SANTA MONICA MUNICIPAL AIRPORT

A REPORT ON THE GENERATION AND DOWNWIND EXTENT OF EMISSIONS GENERATED FROM AIRCRAFT AND GROUND SUPPORT OPERATIONS

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JUNE 1999

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1.0 Introduction

In August 1995, the Los Angeles Unified School District (LAUSD) approved a resolution requesting the Federal Aviation Administration (FAA) to determine the potential health and safety impacts of airport operations on the students and staff who attend local schools in proximity of the Santa Monica Municipal Airport. It was LAUSD's contention that proposed navigational and related changes planned for the airport would not receive a thorough evaluation to assess the potential adverse effects on our local schools prior to implementation.

In addition to concern over FAA accountability regarding a full environmental evaluation of operational changes made at the airport, the LAUSD along with three Los Angeles City Council Districts which adjoin the airport, as well as representatives from the local community requested that a permanent safety committee be formed to evaluate local airport operations affecting the health and safety of the surrounding community.

In December 1995, the Santa Monica Airport Commission initiated several meetings to discuss the creation of the committee. During the ensuing months, the Airport Commission heard relevant testimony from community representatives regarding the committee's proposed composition, purpose and goals. At issue were concerns associated with aircraft noise, safety and the environment.

In October 1996, the safety committee was formed and included representatives from the LAUSD, FAA, Santa Monica Airport, local pilots, fixed based operators and members of several Los Angeles homeowners associations representing the Fifth, Sixth and Eleventh Council Districts. The safety committee, now referred to as the Santa Monica Airport Working Group (AWG), was limited to an eight month tenure and charged with the task of assessing noise, safety and environmental issues associated with existing and future airport operations. Recommendations were encouraged by the Airport Commission to mitigate negative impacts in a "realistic fashion." The goal of the AWG was to bring these recommendations to the Airport Commission for their consideration and, if deemed appropriate, forwarded to the Santa Monica City Council for their deliberation.

In response to the concerns of the community and in consideration of the tasks charged to the AWG, the LAUSD offered its expertise and resources to prepare a health risk assessment to determine the impact of toxic and associated pollutants generated from the Santa Monica Airport.

The assessment was designed to quantify community exposures assigned to an operational scenario that eliminates all fixed wing turboprop/turbojet operations (i.e., piston only), an existing baseline operational profile and another that assumed a projected increase in turbojet activity. It is believed that this comparative approach will provide relevant information to the community to determine the potential risk associated with each operational scenario from both an historic and future perspective.

Under the 1990 federal Clean Air Act (Act), 188 compounds are identified as hazardous air pollutants. These compounds are classified as "hazardous" due to their potential to cause adverse health effects such as cancer. Additionally, the Act required the U.S. Environmental Protection Agency (U.S. EPA) to control the emissions of hazardous air pollutants from major sources such as factories, refineries and mobile sources. As such, the U.S. EPA is charged with developing emission standards to prevent "an adverse environmental effect" or "provide an ample margin of safety to protect public health." For cancer risks, the margin of safety is defined as a lifetime cancer risk no greater than one in a million (1×10^{-6}).

In consideration of the above referenced value, results of the assessment revealed that cancer risks for the maximum exposed individuals who live in proximity of the airport were thirteen, twenty-two and twenty-six in one million, respectively. These values represent discrete cancer risks associated with airport related exposures. No background or ambient concentrations were incorporated into the risk quantification. Notwithstanding, emissions associated with airport operations were clearly found to exceed the Act's clean air goal of one in a million.

In addition to the quantification of carcinogenic risk, the assessment evaluated the impact of two criteria pollutants (i.e., particulates and lead). Particulates (PM_{10}) were evaluated due to community reports of excessive soot and dust associated with the operation of fixed wing turboprop/turbojet aircraft. Lead was considered due to the continued use of leaded aviation fuels by the piston aircraft fleet.

