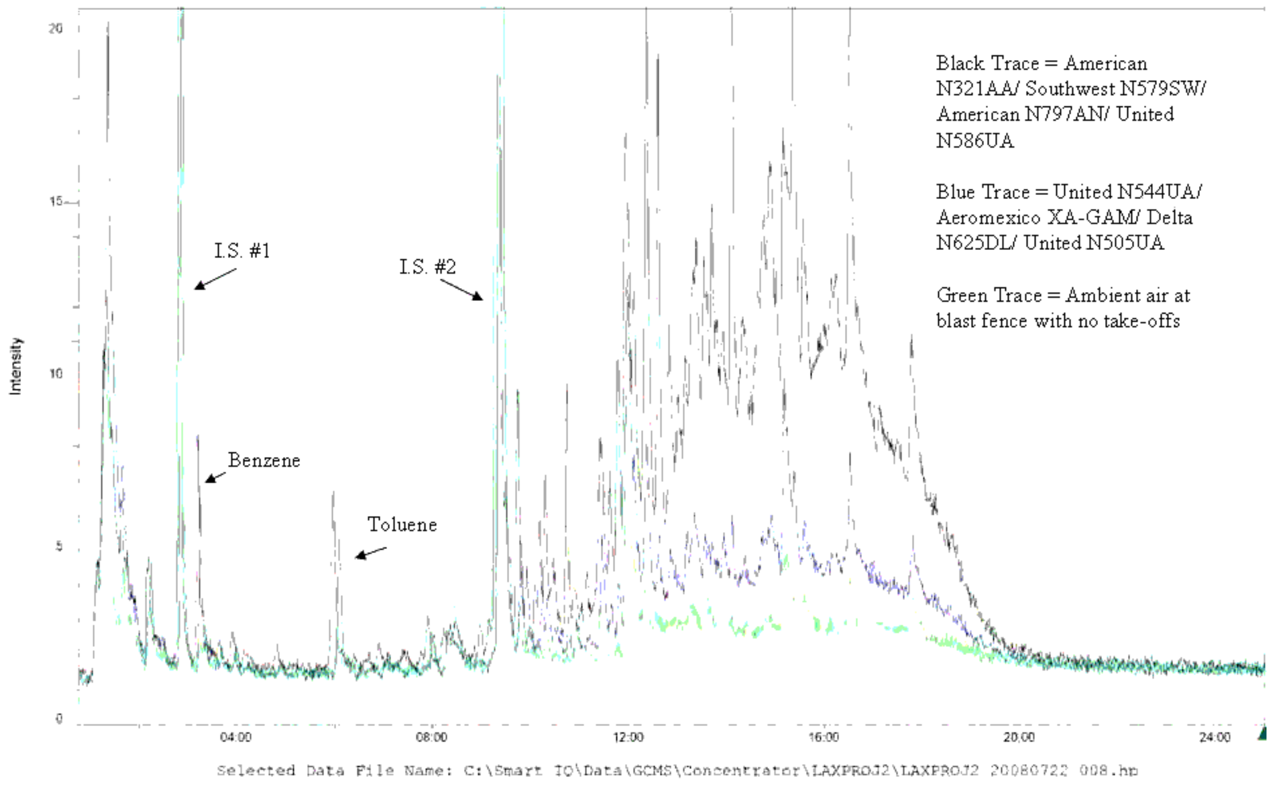


Mass spectral ID's are of sufficient quality to identify the majority of VOC's present. Profile and compounds agree with literature references. Compare with this reference TIC for JP-5 shown below.



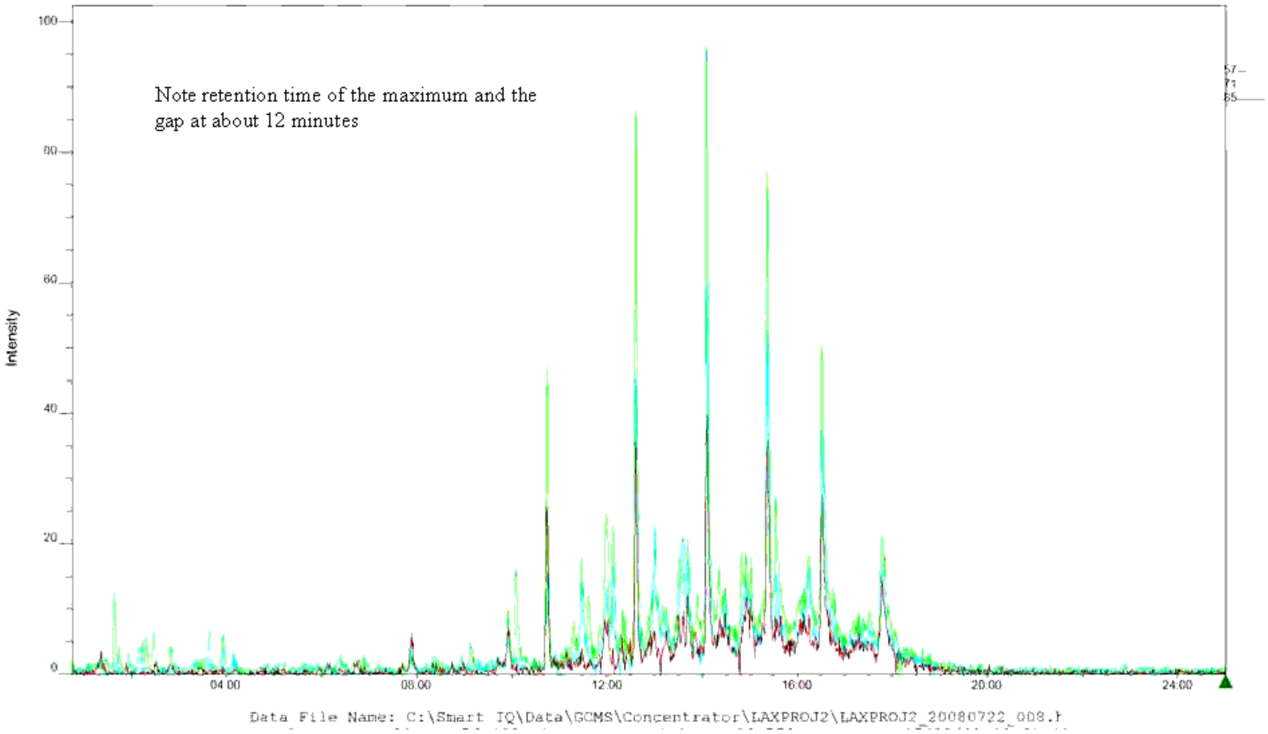
Tuesday, 22 July, Weston performed blanks and bake-out. There were still unresolved blank issues. Blanks with charcoal tube on probe tip sometimes are not as clean as ambient air blanks without any VOC scrubber. Weston suspects possible causes to include pump oils, plasticizers back-streaming due to flow restriction of the charcoal tube, or artifacts from the charcoal tube itself. Despite blank issues, Weston collected two good sets of take-off data with four take-offs occurring during each concentrator fill. Compounds identified using spectral searches are similar and reproducible. Also, two ambient air samples were collected at blast fence without any take-offs.

Two Runs With 4 Take-offs Each and Ambient Air Run at Blast Fence Without Take-offs



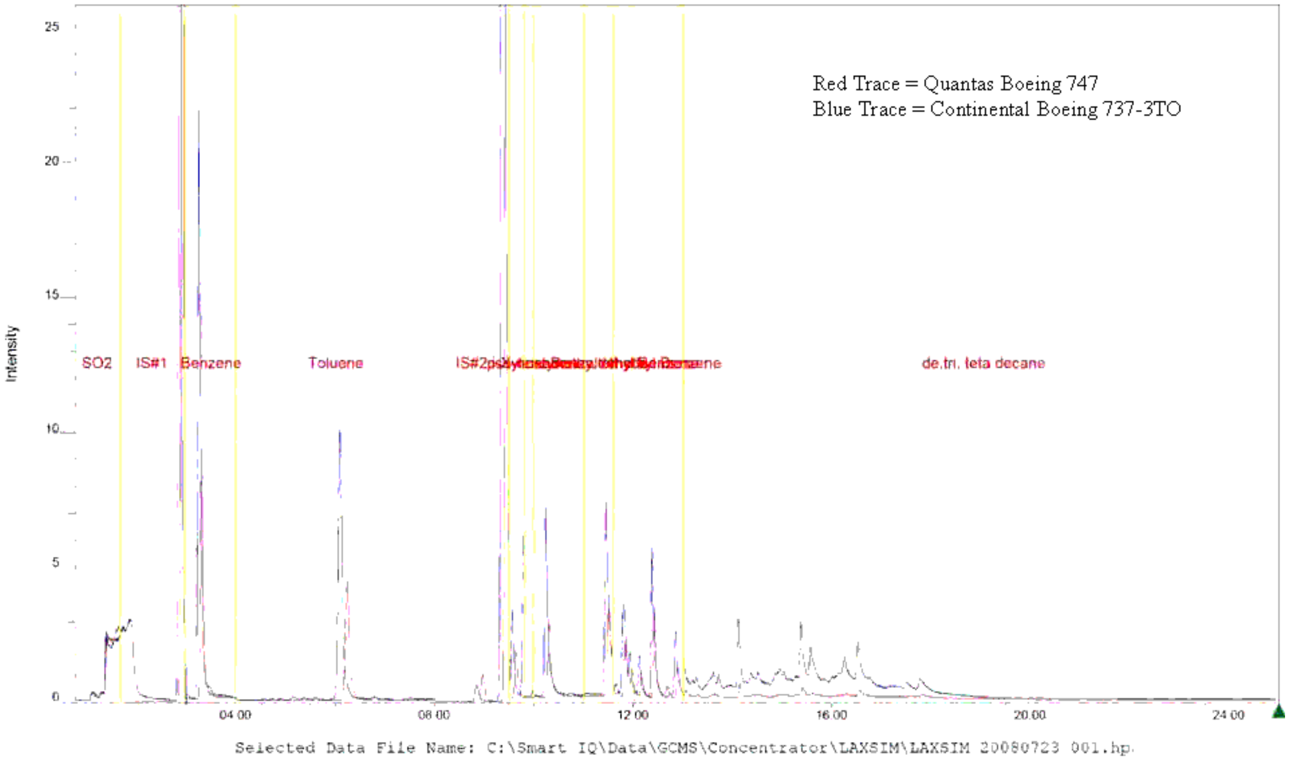
The Extracted Ion Chromatogram below (RIC on the Inficon Software) for masses 57, 71, and 85, (corresponding to butyl, pentyl and hexyl (C_4-C_6) straight chain fragments) clearly illustrates the boiling fraction nature of the black trace fingerprint above.

Extracted Ion Chromatogram for C_4, C_5, and C_6 n- alkane fragments in Black Trace Chromatogram Above – (For N321AA/N579SW/N797AN/N586UA Take-offs)



Wednesday, 23 July, focused on preparing a selected ion monitoring (SIM) program method. SIM mode MS detection can be one thousand times more sensitive than scan mode. Using a tentative list of compounds in aircraft exhaust, the retention times and primary ions were used to develop a SIM table looking only for those specific compounds with much greater sensitivity. Concentrator fill time was cut to thirty seconds (from five minutes) to take advantage of SIM's much improved sensitivity. Other GC and MS parameters, such as oven ramp and transfer line temperature, were unchanged. This configuration was an attempt to obtain information about a specific aircraft's exhaust profile. This new method was named LAXSIM. Note scale on total ion chromatogram and that these are single take-off events with 30-second concentrator fill.

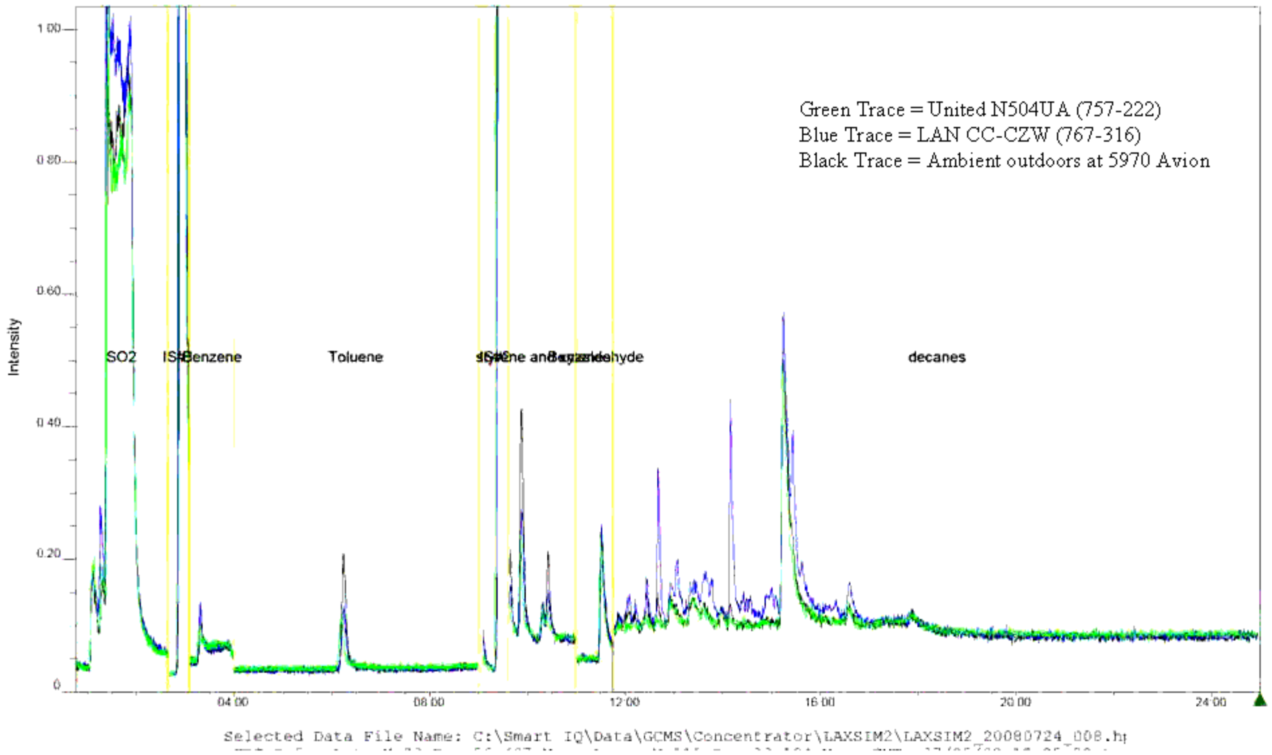
First SIM Mode data – Two Take-off Events With Single Take-offs Captured During 30 Second Concentrator Fill



After acquiring these two takeoffs in the morning, Inficon sampling was suspended to assist the project team in relocating the main Demonstration Project sampling trailer to the PS2 location in the terminal parking area. After the trailer move, the Inficon began malfunctioning with hardware errors and had to be restarted several times. After several different errors and spontaneous re-boots by the Inficon system computer, testing was abandoned and the instrument was returned to Jacobs' project office. Heat on the flight line may have led to the hardware errors and possibly a corrupted method file.

Thursday, 24 July, Weston rebuilt the SIM method program (naming it LAXSIM2) and continued the test with hardware fault problems. Weston worked through hardware and software faults and began to acquire SIM mode data after noon. Four good take-off events were acquired in SIM mode acquisition. The SIM mode, with 30-second concentrator fill, allows data acquisition from single take-offs. It is not possible to separate the effects of aircraft distance from the blast fence and aircraft size, but there appear to be differences in SIM mode VOC profile with aircraft type.

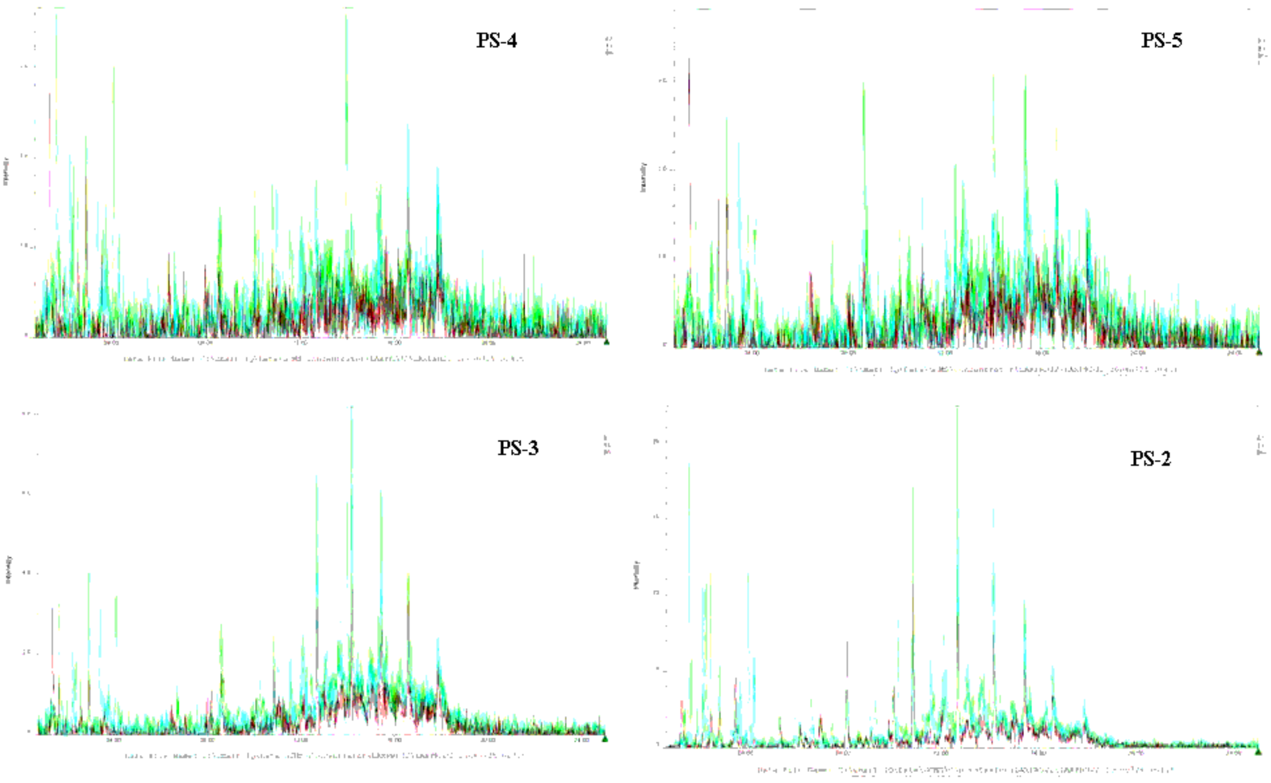
Two take-offs verses Ambient at Jacobs Avion Office Friday Afternoon
Selected Ion Monitoring (SIM) Mode Total Ion Chromatogram (TIC)



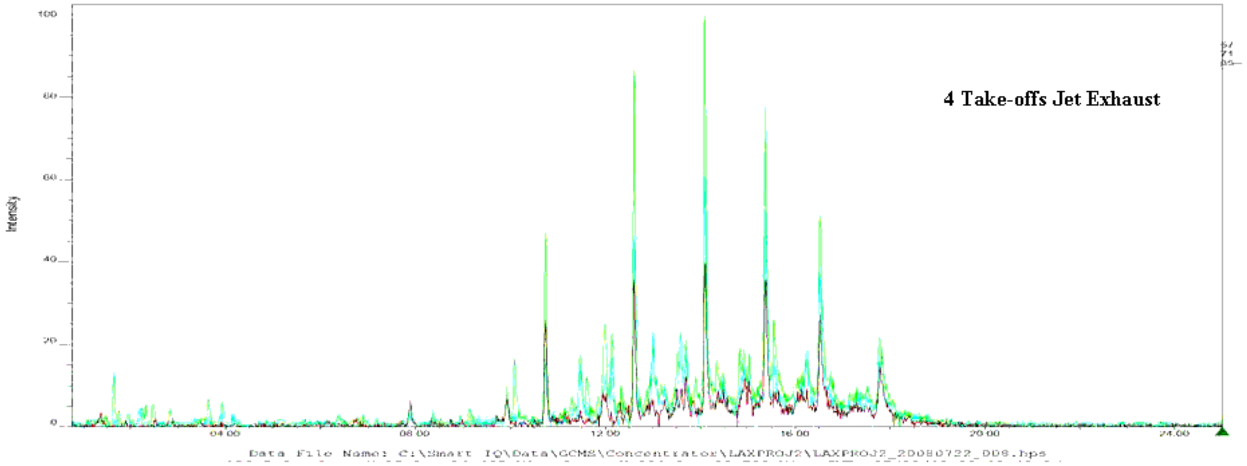
Friday, 25 July, Weston began acquiring both scan and SIM mode data for the PS4 and PS5 locations in the approach field east of Aviation Boulevard. Instrument rebooted during first scan run at PS4. Weston acquired two good scan and two good SIM runs at each location. Basic features of TICs at each location were reproducible. The test was then moved to the PS3 location in the southeast cargo complex by Japan Airlines Cargo, where one scan mode sample run and one SIM mode sample run were acquired in the early evening.

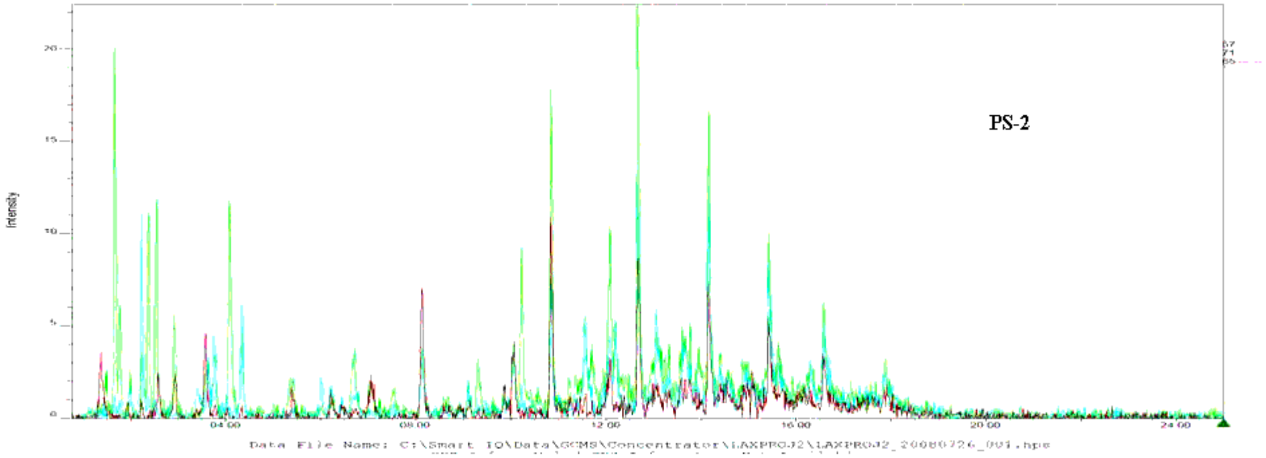
Saturday, 26 July, Weston acquired two scan mode TICs and two SIM mode chromatograms at the PS2 terminal parking location. Interestingly, the extracted ion chromatogram of C_4 through C_6 alkane fragments at the PS2 site produced a different “fingerprint” from the PS4 & PS5 locations. The extracted ion chromatogram from PS3 is similar to PS4 & PS5. A comparison of runs at the sites is shown below.

Extracted Ion Chromatograms From Scan Runs at Remote Locations



Notice the similarities in locations PS4 and PS5. Note the retention time of maxima at about 14 minutes and spacing between peaks. Notice the shift in maxima in the PS2 location indicating a lighter boiling fraction cut of gasoline versus kerosene. Notice the difference in ion abundance in the peak at about 8.2 minutes in the PS2 sample versus PS3. Compare PS2 RIC with the RIC for the “Black Trace” from Wednesday the 22nd below.





Finally, Weston returned the Inficon instrument and accessories to the AQMD office in Diamond Bar, CA at approximately noon on Saturday.

Conclusions

The Inficon portable GC/MS can be used to detect VOC’s from unburned fuel at ambient concentration levels with sufficient sample concentration time, especially in SIM mode. Using SIM mode, the Inficon can probably detect aromatic VOCs at low part-per-trillion (ppt) levels using a 30-second concentration step. Since gasoline, jet fuel, and diesel fuel are distinct petroleum distillate fractions, a fingerprint is apparently discernable reflecting the unburned portion of each fuel source. Analyzing this potential fingerprint observed in the Inficon data was beyond the scope of this study.

Some additional method development is needed to optimize retention windows and masses scanned in each window for SIM mode data acquisition. Retention time shifts due to heat buildup, and the effect of running a scan immediately after the previous run finished without enough cool-down and equilibrium time made setting retention time windows difficult.

To move towards acquiring more robust semi-quantitative data in either mode, a system must be developed to analyze true zero-air blanks and possibly provide for compound by compound calibration. Tedlar bags and charcoal tubes do not provide acceptable blanks, since each apparently produces artifact peaks larger than the fuel constituent compounds of interest. Calibration gases are readily available for a wide variety of fuel components in TO-14 and TO-15 calibration gas mixes, or alkane “C” range mixes, but these are usually available in the low parts per million (ppm) to high parts per billion (ppb) ranges, not parts per trillion. Performing accurate dilutions without introducing artifacts to achieve sub-ppb calibration levels will be a challenge.

Comparative relative “fingerprint” or “signature” data may prove valuable even without absolutely accurate compound-by-compound calibration. A multivariate statistical analysis package for chromatography using principal component regression or analysis might be beneficial to extract information from TIC “signatures”. These methods are commonly used in near-infrared spectroscopy applications for process control. Given a reference set of chromatograms that are representative primarily of gasoline combustion, jet exhaust, and diesel exhaust separately or even using known mixtures, these numerical methods might be able to predict the contribution of each fuel type in an unknown field sample.

Phase III of the LAX Air Quality and Source Apportionment Study

Volume 3

Evaluation of Demonstration Project Data in Conjunction with Initiation of Phase III

Completed by Countess Environmental in May-June 2011

June 18, 2013

Evaluation of Monitoring Data from the LAX Air Quality Source Apportionment Study's Demonstration Project

Prepared for CDM by

Countess Environmental

May 2, 2011

INTRODUCTION

This report summarizes Countess Environmental's (CE) evaluation of the continuous monitoring data collected from July through August, 2008, as part of the Technology and Methodology Feasibility Demonstration Project (Demonstration Project) at LAX. This evaluation is being conducted to provide the Los Angeles World Airport's (LAWA) on-call environmental contractors with information for the Long-Term Study. Future reports will contain CE's evaluation of the sampling data, the portable gas chromatograph/mass spectrometer (GC/MS) results collected at the blast fence, and the recently revised canister data for speciated volatile organic compounds (VOCs). Corrected carbon dioxide (CO_2) data were obtained from AECOM before starting this evaluation.

In 2009 Jacobs Consultancy[1] (the prime contractor for the Demonstration Project) performed a preliminary analysis of the monitoring data to examine whether any of the data tracked aircraft activity and Dr. Ron Henry (a subconsultant to Jacobs Consultancy) examined the relationship of UFP measurements with NO, SO_2, and i-PAH at PS4, PS5 and SR. Their findings are summarized in Appendices A and B.

The evaluation of the monitoring data has focused on the following areas:

- Were the methods used able to quantify the concentrations of the pollutants of interest?
- What was the data recovery rate for the methods used?
- Which methods need to be revised?
- Which methods failed to provide useful data?
- Assessment of the impact of wind direction on pollutant concentrations for onshore winds versus offshore winds.

The locations of the five monitoring sites are shown on Figure 1. These sites included: South Runway (SR) located behind the blast fence at Runway 25R, Portable Site 2 (PS2) located in a parking lot in the Central Terminal Area, Portable Site 3 (PS3) located in a cargo operations area, Portable Site 4 (PS4) located approximately 850 feet east of SR, and Portable Site 5 (PS5) located approximately 1,650 feet east of SR.

The sampling dates and the time resolution of the continuous monitoring data collected at the five monitoring sites during the Demonstration Project are presented in Table 1. Due to budget constraints, monitoring was conducted at only one site at a time.

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[1] Since 2009, Jacobs Consultancy has been reorganized and renamed as LeighFisher, Inc.

Figure 1. Demonstration Project Monitoring Site Locations

Table 1. Monitoring Data During the Demonstration Project

Parameter	SR[a]	PS2	PS3	PS4	PS5
Start Date	7-Jul	28-Jul	5-Aug	15-Aug	23-Aug
End Date	28-Jul	5-Aug	13-Aug	21-Aug	31-Aug
# of Days	27	7	7	7	7
	Time Resolution of Measurements, minutes				
NO, NO_2, NO_x, O_3, CO, CH_4, NMHC[b]	1, 5, 15, 60				
CO_2, SO_2	1, 5, 15, 60	1, 5, 15, 60	1, 5, 15, 60	1, 5, 15, 60	1, 5, 15, 60
i-PAH[c]	1, 5, 15, 60	1, 5, 15, 60	1, 5, 15, 60	1, 5, 15, 60	1, 5, 15, 60
PM2.5 and PM10	60	60	60	60	60
Light Scattering (Bscat)	60	60	60	60	60
Black Carbon (BC)	5, 15, 60	5, 15, 60	5, 15, 60	5, 15, 60	5, 15, 60
UFP	1	1	1	1	1

[a] Started sampling for i-PAH, PM2.5 and PM10 at SR on June 25.

[b] NMHC as propane.

[c] The EcoChem PAS 2000 measures a surrogate that is generally proportional to PAH concentration.

The equipment used to monitor the different ambient species is identified in Table 2.

Table 2. Monitoring Equipment Used During the Demonstration Project

Species	Analyzer
Polycyclic Aromatic Hydrocarbons (PAH)	EcoChem Analytics PAS 2000
Black Carbon (BC)	Magee Model AE-31 Aethalometer
PM_{10}	Met One BAM-1020 PM_{10} Monitor
$PM_{2.5}$	Met One BAM-1020 $PM_{2.5}$ Monitor
Carbon Dioxide (CO_2)	Thermo Scientific Model 410i-D
Methane (CH_4)	Thermo Scientific Model 55C
Non-Methane Hydrocarbons (NMHC)	Thermo Scientific Model 55C
Carbon Monoxide (CO)	Thermo Scientific Model 48
Sulfur Dioxide (SO_2)	Thermo Scientific Model 43C
Nitrogen Oxides (NO, NO_2, NO_x)	Thermo Scientific Model 42C
Ozone (O_3)	Thermo Scientific Model 49C
Light Scattering (Bscat)	Optec NGN-2 Nephelometer
Ultrafine Particles (UFP)	TSI Model 3091 Fast Mobility Particle Sizer (FMPS)

The periods that Runway 25R was closed due to maintenance as well as other events that impacted monitoring (and sampling) data during the Demonstration Project are summarized below.

- June 28 – South runway closed from 0300 to 1200 for maintenance.
- July 10-11 – Onsite audit conducted by T&B Systems.
- July 17-21 – FMPS off line.
- July 19 – South runway closed from 0200 to 0900 for maintenance.
- July 20 – South runway closed from 0200 to 1600 for maintenance
- July 21-24 – PM_{10} monitor off line for repairs.
- July 23 – Portable monitoring platform moved to PS2.
- July 27-28 – Gaseous analyzers moved to PS2.
- July 30 – FMPS off line.
- Aug. 4-5 – Portable monitoring platform moved to PS3.
- Aug. 6 – System audit performed by T&B Systems.
- Aug. 7 – New FMPS computer installed.
- Aug. 13-14 –Portable monitoring platform moved to PS4.
- Aug. 20-29 – PM_{10} monitor off line.
- Aug. 22-23 – Portable monitoring platform moved to PS5.
- Aug. 28 - Sept. 1 – Nephelometer off line.
- Aug. 30 - Sept. 1 – $PM_{2.5}$ monitor off line.
- Sept. 2 – Shut down monitoring at PS5.

The terminals are open 24-hours per day, and aircraft and cargo operations are conducted 24 hours per day.. The airfield operates on instrument flight rules (IFR) at times of low visibility. If the weather falls below the minimum visibility requirements, the Federal Aviation Administration (FAA) will cease operations and divert aircraft to other airports.

SUMMARY OF MONITORING DATA

Many of the SO_2 concentrations were recorded as 0 ppm; several records were recorded as a negative 0.001 ppm. Many of the CO concentrations were recorded as 0 ppm, and several of the O_3 concentrations were negative. There were also negative readings recorded for black carbon. According to the South Coast Air Quality Management District's (AQMD) Data Validation Group, the AQMD's policy is to keep slightly negative concentrations (i.e., within 1 MDL of 0), replace other negative values with a 0, and keep all the records recorded as 0 so as not to bias the averages high (private communication, April 2011). CE adopted the AQMD's policy for the analyses.

Measurements of Gases and Black Carbon at the SR Site

Table 3a summarizes the 1-minute average concentrations of NO_x, NO_2, NO, O_3, CH_4, and NMHC at the SR site. Due to a programming error, the nephelometer collected hourly average readings instead of one-minute. Table 3b summarizes the 5-minute average concentrations of black carbon (BC) obtained with the 7-channel aethalometer at the SR site.

Table 3a. Gas Phase Measurements at SR (1 min. averages)

PARAMETER	NOx	NO2	NO	CO	O3	CH4	NMHC
units	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Average	0.172	0.044	0.134	0.351	0.020	1.816	0.014
Std Dev	0.227	0.041	0.206	0.681	0.015	0.395	0.071
Min	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max	0.993	0.356	0.997	40.8	0.45	9.37	3.672
Count	29033	29033	29033	29022	27940	26029	28994

Table 3b. Measurements at SR (5 min. averages, ng/m³)

	BC_370	BC_470	BC_520	BC_590	BC_660	BC_880	BC_950
Average	7184	7896	7912	8263	8454	8741	8541
Std Dev	8037	8906	8934	9323	9548	9900	9702
Min	0	0	0	0	0	0	0
Max	71205	78104	76806	80390	83184	85188	85207
Count	7027	7027	7027	7027	7027	7027	7027

Measurements of Other Pollutants

Tables 4a – 4d summarize the measurements of i-PAH, Bscat, PM10, PM2.5, CO_2 and SO_2 and Table 4e summarizes the results for two channels of the aethalometer for the five monitoring sites.

Table 4a. Measurements of i-PAH (1 min. averages)

	i-PAH (pA)				
	PS2	**PS3**	**PS4**	**PS5**	**SR**
Average	20.6	10.8	17.1	11.3	64.1
Std Dev	17.4	29.7	30.9	12.9	117.9
Min	0.0	0.0	0.0	0.0	0.0
Max	243.3	559.5	48.8	272.2	1654
Count	16440	11940	12180	12959	39417

Table 4b. Measurements of Bscat (hourly averages)

	Bscat (Mm^{-1})				
	PS2	**PS3**	**PS4**	**PS5**	**SR**
Average	173	112	110	144	134
Std Dev	97	40	52	82	66
Min	54	48	23	41	31
Max	509	275	253	397	601
Count	102	197	166	76	415

Table 4c. Measurements of PM10 and PM2.5 (hourly averages)

	PM10 (μg/m^3)					PM2.5 (μg/m^3)				
	PS2	**PS3**	**PS4**	**PS5**	**SR**	**PS2**	**PS3**	**PS4**	**PS5**	**SR**
Average	39.9	32.8	32.7	38.8	50.0	29.9	23.5	23.3	27.9	38.7
Std Dev	10.7	7.0	8.4	11.9	14.2	8.2	6.5	6.8	7.9	10.9
Min	14.1	13.9	9.6	20.1	13.4	2.4	5.6	9.6	11.0	11.6
Max	72.8	52.1	55.9	76.2	96.8	57.1	42.2	47.0	49.5	73.9
Count	263	198	136	86	566	263	198	203	203	657

Table 4d. Measurements of CO_2 and SO_2 (1 min. averages)

	CO_2 (ppm)					SO_2 (ppm)				
	PS2	**PS3**	**PS4**	**PS5**	**SR**	**PS2**	**PS3**	**PS4**	**PS5**	**SR**
Average	400	398	401	393	422	0.010	0.002	0.003	0.001	0.013
Std Dev	91	33	32	21	60	0.033	0.002	0.005	0.010	0.019
Min	8	335	352	354	252	0.000	0.000	0.000	0.000	0.000
Max	3345	535	566	471	801	0.216	0.026	0.062	0.401	0.175
Count	9160	10501	11734	14151	28092	10815	10470	11752	14188	6945

Table 4e. Measurements of Black Carbon (5 min. averages)

	BC_370 (ng/m^3)					BC_880 (ng/m^3)				
	PS2	**PS3**	**PS4**	**PS5**	**SR**	**PS2**	**PS3**	**PS4**	**PS5**	**SR**
Average	1729	1000	1953	1247	7184	1953	1130	2267	1453	8741
Std Dev	1061	1584	2282	938	8037	1213	1859	2581	1217	9900
Min	87	-89	73	38	-79	-645	-981	-430	-577	-1129
Max	7709	17235	20044	9701	71205	8273	20612	24634	24278	85188
Count	3176	2326	2358	2817	7027	3176	2326	2358	2817	7027

There are suspect records in these data sets, namely:

- PM2.5 greater than PM10
- NO plus NO_2 not equal to NO_x
- CO_2 less than 360 ppm (i.e., background level) at all sites
- The 5-minute SO_2 measurements at PS2 had two very large readings within 5 minutes of each other (0.975 ppm and 0.592 ppm) that are not supported by the 1-minute readings where the highest value was 0.216 ppm. The average SO_2 levels at PS2 were 0.0106 ppm for the 5-minute readings and 0.010 ppm for the 1-minute readings whereas the average SO_2 levels were 0.002 ppm for both the 15-minute averages and the 60-minute averages.
- NMHC at SR is suspect; 78% of the records were 0.006 ppm
- CH_4 at SR is suspect; many cases where CH_4 equals NMHC

Findings

- There are missing records in a string of continuous measurements without an explanation.
- Several records had the same time stamp.
- There were high PM10 and PM2.5 levels observed at all sites.
- The data capture for PM10 at Ps5 was low due to the monitor being off-line for repair.
- The data capture for PM10 at SR was low due to the monitor being off-line for repair.
- The data capture for Bscat at PS5 was low due to the nephelometer being off-line for repair.
- The highest pollutant concentrations were observed at SR except for Bscat that was highest at PS2.
- There were very high CO_2 and CO levels observed at SR; the CO_2 maximum was 801 ppm and the maximum CO was 40.8 ppm.
- There were very high NMHC and CH_4 levels observed at SR; the maximum NMHC was 3.7 ppm and the maximum CH_4 was 9.4 ppm.
- Pollutant concentrations decreased with distance, e.g., ~850 feet from SR to PS4, and ~800 feet from PS4 to PS5.
- PS2 has 12 records with CO_2 over 1000 ppm.
- There were high CO_2 at PS4 between August 19 and August 22.
- Many SO_2 values at PS2 and PS3 were near the detection level of the analyzer (0.001 ppm)
- There was a moderate correlation between NO and SO_2 at SR ($R^2 = 0.71$)

- There was a weak correlation between CO_2-360 ppm and SO_2 ($R^2 = 0.52$)
- The 370 nm channel of the aethalometer gave a higher reading than the 880 nm channel; this was also true for the Roseville Railyard Study.
- All the data appear to be log-normally distributed with the following exceptions:
  - (a) Bscat appears to be bimodal at PS3 and PS4 with one mode log-normally distributed and the second mode either normally distributed or log-normally distributed.
  - (b) PM2.5 and PM10 appear to be normally distributed at all sites. PM2.5 and PM10 would be expected to be log-normally distributed. The reason that they appear to be normally-distributed may be due to the limited number of measurements at each site.
- CO_2 appears to be bimodal at PS3, PS4 and PS5 with each mode being log-normally distributed. It appears that the two modes may be related to the times the measurements were made since in general the highest CO_2 concentrations occurred during daytime hours; however, there were many exceptions.

Diurnal Variation in Pollutant Concentrations
The major findings regarding the diurnal variation in the average hourly pollutant concentrations for the 7 days of sampling at PS2, PS3, PS4 and PS5 and for the 27 days of sampling at SR are presented below. There are no SO_2 or CO_2 measurements recorded between 6 AM and 7 AM for any of the sites except for the first two days at SR. This was true for all the other gas phase species measured at SR other than for the first two days of monitoring. The analyzers may have been off-line for calibration during this time period each day.

SO_2 and CO_2 These two pollutants appear to track together at each site

- PS2: The highest SO_2 levels occurred from 8 AM to noon with a second peak from 11 PM to 1 AM; the highest CO_2 levels occurred from 8 AM to 2 PM with a second peak from 10 PM to 2 AM.
- PS3: The highest SO_2 levels occurred from 8 AM to 9 AM with a second peak from 11 PM to midnight; the highest CO_2 levels occurred from 11 AM to noon with a second peak from 10 PM to 11 PM.
- PS4: The highest SO_2 levels occurred from 10 AM to 3 PM; the highest CO_2 levels occurred from 8 AM to 2 PM.
- PS5: The highest SO_2 levels occurred from 10 AM to 3 PM; the highest CO_2 levels occurred from 8 AM to 2 PM
- SR: High SO_2 levels occurred from 7 AM to 1 AM with one peak from 1 PM to 2 PM and a second peak from 11 PM to midnight as shown in Figure 2 (note the absence of data from 6 AM to 7 AM); the CO_2 measurements have a broad peak from 9 AM to 2 PM and a second peak from 11 PM to midnight as shown in Figure 3 where the background CO_2 level (assumed to be 360 ppm) has been subtracted from the measured CO_2 concentrations. Figure 2 shows two peaks midday when in reality there is only a single peak on a given day; the double peaks arise from averaging the data for 26 days.

Figure 2. Diurnal Variation in SO_2 at SR

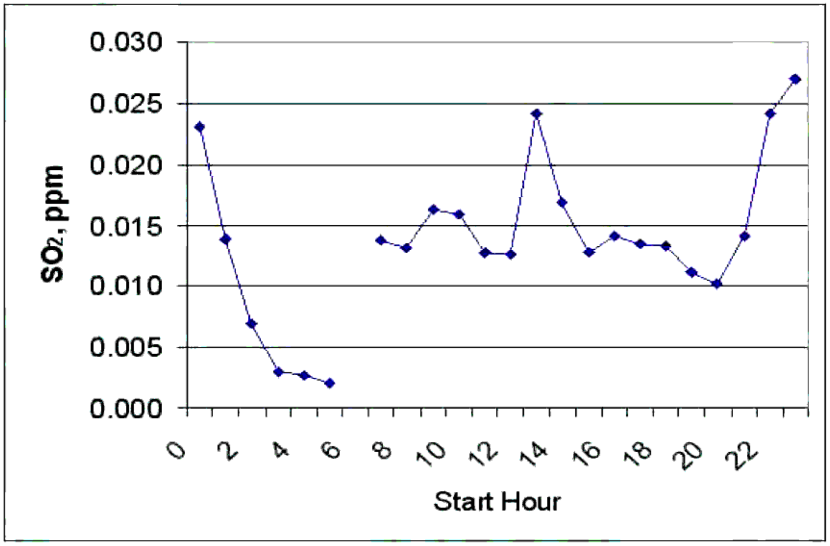
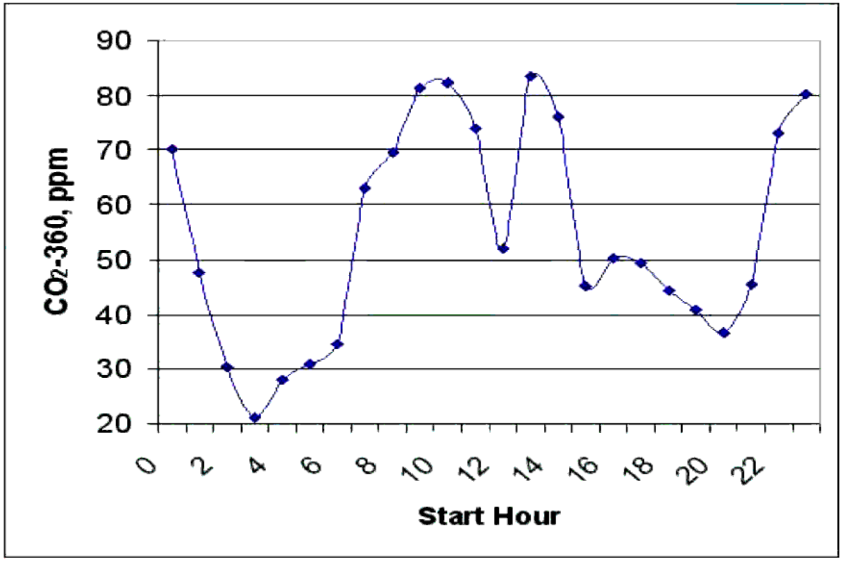


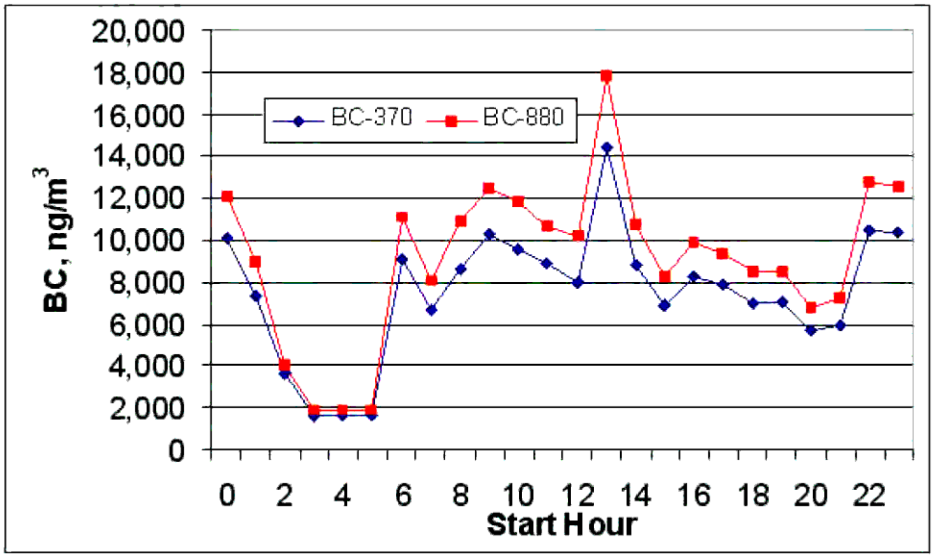
Figure 3. Diurnal Variation in CO_2-360 at SR



Black Carbon

- PS2: High BC levels were observed from 8 AM to 2 PM and from 9 PM to midnight.
- PS3: The BC profile is relatively flat with a large increase above the baseline from 3 AM to 4 AM.
- PS4, PS5 and SR have similar diurnal BC profiles with the lowest levels observed from 2 AM to 7 AM, increasing levels to a maximum between 1 PM and 2 PM, and remaining relatively high until 10 PM. The diurnal profile of BC at SR is shown in Figure 4.

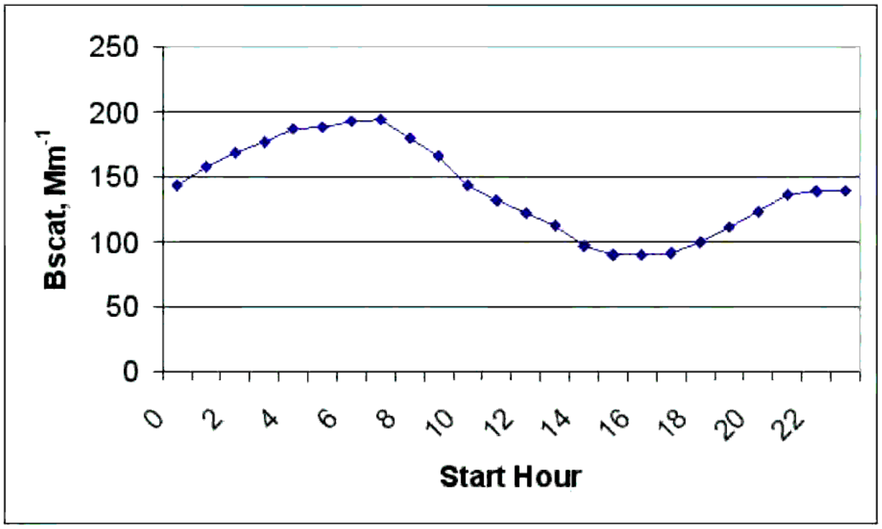
Figure 4. Diurnal Variation in BC at SR



Bscat

- PS2: The highest Bscat levels occurred from 5 AM to 6 AM and from 11 PM to midnight, with a minimum from 2 PM to 6 PM
- PS3: The highest Bscat levels occurred from 5 AM to 6 AM and from 9 PM to 1 AM, with a minimum from 3 PM to 4 PM
- PS4: The highest Bscat levels occurred from 6 AM to 7 AM and from 11 PM to 1 AM, with a minimum from 1 PM to 6 PM
- PS5: The highest Bscat levels occurred from 4 AM to 5 AM and from 11 PM to 1 AM, with a minimum from 1 PM to 6 PM
- SR: The highest Bscat levels occurred from 6 AM to 8 AM and from 10 PM to midnight, with a minimum from 3 PM to 6 PM as shown in Figure 5.

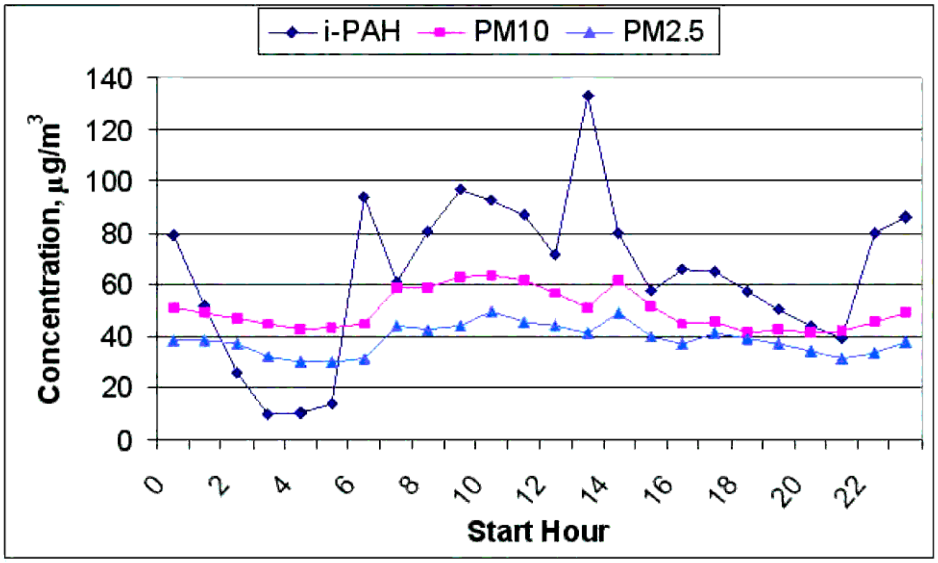
Figure 5. Diurnal Variation in Bscat at SR



i-PAH, PM10 and PM2.5

- PS2: The lowest i-PAH levels occurred from 3 AM to 4 AM with a broad peak between 7 AM and midnight; the PM10 and PM2.5 levels appear to track together with the highest levels occurring from 9 AM to 1 PM.
- PS3: Very high i-PAH level were observed from 3 AM to 4 AM on many days; the PM10 profile is relatively flat whereas PM2.5 has a broad peak between 10 AM and 4 PM suggesting the possibility of the presence of secondary aerosol.
- PS4: The lowest i-PAH levels occurred from 2 AM to 7 AM with a broad peak between 11AM and 3 PM; the PM10 profile is different from that for PM2.5 with the highest PM10 levels between 11 AM and noon whereas PM2.5 has a broad peak between 11 AM and 3 PM suggesting the possibility of the presence of secondary aerosol.
- PS5: The i-PAH profile is relatively flat with a peak from 1 PM to 2 PM; PM10 and PM2.5 track together with the highest levels occurring between 11 AM and 3 PM.
- SR: The i-PAH profile at this site is very different than the diurnal profiles observed at the other sites; PM10 and PM2.5 track together with only a moderate variation in concentrations throughout the 24-hour period as shown in Figure 6.

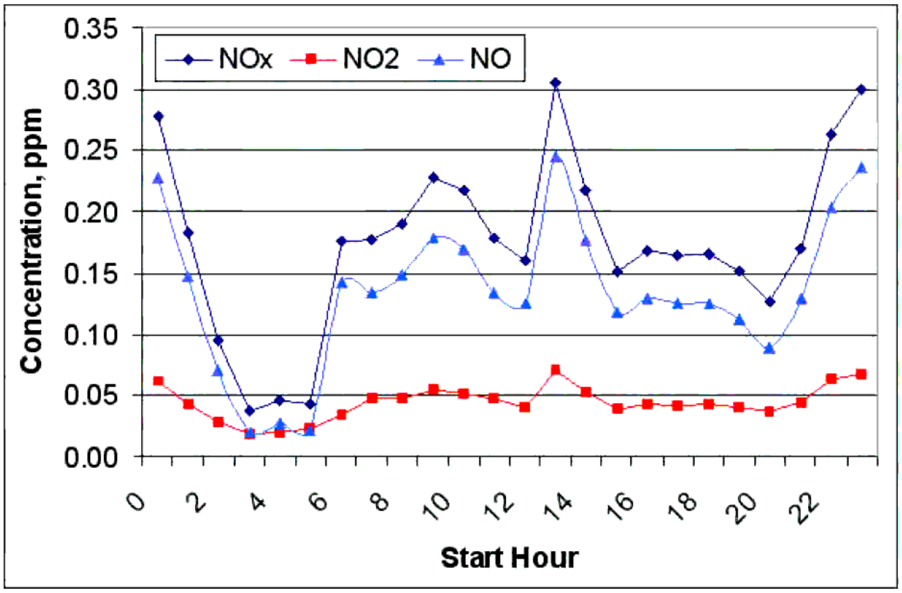
Figure 6. Diurnal Variation in i-PAH, PM10 and PM2.5 at SR



Other Pollutants at SR

- NO_x and NO track each other and have similar temporal profiles to SO_2 with one peak occurring from 1 PM to 2 PM and a second peak occurring from 11 PM to midnight as shown in Figure 7.
- The NO_2 levels were relatively flat during each 24-hour period.
- The highest CO levels were observed from 9 AM to 10 AM.
- O_3 has the typical profile with a maximum concentration between noon to 4 PM.
- CH_4 has a very flat profile with a small increase above the baseline from 6 AM to 7 AM.
- NMHC has a profile similar to CH_4 but with a much larger increase above the baseline from 6 AM to 7 AM.

Figure 7. Diurnal Variation in NO_x, NO_2 and NO at SR



Background Concentrations at SR with South Runway 25R Shut Down

The south Runway 25R was shut down for maintenance on three separate occasions during the Demonstration Project. The average pollutant concentrations at SR for the periods when Runway 25R was open were much higher than when it was closed for the following pollutants:

- SO_2 was higher by a factor of 44
- NO was higher by a factor of 17
- i-PAH was higher by a factor of 11
- NO_x was higher by a factor of 9
- Black carbon was higher by a factor of 8
- CO and CO_2-360 were higher by a factor of 2

The difference in pollutant levels between the times Runway 25R was shut down for maintenance and the times it was operational may be representative of the background pollutant levels at LAX. The aircraft activity records are suspect since there was aircraft activity recorded for Runway 25R for the times the runway was shut down.

Ultra Fine Particle Measurements

The ultra fine particle (UFP) measurements collected during the Demonstration Project are summarized in Tables 5a – 5c. The total UFP number count represents the number of particles per cubic centimeter for particles with diameters between 6.04 nm and 523.3 nm. The total UFP count is broken down into three size categories based on jet engine exhaust tests conducted by Dr. Philip Whitefield and others as follows:

- UFP-1 = condensable particles (diameter <29.4 nm)
- UFP-2 = carbonaceous particles from aircraft (45.3 nm < diameter <107.5 nm)
- UFP-3 = non-aircraft particles (191.1 nm < diameter < 523.3 nm)

Table 5a. UFP Measurements for PS2 and PS3 (1 minute averages)

	PS2				PS3			
	Total UFP	**UFP-1**	**UFP-2**	**UFP-3**	**Total**	**UFP-1**	**UFP-2**	**UFP-3**
Average	64,239	51,659	6250	186	34,265	25,538	4,676	175
Std dev	64,036	56,761	4782	89	82,195	76,881	6,448	72
Min	4,540	2,301	529	59	3,750	1,432	220	0
Max	674,000	616,254	81967	489	1,810,000	1,771,275	101,729	1,854
Median	44,100	32,993	5205	166	16,150	9,793	3,263	156
Count	2,151	2,151	2,151	2,151	8,678	8,678	8,678	8,678

Table 5b. UFP Measurements for PS4 and PS5 (1 minute averages)

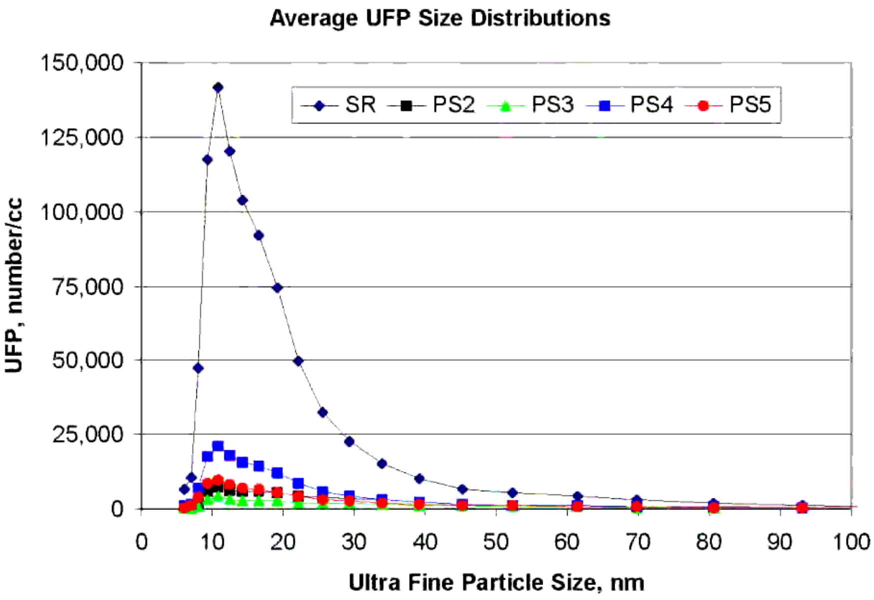
	PS4				PS5			
	Total	**UFP-1**	**UFP-2**	**UFP-3**	**Total**	**UFP-1**	**UFP-2**	**UFP-3**
Average	140,100	127,748	6,047	211	71,509	61,842	5,304	267
Std Dev	250,130	237,642	8,176	92	78,314	73,787	3,764	75
Min	2,150	219	360	0	2,760	998	685	97
Max	2,890,000	2,799,339	149,691	570	962,000	931,754	96,049	757
Median	49,900	42,745	4,015	209	46,700	39,283	4,385	260
Count	12,292	12,292	12,292	12,292	14,340	14,340	14,340	14,340

Table 5c. UFP Measurements for SR (1 minute averages)

	Total	**UFP-1**	**UFP-2**	**UFP-3**
Average	868,905	819,204	23,500	333
Std Dev	1,355,659	1,299,447	41,026	134
Min	2,070	506	606	0
Max	11,500,000	11,255,990	1,402,591	1,675
Median	182,000	163,371	8,141	306
Count	17,033	17,033	17,033	17,033

The average UFP size distributions for each monitoring site are presented in Figure 7 for the size range 6 nm to 100 nm. Figure 8 shows the large UFP-1 component representing condensable particles with diameters less than 29.4 nm.

Figure 8.



Findings

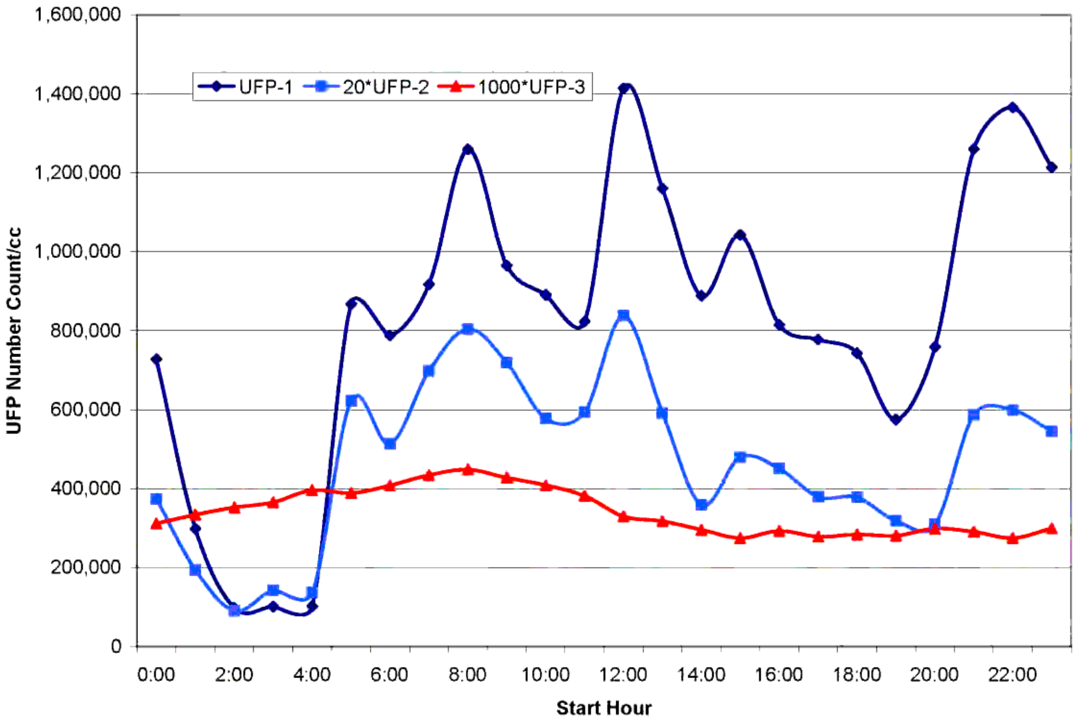
- The UFP-1 component (condensable PM) is the dominant component of the three size categories at all five sites accounting for 94% of the total UFP number count at SR, 91% at PS4, 86% at PS5, 80% at PS2, and 75% at PS3.
- The UFP-2 component (i.e., carbonaceous PM from aircraft) is the next most abundant component ranging from 14% at PS3, to 10% at PS2, to 7% at PS5, to 4% at PS4, to 3% at SR.
- The UFP-3 component (i.e., non-aircraft PM) is a minor component at all five sites ranging between 0.2% to 0.5% for PS2, PS3, PS4 and PS5 and accounting for less than 0.04% of the total UFP number count at SR. Note: The sum of the three UFP components is less that the total since the total UFP number count includes data for several other particle diameters between 6.04 nm and 523.3 nm.
- Even though the UFP measurements were not conducted simultaneously at any of the sites, Tables 4b and 4c indicate that the number count for the UFP-1 component decreases significantly with distance as one moves further away from the source of fresh jet exhaust at SR to PS4 and then further away to PS5.
- The number count for all three UFP components appears to be log-normally distributed at each site.
- The data capture for UFP measurements was low at SR, PS2 and PS3 due to the FMPS being offline for five days during the 27 days of monitoring at SR, five days during the seven days of monitoring at PS2, and two days during the seven days of monitoring at PS3.

Diurnal Variation in UFP Number Count

The major findings regarding the diurnal variation in the average hourly UFP number counts for the 7 days of sampling at PS2, PS3, PS4 and PS5 and for the 27 days of sampling at SR are presented below.

- PS2: The UFP-1 and UFP-2 components track together with one peak occurring from 5AM to 7 AM and a second larger peak occurring from 10 AM to noon; the UFP-3 profile shows a broad peak from 3 AM to 11 AM.
- PS3: The maximum UFP-1 levels occurred from 2 AM to 6 AM with smaller peaks observed between 1 PM to 2 PM and 9 PM to 10 PM; the maximum UFP-2 levels occurred from 2 AM to 3 AM; the UFP-3 profile is relatively flat all day.
- PS4 and PS5: The UFP profiles for these two sites are similar. The UFP-1 levels are low from midnight to 7 AM, increase to a maximum between noon and 2 PM and stay high until 11 PM; the UFP-2 levels are highest from 9 AM to 5 PM at PS4 and from 9 AM to 2 PM at PS5 with a maximum from noon to 1 PM at both sites and a second peak from 9 PM to 10 PM at PS5; the UFP-3 profile is relatively flat all day at both site with slightly elevated levels above the baseline at PS4 from 7 AM to noon.
- SR: The diurnal variation in the UFP components is presented in Figure 9. Overall, the profiles at this site are similar to the profiles observed for PS4 and PS5. The UFP-1 and UFP-2 levels are low from 2 AM to 5 AM, increase to a maximum from noon to 1 PM and stay high to 1 AM with a second peak occurring between 9 PM and midnight; the UFP-3 profile is relatively flat all day with the highest levels occurring from 7 AM to 10 AM.

Figure 9. Diurnal Variation in UFP Number Count at SR



Meteorological Data

A meteorological (met) station was set up at PS5 during the Demonstration Project after monitoring had been completed at SR and PS2. To fill in for the missing wind speed (WS) and wind direction (WD) data, there was the option of using either the met data from the AQMD's Southwest LA County Coastal site (i.e., the LAX-Hastings site) located northwest of LAX, or the surface met data from the AQMD's upper air site located west of LAX. Review of the met data from these two sites and the PS5 site indicated the following:

- There was a strong correlation between WS measured at the LAX-Hastings site and WS measured the PAMS site.
- The correlation between WD measured at the LAX-Hastings site and WD measured at the PAMS site was weak.
- The correlation between WS and WD measured at LAX-Hastings site and WS and WD measured at the PS5 site was weak.
- The correlation between WS and WD measured at the PAMS site and WS and WD measured at the PS5 site was moderate.

According to T&B Systems, the LAX-Hastings site had problems with WD measurements. Thus, the surface met data from the AQMD's upper air PAMS site for the entire study period was used for the analyses of the Demonstration Project data.