To evaluate the extent of PM_{10} and lead emissions on the local community, existing background values were added to the predicted concentrations for each operational scenario. Results of the analysis revealed that both short-term (i.e., 24 hour) and annual PM_{10} concentrations would not contribute to a violation of the National Ambient Air Quality Standard (NAAQS). For lead, contaminant concentrations were also found to be diminutive and not anticipated to meet or exceed the NAAQS of 1.5 micrograms per cubic meter (μg/m3).

It is relevant to note that the risk estimates and contaminant concentrations predicted in the assessment are estimates of exposure. Although there are uncertainties associated with discrete variates or assumptions (e.g., aircraft exhaust emission factors) used to perform the assessment, it is believed that attention to regulatory guidance and the use of relevant "tools" (i.e., conceptual and mathematical models) utilized to prepare the assessment provide for a "best estimate" of community-based exposures.

The following discussion outlines the relevant background documentation and technical approach used to quantify contaminant exposures associated with aircraft and ground support operations at the Santa Monica Airport facility.

2.0 Assessment Design

The assessment was designed to identify aircraft and ground support operations utilized at the Santa Monica Airport facility that might reasonably be anticipated to emit hazardous air emissions and determine the actual or potential endangerment of public health to persons who live within the surrounding community. Fixed base operations and related facilities including traditional on-site mobile source activity were also assessed.

The assessment's primary focus was to quantify community exposures assigned to a baseline operational profile and compare the predicted risks with those associated with an operational scenario that eliminates all fixed wing turboprop/turbojet operations (i.e., piston only) and another that assumes a projected increase in turbojet activity.

Historically, aircraft activity at the airport will exceed 200,000 operations annually. Although current operations fall well below an historic peak value of 356,853 recorded in 1966, a review of recent aircraft activity (1993 through 1997) showed an average rate of 203,699. Annual operations for both turbojet and rotocraft activity averaged approximately 5,000.

As a result, the assessment considered an annual activity rate of 200,000 as a viable baseline value consisting of 195,000 fixed wing and 5,000 rotocraft operations. For the increased turbojet scenario, a review of the five-year activity data revealed an operational increase from 4,209 recorded in 1993 to 6,203 identified for 1997. This represents an increase of more than 47 percent. However, due to the annual fluctuation in turbojet activity, it was difficult to establish a short-term annual trend. Nevertheless, due to the relative increase in turbojet operations, an effective doubling of the average rate was considered a viable upper bound estimate of airport activity. As such, a value of 10,000 operations was utilized for the increased turbojet scenario.

Although recent rotocraft activity exhibits an annual average of 5,000 operations, a significant decrease has been observed over recent years. In fact, a comparison of rotocraft operations for 1994 and 1997 show a decrease of more than 35 percent. Nonetheless, to ensure a conservative or health protective assessment of risk, no adjustments were made to the baseline or average activity value. Table 1 presents the number of aircraft operations considered for each operational scenario.

Table 1
Aircraft Operational Scenarios

Operational Profile	Aircraft Type		Total Operations
	Fixed Wing	Rotocraft	
Baseline and Piston	195,000	5,000	200,000
Increased Turbojet	200,000	5,000	205,000

For on-site mobile source activity (e.g., internal roadways), the assessment utilized established baseline values for all operational scenarios. This is due primarily to the assignment of most on-site mobile source activity to non-aviation use (e.g., restaurant and tenant parking). However, where the exclusion of the turboprop/turbojet aircraft eliminated ground support or fixed base sources (e.g., aircraft refueling), adjustments were made to deduct their emissions from the risk quantification.

3.0 Site Description

Established in 1919, the Santa Monica Airport is the oldest community airport operating in Los Angeles County. Originally known for its barley crop production, the site's first aviation use was dedicated to pilot training during World War I. Today, the facility is the busiest single runway airport in the nation. The airport also provides for numerous aviation related businesses including fixed based operators, supply services and aircraft maintenance. In addition, the airport offers restaurant dining, a world-class museum of flying and art studios. Various non-aviation commercial businesses are also located throughout the facility.