Pollutant Concentrations by Wind Sector

To examine the effect of wind direction on pollutant concentrations, the met data (hourly average WS and WD) from the AQMD's PAMS site was merged with the monitoring data, and then Ron Henry's definitions were used of wind sectors, as presented in his draft receptor modeling report for the Demonstration Project (April 2009):

- Onshore: WD = 247.5° to 292.5°
- Offshore: WD = 348.75° to 191.25°
- Neutral (i.e., transition between onshore and offshore): WD = 295.5° to 348.75° plus 191.25° to 247.5°

During the Demonstration Project the wind was onshore 71% of the time, offshore 8% of the time, and in transition between onshore and offshore winds 21% of the time.

The hourly average results for each pollutant are presented in Tables 6a – 6e as a function of the wind direction for each of the five sites. The percentages of the time that the wind direction was either onshore, offshore or in transition are shown in each table. The ratios of the average pollutant concentrations measured during onshore winds to those measured during offshore winds are presented in Table 6f.

Table 6a. Hourly Pollutant Concentrations at PS2 by Wind Sector

	Offshore (7%)			Onshore (78%)			Transition (15%)		
	Mean	Std Dev	Count	Mean	Std Dev	Count	Mean	Std Dev	Count
i-PAH	13.8	8.8	18	21.6	10.5	203	20.9	10.8	42
PM10	42.2	8.9	18	39.0	10.9	203	43.0	10.1	42
PM2.5	31.4	7.4	18	29.6	8.1	203	30.8	9.3	42
CO_2	401	16	12	396	17	111	404	16	23
SO_2	0.002	0.001	12	0.002	0.002	128	0.003	0.002	24
Bscat	255	137	14	149	76	73	213	94	15
BC_370	1543	661	18	1758	862	200	1782	763	42

Table 6b. Hourly Pollutant Concentrations at PS3 by Wind Sector

	Offshore (2%)			Onshore (79%)			Transition (19%)		
	Mean	Std Dev	Count	Mean	Std Dev	Count	Mean	Std Dev	Count
i_PAH	12.9	10.1	9	11.3	23.8	150	8.1	10.0	39
PM10	33.4	7.7	9	32.6	7.1	150	33.3	6.5	39
PM2.5	23.0	6.0	9	24.2	6.6	150	21.0	5.7	39
CO_2	411	41	9	400	32	129	387	23	35
SO_2	0.002	0.001	9	0.002	0.001	128	0.002	0.002	35
Bscat	170	68	9	108	38	148	114	28	40
BC_370	1380	1296	9	1053	1445	147	820	753	39

Table 6c. Hourly Pollutant Concentrations at PS4 by Wind Sector

	Offshore (7%)			Onshore (73%)			Transition (20%)		
	Mean	Std Dev	Count	Mean	Std Dev	Count	Mean	Std Dev	Count
i_PAH	12.9	10.6	19	18.3	11.1	162	12.2	7.2	41
PM10	30.9	16.3	2	33.0	8.7	110	31.7	6.7	26
PM2.5	17.1	6.0	19	23.6	7.0	162	22.1	5.5	41
CO_2	432	21	17	402	30	150	401	29	39
SO_2	0.001	0.002	17	0.003	0.002	150	0.002	0.002	39
Bscat	133	69	10	102	50	129	138	49	37
BC_370	1324	995	19	2132	1237	162	1361	873	41

Table 6d. Hourly Pollutant Concentrations at PS5 by Wind Sector

	Offshore (11%)			Onshore (70%)			Transition (19%)		
	Mean	**Std Dev**	**Count**	**Mean**	**Std Dev**	**Count**	**Mean**	**Std Dev**	**Count**
i_PAH	8.8	6.1	33	11.7	5.2	155	9.5	5.7	52
PM10	32.8	6.6	10	41.8	13.5	50	35.6	7.9	26
PM2.5	30.1	6.4	24	28.8	7.9	137	23.6	7.0	42
CO_2	401	18	29	391	19	153	396	22	51
SO_2	0.001	0.002	29	0.001	0.001	153	0.001	0.001	51
Bscat	230	156	4	134	60	57	163	116	15
BC_370	1031	721	33	1369	662	155	1036	555	52

Table 6e. Hourly Pollutant Concentrations at SR by Wind Sector

	Offshore (5%)			Onshore (72%)			Transition (23%)		
	Mean	**Std Dev**	**Count**	**Mean**	**Std Dev**	**Count**	**Mean**	**Std Dev**	**Count**
i_PAH	28.9	37.9	21	68.0	43.7	432	63.2	51.5	171
PM10	41.1	11.5	14	50.4	14.8	380	51.0	12.9	146
PM2.5	30.1	7.1	21	40.0	10.8	432	38.3	10.3	171
CO_2	390	10	10	419	37	337	408	29	91
SO_2	0.002	0.002	7	0.015	0.010	203	0.008	0.009	52
Bscat	126	40	14	126	56	261	153	87	114
BC_370	2966	2838	21	8203	4317	432	6706	4754	169
NO_x	0.054	0.034	10	0.190	0.094	342	0.147	0.107	97
NO_2	0.022	0.010	10	0.048	0.019	342	0.039	0.020	97
NO	0.035	0.028	10	0.149	0.080	342	0.112	0.091	97
CO	0.211	0.0638	10	0.373	0.2808	341	0.615	2.3401	97
O_3	0.021	0.008	10	0.020	0.008	342	0.020	0.010	97
CH_4	1.9	0.03	10	1.7	0.55	342	1.6	0.79	97
NMHC	0.010	0.013	10	0.016	0.049	341	0.038	0.132	97

Table 6f. Onshore/Offshore Ratio

	PS2	**PS3**	**PS4**	**PS5**	**SR**
i-PAH	1.56	0.87	1.42	1.34	2.36
PM10	0.93	0.98	1.07	1.27	1.22
PM2.5	0.94	1.05	1.38	0.96	1.33
CO_2	0.99	0.97	0.93	0.98	1.07
SO_2	1.01	0.98	1.96	1.44	7.44
Bscat	0.59	0.63	0.77	0.58	1.00
BC_370	1.14	0.76	1.61	1.33	2.77
NO_x					3.53
NO_2					2.18
NO					4.32
CO					1.77
O_3					0.97
CH_4					0.89
NMHC					1.57

Findings

The average concentrations during onshore winds and offshore winds were within 10% of each other for the following species:

- PM10, PM2.5, CO_2 and SO_2 at PS2
- PM10, PM2.5, CO_2 and SO_2 at PS3
- PM10 and CO_2 at PS4
- PM2.5 and CO_2 at PS5
- CO_2, Bscat and O_3 at SR

The average concentrations were at least 10% higher during onshore winds than during offshore winds for the following species:

- i-PAH at PS2, PS4, PS5 and SR
- PM10 at PS5 and SR
- PM2.5 at PS4 and SR
- SO_2 at PS4, PS5 and SR
- BC at PS2, PS4, PS5 and SR
- NO_x, NO_2, NO, and NMHC at SR

The average concentrations were at least 10% lower during onshore winds than during offshore winds for the following species:

- i-PAH at PS3
- Bscat at PS2, PS3, PS4 and PS5
- BC at PS3
- CH_4 at SR

UFP by Wind Sector

Tables 7a – 7e present the hourly average UFP results by wind sector for each of the five sites. The ratios of the average UFP number counts measured during onshore winds to those measured during offshore winds or during transition periods are presented in Tables 7f and 7g.

Table 7a. Hourly Average UFP Number Count at PS2

	Offshore (11%)		Onshore (81%)		Transition (8%)	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Total	42,810	21,082	62,010	34,677	114,638	47,644
UFP-1	30,199	18,462	50,026	30,040	96,054	45,286
UFP-2	6,583	1,859	5,963	2,979	8,722	1,788
UFP-3	297	37	164	76	255	107

Table 7b. Hourly Average UFP Number Count at PS3

	Offshore (5%)		Onshore (77%)		Transition (18%)	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Total	50,160	30,566	24,680	19,300	26,604	24,106
UFP-1	36,575	23,844	16,521	13,899	18,428	17,589
UFP-2	6,898	4,423	4,483	4,493	4,215	4,131
UFP-3	240	97	170	57	161	54

Table 7c. Hourly Average UFP Number Count at PS4

	Offshore (9%)		Onshore (70%)		Transition (21%)	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Total	24,902	13,542	175,572	109,106	74,070	61,673
UFP-1	17,071	13,267	161,501	103,587	65,246	58,230
UFP-2	4,459	1,143	6,725	3,272	4,579	2,374
UFP-3	160	100	213	86	229	92

Table 7d. Hourly Average UFP Number Count at PS5

	Offshore (14%)		Onshore (65%)		Transition (21%)	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Total	23,547	12,634	86,213	45,203	58,492	37,936
UFP-1	16,602	11,870	75,431	42,243	50,413	35,383
UFP-2	4,462	2,631	5,717	2,605	4,613	2,201
UFP-3	284	79	269	72	253	68

Table 7e. Hourly Average UFP Number Count at SR

	Offshore (4%)		Onshore (71%)		Transition (26%)	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Total	308,662	212,384	921,267	539,140	819,062	639,775
UFP-1	288,076	201,746	869,697	513,835	769,563	609,494
UFP-2	11,126	5,607	23,971	12,457	24,351	16,596
UFP-3	287	60	316	105	386	113

Table 7f. Onshore UFP/Offshore UFP Ratio

	PS2	PS3	PS4	PS5	SR
Total	1.45	0.49	7.05	3.66	2.98
UFP-1	1.66	0.45	9.46	4.54	3.02
UFP-2	0.91	0.65	1.51	1.28	2.15
UFP-3	0.55	0.71	1.33	0.95	1.10

Table 7g. Onshore UFP/Transition UFP Ratio

	Onshore/Transition				
	PS2	PS3	PS4	PS5	SR
Total	0.54	0.93	2.37	1.47	1.12
UFP-1	0.52	0.90	2.48	1.50	1.13
UFP-2	0.68	1.06	1.47	1.24	0.98
UFP-3	0.64	1.06	0.93	1.26	0.82

Findings

- PS2: The total UFP number count as well as the number count for the UFP-1 component (representing condensable particles) and the UFP-2 component (representing carbonaceous particles from aircraft) were significantly higher for winds in transition than for either offshore or onshore winds; the number count for the UFP-3 component (representing non-aircraft particles) was similar for all wind sectors.
- PS3: The total UFP number count as well as the number count for the UFP-1 component and the UFP-2 component were significantly higher for offshore winds than either of the other two wind sectors where the number counts were similar; the number count for the UFP-3 component was similar for all wind sectors.
- PS4 and PS5: The total UFP number count as well as the number count for the UFP-1 component and the UFP-2 component were significantly higher for onshore winds than for either offshore winds or winds in transition between onshore and offshore with the number count for offshore winds being the lowest of the three wind regimes; the number count for the UFP-3 component was similar for all wind sectors.
- SR: The total UFP number count as well as the number count for the UFP-1 component were significantly higher for onshore winds than for offshore winds and only slightly higher than for winds in transition between onshore and offshore; the number count for the UFP-2 component were similar for both onshore winds and for winds in transition between onshore and offshore, with both significantly higher than that for offshore winds; the number count for the UFP-3 component was similar for all wind sectors.

CONCLUSIONS

Methods Used to Quantify Pollutants

The instruments used to quantify the concentrations of the species of interest have been used extensively in field projects in the past and are generally reliable. There were some equipment malfunctions during the Demonstration Project that took some time to be remedied. They included (a) the TSI Model 3091 FMPS used to monitor UFP concentrations (up to a week to repair the instrument in one case), (b) the MetOne BAM-100 used to measure PM10 (3 days to repair), and (c) the Radiance Research Model M903 with heater to measure Bscat (3 days to replace the light source). Both PM2.5 and PM10 monitors are required for the Phase 3 study since they provide short-time resolved measurements that will complement the 12-hour filter-based sampling methods for source apportionment.

Data Recovery Rate for the Methods Used

The data recovery rate for all species was generally high except for times that of monitoring equipment failure.

Methods Needing Revision

The Thermo Scientific Model 43C instrument used to measure SO_2 is not sensitive enough; many of the readings at all sites other than SR were near the detection level of 1 ppb.

It is imperative that a reliable met station capable of providing wind speed and wind direction measurements that are representative of the study area be utilized in the Phase 3 study.

An instrument capable of obtaining real-time measurements of speciated hydrocarbons would be a useful addition to the suite of monitors to be deployed during the Phase 3 study.

A seven-channel aethalometer for the Phase 3 study is overkill; a dual channel unit to monitor black carbon at 370 nm and at 880nm will suffice.

Based on the results of the Demonstration Project, a 32-channel FMPS to measure UFP number concentrations for the Phase 3 study is overkill; a one or two channel condensation nuclei counter (CPC) will suffice to measure condensable particulate matter with diameters below 30 nm. This UFP component is the most abundant of the three UFP components in terms of number count. It should be pointed out that UFP number count is not used for source apportionment and that the total UFP number count decreases very rapidly with distance from the source. Although UFP measurements were not conducted at more than one site at a time during the Demonstration Project to quantify how much the UFP number count decreases with distance, the results for SR, PS4 and PS5 tell the following story: the average total UFP number count dropped by 84% from ~870,000/cc at SR to ~140,000/cc at PS4 (approximately 850 feet from SR), and by an additional 50% to ~70,000/cc at PS5 (approximately 800 feet from PS4).

Methods Failing to Provide Useful Data

The Thermo Scientific Model 49C instrument used to measure O_3 obtained reliable results but the results are not used for source apportionment.

It is unclear how measurements of i-PAH would be useful in the Phase 3 study since the EcoChem PAS Model 2000 does not measure PAH concentrations directly. Instead, the instrument reads a current that may be proportional to PAH concentration. Therefore, the instrument gives semi-qualitative readings of PAHs at best.

Impact of Wind Direction on Pollutant Concentrations

The concentrations of most species monitored during the Demonstration Project were generally highest during onshore wind conditions. The exceptions were:

- light scattering (Bscat) measurements at PS2, PS3 and PS5 were highest during offshore wind conditions;
- light scattering (Bscat) measurements at PS4 and SR were highest for winds in transition between onshore and offshore;
- black carbon (BC) levels at PS2 were highest for winds in transition between onshore and offshore;
- black carbon (BC) levels at PS3 were highest for offshore winds;
- CO_2 levels at PS2 were highest for winds in transition between onshore and offshore;
- CO_2 levels at PS3, PS4 and PS5 were highest during offshore wind conditions;
- CO and NMHC levels at SR were highest for winds in transition between onshore and offshore; and
- CH_4 levels at SR were highest during offshore wind conditions.

FINAL REMARKS

The Demonstration Project obtained monitoring data that may not be representative of a full 12-month's of monitoring. Thus, some of the findings and conclusions presented in this report may not be applicable for the Phase 3 study.

WORKING DRAFT

Evaluation of Sampling Data from the LAX Air Quality Source Apportionment Study's Demonstration Project

Prepared for CDM by

Countess Environmental

May 17, 2011

INTRODUCTION

This report summarizes Countess Environmental's (CE) evaluation of the sampling data collected from July through August 2008, as part of the Technology and Methodology Feasibility Demonstration Project (Demonstration Project) at LAX. This evaluation is being conducted to provide the Los Angeles World Airport's (LAWA) on-call environmental contractors with information for the Long-Term Study. A future report will summarize CE's evaluation of speciated light hydrocarbon measurements collected at LAX during the Demonstration Project.

The evaluation of the sampling data focused on the following areas:

- Were the methods used able to quantify the concentrations of the pollutants of interest?
- What was the data recovery rate for the methods used?
- Which methods need to be revised?
- Which methods failed to provide useful data?
- Assessment of the impact of wind direction on pollutant concentrations.
- Assessment of the optimal averaging period for sample collection.
- Examining ratios of pollutants to look for potential markers for source apportionment.

The locations of the five monitoring sites are shown in Figure 1. These sites were: South Runway (SR) located behind the blast fence at Runway 25R, Portable Site 2 (PS2) located in a parking lot in the Central Terminal Area, Portable Site 3 (PS3) located in a cargo operations area, Portable Site 4 (PS4) located approximately 850 feet east of SR, and Portable Site 5 (PS5) located approximately 1,650 feet east of SR. Sampling was conducted at one site at a time, starting with nine days of sampling at the SR site, followed by seven days of sampling at the other four sites.

Figure 1. Demonstration Project Monitoring Site Locations

The equipment used to sample the different ambient species is identified in Table 1. As one can see from this table, a core set of PM2.5 particulate samples plus gas phase species was collected at each site for subsequent analysis. The sampling duration for most samples was 12 hours (8 AM to 8 PM and 8 PM to 8 AM), whereas the sampling duration for the Minivol sampler and the Summa canisters was 24 hours (8 AM to 8 AM the next day). The core set of samplers was augmented at the SR site with additional sampling equipment to expand the types of measurements being made as well as including measurements by more than one method. Deposition plates were deployed at SR in triplicate for two one-week periods and then discontinued. Detection limits for each analyte are presented in Table 2. Since the sampling volume for the 24-hour Minivol filter samples was the same as that for the 12-hour aerosol speciation sampler (i.e., 7.2 cubic meters, m^3), the detection limits are the same for both samplers. The sample volumes for the DNPH cartridge samplers for carbonyls and the Tenax charcoal cartridge samplers for heavy hydrocarbons were 0.5 m^3 and 0.36 m^3, respectively.

Table 1. Sampling Equipment Used During the Demonstration Project

Species Measured	Sampler	Sampling Media	Sites	Sampling Period
PM2.5 Mass, Ammonium & Elements	Speciation Sampler	Teflon Filter (47 mm diameter)	All	12-hr
PM2.5 Mass, Ions, Carbon	Speciation Sampler	Quartz Filter (47 mm diameter)	All	12-hr
Nitrate	Speciation Sampler	Sodium Chloride Coated Filter	All	12-hr
Nitric Acid as Nitrate	Speciation Sampler	Sodium Carbonate Coated Denuder	All	12-hr
Ammonia as Ammonium	Speciation Sampler	Citric Acid Coated Denuder	SR	12-hr
Ammonium	Speciation Sampler	Citric Acid Coated Filter	SR	12-hr
PAHs, Hopanes and Steranes	Speciation Sampler	Quartz Filter (47 mm diameter)	All except PS4	12-hr
PM2.5 Mass, Ammonium & Elements	Minivol	Teflon Filter (47 mm diameter)	SR	24-hr
PM2.5 Mass, Ions, Carbon	Minivol	Quartz Filter (47 mm diameter)	SR	24-hr
PAHs, Hopanes and Steranes	Minivol	Quartz Filter (47 mm diameter)	SR	24-hr
Carbonyls	DNPH Impregnated Silica Del Cartridge		Sr	12-hr
Heavy Hydrocarbons (C9-C41)	Charcoal Sorbent Cartridge		SR	12-hr
Number and composition of deposited particles	Deposition Plate	Oiled Teflon Filter	SR	1-week

The quartz filters were prefired before sampling to minimize the organic background.

Table 2. Detection Limits for Compounds Measured

Analyte	Detection Limit
PM2.5 Mass on Teflon filters	1.0 μg/m^3
PM2.5 Mass on Quartz filters	18 μg/m^3
PM2.5 Elements by XFR or by ICP/MS	0.003-0.3 μg/m^3
PM2.5 Elements by ICP/MS	0.001-0.002 μg/m^3
PM2.5 Ions	0.004-0.04 μg/m^3
NH_3 as NH_4^+ on citric acid coated denuder (CAD)	0.11 – 0.12 μg/m^3
NH_4^+ on citric acid coated filter (CF2)	0.11 – 0.12 μg/m^3
HNO_3 as NO_3^- on sodium carbonate coated denuder (SCD)	0.13 – 0.15 μg/m^3
NO_3^- on sodium chloride coated filter (SF2)	0.13 – 0.15 μg/m^3
PM2.5 Carbon	0.8 – 2.1 μg/m^3
PM2.5 PAHs, Hopanes and Steranes	0.001 – 0.004 μg/m^3
Light Hydrocarbons by TO-12	1 ppbC
Light Hydrocarbons by TO-15	0.2-0.5 ppbV
Heavy Hydrocarbons	15 μg/m^3
Carbonyls	0.075 μg/m^3

Note: Many of the Detection Limits are higher than those listed in the Quality Assurance Program Plan (QAPP).
μg/m^3 = micrograms per cubic meter
ppbC = parts per billion carbon
ppbV = parts per billion by volume

The samples were analyzed using the following analytical methods:

- Mass by gravimetry.
- Ions (K^+, NH_4^+, Na^+, NO_3^- and $SO_4^=$) by EPA Method IO-4.2 (IC and AA).
- 44 elements (Al, Sb, Ba, Br, Ca, Ce, Cs, Cl, Cr, Co, Cu, Eu, Ga, Au, Hf, In, Ir, Fe, La, Pb, Mg, Mo, Ni, Nb, P, K, Ru, Sm, Sc, Se, Si, Ag, Na, Sr, S, Ta, Tb, Sn, Ti, W, V, Yb, Zn, and Zr) by XRF (X-ray Fluorescence).
- 12 elements (Sb, As, Be, Cd, Cr, Pb, Mn, Hg, Ni, Sr, V, and Zn) by ICP/MS (Inductively Coupled Plasma Spectroscopy/Mass spectrometry).
- Carbon by IMPROVE_A: DRI Model 2001 Thermal Optical (TOR/TOT) analyzer.
- PAHs, hopanes and steranes by GC/MS (Gas Chromatography/Mass Spectrometry, EPA Method TO13M).
- Carbonyls by HPLC (High-performance liquid chromatography, EPA Method TO-11).
- Light hydrocarbons by GC-FID (Gas Chromatography with Flame Ionization Detector, EPA Method TO-12 [PAMS]) and by GC/MS (Gas Chromatography/Mass Spectroscopy, EPA Method TO-15).
- Heavy hydrocarbons (C9-C41) by GC-FID (Gas Chromatography with Flame Ionization Detector, EPA Method 8015D/GC-MS).
- Chemical composition and number count of deposited particles by CCSEM (Computer-controlled scanning electron microscopy).

SUMMARY OF SAMPLING DATA

Measurements above Detection Limit

The concentrations of many species for the samples collected during the Demonstration Project were below the detection limits shown in Table 2. Thus, revisions to either the sampling method or the analytical method or both will be required for the Long-Term Study. The percentages of records above detection limits for the different species measured during the Demonstration Project are summarized below.

- Ions on quartz filters: 30% for K^+, 97% for Na^+, NH_4^+, NO_3^-, and $SO_4^=$
- Sodium chloride coated filter: 77% for NO_3^-
- Elements by ICP/MS: 0% for antimony, arsenic, beryllium, cadmium, and mercury; 33% for manganese, 50% for strontium; 100% for chromium, lead, nickel, vanadium, and zinc.
- Elements by XRF: 0% for barium, cerium, cesium, europium, gallium, gold, hafnium, iridium, molybdenum, niobium, phosphorus, rubidium, samarium, scandium, selenium, tantalum, terbium, tin, tungsten and yttrium; less than 10% for antimony, chromium, cobalt, indium, lanthanum, lead, silver, strontium, titanium, and zirconium; 31% for zinc; 51% for nickel; 57% for copper; 61% for vanadium; 65% for aluminum; 88% for bromine; 94% for magnesium; 97% for silicon; 100% for calcium, iron, potassium, sodium and sulfur.
- Carbon by IMPROVE: 0% for E3 and O4; 20% - 40% for E1, E2, Total EC by TOR, Total EC by TOT; ~50% for O3; ~75% for O1, Total OC by TOR, Total OC by TOT, PC by TOR, and PC by TOT; 93% for O2 and Total Carbon.
- Carbonyls: 7% for m-tolualdehyde; 28% for acrolein; 50% for butyraldehyde; 71%-79% for crotonaldehyde, hexaldehyde, and methyl ethyl ketone; 86%-93% for methacrolein and valeraldehyde; 100% for acetaldehyde, benzaldehyde, formaldehyde and propionaldehyde.
- PAHs, Steranes and Hopanes: 1%. Only 23 compounds were detected above their respective ultra low detection limits as shown in Table 3. No compounds were detected at PS4 or PS5. If these species are to be included in the Long-Term Study, either lower detection limits will be needed, or larger sample volumes will be needed, or both.
- Heavy Hydrocarbons: 1%. There were only three records where heavy hydrocarbons were detected above their respective detection limits of 15-20 $\mu g/m^3$. They all occurred on the same day at the SR site (C9-C11, C12-C13 and C14-C15). If these species are to be included in the Long-Term Study, either lower detection limits will be needed, or larger sample volumes will be needed, or both.

Table 3. PAHs, Steranes and Hopanes Above Detection Limit

Compound	12-hr Day	12-hr Night	24-hr Minivol
17A(H)-21B(H)-HOPANE	PS2, SR	PS3	SR
17B(H)-21A(H)-30-NORHOPANE		PS2	
ACEPHENANTHRYLENE	SR	PS2, SR	
BENZO(A)PYRENE		PS2	
BENZO(B)FLUORANTHENE		PS2	
BENZO(E)PYRENE		PS2	
BENZO(J)FLUORANTHENE		PS2	
BENZO(K)FLUORANTHENE		PS2	
CHRYSENE		PS2	
INDENO(1,2,3-CD)PYRENE		PS2	
ABB-20R-C29-SITOSTANE		PS3	
ABB-20S-C29-SITOSTANE		PS3	
BENZO(GHI)FLUORANTHENE	SR		
FLUORANTHENE	SR	SR	
PYRENE	SR	SR	
AAA-20S-C27-CHOLESTANE			SR

Evaluation of Sampling Data

To address the questions listed in the Introduction, CE's approach for evaluating the limited number of samples collected during the Demonstration Project focused on identifying daytime versus nighttime differences as well as differences between sites rather than focusing on the actual concentrations observed. CE's findings regarding PM2.5 mass measurements are summarized below, followed by a discussion of the sampling results for the different chemical species.

Findings Regarding the PM2.5 Mass Measurements

- The PM2.5 mass concentrations obtained on quartz filters are suspect; quartz filters are not normally used to measure mass since the filters often lose fibers during handling.
- PM2.5 mass concentrations were measured on both quartz and Teflon filters at all five sites with the measurements on the quartz filters 23% higher on the average than those obtained for the Teflon filters.
- The PM2.5 mass concentrations measured on the Teflon filters designated as the A4 filters were approximately 10% lower than that measured on the Teflon filters designated as the A1 filters (SR site only).
- The daytime (8 AM-8 PM) PM2.5 concentrations were similar to the nighttime (8 PM-8 AM) concentrations.
- The continuous BAM measurements of PM2.5 were higher than the measurements obtained with the aerosol speciation sampler at all five sites by an average of 42%, and higher than the measurements obtained with the Minivol at SR by an average of 23%.

Elements Measured by XRF

Figures 2 and 3 show the average daytime (8 AM to 8 PM) and nighttime (8 PM to 8 AM) concentrations of elements measured by XRF. Ratioing concentrations of different species at one site to those at another site (this is called normalization) has the advantage of placing all species on an equal basis regardless of their concentration. Figures 4 and 5 show the average daytime and nighttime concentrations of elements measured by XRF at each site normalized to (i.e., divided by) the concentrations observed at the SR site. In looking for a marker for source apportionment, previous studies have normalized the concentrations for individual species to a common species. Figures 6 and 7 show the elements measured by XFR normalized to sulfur. Sulfur was selected because it may serve as a marker for sulfur in jet fuel. Figures 8 and 9 show the ratios of elements measured by XFR normalized to sulfur at each site divided by the corresponding ratio for the SR site; this technique is referred to as “enhancement.”

Figure 2. Daytime Concentrations of Elements Measured by XRF

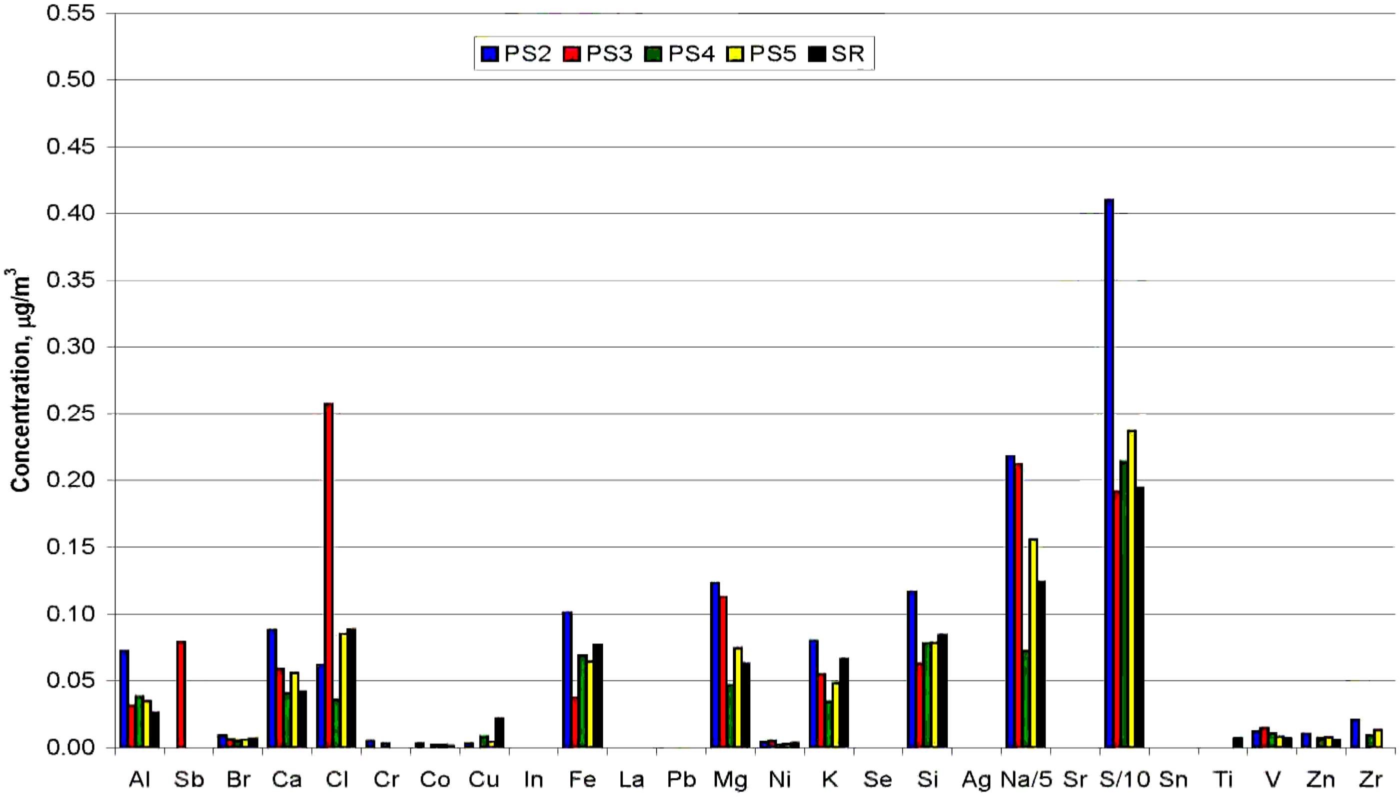


Figure 3. Nighttime Concentrations of Elements Measured by XRF

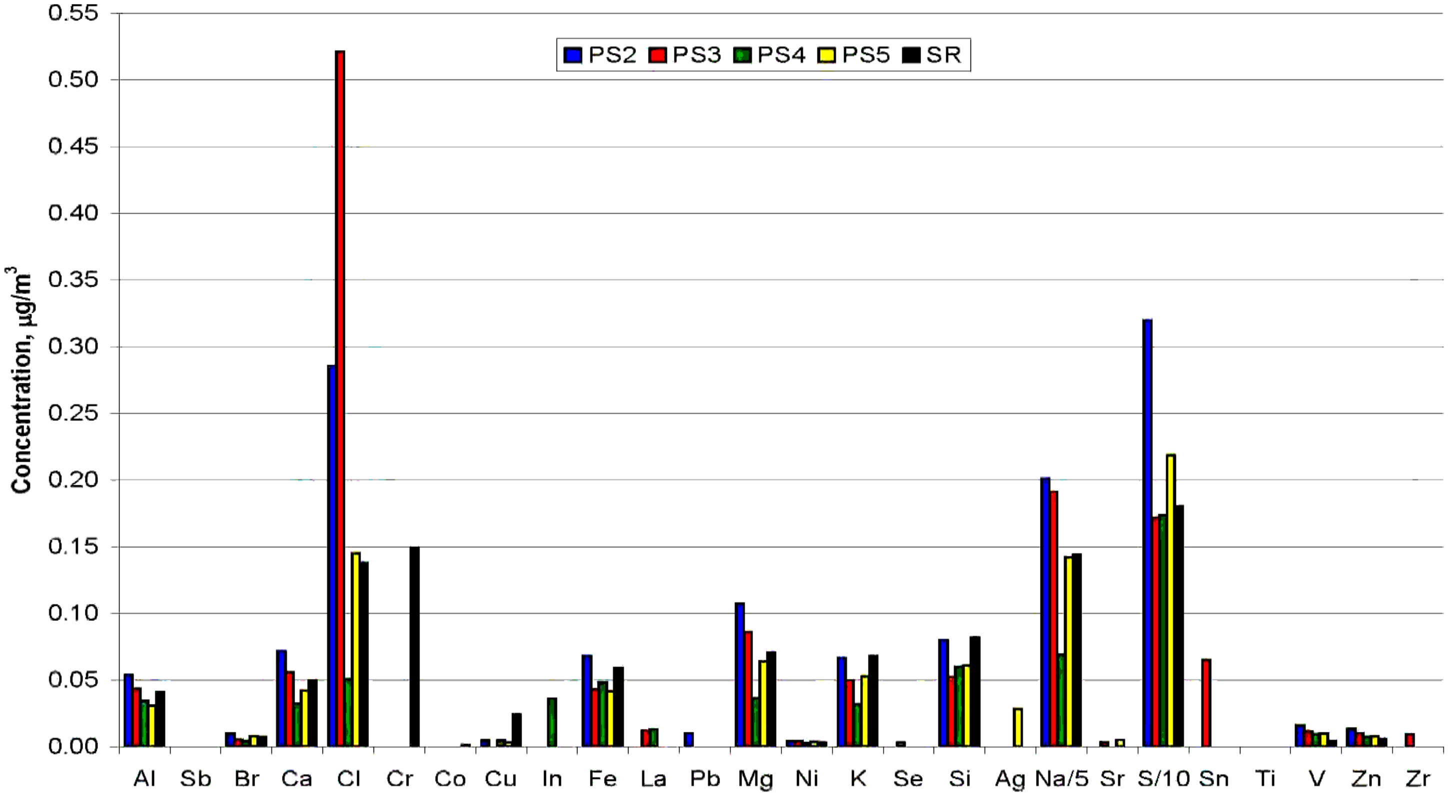


Figure 4. Daytime Ratios of Elements Measured by XRF Normalized to SR

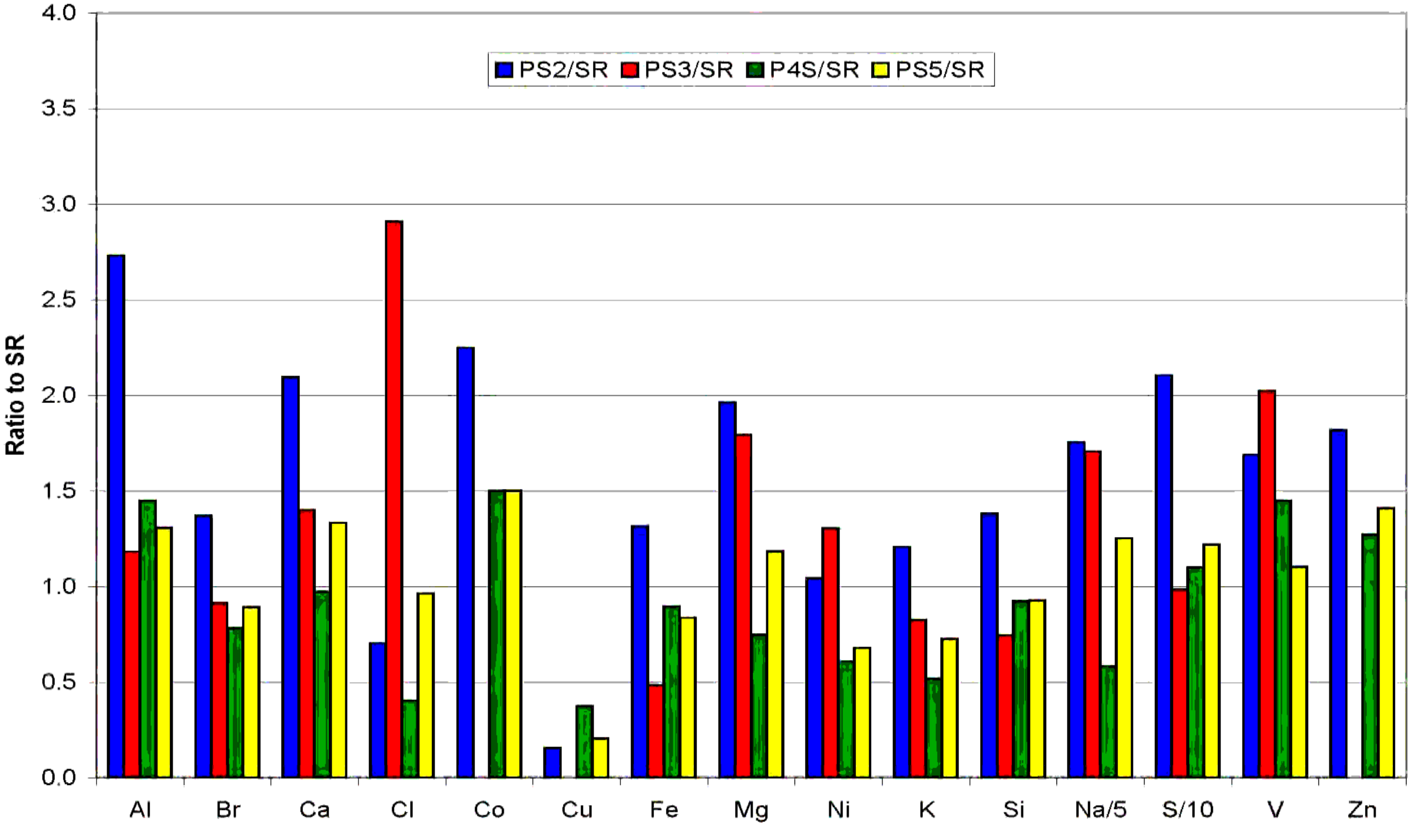


Figure 5. Nighttime Ratios of Elements Measured by XRF Normalized to SR

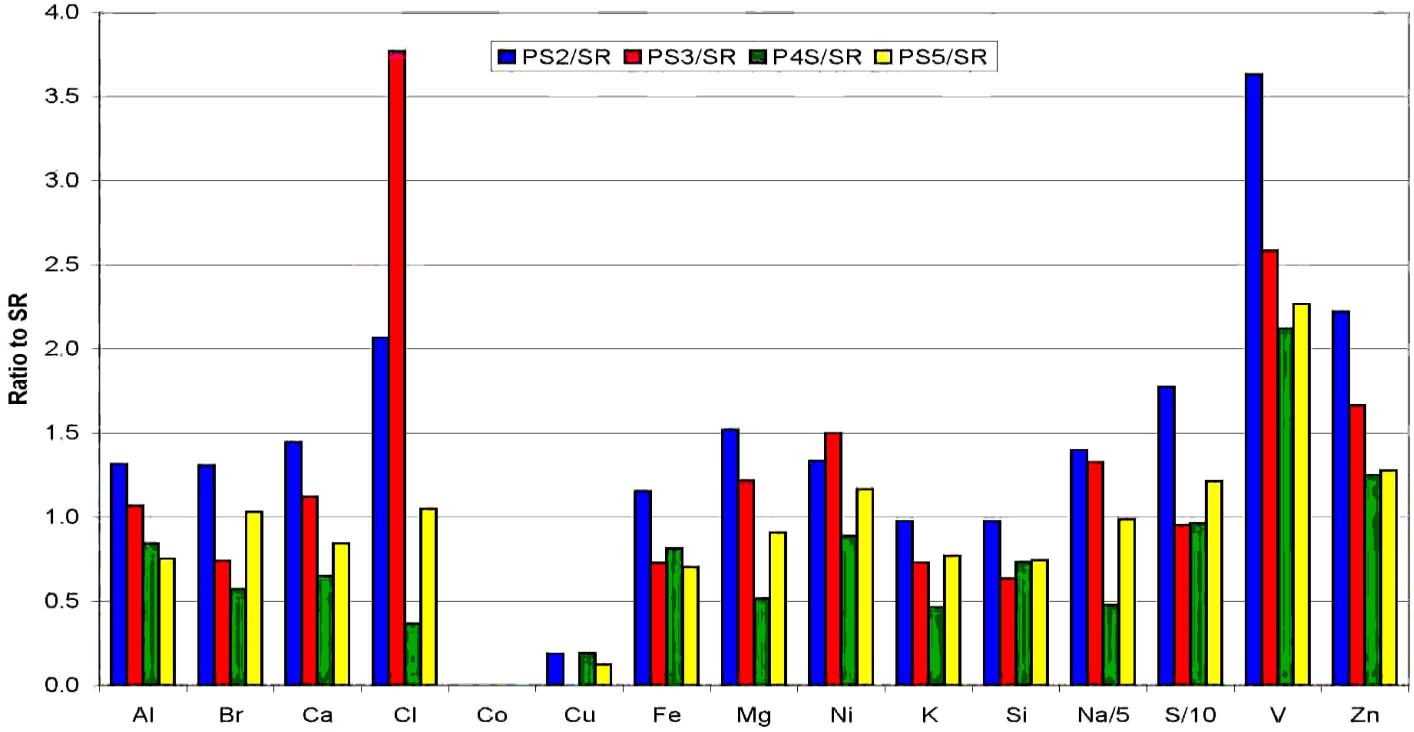


Figure 6. Daytime Ratios of Elements to Sulfur

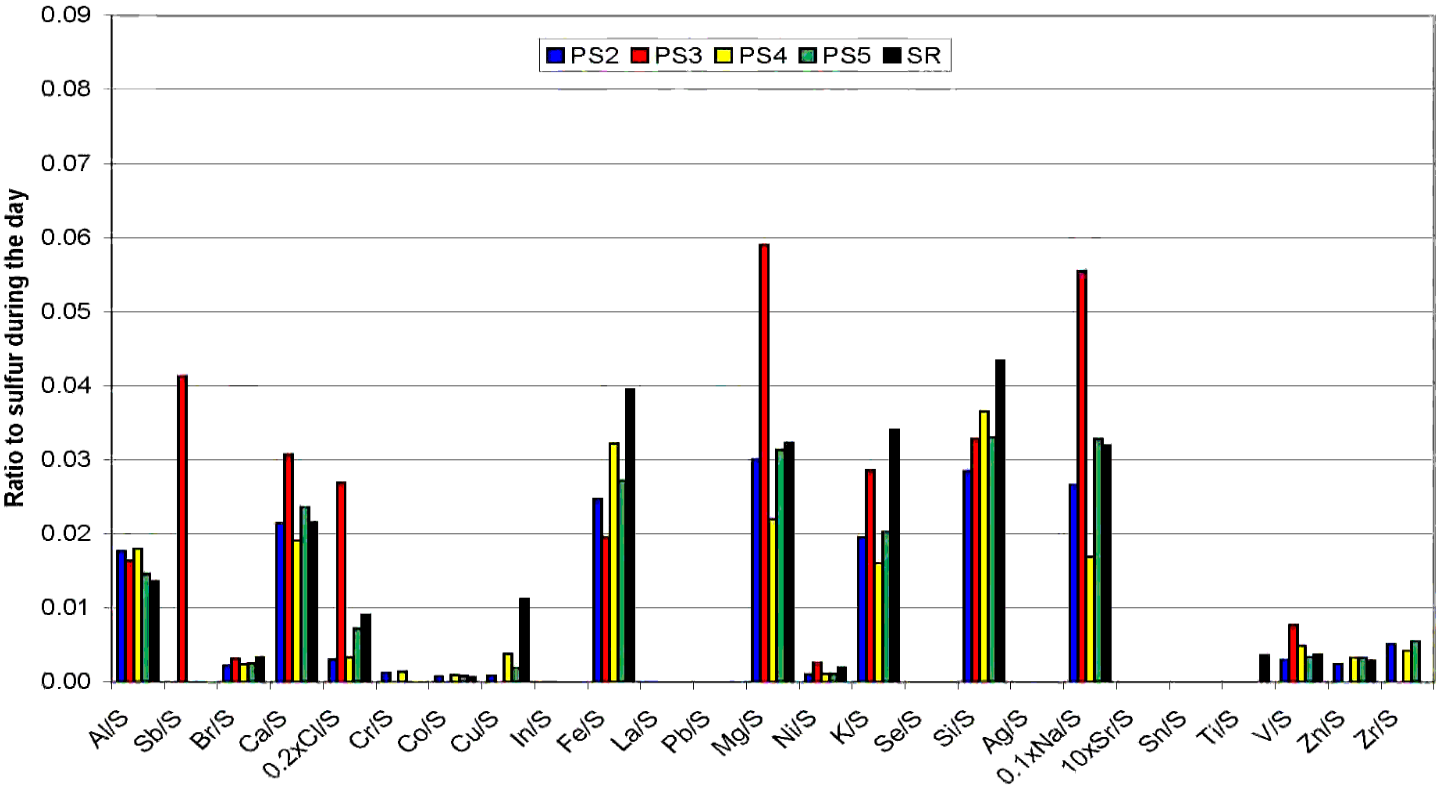


Figure 7. Nighttime Ratios of Elements to Sulfur

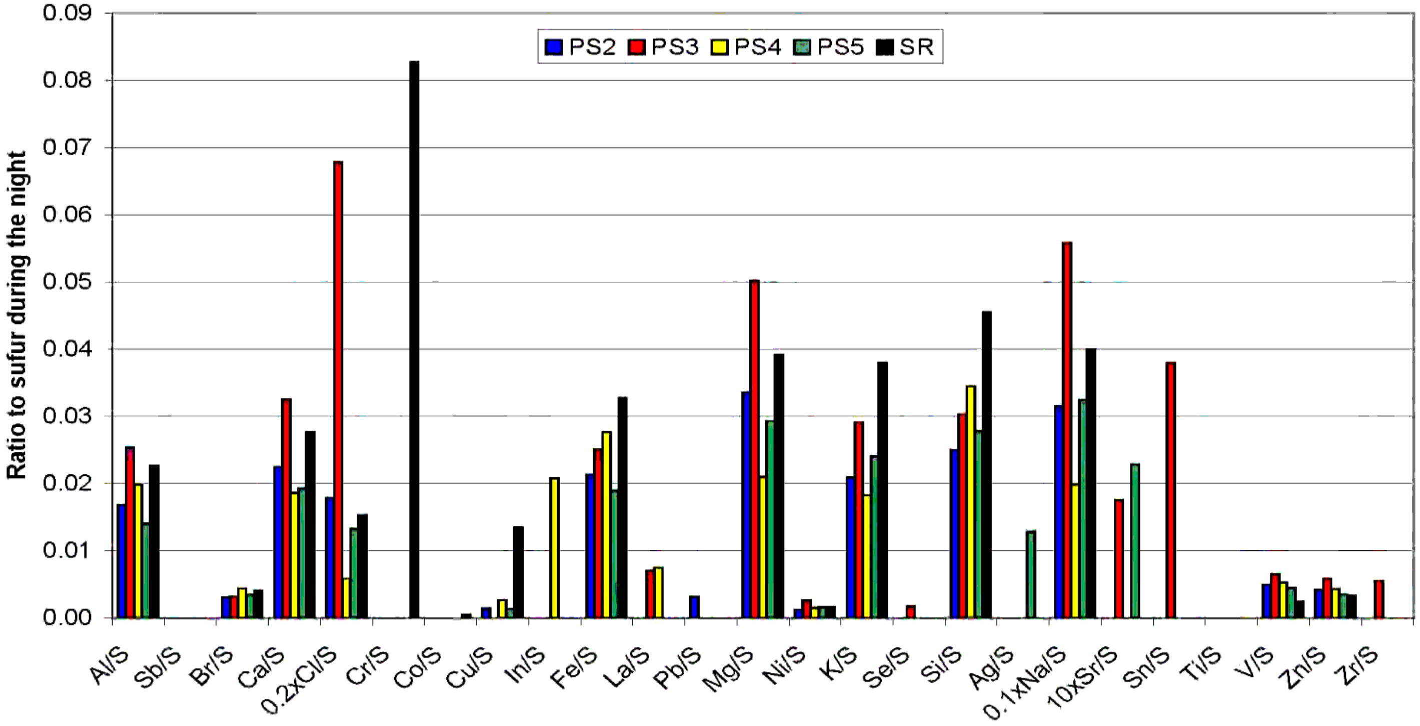


Figure 8. Daytime Ratio of Elements to Sulfur Normalized to Ratio at SR

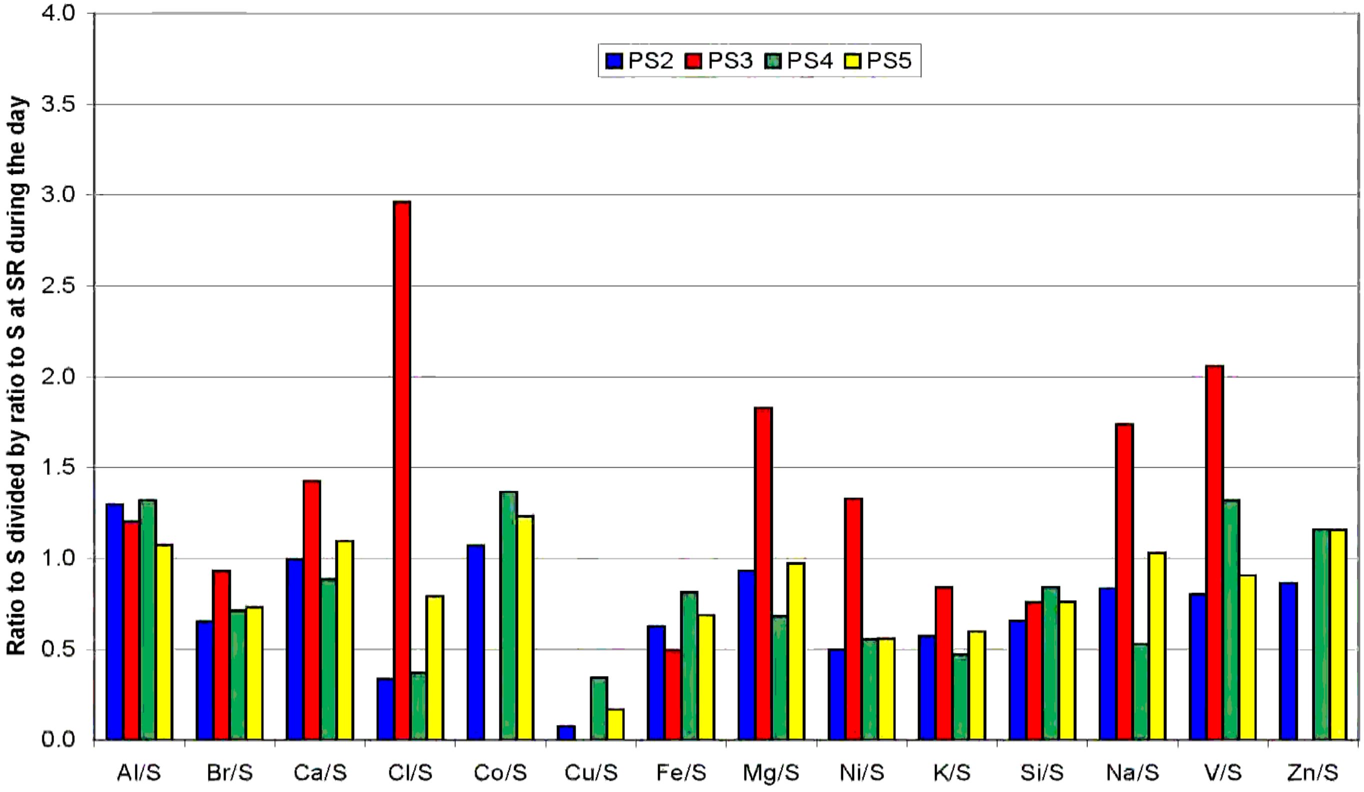
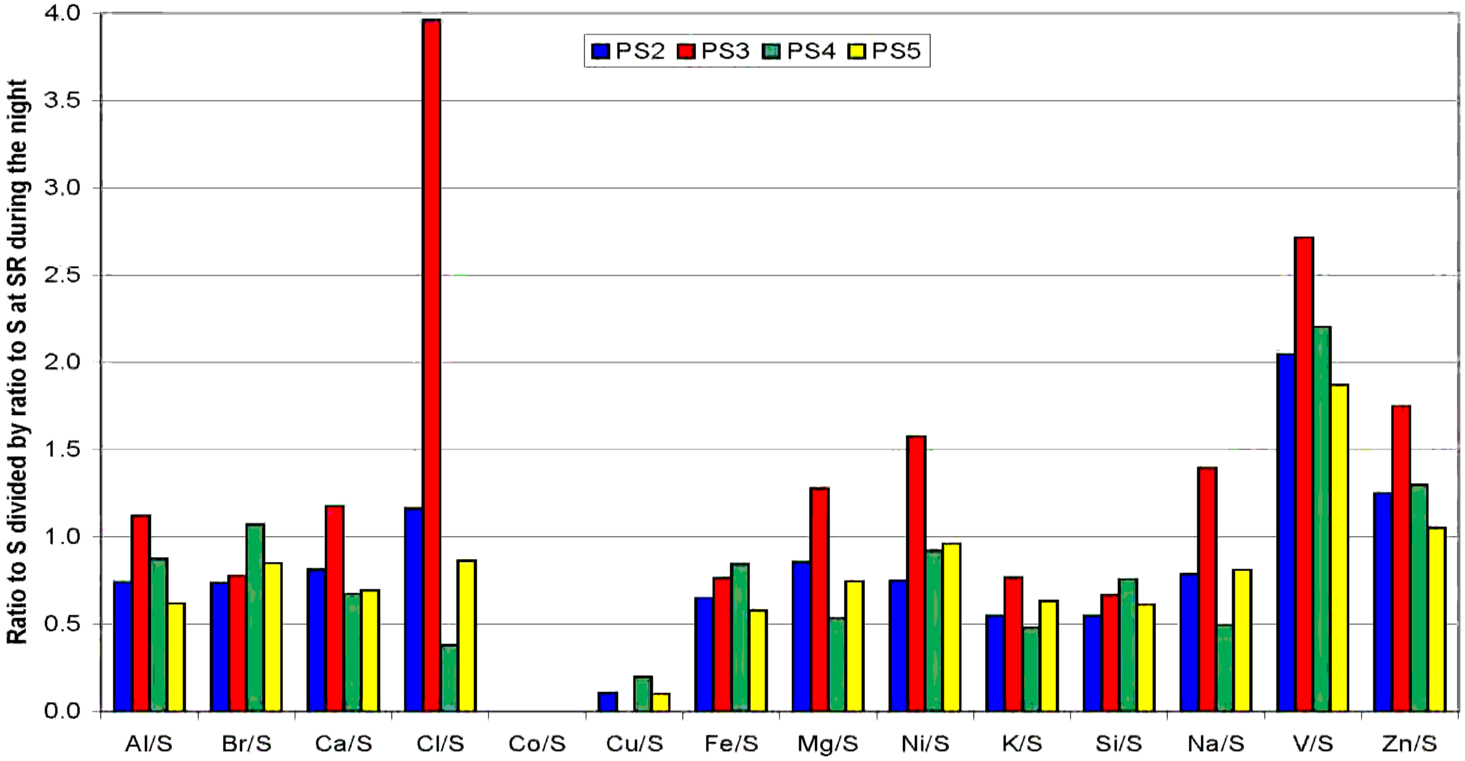


Figure 9. Nighttime Ratio of Elements to Sulfur Normalized to Ratio at SR



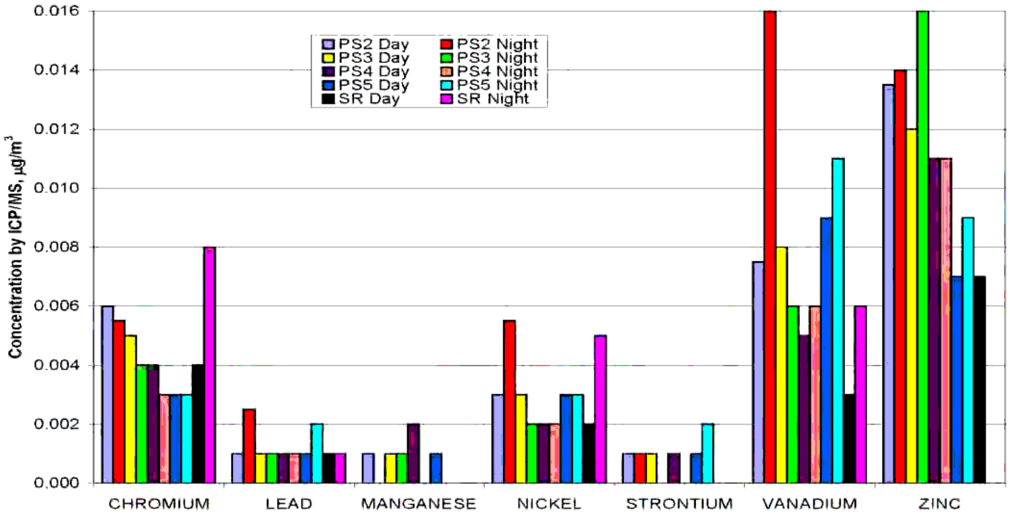
Findings Regarding the XRF Results

- The dominant elements were sulfur, sodium, and chlorine, indicating the presence of sea salt as well as sulfur compounds presumably associated with combustion of fuels containing sulfur.
- The PS2 site had the highest sulfur levels of all the sites, the highest daytime levels of aluminum and calcium, and the highest nighttime levels of vanadium.
- The PS3 site had substantially higher chlorine levels than the other sites.
- The SR site had the highest copper levels of all the sites.
- The daytime samples of calcium, chlorine, magnesium, nickel, sodium, and vanadium at the PS3 site had a higher ratio to sulfur than that observed at the SR site as did (a) aluminum at PS2, PS3 and PS4, (b) cobalt and zinc at PS4 and PS5, and (c) vanadium at PS4 (i.e., "enhancement" relative to the SR site"), whereas (a) bromine, copper, iron, potassium and silicon at all sites, (b) chlorine and nickel at PS2, PS3 and PS4, and (c) magnesium and sodium at PS4 at had lower ratios to sulfur than that observed at the SR site (i.e., "depletion" relative to the SR site).
- The nighttime samples of calcium, chlorine, magnesium, nickel, sodium, vanadium and zinc at the PS3 site had a higher ratio to sulfur than that observed at the SR site as did vanadium at PS2, PS4 and PS5 (i.e., "enhancement" relative to the SR site); whereas (a) cobalt, copper, iron, potassium and silicon at all sites, (b) aluminum, bromine, calcium, magnesium, nickel and sodium at PS2, (c) bromine at PS3, (d) aluminum, calcium, chlorine, magnesium, and sodium at PS4, and (e) aluminum, bromine, calcium, magnesium, and sodium at PS5 had lower ratios to sulfur than that observed at the SR site (i.e., "depletion" relative to the SR site).

Elements Measured by ICP/MS

The ICP/MS results for two daytime and two nighttime samples for PS2 plus one daytime and one nighttime sample for the other four sites are shown in Figure 10. One very large nighttime concentration of zinc observed at SR (0.099 $\mu g/m^3$) is not shown in Figure 10. The results shown in Figure 10 should be viewed with caution due to the very limited number of samples collected. The daytime results for manganese at PS2 is based on one 12-hour record. The results shown for lead, manganese and strontium are essentially equal to the detection levels for these three elements. Only the concentrations of chromium, nickel, vanadium and zinc were greater than twice their detection limits.

Figure 10. Diurnal Variation in Concentrations of Elements Measured by ICP/MS



Findings Regarding the ICP/MS Results

- For elements detected by ICP/MS and by XRF (Ni, V, and Zn), ICP/MS gave substantially higher readings than XRF.
- Although there is overlap between the elements measured by XRF and ICP/MS, one will need ICP/MS to measure arsenic, beryllium, cadmium, manganese, and mercury in the Long-Term Study.

Carbon Measurements

The method used to quantify carbon species on quartz filters is a hybrid IMPROVE method that incorporates TOR (Thermal Optical Reflectance) and TOT (Thermal Optical Transmittance). The laser light is reflected off the deposit (the TOR mode) as well as through the deposit (the TOT mode). During the analysis, some of the organic carbon is pryolyzed and looks like EC due to darkening of the deposit. The laser signal is used to determine how much pyrolyzed organic mass needs to be subtracted from EC and added back to OC. The equations used to determine the different carbon fractions are:

- OC_TOR (total OC by TOR method) = O1+O2+O3+O4+PCR
- OCT_TOT (total OC by TOT method) = O1+O2+O3+O4+PCT
- EC_TOR (total EC by TOR method) = E1+E2+E3-PCR
- EC_TOT = (total EC by TOT method) = E1+E2+E3-PCT
- TC (total carbon) = O1+O2+O3+O4+E1+E2+E3

Figures 11 and 12 show the average daytime and nighttime concentrations of the different carbon species. Figures 13 and 14 show the ratios of the daytime and nighttime concentrations normalized to total carbon. Figure 15 and 16 show the daytime and nighttime ratios of the different carbon species to total carbon at each site divided by the corresponding ratio for the SR site.