The airport occupies over 200 acres situated at the southeastern portion of the City of Santa Monica. The City's southern boundary coincides with the airport's southern property line. A triangular portion (approximately 34 acres) of the site's eastern boundary lies within the City of Los Angeles. This land is owned in fee by the City of Santa Monica.

The site is well served by arterial streets with primary access via Bundy Drive which borders the airport's eastern boundary. Twenty-third Street, which adjoins the airport's western boundary, connects between Ocean Park and Venice Boulevards. Airport access to the north is accomplished by traversing south from Ocean Park Boulevard via Twenty-eighth or Thirty-first Street. Airport Avenue, which parallels the site's southern boundary, provides internal access to the airport.

The airport is surrounded to the south, east and west by existing residential neighborhoods. Commercial structures and recreational facilities predominate to the north. Situated on a plateau above the surrounding community, the local topography provides a relatively horizontal land formation which accommodates a long runway across the length of the property. Along the terminus of the runway, the land mass slopes sharply in a downward trend producing a discrepancy in local elevation by more than thirty feet. Figure 1 presents an aerial photograph of the airport and surrounding community.

Figure 1
Santa Monica Airport and Vicinity

4.0 Background

Traditionally, air quality assessments associated with airport operations have been devoted to the quantification of six pollutants identified in the Federal Clean Air Act. These criteria pollutants are nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), particulate matter (PM_{10}) and lead (Pb). Assessments for proposed Federal actions are required to determine compliance with the National Environmental Policy Act (NEPA) and general conformity requirements of the Clean Air Act. The quantification and assessment of toxic emissions generated from airport operations is, therefore, an exception rather than a requirement under existing Federal regulation. As such, approval to conduct an air toxic assessment and develop a methodology to perform the analysis must be made in conjunction with the appropriate FAA regional program office.

In addition to these Federal requirements, individual states may promulgate local requirements applicable to various airport operations. In California, the assessment of toxic emissions is not expressly implied for project’s subject to the California Environmental Quality Act (CEQA). However, CEQA requires a determination of environmental significance based on project emissions either violating an ambient air quality standard, contributing substantially to an existing or projected air quality violation or exposing sensitive receptors to substantial pollutant concentrations. It is under the auspices of this third criterion that an assessment of toxic emissions may be performed.

Although Federal and state laws regulate the generation and subsequent risk associated with toxic air emissions from select stationary source operations, airports as a discrete “source” category are not expressly evaluated as a generator of toxic air emissions. Notwithstanding, airports are among the largest single source emitters of pollutants due to an array of emission sources associated with their operation (i.e., aircraft, motor vehicles, ground support equipment and stationary plant operations). However, existing regulations at the Federal and state level offer some control for limited stationary source categories (e.g., gasoline distribution facilities) should these operations relate to airport operations.

Nonetheless, it is by exception rather than rule that an air toxic assessment is prepared for an airport landing facility. It is relevant to note, however, that a health risk assessment conducted in 1993 for the U.S. EPA reported that aircraft engines are responsible for approximately 10.5 percent of the cancer cases within a defined geographic location (approximately 16 square miles) surrounding Chicago’s Midway Airport. The authors of the report additionally note that “it is no surprise that emissions from aircraft engines may have a significant impact on the people living in the study area, especially to people living at receptors adjacent to the airport.” The National Resources Defense Council (NRDC) commenting on the U.S. EPA assessment believes that “(t)he same conclusion might apply to people living immediately adjacent to airports all over the country.”

It is in the context of the latter citation that community concern for the health and safety of the children who attend their neighborhood schools and the welfare of their own families prompt the preparation of this health risk assessment.

5.0 <u>The Assessment Process</u>

The assessment of risk is a process whereby a detailed analysis is performed to determine the likelihood of an adverse health consequence arising from exposure to a hazardous agent.

Human health risk assessment, as formally described in a 1983 National Research Council Report: *Risk Assessment in the Federal Government: Managing the Process*, consists of four steps: hazard identification; dose-response assessment; exposure assessment; and risk characterization.