Figure 11. Daytime Concentrations of Carbon Species

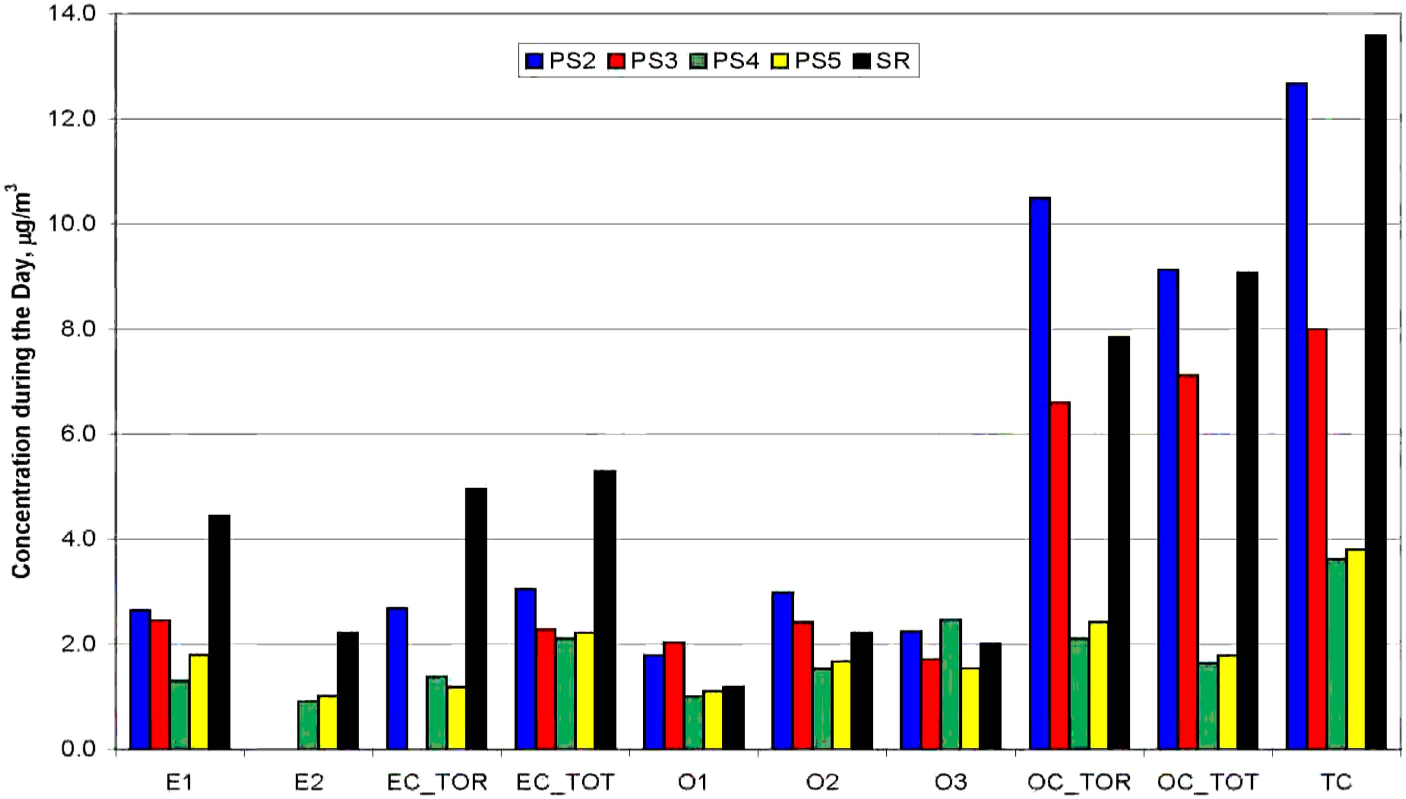


Figure 12. Nighttime Concentrations of Carbon Species

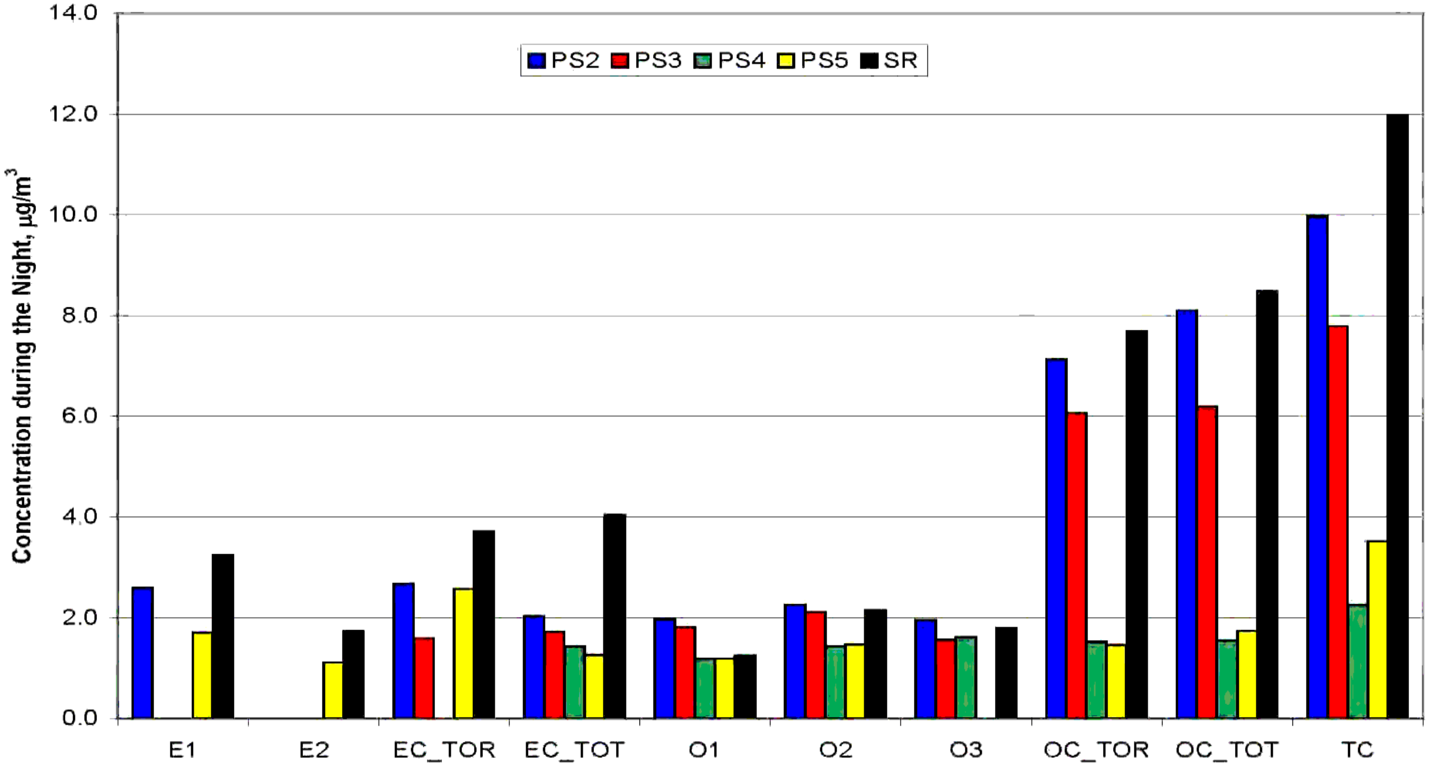


Figure 13. Daytime Ratios of Carbon Species to Total Carbon

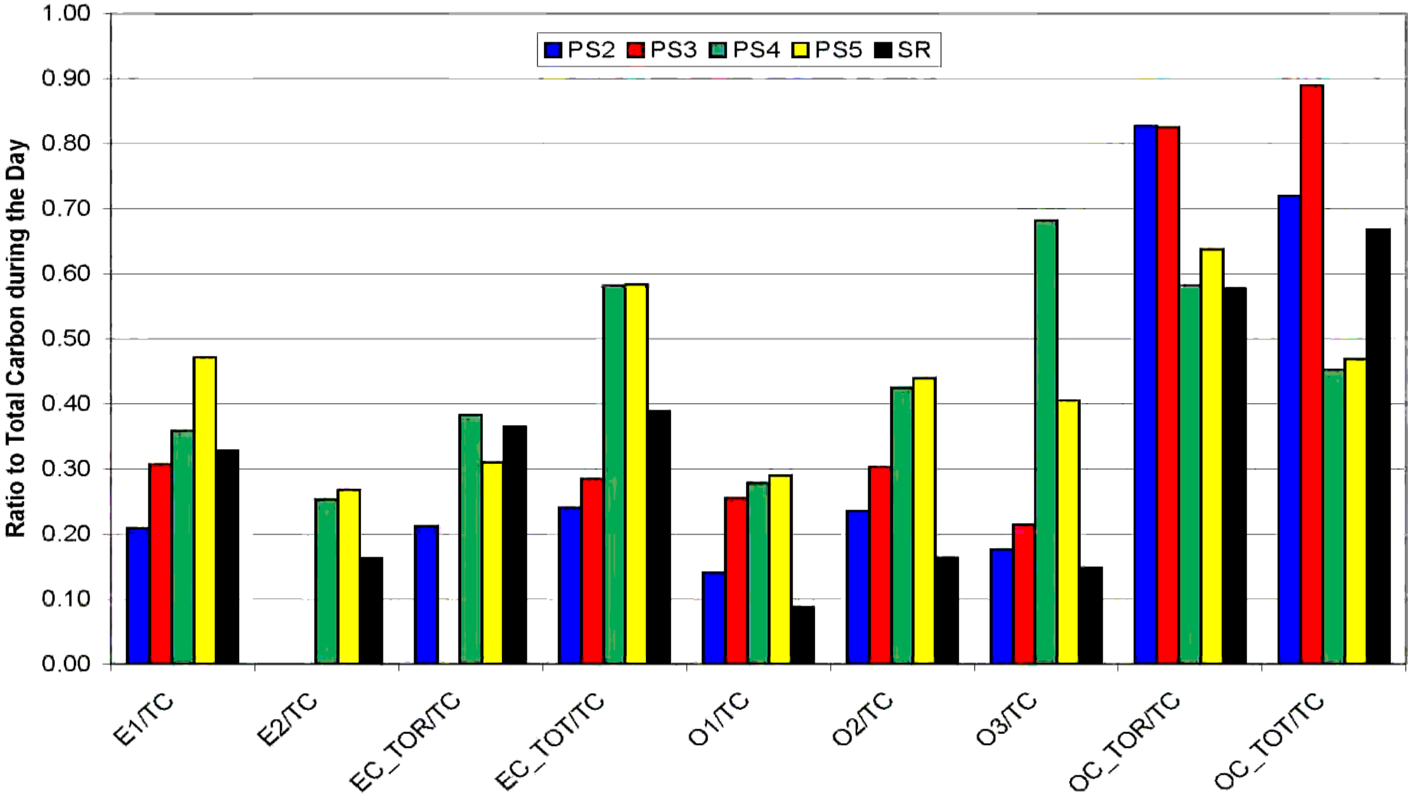


Figure 14. Nighttime Ratios of Carbon Species to Total Carbon

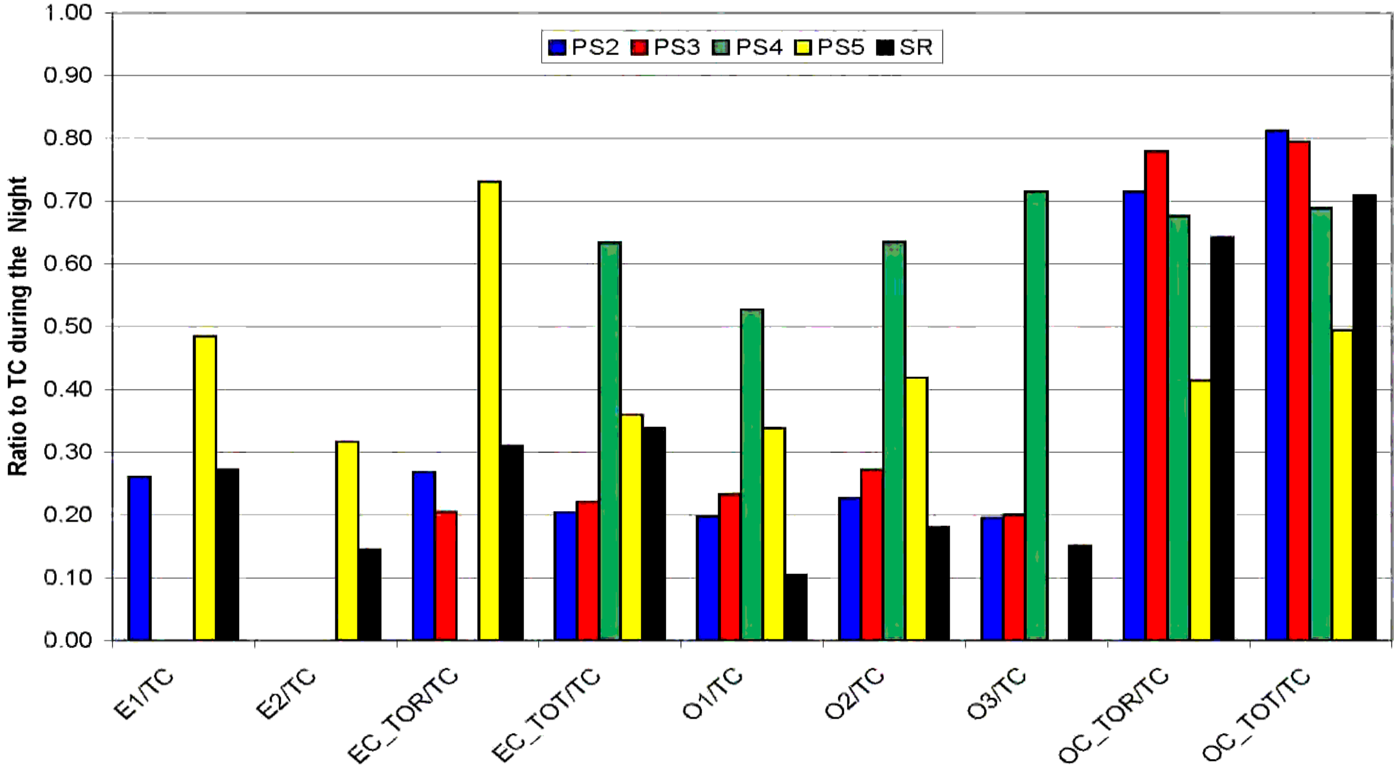


Figure 15. Daytime Ratio of Carbon Species to TC Normalized to Ratio at SR

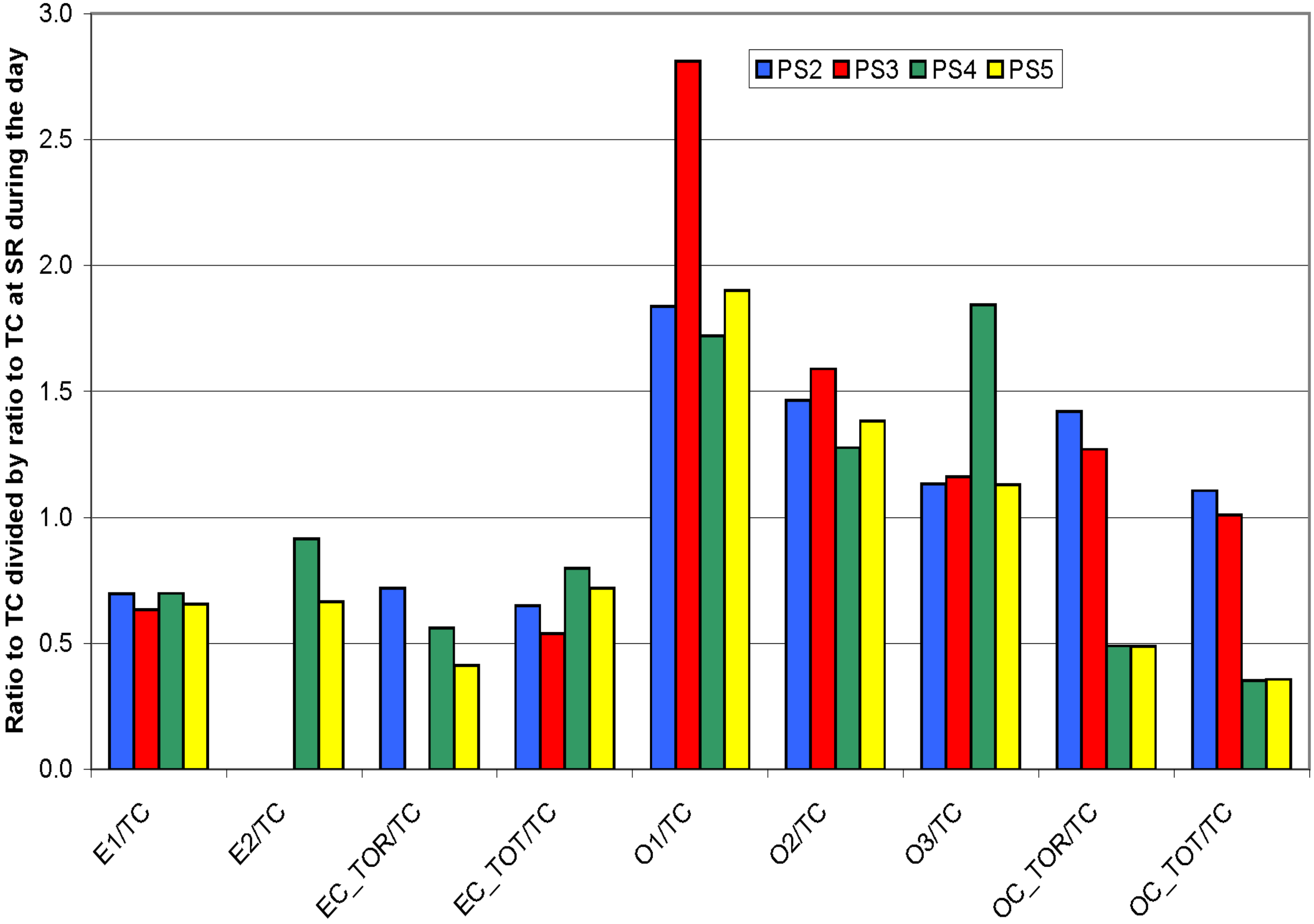
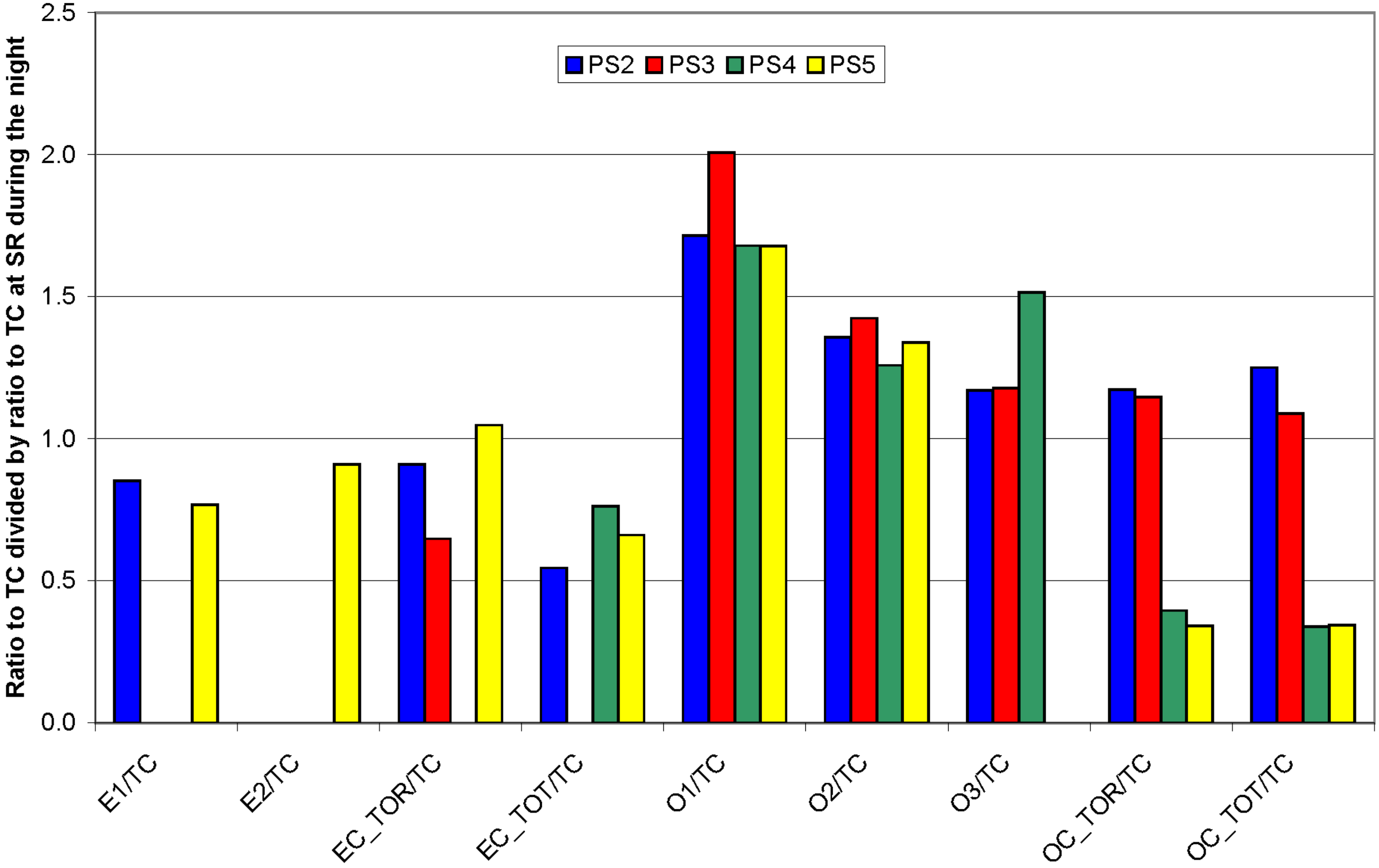


Figure 16. Nighttime Ratio of Carbon Species to TC Normalized to Ratio at SR



Findings Regarding the Carbon Results

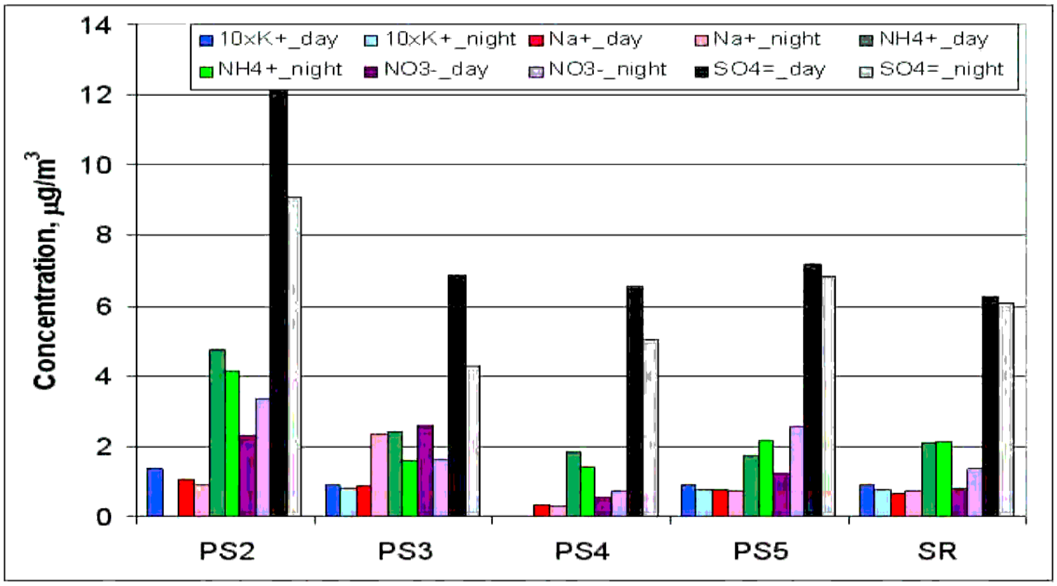
- The highest total carbon concentrations were observed at the SR site followed by those at the PS2 site.
- The organic carbon fraction is higher than the elemental carbon fraction at each site.
- There are internal problems with the carbon results since the sum of elemental carbon plus organic carbon is greater than total carbon.
- There were many records where the concentrations are identical for more than one carbon species and records where the pyrolyzable carbon is equal to the total organic carbon and to the total carbon.
- None of the records contained E3 or O4.
- None of the results were corrected for organic carbon artifacts on the quartz filters.
- There appears to be an enhancement for O1, O2 and O3 and a depletion for E1 and E2 at all four sites relative to the SR site.
- Sites PS2 and PS3 show an enhancement for total carbon relative to the SR site, whereas sites PS4 and PS5 show a depletion for total organic carbon relative to the SR site.

Because the carbon measurements are suspect, the findings listed above may be incorrect.

Measurements of Ions

Figure 17 shows the average daytime and nighttime concentrations of K^+, Na^+, NH_4^+, NO_3^- and $SO_4^=$ at the five sites. Note: the K^+ results have been multiplied by a factor of 10 to include them on the same chart as the other ionic species.

Figure 17. 12-hour Concentrations of Ionic Species



Findings Regarding the Ionic Species

- The PS2 site had the highest NH_4^+, NO_3^- and $SO_4^=$ concentrations of all the sites for both the daytime and nighttime sampling periods.
- The NH_4^+ concentrations measured on Teflon filters were 10% lower than the NH_4^+ concentrations measured on quartz filters.

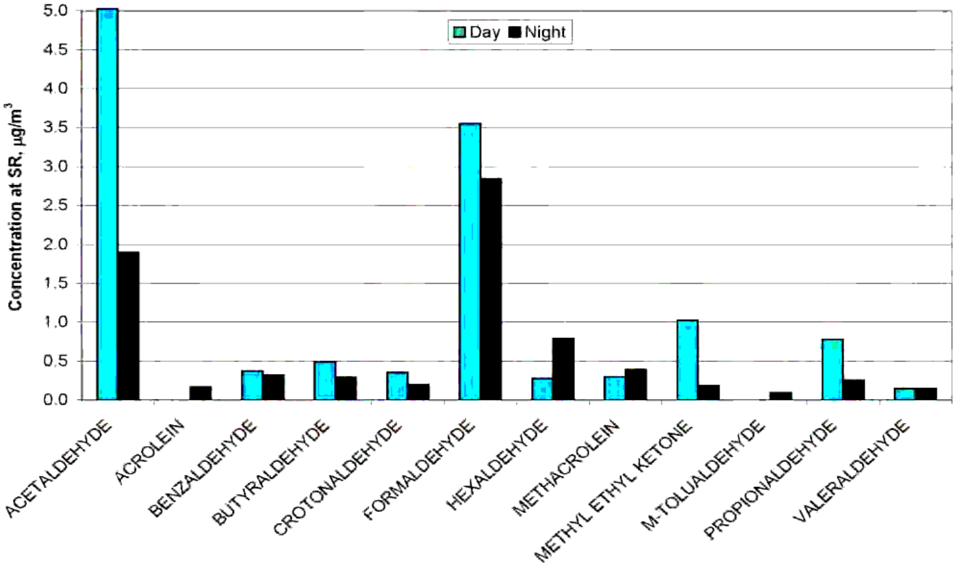
- There was excellent agreement between the Na^+ concentrations measured by ion chromatography and Na measured by XRF; the average Na^+/Na ratio was 0.98.
- There was excellent agreement between the $SO_4^=$ concentrations measured by ion chromatography and S measured by XRF; the average $SO_4^=$/3 to S ratio was 1.03.
- Water-soluble K^+ measured by ion chromatography was 42% higher on the average than K measured by XRF; thus, either the K^+ or the K measurements are incorrect.
- The average ratio of the measured NH_4^+ concentrations to the amount of NH_4^+ necessary to balance the measured concentrations of NO_3^- and $SO_4^=$ was 0.73. Thus, some of the nitrate and/or some of sulfate are present in forms other than ammonium nitrate and ammonium sulfate (e.g. ammonium bisulfate).
- Both the nitrate levels captured on sodium chloride coated filters and the nitric acid levels captured on sodium carbonate coated denuders at the SR site were approximately six times higher during the day than at night.
- On the average, the nitric acid levels at SR were 30% lower than the nitrate levels during the day and 20% higher at night, and accounted for 33% of sum of the nitric acid plus nitrate levels during the day and 47% at night.
- The ammonium levels captured on the citric acid coated filters at the SR site were about 50% higher during the day than at night, whereas the ammonia levels captured on the citric acid coated denuders at the SR site were 3 to 4 times higher during the day than at night.
- On the average, the ammonia levels at SR were approximately twice the ammonium levels during the day and about the same at night, and accounted for 67% of the sum of ammonia plus ammonium at the SR site during the day and 47% at night.
- On the average, the ammonium levels captured on quartz filters at the SR site were 10% higher than the levels captured on Teflon filters and the ammonium levels captured on both the quartz and Teflon filters at the SR site were 10% higher during the day than at night.
- The average nitrate levels captured on quartz filters at the SR site were one-quarter of the nitrate levels captured on sodium chloride coated filters for the daytime samples, but 70% higher for the nighttime samples. Furthermore, there was a negative correlation between nitrate levels captured on quartz filters at the SR site versus nitrate levels captured on sodium chloride coated filters for the daytime samples (R2 = -0.66) and a positive correlation for the nighttime samples (R2 = 0.95). Theses differences will need to be addressed before implementing the Long-Term Study.
- The nitrate levels captured on the quartz filters and sodium chloride coated filters and the nitric acid levels captured on sodium carbonate coated denuders at the SR site had no correlation with the NO, NO2, or NOx levels measured at this site.
- The highest SO4= levels and highest SO2 levels did not occur at the same site. The highest SO4= levels were observed at the PS2 site with an average concentration of 10.68 µg/m3 versus an average concentration of 6.16 µg/m3 at the SR site, whereas the highest concentrations of SO2 were observed at the SR site with an average concentration of 0.013 ppm versus an average of 0.010 ppm at the PS2 site.
- There was a moderately strong correlation between sulfate levels captured on quartz filters and SO2 measurements for the daytime samples for the PS2, PS3 and PS5 sites (R2 = 0.79, 0.67, and 0.60, respectively) but no correlation for the nighttime samples.

- There was no correlation between sulfate levels captured on quartz filters and SO2 measurements for either the daytime samples or the nighttime samples for the PS4 and SR sites.

Carbonyls at the SR Site

Figure 18 shows the average daytime and nighttime concentrations of different carbonyl compounds at the SR site. The nighttime results for acrolein and m-tolualdehyde are based on four samples and one sample, respectively.

Figure 18. Diurnal Variation in Carbonyl Concentrations at SR



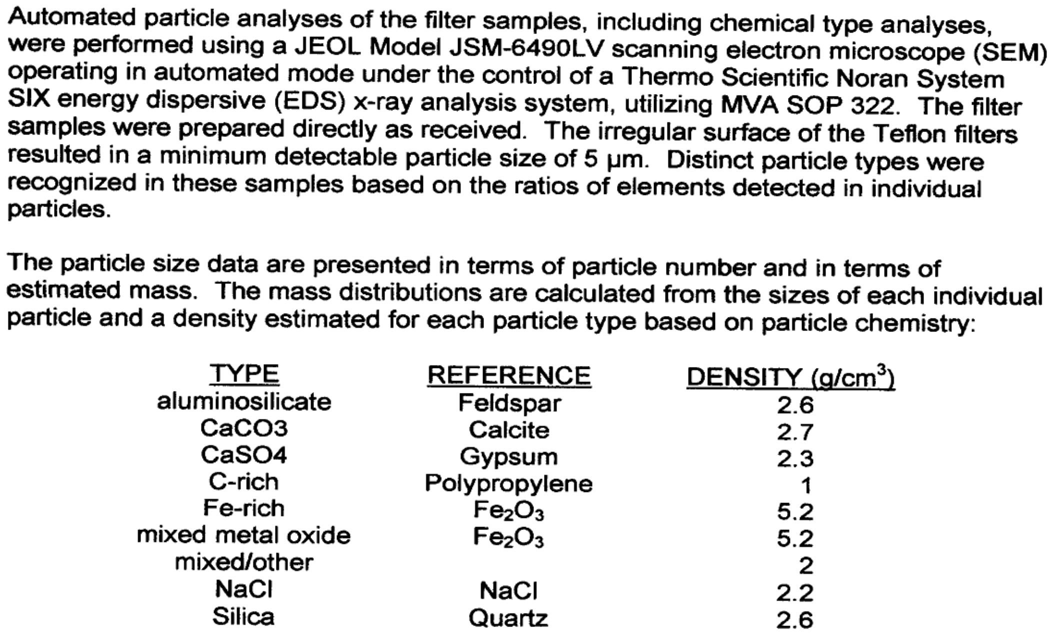
Findings Regarding the Carbonyl Results

- The highest carbonyl concentrations were observed for acetaldehyde and formaldehyde.
- One TWG member has reservations regarding the accuracy of the acrolein measurements (personal communication, March 2011).

Deposition Samples

Deposition samples were collected at SR in triplicate (P1, P2 and P3) for two one-week periods and then the sampling was terminated. According to MVA Scientific that analyzed the deposition samples, iron-rich particles found in the samples included steels and stainless steels, and/or their oxidation products. Mixed metal oxide particles contained appreciable copper and iron. Some particles ("mixed/other") could not be classified into any of the identified groups; a presumed density of 2.0 grams/cubic centimeter (g/cm^3) was assigned to these particles.

Details regarding the analyses of the deposition samples contained in the hard copy laboratory report indicate that:



> Automated particle analyses of the filter samples, including chemical type analyses, were performed using a JEOL Model JSM-6490LV scanning electron microscope (SEM) operating in automated mode under the control of a Thermo Scientific Noran System SIX energy dispersive (EDS) x-ray analysis system, utilizing MVA SOP 322. The filter samples were prepared directly as received. The irregular surface of the Teflon filters resulted in a minimum detectable particle size of 5 µm. Distinct particle types were recognized in these samples based on the ratios of elements detected in individual particles.
>
> The particle size data are presented in terms of particle number and in terms of estimated mass. The mass distributions are calculated from the sizes of each individual particle and a density estimated for each particle type based on particle chemistry:

TYPE	REFERENCE	DENSITY (g/cm^3)
aluminosilicate	Feldspar	2.6
CaCO3	Calcite	2.7
CaSO4	Gypsum	2.3
C-rich	Polypropylene	1
Fe-rich	Fe_2O_3	5.2
mixed metal oxide	Fe_2O_3	5.2
mixed/other		2
NaCl	NaCl	2.2
Silica	Quartz	2.6

The percentages of particles by mass for different chemical species are presented in Figure 17; the cumulative size distribution by particle number for particles less than a given diameter are presented in Figure 18.

Figure 18. Percent Composition by Mass for Deposits Collected in Triplicate at SR

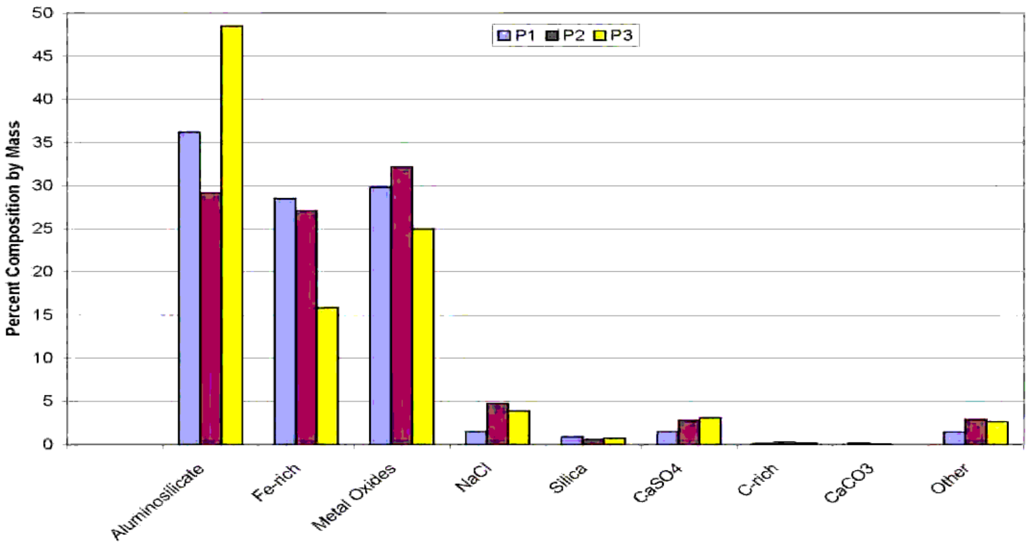
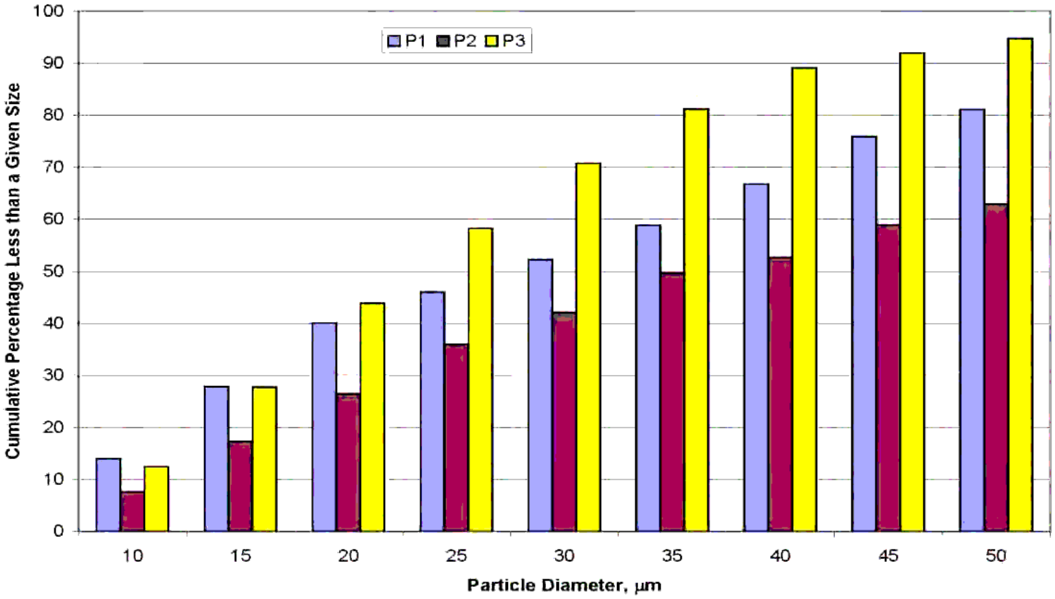


Figure 19. Cumulative Size Distribution of Deposited Particles Collected in Triplicate at SR



Findings Regarding the Deposition Samples

- The average variability in the replicate measurements was 30%.
- The dominant chemical species were aluminosilicate, iron-rich, and metal oxides.
- Because none of the deposits were weighed, the deposition rates could not be calculated.

Impact of Wind Direction on Pollutant Concentrations

There are several major sources of ambient gas phase and particulate phase species near LAX. Thus, it is important to select sampling periods that conform to time periods when the wind direction is relatively consistent such that the samples collected represent concentrations of pollutants from as few sources as possible. The hourly average wind direction measurements obtained from the AQMD's PAMS site were used to characterize the wind direction during the different 12-hour sampling periods for each site into one of three wind sectors defined previously in the Jacobs Consultancy reports on the Demonstration Project (April 2009):

- Onshore: WD = 247.5^0 to 292.5^0
- Offshore: WD = 348.75^0 to 191.25^0
- Neutral (i.e., transition between onshore and offshore): WD = 295.5^0 to 348.75^0 plus 191.25^0 to 247.5^0

The wind sectors for the daytime and nighttime sampling periods for each site are shown in Table 4. These results indicate that the wind direction for the daytime samples was consistently onshore over 85% of the time at all five sites, and that the wind direction for the nighttime samples was onshore over 50% of the time for four sites. The wind direction for the nighttime samples for PS5 was onshore 40% of the time.

Table 4. Wind Sectors for 12-hour Sampling Periods at each Site

SITE	Day (8 AM – 8 PM)			Night (8 PM – 8 AM)		
	Onshore	Offshore	Transition	Onshore	Offshore	Transition
PS2	90%	0%	10%	56%	20%	24%
PS3	89%	0%	11%	51%	7%	42%
PS4	90%	1%	9%	52%	24%	24%
PS5	86%	1%	13%	40%	14%	35%
SR	86%	1%	13%	51%	14%	35%

Wind direction had an impact on most pollutant concentrations (the major exception was PM2.5 mass), in some cases a large impact, as one can see from the differences in the daytime results versus the nighttime results presented in the figures above. However, it is impossible to quantify the impact since the wind direction was not constant for any of the 12-hour sampling periods.

CONCLUSIONS

Methods Used to Quantify Pollutants

The collocated aerosol speciation sampler (AS sampler) and Minivol sampler deployed at the SR site provided a redundant set of measurements in order to evaluate different samplers and sampling components for the Long-Term Study. The AS sampler is superior to the Minivol in that it samples at a higher flow rate thus collecting a larger sample for analysis in the same time period and can collect samples simultaneously on multiple filters for different analytes. Furthermore, the AS sampler can be equipped with denuders to capture gas phase species such as nitric acid and ammonia, whereas this technology has not been applied to the Minivol sampler.

The differences observed between the nitrate levels captured on quartz filters versus sodium chloride coated filters will need to be addressed before implementing the Long-Term Study. Since the ammonium levels on quartz filters at the SR site were within 10% of the levels captured on Teflon filters, one of these measurements can be deleted from the Long-Term Study.

The Demonstration Project found high levels of carbon at the SR site as well as at the PS2 and PS3 sites. However it is not known if the carbon species present in jet aircraft exhaust constitute a distinct fingerprint compared to other sources. Thus, more information is needed on the source profiles for aircraft exhaust as well as other sources in the Study Area. It appears that a Level 1 validation was not implemented for the carbon data.

Data Recovery Rate for the Methods Used

Although the overall data recovery rate for samples collected during the Demonstration Project was high, many of the samples had concentrations that were below the detection limit of the analytical methods used. This issue will be addressed in the paragraph below.

Methods Needing Revision

Based on the low percentage of records that were above detection limits, it is clear that many of the methods utilized during the Demonstration Project need revision. Several approaches to improve detection limits include:

- Increase the density of the deposits captured on a filter by either increasing the flow rate or the sampling time, or both
- Switch to a smaller diameter filter than the 47 milimeter (mm) diameter filters used during the Demonstration Project (such as a 37 mm diameter filter or a 25 mm diameter filter) that will increase the density of the filter deposit several fold
- Reuse the same filter several times to capture multiple daytime or nighttime samples over several days or a week.

Although this report does not address the speciated light hydrocarbons collected in six-liter Summa canisters at each site during the Demonstration Project, it is important that LAWA's on-call environmental contractors be aware of a major problem. CE's review of the speciated light hydrocarbon data found that the analytical methods used to quantify these species need to be at least an order of magnitude more sensitive than those used for the Demonstration Project. The TO-15 method that was run in the "SCAN" mode for the samples collected during the Demonstration Project has detection limits of 0.5 to 2 parts per billion. Running the TO-15 method in the "SIM" mode will achieve detection limits of 10 to 50 parts per trillion. Each canister used during the Demonstration Project was individually certified prior to deployment in the field. Further investigation is needed to see whether "batch" certification of the canisters would suffice for the Long-Term Study. The speciated light hydrocarbon results will be addressed in another report once the AQMD's recent results taken downwind of the taxiway for the south runway become available.

The URG 3000N sampler (or equivalent) is recommended as the Aerosol Speciation sampler for the Long-Term Study. These samplers are based on the IMPROVE sampler, but include a mass flow controller instead of orifice flow control. The 3000N uses a 25 mm diameter filter with flow rate of 22 liters per minute, which should deliver ~5x improvement in sensitivity over the sampling that was done in 2008. LAWA's on-call environmental contractors are encouraged to contact URG to find out the availability and delivery schedule for these samplers.

Methods Failing to Provide Useful Data

Because of the known problem of losing fibers from quartz filters during handling, it was futile to attempt to measure mass on quartz filters when one had Teflon filters that have stable weights and a detection limit for quantifying the PM2.5 mass concentrations that is about 20X lower than that for quartz filters.

Neither the measurements of heavy hydrocarbons or PAHs, steranes and hopanes provided useful data. The percentage of records that were above their respective detection limits was 1% for both sets of samples. This is not surprising for heavy hydrocarbons given the high detection limit of 15 µg/m^3. However, the detection limits for the different PAH, sterane and hopane compounds are ultra low ranging from 0.001 to 0.004 µg/m^3. Either these compounds weren't detected during the Demonstration Project because they weren't present or they were present in concentrations below the detection limits.

Impact of Wind Direction on Pollutant Concentrations

Wind direction definitely had an impact on most pollutant concentrations; however, it is impossible to quantify the impact on filter samples since the wind direction was not constant for any of the 12-hour sampling periods.

Optimum Sample Collection Period

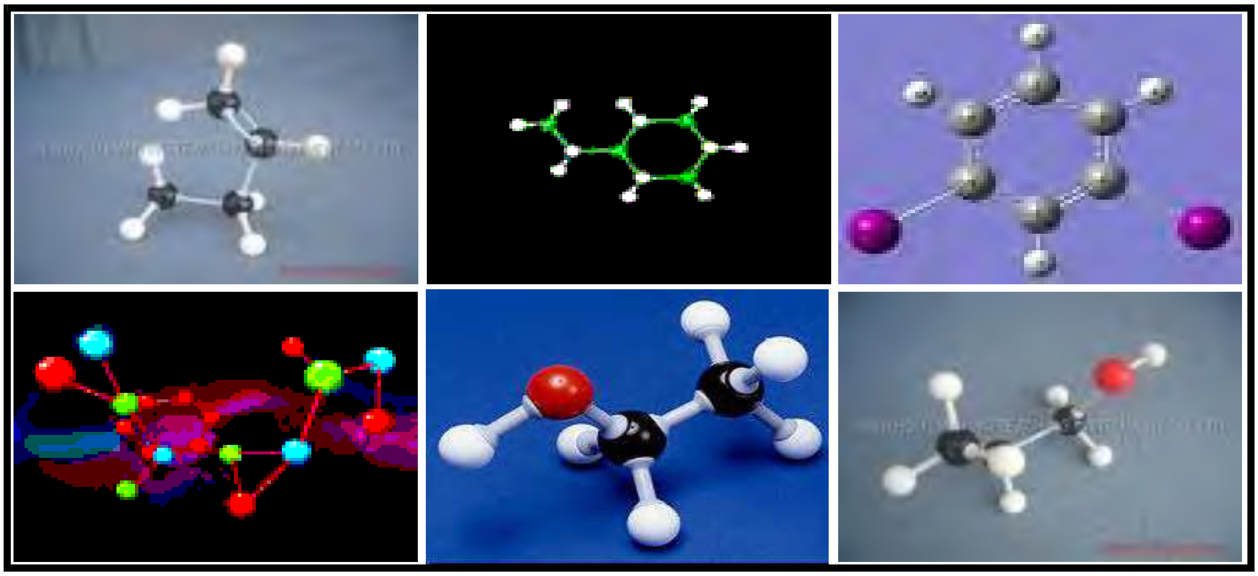
It is important to select sampling periods that conform to time periods when the wind direction is relatively consistent such that the samples collected represent concentrations of pollutants from as few sources as possible in order to be able to conduct the source apportionment analysis successfully. Thus, one needs as short a sampling period as possible that at the same time will provide a large enough sample for analysis. Based on CE's evaluation of the winds that occurred during the Demonstration Project, the wind direction was not constant for the 12-hour daytime and nighttime sampling periods in July and August of 2008. Furthermore, the frequency of onshore and offshore winds will change throughout the year during the Long-Term Study such that an optimum sampling period for one season would not typically work for another season. The sampling periods should be adjusted throughout the Long-Term Study to fit the wind pattern. This may mean adopting sampling periods shorter than 12 hours, adjusting the start time and end time of the sampling periods, and having more than two sampling periods per day. One should consider using wind-direction activated samplers that only sample when the wind direction is within a relatively narrow range.

FINAL REMARKS

The two-month Demonstration Project obtained sampling data that may not be representative of longer term monitoring. Thus, some of the findings and conclusions presented in this report may not be applicable for the Long-Term Study.

WORKING DRAFT

Evaluation of Hydrocarbon Data from the LAX Air Quality Source Apportionment Study's Demonstration Project



Prepared for CDM by

Countess Environmental

June 17, 2011

INTRODUCTION

This report summarizes Countess Environmental's (CE) evaluation of the speciated hydrocarbon data collected for the LAX Air Quality Source Apportionment Study's Technology and Methodology Feasibility Demonstration Project (Demonstration Project) conducted from July through August 2008 at LAX, plus an evaluation of taxiway samples collected by the South Coast AQMD in April 2011. This evaluation is being conducted to provide information and recommendations to Los Angeles World Airport's (LAWA) staff and LAWA's on-call environmental contractors for planning purposes for the Long-Term Study.

The evaluation of the hydrocarbon data focused on the following areas:

- Were the methods able to quantify the concentrations of the pollutants of interest?
- What was the data recovery rate for the methods?
- Which methods need to be revised?
- What is the optimal averaging period for sample collection?
- Which species are potential markers for source apportionment?

The locations of the five monitoring sites are shown in Figure 1. These sites were: South Runway (SR) located behind the blast fence at Runway 25R, Portable Site 2 (PS2) located in a parking lot in the Central Terminal area, Portable Site 3 (PS3) located in a cargo operations area, Portable Site 4 (PS4) located approximately 850 feet east of SR, and Portable Site 5 (PS5) located approximately 1,650 feet east of SR. Sampling was conducted at one site at a time using evacuated 6-liter Summa canisters, starting with seven days of sampling at the SR site, followed by seven days of sampling at the other four sites. One pair of duplicate samples was collected at both the SR and PS5 sites and a trip blank was collected at the SR site. The sampling duration for each ambient canister sample was 24 hours (8 AM to 8 AM the next day). A portable Gas Chromatograph/Mass Spectrometer (GC/MS) was used for several days at the SR site to test its feasibility for the Long-Term Study. These results were analyzed recently by the South Coast AQMD and provided directly to Countess Environmental for assessment.

Figure 1. Demonstration Project Monitoring Site Locations

In addition to the ambient samples collected at LAX, four ambient 24-hour samples were collected in Summa canisters at the north and south ends of the Sepulveda tunnel on August 25th and 26th, 2008 and two ambient samples were collected in Summa canisters at the LAX fuel farm on August 5, 2008 (one 24-hour sample and one grab sample of the headspace for a fuel tank containing jet fuel) to compare with the ambient samples collected at LAX. Several liquid fuel samples were collected on July 16, 2008: one sample each of aviation fuel (Jet-A), unleaded gasoline, diesel fuel used by construction equipment at LAX (Diesel-A), and diesel fuel used by ground support equipment at LAX (Diesel-B). The working hypothesis is that the compounds seen in fuel are characteristic of what is seen in the unburned hydrocarbon component of exhaust. Thus, species that could comprise a distinct aircraft signature will have much higher concentrations in Jet-A fuel than diesel or unleaded gasoline.

The ambient samples from the sites at LAX and from the Sepulveda tunnel were analyzed for hydrocarbon species using the following methods:

- EPA Method TO-12 [PAMS protocol] whereby a 500-ml sample is concentrated, put through a water and a CO_2 management system, cryofocused and injected into a GC-FID (Gas Chromatograph with Flame Ionization Detector) for analysis; and
- EPA Method TO-15 whereby a 500-ml sample is concentrated, put through a water and a CO_2 management system, cryofocused and injected into a GC/MS for analysis in the full scan mode.

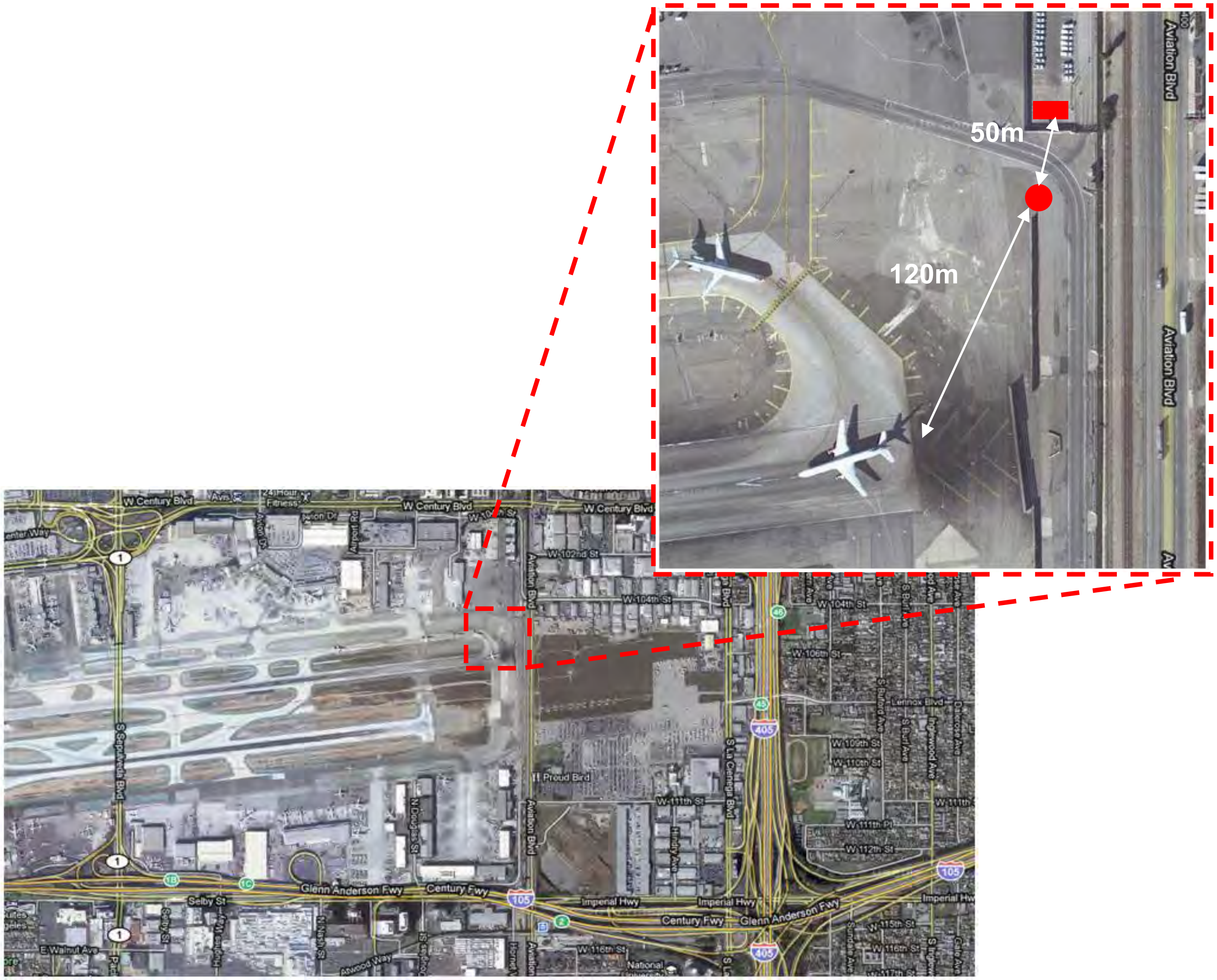
The liquid fuel samples were analyzed by the following methods:

- ASTM D-5623 for speciated sulfur compounds (for Jet-A and unleaded gasoline only),
- EPA 8260/8082 for volatile organic compounds (VOC), halogenated hydrocarbons, and poly-chlorinated biphenyls,
- ASTM D-6729/6733 and GC/MS for detailed hydrocarbon analysis, and
- EPA TO-15/TO-12 PAMS for VOC and hydrocarbons present in the headspace above the stored liquid samples.

Each Summa canister used during the Demonstration Project was individually certified prior to deployment in the field. The practical quantifiable detection limits (PQL) were 1 ppb carbon for method TO-12/PAMS, 0.2 ppb compound for most species measured by method TO-15, 0.4 ppb for m,p-xylenes and vinyl acetate, and 0.5 ppb for methanol. Methods TO12 and TO15 are used to quantify the concentrations of 56 compounds and 68 compounds, respectively. There is some overlap between the two methods with the TO15 results considered more accurate. The initial VOC results reported by Atmospheric Analysis and Consulting, Inc (AAC) were limited to species that were at or above their PQLs. Because over 70% of these results were below their PQLs, LAWA authorized AAC to reanalyze the archived electronic data records and include estimated concentrations for species below their PQLs that might serve as markers for source apportionment in the Long-Term Study.

The South Coast AQMD conducted several days of VOC monitoring at two sites downwind of a taxiway at LAX in April 2011 to complement the measurements made during the Demonstration Project. The two monitoring sites are shown in Figure 2; the rectangle represents the AQMD trailer in a parking lot and the circle represents the blast fence site. The two sites are approximately 170 meters and 120 meters respectively from the SR site. The preliminary VOC results from this monitoring effort will be discussed in this report.

Figure 2. AQMD Monitoring Sites (April 2011).



FUEL COMPOSITION

Table 1 shows the EPA Method 8260 results for the four liquid fuel samples with the results for Jet-A arranged in order of decreasing concentration. The concentrations of the trimethyl benzenes and xylenes are much higher in Jet-A fuel than in diesel, and could potentially delineate jet aircraft emissions from diesel emissions. However, unleaded gasoline also has very high concentrations of these species.

Table 1. Composition of Fuels Used at LAX (weight % by Method 8260)

Analyte	Jet-A	Diesel (A)	Diesel (B)	Unleaded Gasoline
1,2,4-Trimethyl benzene	0.410	0.065	0.048	2.55
m,p-Xylenes	0.190	0.039	0.054	5.94
o-Xylene	0.115	0.019	0.023	2.20
1,3,5-Trimethyl benzene	0.096	0.016	0.012	0.483
n-Propyl benzene	0.062	0.008	0.005	0.244
Methylbenzene	0.052	0.011	0.012	1.18
n-Butyl benzene	0.048	0.001	0.001	0.004
Toluene	0.045	0.019	0.046	6.60
Naphthalene	0.038	0.002	0.002	0.038
p-Isopropyl toluene	0.031	0.003	0.002	0.004
sec-Butyl benzene	0.024	0.004	0.003	0.014
Isopropyl benzene	0.021	0.003	0.002	0.069
Benzene	0.002	0.002	0.004	0.800

The fuel samples were also analyzed by GC/MS maximizing the number of chemical species that can be identified and measured. The different VOC species the four liquid fuels are presented in Table 2. The high carbon number species, dodecane and above (10 or more carbons) are very low in gasoline compared to Jet-A and diesel fuel and if present in ambient air samples, can be used in receptor modeling of VOCs to separate gasoline from Jet-A and diesel fuel. It is important to note that these results come from a single sample of each fuel and do not reflect or quantify variability in the fuel compositions. In order to support Chemical Mass Balance (CMB) modeling, species that are high in Jet-A compared to diesel must be identified and quantified. There are three dimethyl- 2, 3-dihydro-1H-indenes that have concentrations of about 1 percent in Jet-A that are very low in diesel fuel. These explain most of the total indene concentration in Jet-A of about 3.1 percent. Total indenes in the diesel fuels are 0.7 and 1.5 percent. The two largest indene species in diesel (A) and diesel (B) are also shown in Table 2. These are quite different from the Jet-A indene species; thus, the presence of dimethyl-2,3-dihydro-1H-indenes in ambient air is possibly indicative of jet aircraft VOC emissions.

Table 2. Composition of Fuels Used at LAX (weight % by GC/MS)

Analyte	**Jet-A**	**Diesel (A)**	**Diesel (B)**	**Unleaded Gasoline**
Cyclic Paraffins (Naphthenics)	27.4	34.6	34.4	7.1
Isoparaffins	27.1	35.6	36.3	41.9
Mono-Aromatics	15.6	1.4	1.5	
Di-Aromatics	14.2	6.7	6.9	
Total Aromatics	29.8	8.1	8.4	31.7
Paraffins	11.0	14.4	14.5	7.3
Indenes	3.1	0.7	1.5	0.02
Aldehydes	1.2	1.8	2.5	
Dodecane	2.0	1.0	1.2	0.05
Undecane	2.0	0.7	0.7	0.11
Tridecane	1.6	1.2	1.2	0.02
Undecane, 2,6-dimethyl-	1.5	0.6	0.5	
Trans-anti-1-methyl-decahydronaphthalene	1.3	0.5	0.5	
Naphthalene, decahydro-2-methyl-	1.2	0.01	0.7	
Cyclohexane, 2-butyl-1, 1, 3-trimethyl	1.2	0.01	0.2	
Tetradecane	1.2	1.5	1.4	
Decane	1.1	0.3	0.3	0.11
Naphthalene, 1,2,3,4-tetrahydro-	1.2	0.5	0.8	
1H-Indene, 2,3-dihydro-1,6-dimethyl-	1.1	0.01	0.01	
1H-Indene, 2,3-dihydro-1,3-dimethyl-	1.0	0.01	0.01	
1H-Indene, 2,3-dihydro-4-methyl-	0.8	0.01	0.01	
1H-Indene, 2, 3-dihydro-4, 7-dimethyl-			0.5	
1H-Indene, 2,3-dihydro-4,5,7-trimethyl-			0.3	
1H-Indene, 2,3-dihydro-1,1,3-trimethyl-		0.3		
1H-Indene, 2,3-dihydro-1,1,5-trimethyl-		0.2		

The ASTM D-5623 results for the two liquid fuel samples collected at the LAX fuel farm are summarized in Table 3. These speciated sulfur results indicate major differences in the sulfur compounds present in these two fuels. It is important to note that these results come from a single sample of each fuel, did not include diesel, and do not reflect or quantify variability in the fuel compositions. In order to support Chemical Mass Balance (CMB) modeling for the Long-Term Study, sulfur compounds that are high in Jet-A compared to diesel and gasoline must be identified and quantified.

Table 3. Sulfur Compounds Detected in Fuel Samples (ppbV by ASTM D-5623)

Analyte	Jet-A	Unleaded Gasoline
Diethyl Disulfide	0.6	
Ethyl Methyl Sulfide	0.2	
Thiophene		3.6
2-Methyl Thiophene		0.9
3-Methyl Thiophene		1.1
2-Ethyl Thiophene		0.3
3-Ethyl Thiophene	0.4	0.3
3,4-Dimethyl Thiophene	0.3	
Methyl Ethyl Thiophenes	5.9	0.2
Trimethyl Thiophenes	2.5	0.3
Tetramethyl Thiophenes	30	0.5
2,4 & 2,3-Dimethyl Thiophene	0.2	0.2
Benzothiophene	5.7	0.2
Dibenzothiophene	0.6	
Methyl Benzothiophenes	18	
Dimethyl Benzothiophenes	55	
Trimethyl Benzothiophenes	80	
Tetramethyl Benzothiophenes	10	
Tetra-Hydro Thiophene		0.2
2-Methyl-Tetra-Hydro-Thiophene		0.2
Ethyl Mercaptan		0.9
N-Propyl Mercaptan		0.4
Isopropyl Mercaptan		0.2
Unidentified Volatile Sulfur	176	

AMBIENT HYDROCARBON DATA

General Findings

- The reanalyzed hydrocarbon results contain approximately two and a half times more measurements than the initial analyses since the reanalyzed data package contains estimated concentrations for species below their PQL.
- No compounds were detected in the trip blank.
- No compounds were detected in the pre-cleaned canisters analyzed prior to sampling.

- The average percent difference for the duplicate samples collected at the SR and PS5 sites was 30%.
- There was a lot of variability in the day-to-day measurements with several species showing as much as a ten-fold variation in concentration.

Measurements above Detection Limit

The concentrations of many species for the samples collected during the Demonstration Project were below the analytical detection limits. The percentage of records above the PQLs averaged 38% for the TO12 analyses and 23% for the TO15 analyses. Thus, revisions to the sampling and/or analytical methodology will be required for the Long-Term Study. The detection level for TO-15 analyses run in the SIM mode are approximately 10 pptV rather than 500pptV for the SCAN mode.

Average Hydrocarbon Concentrations

To address the questions listed in the Introduction, CE's approach for evaluating the limited number of samples collected during the Demonstration Project focused on identifying differences between the sites rather than focusing on the actual concentrations observed. There were day-to-day variations in the concentrations of each hydrocarbon compound that reflect the differences in emissions from different sources in the Study Area impacting each monitoring site as the wind direction shifted during each 24-hour sampling period. During the Demonstration Project the wind was predominantly from the west. However about 25% of the time the wind was either from the east or in transition between the onshore and offshore wind regimes. Thus, each Summa canister sample was impacted from both on-airport and off-airport sources.

Figures 3 through 9 show the average 24-hour concentrations of different categories of hydrocarbon species for the five monitoring sites. The data for the TO12 analyses (with units of ppb carbon) were grouped into the following categories: straight chain and cyclo-alkanes, branched chain alkanes, alkenes, and aromatics; the TO15 results (with units of ppb by volume) were grouped into the following categories: halogenated compounds, non-oxygenated compounds and oxygenated compounds. The acetone concentrations were divided by 100 and the methanol and ethanol concentrations were divided by 10 to present these compounds on the same scale (i.e., Figure 9) as the other oxygenated species. The differences in hydrocarbon concentrations measured at the five sites are listed after Figure 9.

Figure 3. Average Concentration of Straight Chain and Cyclo-Alkanes by TO12

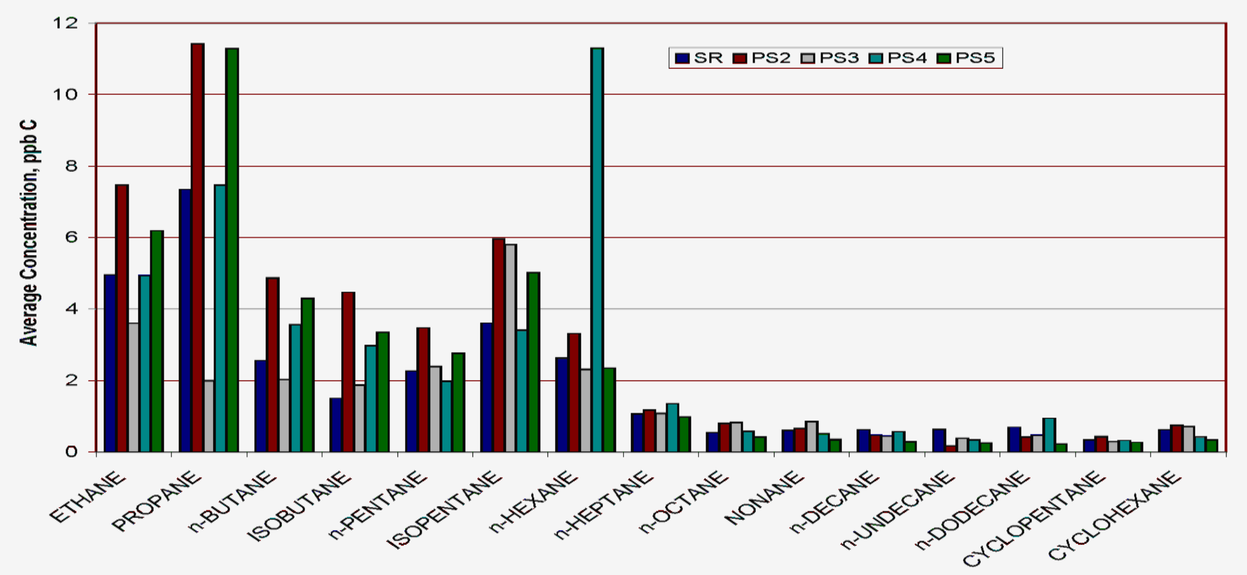


Figure 4. Average Concentration of Branched Chain Alkanes by TO12

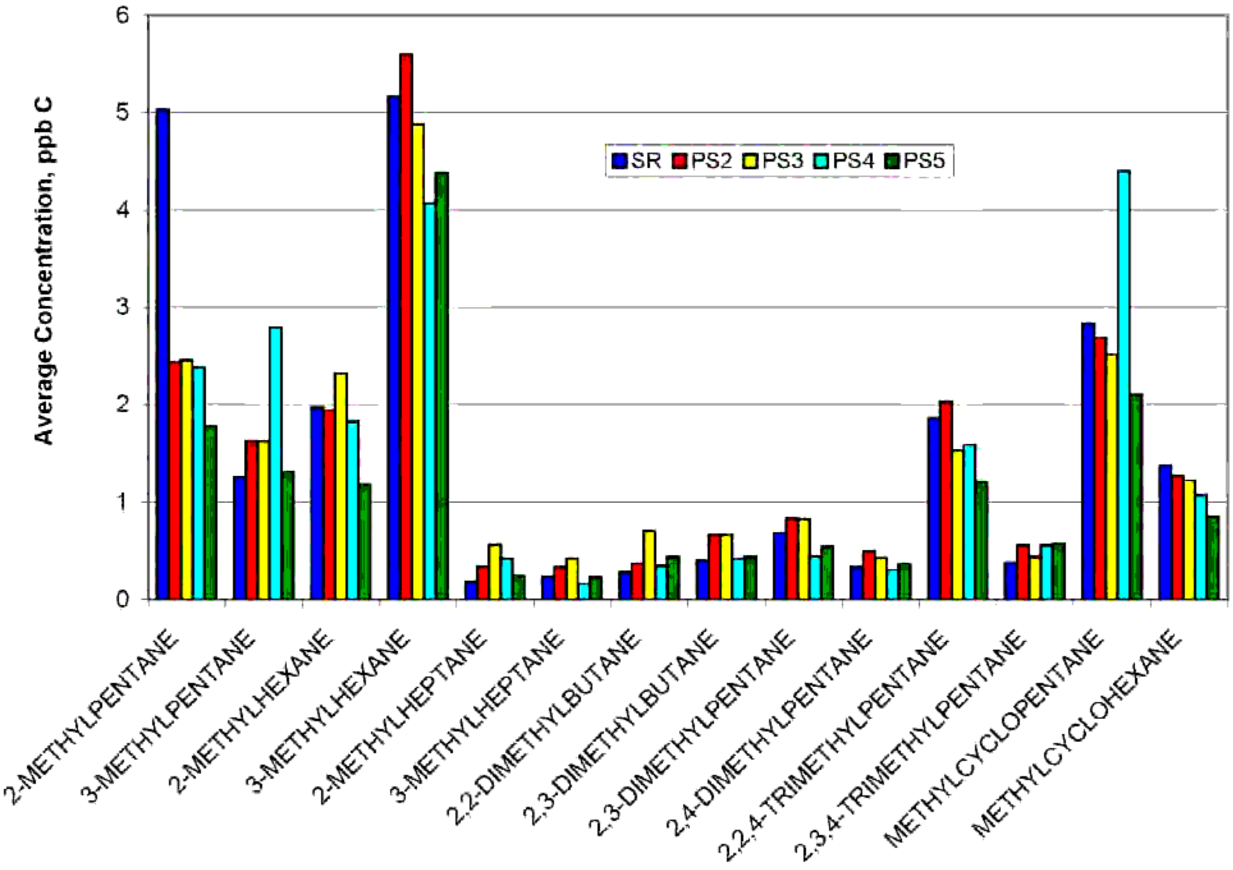


Figure 5. Average Concentration of Alkenes by TO 12

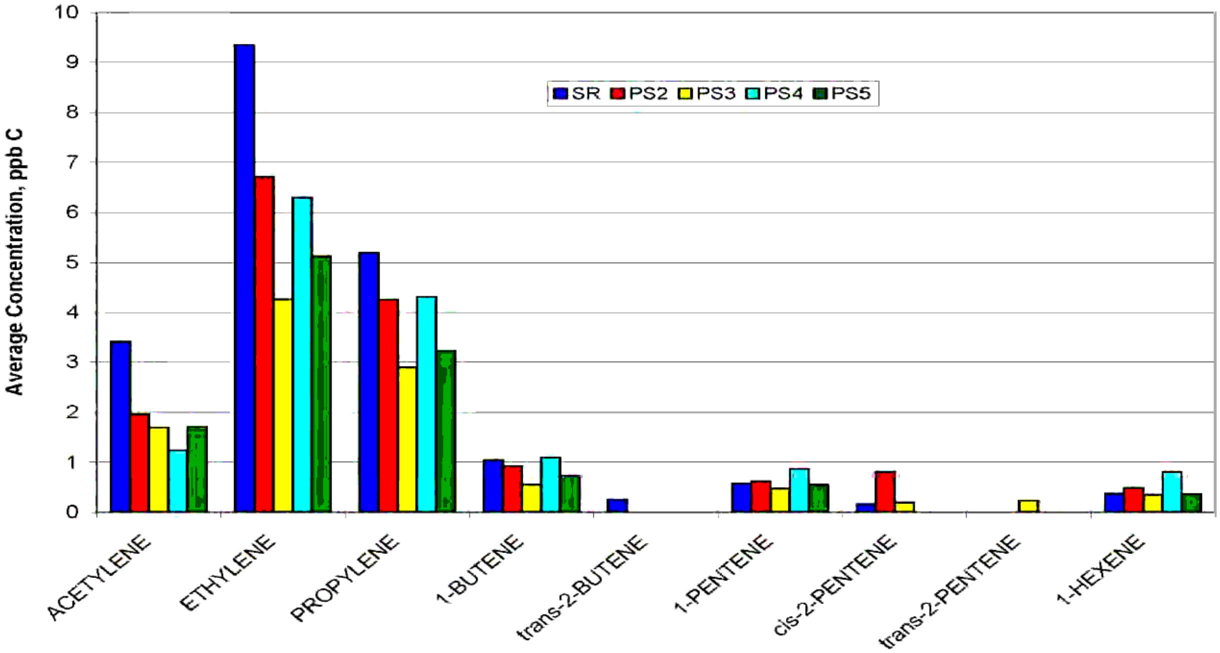


Figure 6. Average Concentration of Aromatics by TO12

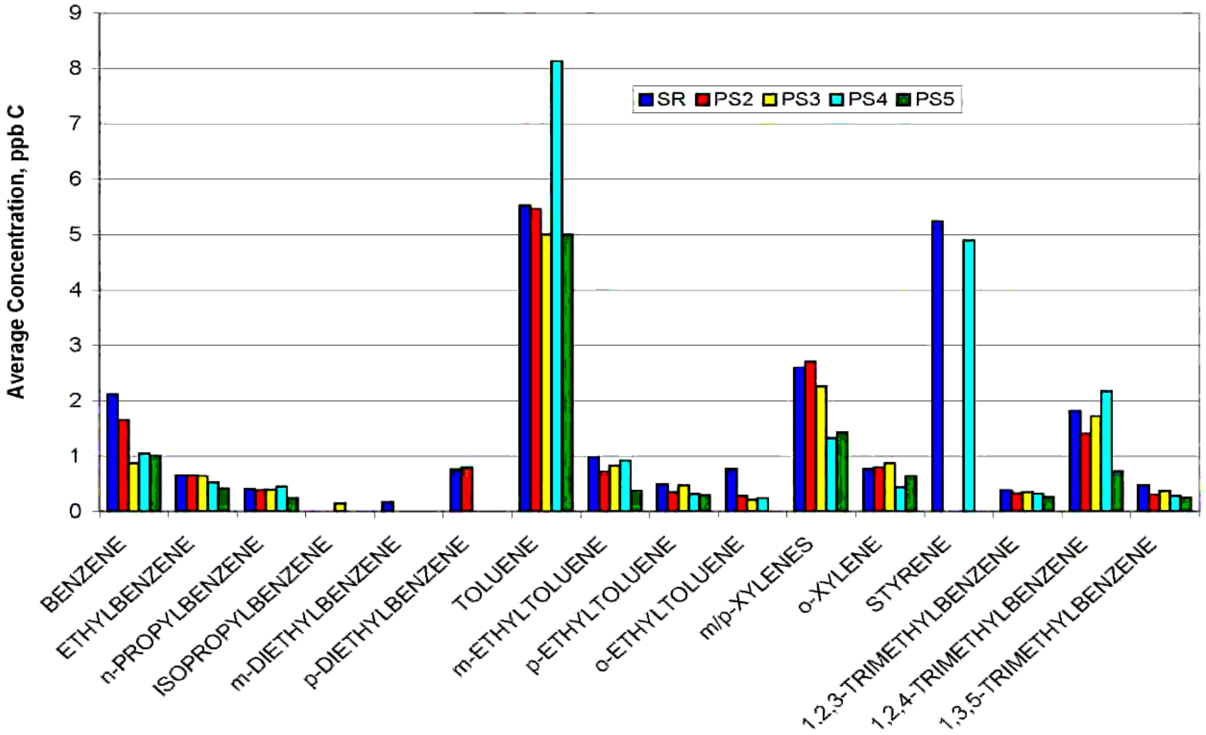


Figure 7. Average Concentration of Halogenated Compounds by TO15

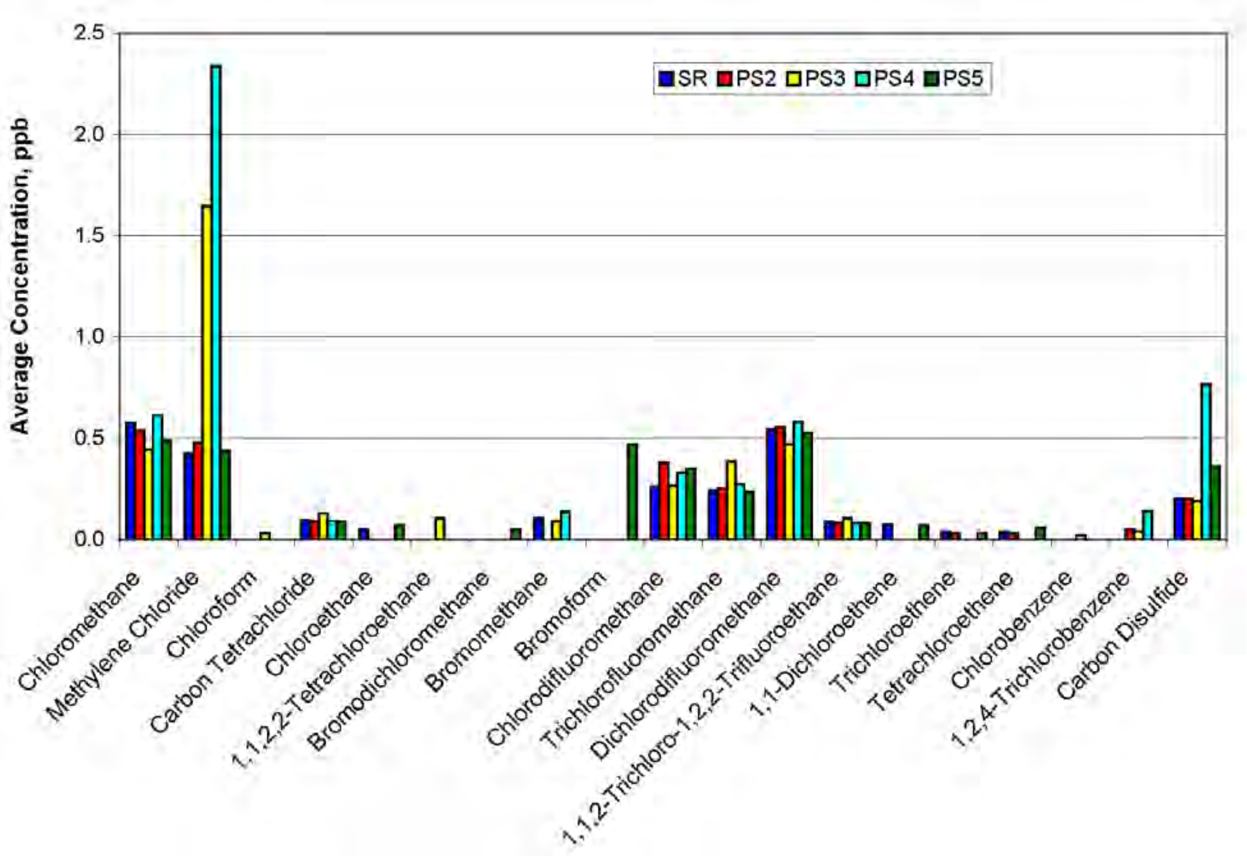


Figure 8. Average Concentration of Non-oxygenated Compounds by TO15

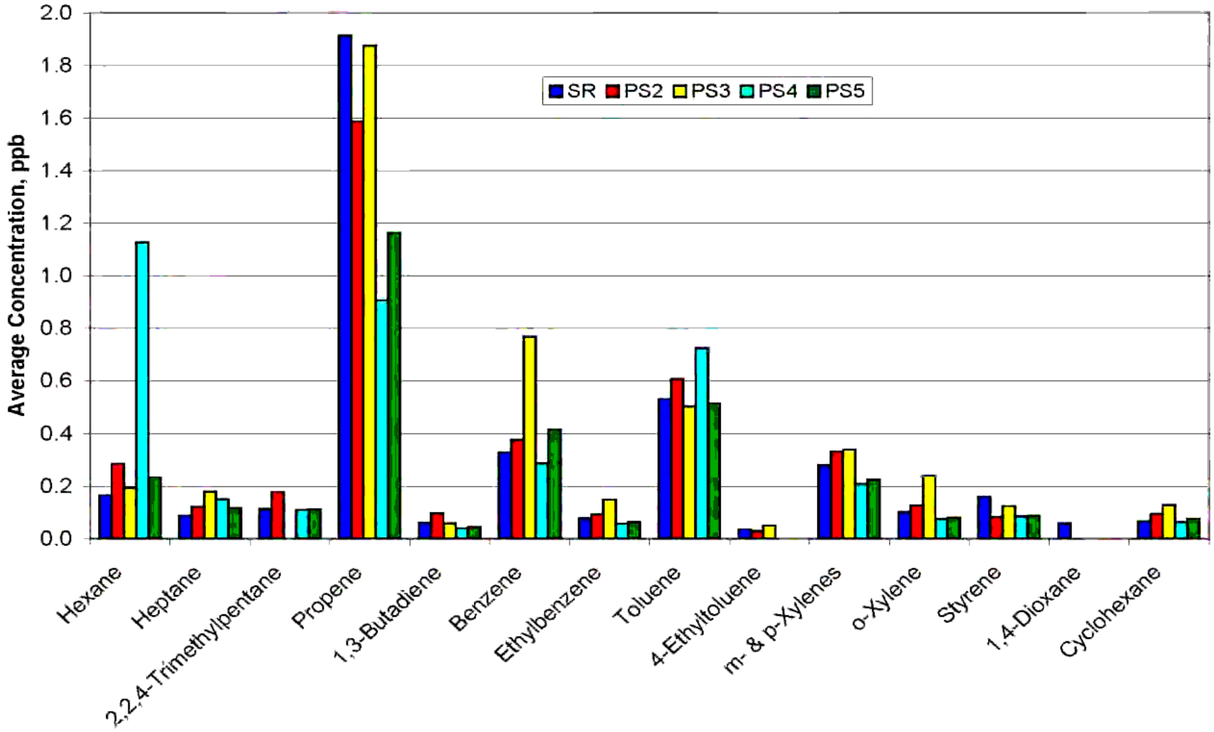
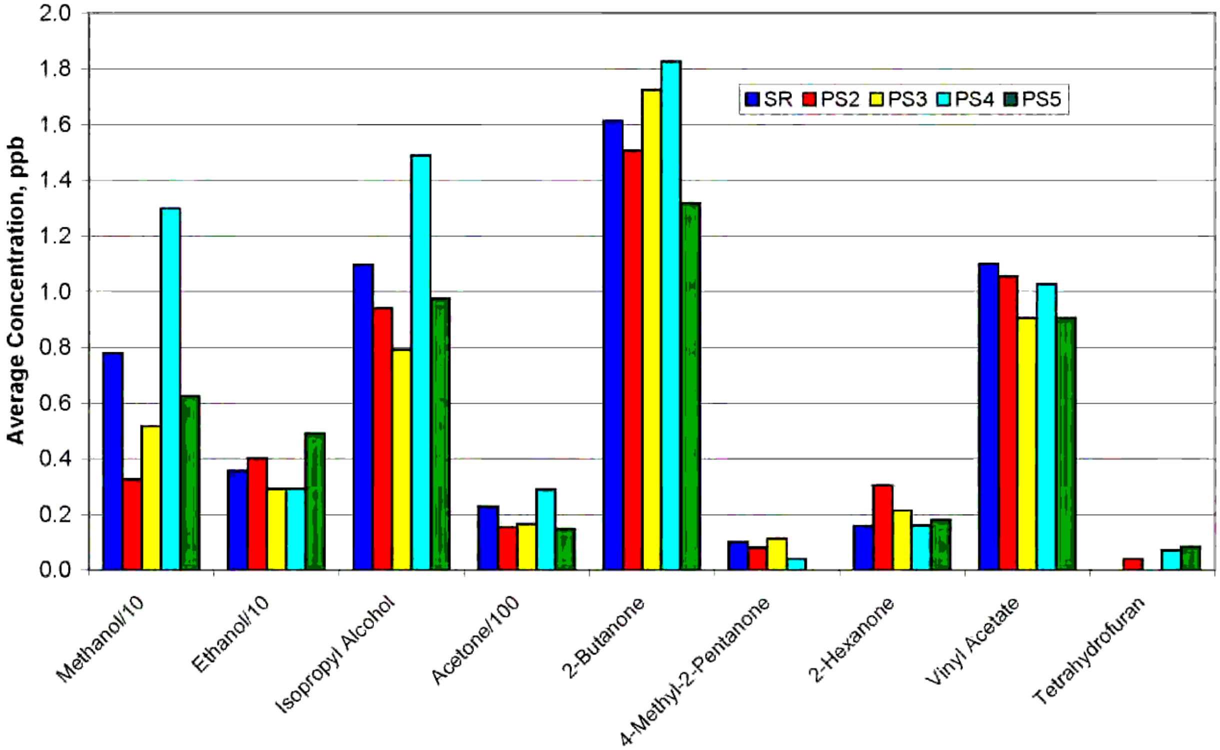


Figure 9. Average Concentration of Oxygenated Compounds by TO15



Differences in Hydrocarbon Concentrations at the Five Sites

Styrene was observed only at the SR and PS4 sites whereas chloroethane and 1,1-dichlorothene were only observed at the SR and PS5 sites suggesting that these compounds may be associated with aircraft exhaust emissions. This warrants further investigation since halogenated compounds are not present in Jet-A fuel.

The following compounds were observed only at a single site suggesting that they may represent emissions from unique operations at each site: m-diethyl benzene, trans-2-butene, and 1,4-dioxane at the SR site; Isopropyl benzene, trans-2-pentene, 1,1,2,2-tetrachloroethane, chloroform, and chlorobenzene at the PS3 site; and bromodichloromethane and bromoform at the PS5 site.

The following compounds were observed at several sites suggesting that they may represent emissions from unique operations at LAX or they may be impacted by emissions from roadway traffic: p-diethyl benzene at the SR and PS2 sites; cis-2-pentene and 4-ethyltolune at the SR, PS2, and PS3 sites; tetrachloroethene and trichloroethene at the SR, PS2, and PS5 sites; bromomethane at the SR, PS3, and PS4 sites; tetrahydrofuran at the PS2, PS4, and PS5 sites; 2,2,4-trimethylpentane at every site except the PS3 site; and 4-methyl-2-penanone at every site except the PS5 site.

Hydrocarbon Concentrations Normalized to the SR Site

Ratioing concentrations of different species at one site to those at another site (termed normalization) has the advantage of placing all species on an equal basis regardless of their concentration. Figures 10 through 16 show the average 24-hour hydrocarbon concentrations measured at each site normalized to the concentrations observed at the SR site. A discussion of these results is presented after Figure 16.

Figure 10. Average Ratio of Straight Chain and Cyclo-Alkanes by TO12 Normalized to SR

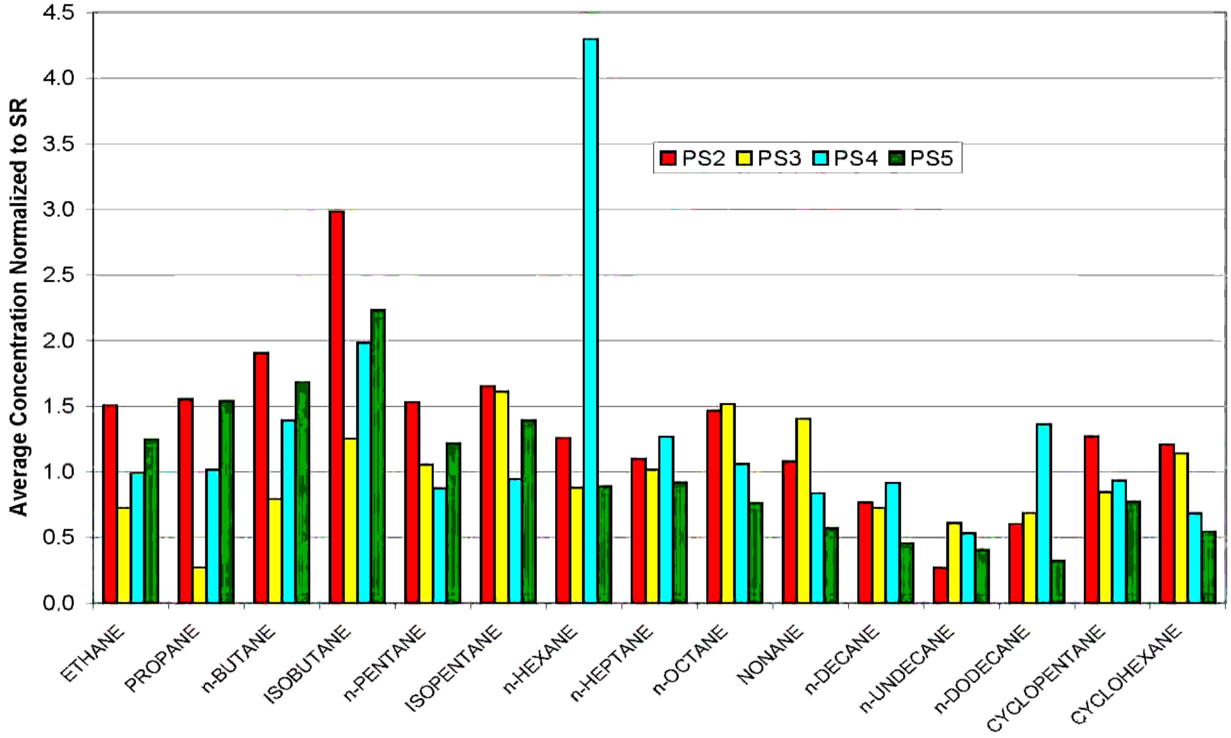


Figure 11. Average Ratio of Branched Chain Alkanes by TO12 Normalized to SR

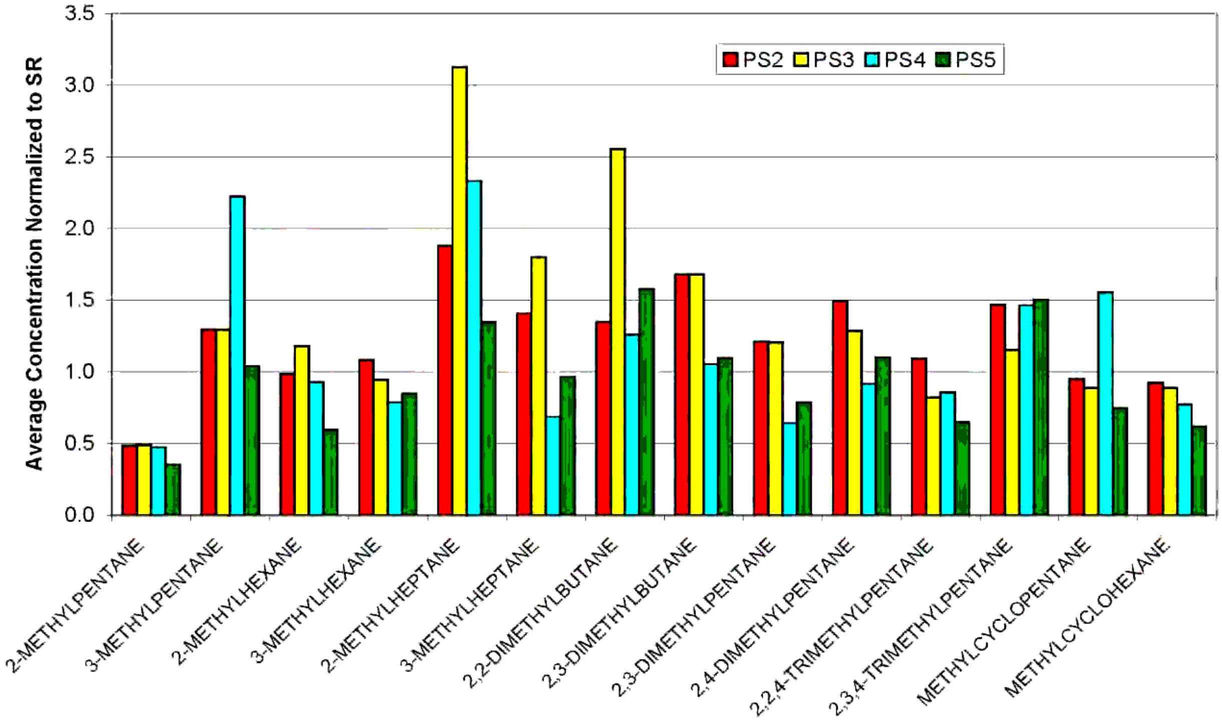


Figure 12. Average Ratio of Alkenes by TO12 Normalized to SR

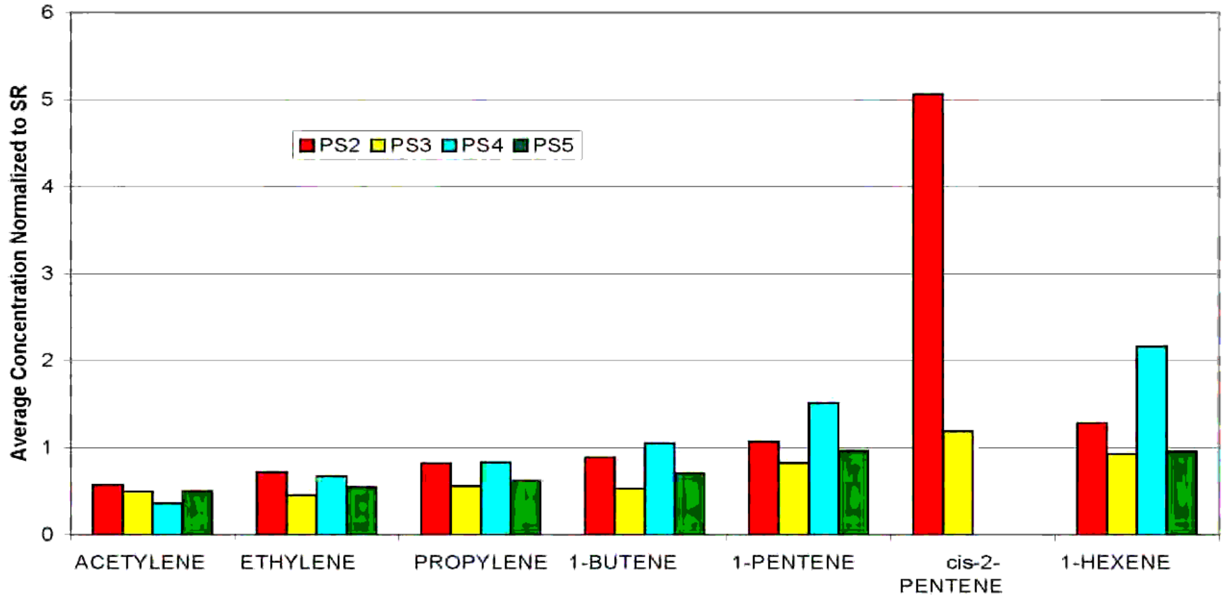


Figure 13. Average Ratio of Aromatics by TO12 Normalized to SR

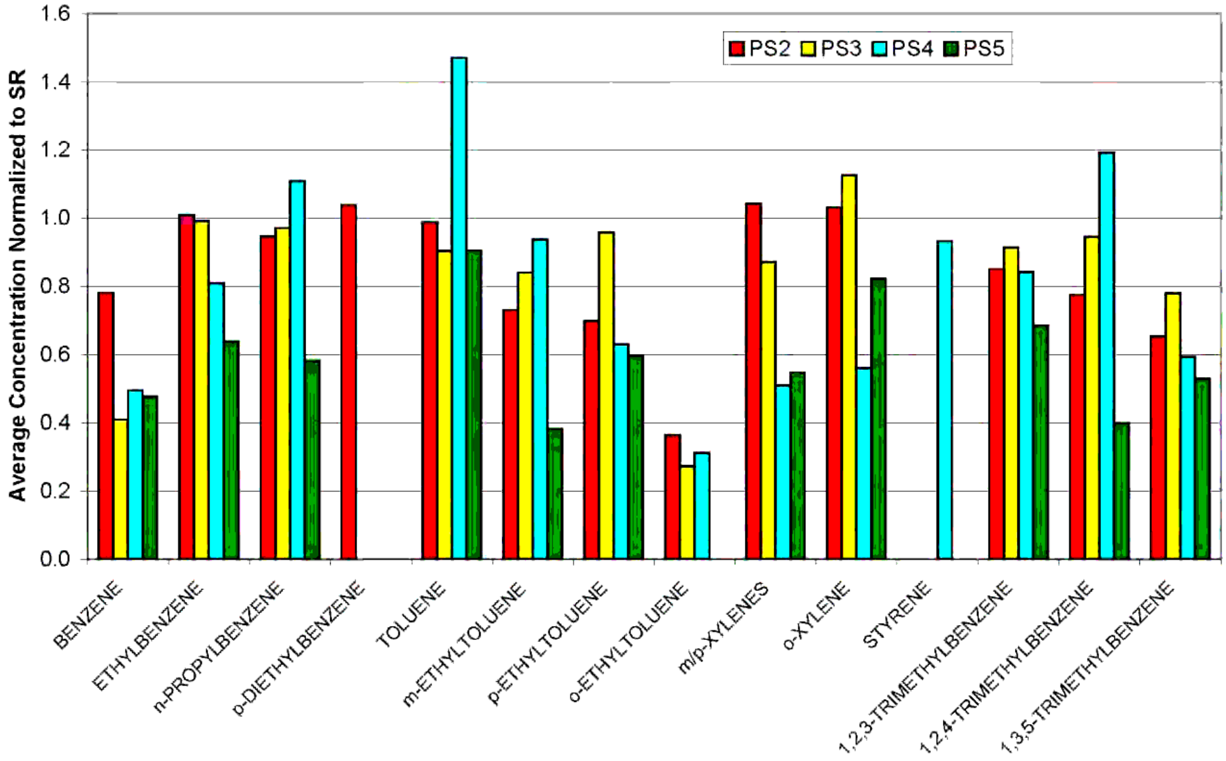


Figure 14. Average Ratio of Halogenated Compounds by TO15 Normalized to SR

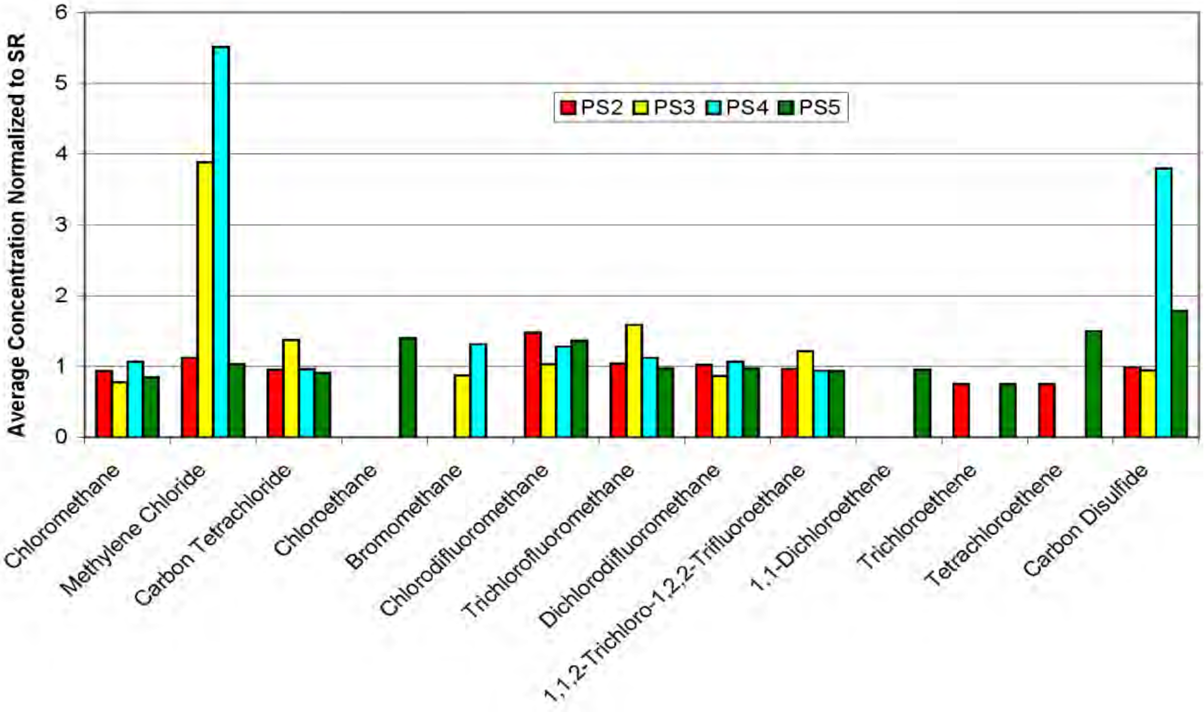


Figure 15. Average Ratio of Non-Oxygenated Compounds by TO15 Normalized to SR

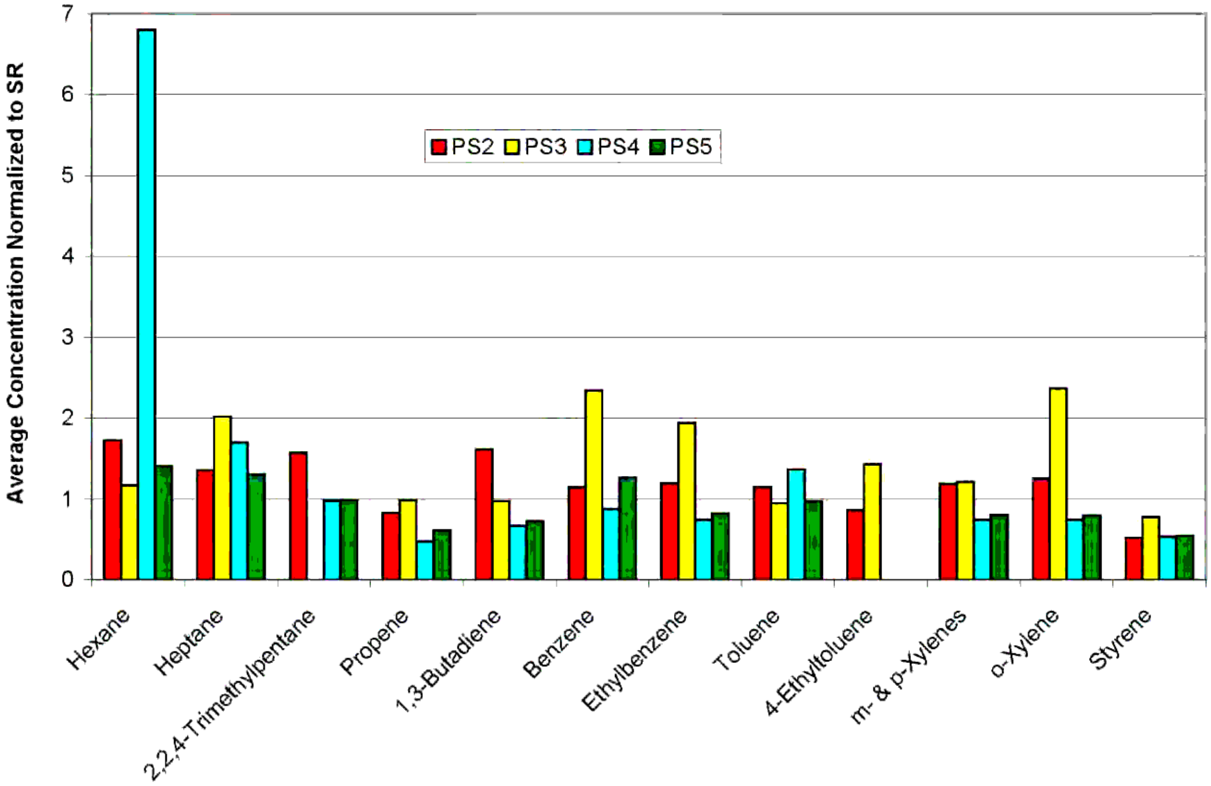
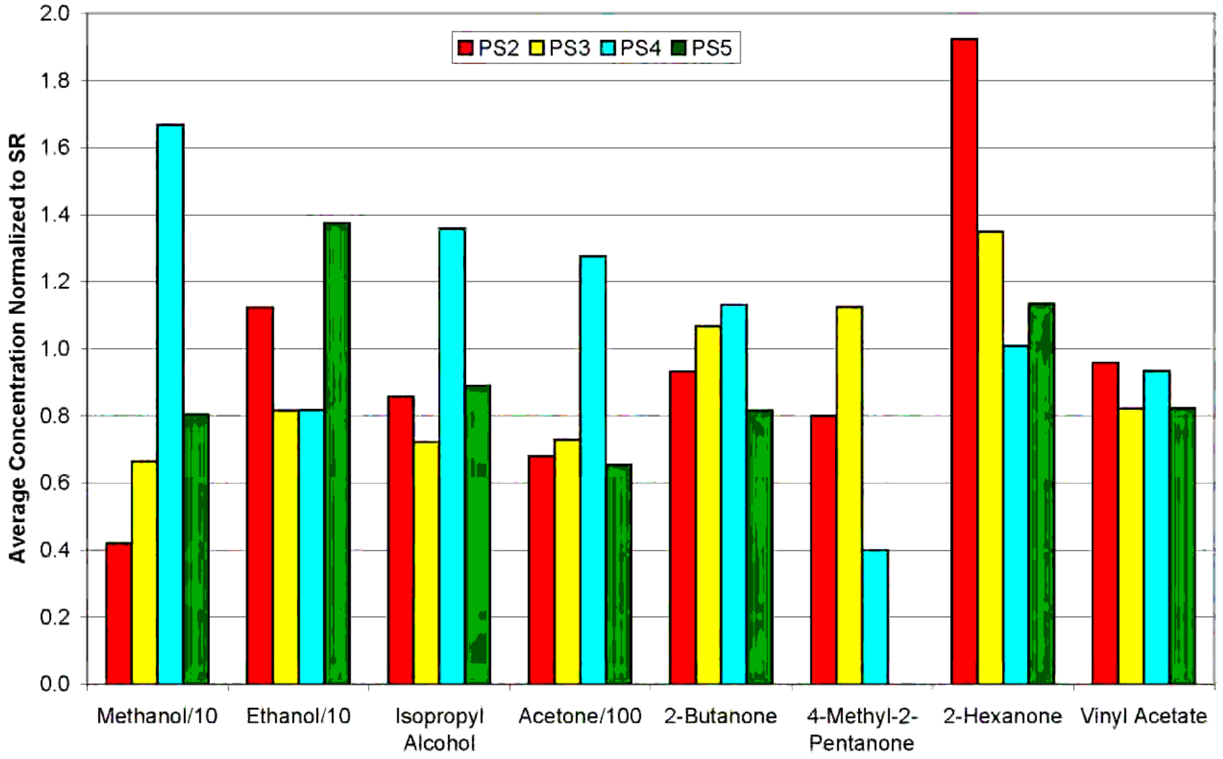


Figure 16. Average Ratio of Oxygenated Compounds by TO15 Normalized to SR



Differences in Hydrocarbon Concentrations Normalized to the SR Site

The PS2 site had significantly higher concentrations than the SR site for isobutene (by a factor of 3), cis-2-pentene (by a factor of 5), and 2-hexanone (by a factor of 1.9). The PS3 site had significantly higher concentrations than the SR site for 2,2-dimethylbutane (by a factor of 2.5), 2-methylheptane (by a factor of 3.1), 3-methylheptane (by a factor of 1.8), and methylene chloride (by a factor of 3.9). The PS4 site had significantly higher concentrations than the SR site for n-hexane (by a factor of 4.3), 2-methylheptane (by a factor of 2.4), 3-methylpentane (by a factor of 12.2), 1-hexene (by a factor of 2.1), methylene chloride (by a factor of 5.5), carbon disulfide (by a factor of 3.8), hexane (by a factor of 6.8), and methanol (by a factor of 1.7). The PS5 site had significantly higher concentrations than the SR site for isobutene (by a factor of 2.2), and n-butane (by a factor of 1.7).

AQMD's PRELIMINARY HYDROCARBON MEASUREMENTS

The South Coast AQMD collected five Summa canister samples at the trailer site and 13 canister samples at the blast fence site. Each sample represents a short-term "grab" sample of less than one minute duration when AQMD personnel detected strong odors from the taxiway. The wind was predominantly from the west to the west-southwest during the monitoring such that any plume from the taxiway would blow towards the two monitoring sites. The AQMD trailer site is a potential candidate site for the Long-Term Study. The preliminary results indicate a large variability in concentrations for the different samples as seen in Figures 17 and 18. The date and time of each sample are identified in these two figures. The report that CE obtained from the AQMD did not separate ethylene from acetylene. The concentrations of several compounds were divided by ten to present all compounds on the same scale.

Figure 17. VOC Concentrations Measured at the Blast Fence Site

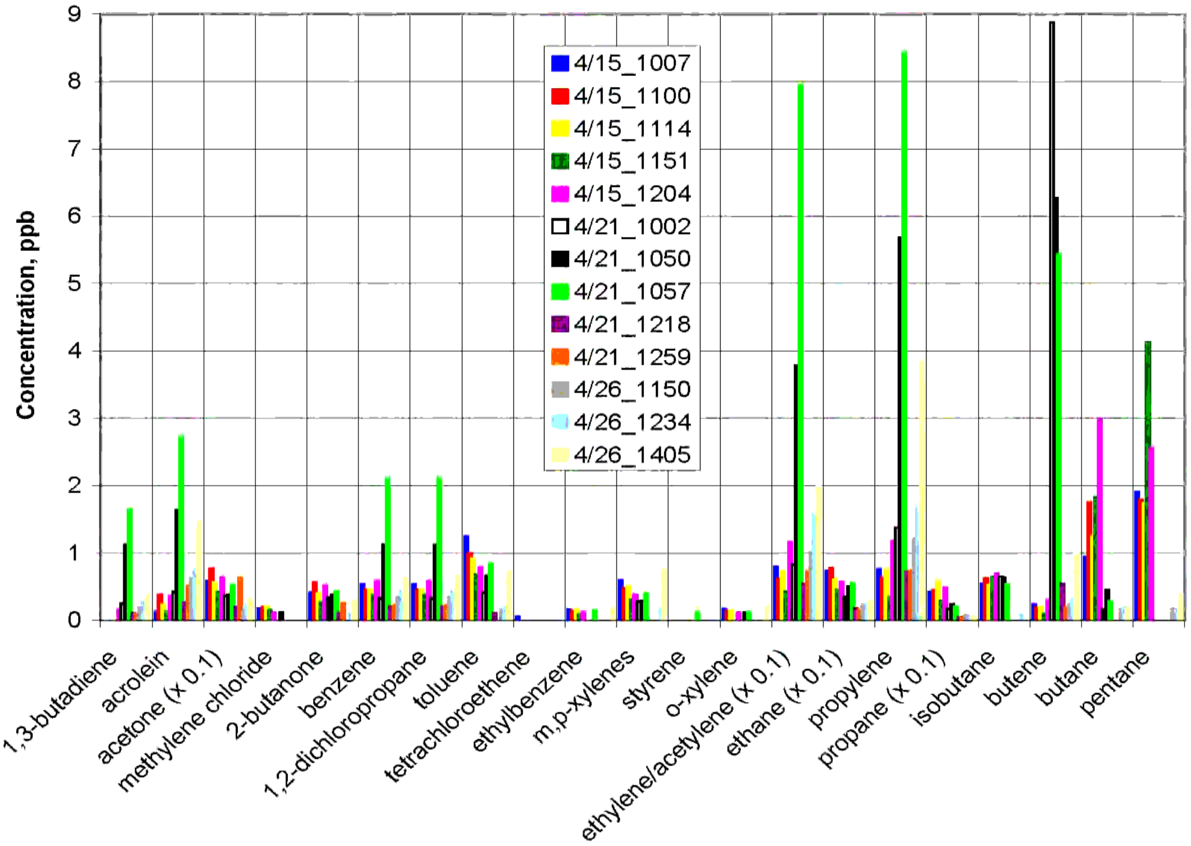
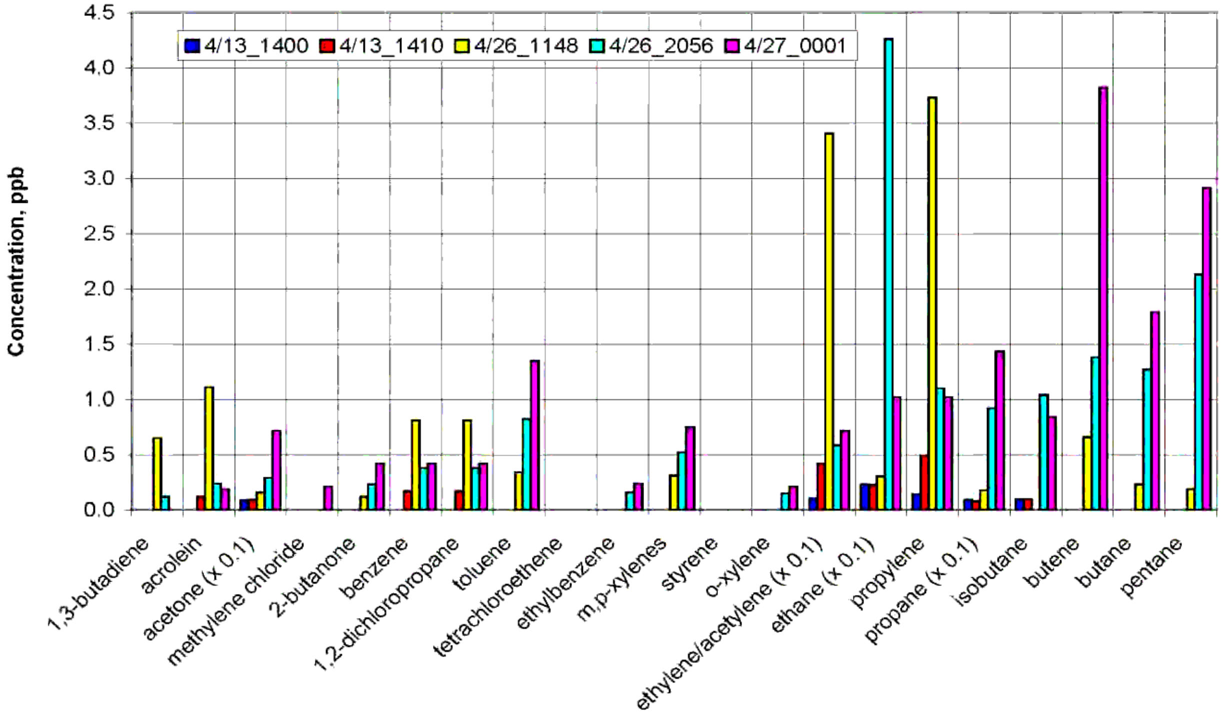
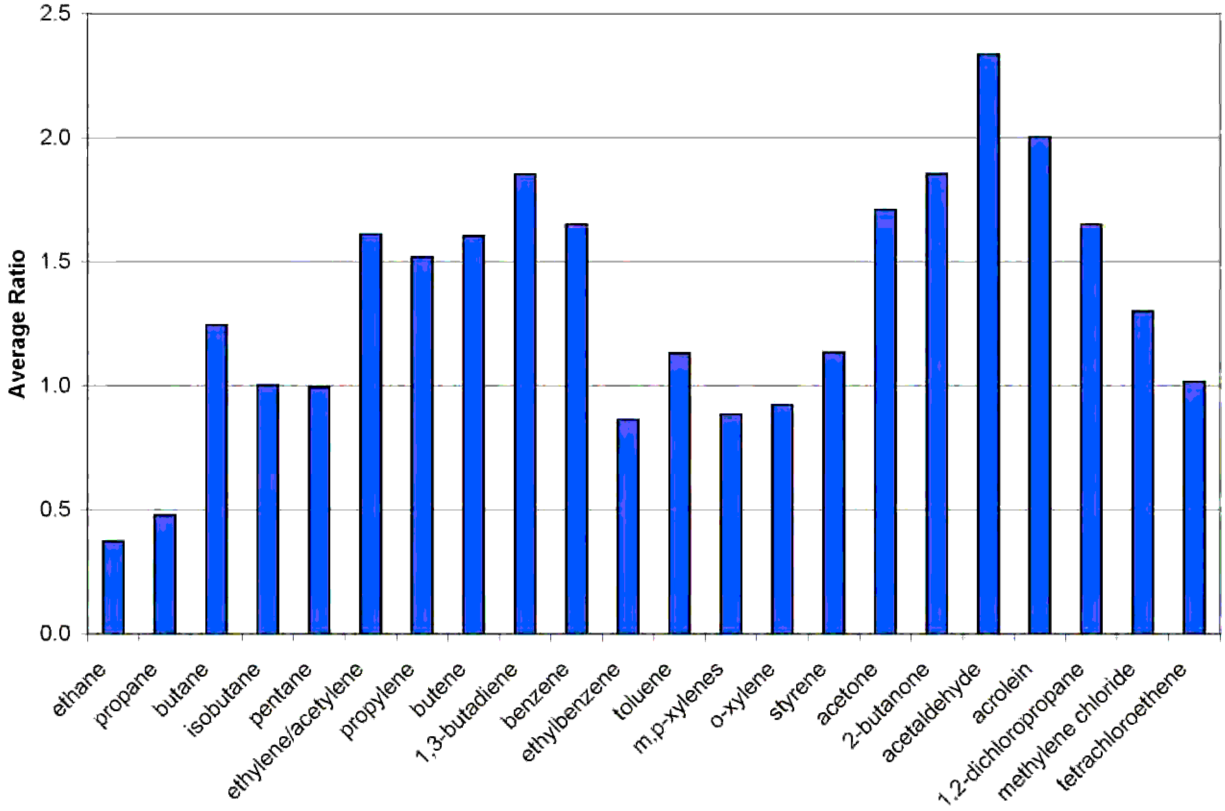


Figure 18. VOC Concentrations Measured at the AQMD Trailer Site



The ratios of the average hydrocarbon concentrations measured at the blast fence divided by the average concentrations measured at the AQMD trailer site are presented in Figure 19. These results indicate that the average concentration for most compounds at the blast fence was higher than the average concentration at the AQMD trailer site. This is not surprising given the fact that the blast fence site was 50 meters closer to the taxiway than the trailer site. However, the average concentrations of ethane, propane, ethyl benzene, m,p-xylenes and o-xylene were higher at the trailer site that at the blast fence. Furthermore, the canister sample collected at the trailer site on April 26th at 11:48 AM had a total VOC concentration that was almost three times the total VOC concentration for the canister sample collected at the blast fence site two minutes later at 11:50 AM. This illustrates the large temporal variability in plume concentrations from minute to minute and demonstrates the need to collect long enough samples during the Long-Term Study that are representative of average conditions.

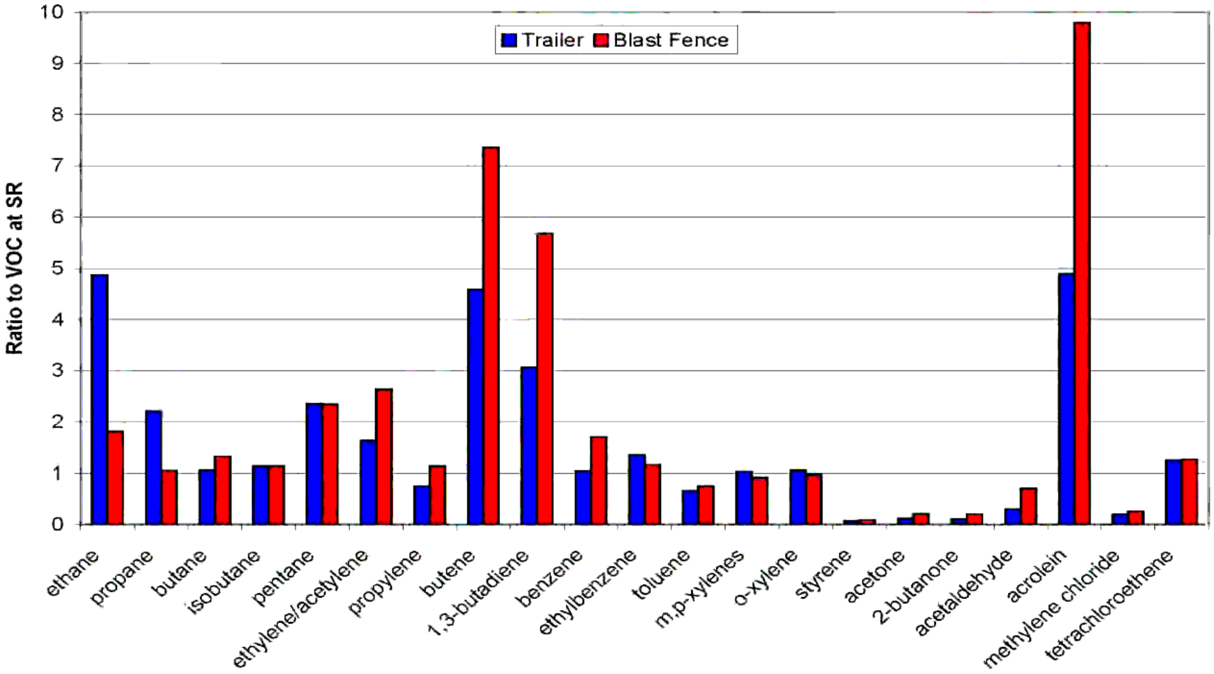
Figure 19. Average VOC Ratio: Blast Fence/AQMD Trailer Site



Differences in VOC Measurements Downwind of the South Runway versus the Taxiway
The ratios of the average hydrocarbon concentrations measured recently by the AQMD at the two sites downwind of the taxiway divided by the average concentrations measured at the SR (south runway) site during the 2008 Demonstration Project are presented in Figure 20. The results include 12-hour average carbonyl concentrations collected on DNPH impregnated silica gel cartridges at the SR site. The ratios for 1,2-dichloropropane are not included in Figure 20 since this compound was not detected at the SR site (or any of the other four monitoring sites during the Demonstration Project). The average concentrations of 1,2-dichloropropane at the blast fence site and the AQMD trailer site were 0.60 ppb and 0.37 ppb, respectively.

Ethane, pentane, ethylene plus acetylene, butene, 1,3-butadiene and acrolein were present in much higher concentrations downwind of the taxiway compared to downwind of the SR site. This may be due to higher amounts of unburned fuel in the exhaust of aircraft operating at low (or idle) power settings compared to higher power settings during take-off. The average acrolein concentration for the SR site is based on only three 12-hour nighttime samples and may not be representative. Conversely, styrene, acetone, 2-butanone (MEK), acetaldehyde and methylene chloride were present in much higher concentrations downwind of the SR site compared to downwind of the taxiway. These differences may be useful for source apportionment during the Long-Term Study

Figure 20. VOC at the AQMD Trailer and Blast Fence Sites Normalized to the SR Site



PORTABLE GC/MS MEASUREMENTS

The Inficon Hapsite portable GC/MS unit used at the SR site during the Demonstration Project only identified the presence of VOC compounds less than 20% of the time. Compounds that were identified at levels approaching the detection level of the portable GC/MS unit (estimated to be 3-5ppb) included decane; 4-methyl decane; tridecane; 1-methyl ethyl benzene; 1,2,3-trimethyl benzene; 1,2,4-trimethyl benzene; 1,3,5-trimethyl benzene; 1-methyl, 4-methyl ethyl benzene; tert-butyl benzene; 1, 4-dichloro benzene; indene; m/p-xylenes; benzaldehye; methyl salicylate; 2,3-dihydro benzofuran; phenol; naphthalene; and 1-methyl naphthalene. The recent portable GC/MS measurements conducted by the South Coast AQMD downwind of a taxiway at LAX generated no useful data. AQMD personnel tested a Tenax concentrator loop to lower the detection level of the Inficon unit. This resulted in identifying benzene; nonane; 1,2,3-trimethyl benzene; decane; and undecane.

Assessment of Markers for Source Apportionment

The TO12 and TO15 results for the ambient air samples collected at LAX were compared to the results for the liquid fuel samples collected at LAX and analyzed by the same laboratory (AAC) to see if their were any unique compounds that may serve for source apportionment in the Long-Term Study. EPA methods TO12 and TO15 provide data for approximately 100 hydrocarbon compounds. Rather than listing all these compounds here (since this information was contained in the data files provided to each of LAWA's on-call environmental contractors), only the differences in the chemical composition measured in the fuel samples and in the ambient air samples are presented in Table 4. These differences are then presented in the section following Table 4.

Table 4. Diffences in VOC Composition between Fuels and Ambient Air Samples

	Head Space Of Liquid Fuel Samples				Ambient Air Samples				
Analyte	**Diesel A**	**Diesel B**	**Jet-A**	**Unleaded Gasoline**	**SR**	**PS2**	**PS3**	**PS4**	**PS5**
n-Decane	X	X	X		X	X	X	X	X
n-Nonane	X	X	X		X	X	X	X	X
n-Undecane	X	X	X		X	X	X	X	X
Acetylene					X	X	X	X	X
Ethylene	X	X		X	X	X	X	X	X
Propylene	X	X		X	X	X	X	X	X
1-Butene	X	X		X	X	X	X	X	X
cis-2-butene	X	X		X					
trans-2-Butene	X	X		X	X				
1-Pentene	X	X		X	X	X	X	X	X
cis-2-pentene	X	X		X	X	X	X		
trans-2-Pentene	X	X	X	X			X		
1-Hexene	X	X		X	X	X	X	X	X
Isoprene	X	X		X					
1,2,3-Trimethyl benzene	X	X	X		X	X	X	X	X
m-Diethyl benzene	X	X	X		X				
p-Diethyl benzene	X	X	X		X	X			
n-Propyl benzene	X	X	X		X	X	X	X	X
Isopropyl benzene			X				X		
p-Ethyl toluene	X	X	X	X					
o-Ethyl toluene	X	X	X		X	X	X	X	
Styrene					X			X	
Methanol	X	X			X	X	X	X	X
Isopropyl Alcohol					X	X	X	X	X
Acetone		X			X	X	X	X	X
Methyl Ethyl Ketone					X	X	X	X	X
2-Hexanone					X	X	X	X	X
Vinyl Acetate					X	X	X	X	X
Chloromethane					X	X	X	X	X
Chlorodifluoromethane					X	X	X	X	X
Dichlorodifluoromethane					X	X	X	X	X
Methylene Chloride		X			X	X	X	X	X
Bromoform									X
Carbon Disulfide					X	X	X	X	X

Differences in Composition between Fuels and Ambient Air Samples at LAX

There were several hydrocarbon species detected at all monitoring sites at LAX that were not present in any of the fuel samples; they included acetylene, carbon disulfide, chloromethane, chlorodifluoromethane, dichlorodifluoromethane, isopropyl alcohol, methyl ethyl ketone, 2-hexanone, and vinyl acetate. Bromoform was only present at the PS5 site, and styrene was only present at the SR and PS5 sites. Acetone and methlyene chloride were present at all monitoring sites located at LAX but only in the diesel fuel sample that had been collected from the aircraft/ground service equipment (GSE) maintenance yard. Methanol was present at all the monitoring sites as well as in the two diesel samples (but not in the Jet-A or unleaded gasoline). Several of the compounds present at the monitoring sites are undoubtedly combustion products.

Unleaded gasoline was the only fuel that did not contain n-decane, n-nonane, n-undecane, 1,2,3-trimethyl benzene, m-diethyl benzene, p-diethyl benzene, n-propyl benzene, or o-ethyl toluene. Jet-A was the only fuel that did not contain ethylene, propylene, 1-butene, cis-2-butene, trans-2-butene, 1-pentene, cis-2-pentene, 1-hexene, or isoprene. Since isopropyl benzene was only present in Jet-A fuel, this compound may serve as a marker for aircraft exhaust. However, the measurements conducted during the Demonstration Project indicated that isopropyl benzene was only detected at the PS3 site.

Compounds present in the fuel samples but not observed in the ambient air samples included cis-2-butene, isoprene, and p-ethyl toluene. Compounds present in the fuel samples that were observed in ambient air samples at only certain sites included trans-2-butene at the SR site; cis-2-pentene at the SR, PS2, and PS3 sites; trans-2-pentene at the PS3 site; m-diethyl benzene at the SR site; p-diethyl benzene at the SR and PS2 sites; isopropyl benzene at the PS3 site; and o-ethyl toluene at the SR, PS2, PS3, and PS4 sites.

Differences in Composition between Ambient Air Samples at LAX versus Sepulveda Tunnel

There were many hydrocarbon compounds observed at one or more of the five monitoring sites at LAX that were not present in concentrations high enough to be detected in the Sepulveda tunnel samples: These compounds, which may serve as markers for source apportionment of airport operations during the Long-Term Study, include 2,2-dimethylbutane, 2,4-dimethylpentane, 3-methylheptane, n-octane, nonane, n-decane, n-dodecane, n-undecane, cyclopentane, cyclohexane, 1-pentene, cis-2-pentene, 1-hexene, isoprene, 1,3-butadiene, m/p-diethyl benzenes, n-propyl benzene, p/o-ethyl toluenes, 4-ethyl toluene, styrene, 4-methyl-2-pentanone, 1,4-dioxane, bromomethane, carbon tetrachloride, chloroethane, trans-1,2-dichloroethene, and trichlorofluoromethane.

Source Profiles for Aircraft Exhaust

There are many reports in the literature that present the chemical composition (i.e., source profiles) of aircraft engine exhaust (e.g., EPA/FAA's APEX and ACRP reports). CE's preliminary review of several of these reports indicate that there is a great deal of variability in the source profiles for aircraft engines tested in the laboratory as well as field measurements of aircraft exhaust operating at airports. There is too much information to summarize in this report. However, for illustrative purposes, CE has compared the source test results for two series of aircraft engines operating at idle and at 80% full power burning JP-5 fuel (Ref: C. Spicer et al., **Ann. Geophicae** 12, 944-955, 1994). The concentrations of most VOCs measured in the TF-39 engine source tests were almost double that measured in the CFM-56 engine source tests, and there was a large variability between the two sets of measurements. Because aircraft engines are very efficient in burning fuel at high power setting, many of the VOC species were below detection level for the engines operating at an 80% power setting.

It is a common practice to ratio VOC concentrations to formaldehyde for engine tests since this compound is present in high concentrations and is easy to measure accurately. Table 5 shows the ratio for different VOC species normalized to formaldehyde (HCHO) measured in the aircraft engine source tests and illustrates the large variability in the engine source tests. These ratios are much lower than those measured at the SR site during the Demonstration Project. Thus, one will need to compare source test results for aircraft burning Jet-A fuel with ambient measurements made in the Study Area during the Long-Term Study.

Table 5. VOC/HCHO Ratio for Aircraft Engine Source Test Profiles

	Engine at Idle		**Engine at 80% Power**		**Idle/80% Power**	
ANALYTE	**TF-39**	**CFM-56**	**TF-39**	**CFM-56**	**TF-39**	**CFM-56**
Ethane	0.070	0.042	0.162		0.43	
Propane	0.020	0.004				
n-Pentane	0.011	0.007				
2-Methylpentane	0.012	0.012				
n-Heptane	0.003	0.002				
n-Octane	0.003	0.001	0.015		0.20	
n-Nonane	0.004	0.001				
n-Decane	0.011	0.005	0.001	0.001	18.40	4.67
n-Undecane	0.015	0.007	0.006	0.012	2.59	0.59
n-Dodecane	0.016	0.007	0.056	0.021	0.29	0.32
Ethylene	2.133	1.345	0.059	0.147	36.26	9.15
Acetylene	0.577	0.369				
Propylene	0.487	0.263	0.020		24.84	
1-Butene	0.129	0.076		0.029		2.60
1-Pentene	0.040	0.027				
1-Hexene	0.036	0.021				
1,3-Butadiene	0.142	0.076		0.015		5.18
Benzene	0.085	0.053	0.015	0.020	5.78	2.68
Ethyl benzene	0.009	0.005				
Toluene	0.027	0.017	0.004		6.31	
m/p-Xylenes	0.013	0.006	0.048		0.27	
o-Xylene	0.007	0.004	0.004	0.007	1.91	0.52
Styrene	0.012	0.007				
Acetaldehyde	0.257	0.237	0.132	0.121	1.94	1.96
Acrolein	0.141	0.107	0.029		4.79	
Propionaldehyde	0.055	0.031	0.017		3.33	
Crotonaldehyde	0.054	0.032	0.011	0.031	4.92	1.05
Benzaldehyde	0.018	0.011				
Acetone	0.018	0.016	0.167	0.135	0.11	0.11

CONCLUSIONS

Methods Used to Quantify Pollutants

The Inficon Hapsite portable GC/MS unit does not have sufficient sensitivity to detect and measure volatile organic compounds (VOCs) in ambient air reliably, and thus is not a candidate for the Long-Term Study. Measurements of the fuels collected at LAX for speciated sulfur compounds indicated potential markers for source apportionment. Thus, measurements of speciated sulfur compounds in fuels (aviation fuel, diesel, and gasoline) as well as in the ambient air should be included in the Long-Term Study.

Data Recovery Rate for the Methods Used

Although the overall data recovery rate for samples collected during the Demonstration Project was high, many of the samples had concentrations that were below the detection limit of the analytical methods used. This issue will be addressed in following paragraph.

Methods Needing Revision

CE's review of the speciated light hydrocarbon data found that the analytical methods used to quantify these species need to be at least an order of magnitude more sensitive than those used for the Demonstration Project. The TO-15 method that was run in the "SCAN" mode for the samples collected during the Demonstration Project has detection limits of 0.5 to 2 parts per billion. Running the TO-15 method in the "SIM" mode will achieve detection limits of 10 to 50 parts per trillion. Each canister used during the Demonstration Project was individually certified prior to deployment in the field. Further investigation is needed to see whether "batch" certification of the canisters would suffice for the Long-Term Study. Measurements of polynuclear aromatic compounds during the Demonstration Project indicated that much more sensitive methods are needed for the Long-Term Study to identify and quantify key markers for source apportionment.

Optimum Sample Collection Period

In order to be able to conduct the source apportionment analysis successfully for the Long-Term Study, one should select sampling periods that conform to time periods when the wind direction is relatively consistent such that the samples collected represent concentrations of pollutants from as few sources as possible. Thus, one needs as short a sampling period as possible that at the same time will provide a large enough sample for analysis. Based on CE's evaluation of the winds that occurred during the Demonstration Project, the wind direction was not constant for the 12-hour daytime and nighttime sampling periods in July and August of 2008. Furthermore, the frequency of onshore and offshore winds will change throughout the year during the Long-Term Study such that an optimum sampling period for one season may not work for another season. The sampling periods should be adjusted throughout the Long-Term Study to fit the wind pattern. This may mean adopting sampling periods shorter than 12 hours, adjusting the start time and end time of the sampling periods, and having more than two sampling periods per day.

Markers for Source Apportionment

More information is needed on the source profiles for aircraft exhaust as well as other sources in the Study Area in order to be able to conduct a successful source apportionment of chemical species measured during the Long-Term Study. The source(s) of halogenated compounds observed during the Demonstration Project warrants further investigation. This report has identified several potential markers for airport operation emissions that could be used for source apportionment of chemical species measured during the Long-Term Study. These compounds are presented in Table 6.

Table 6. Potential Markers for Source Apportionment

Basis for Suggesting Markers	Potential Markers
Analysis of Fuels at LAX	a. Paraffins (e.g., naphthalene, methyl and dimethyl naphthalenes) b Sulfur compounds (e.g., thiophenes and benzothiophenes) c. High molecular weight alkanes (e.g., octane, nonane, decane, dodecane, undecane) d. Indenes
Engine Source Test Profiles	a. Alkenes (e.g., acetylene, ethylene, propylene) b Carbonyls (e.g., formaldehyde, acetaldehyde, acrolein, acetone)
Differences at LAX observed during the Demonstration Project versus the Sepulveda tunnel	a. Halogenated species (e.g., bromoform, methylene chloride) b. Oxygenated species (e.g., acetone, acrolein, methanol, isopropyl alcohol, 1,4-dioxane) c. Miscellaneous compounds: m-ethyl benzene, trans-2-butene, styrene, acetylene, isoprene, carbon disulfide d. Compounds identified on page 21 of this report

FINAL REMARKS

It should be noted that the Demonstration Project had the limitation of sample collection at different sites during different time periods (one site at a time). It is recommended that all samples be collected concurrently at all sites for the Long-Term Study. It is important that aircraft activity information be collected during the Long-Term Study as the chemical composition of the emissions are very different for aircraft that are idling on a taxiway compared to an aircraft in full power mode during take-off.