Hazard identification involves a determination of the specific health effects associated with exposure to a chemical compound. The dose-response assessment is designed to characterize the relationship between the amount or dose of a chemical agent and its toxicological effect on the human body. Exposure assessment involves the estimation of a chemical's concentration and the duration of exposure over a given period of time. Risk characterization is the integration and concluding step in the assessment process where information relative to a chemical's toxicity, concentration and length of exposure are combined to provide a quantitative probability of adverse health effects.

Although the process of hazard identification and the dose-response assessment are not explicitly addressed in this report, the determination of a compound's toxicity and the dose required to elicit an adverse health effect are based on established human health effects data developed and maintained by the U.S. EPA. As such, the latter steps of the assessment process will be addressed to determine the concentration and duration of the airport's collective emissions and integrate the resulting values with published toxicity data to produce a numerical estimate of risk.

5.1 Exposure Assessment

The exposure assessment estimates the extent of public exposure to each emitted compound for which cancer risk will be quantified or noncancer effects evaluated. This involves characterizing each emission source, quantifying the emission stream, modeling the extent of its atmospheric dispersion and estimating contaminant concentrations experienced by the surrounding community.

The following section presents an introduction to the standard methodology utilized to characterize both mobile and stationary source emissions. A discussion of the specific approach used for this assessment is also presented. This is appropriate as the refined nature of this analysis necessitates some enhancement and deviation from the current protocol.

5.1.1 Aircraft Source Characterization

Introduction

Traditionally, emissions generated from aircraft operations at civilian airports are based on the concept of the landing and takeoff cycle (LTO). The standard LTO cycle begins when the aircraft enters the mixing zone (i.e., that portion of the atmosphere extending from the earth's surface to the base of the inversion layer) as it approaches the airport on its decent from cruising altitude, lands and taxis to a respective gate or static location. The cycle continues as the aircraft taxis back out to the runway, takes off and climbs out of the mixing zone to a cruising altitude. The five modes which define the LTO cycle are approach, taxi/idle-in, taxi/idle-out, takeoff and climbout. Rotocraft display a slightly different sequence during the operating cycle. As such, the takeoff and climbout modes are combined to represent one operational sequence. Thus, the modes which typify rotocraft operations are approach, idle and climbout.

During the LTO cycle, each aircraft operates under varied timelines depending on the type of aircraft and operational characteristics of the airport under consideration. Therefore, within the LTO cycle, a discrete operational time or time-in-mode (TIM) must be defined. The U.S. EPA has developed several default TIM values for most LTO variants. Due to the relative "standard" operational timelines for approach and takeoff, it is considered common practice to utilize the U.S. EPA TIM default values. For the taxi/idle sequence, however, it is recommended that due to the variability associated with individual airport configurations and operational procedures, on-site monitoring be utilized to identify discrete TIM values for this sequence.

Although the LTO cycle provides the basis for calculating aircraft emissions, each emission profile varies considerably depending on the category of aircraft, engine type and flight profile. To quantify aircraft emissions, the FAA recommends that site-specific aircraft fleet and activity data be obtained and reviewed to generate a viable fleet mix and effectively characterize the temporal activity at the airport under consideration.

Once an aircraft fleet is identified, engine type and number, along with its respective emission profile should be reviewed to determine the subsequent generation of pollutant emissions. Although the FAA suggests that on-site data collection is feasible, it is not recommended "due to the difficulty in identifying specific engine models." Therefore, the FAA suggests utilizing "typical aircraft-engine combination data" provided by the U.S. EPA. The U.S. EPA provides a listing of limited aircraft and engine combinations, as well as a fleet averaging procedure, should detailed information on specific aircraft mix and activity be unavailable.

Following the assessment of aircraft fleet mix and corresponding engine type, emission factors are used to quantify the amount of pollutants generated by the respective airport's operations. Emission factor values are available from both the U.S. EPA and FAA. Generally, exhaust emission factors are reported in pounds of pollutant per 1000 pounds of fuel consumed. Emission factor values reported in pounds per hour are also available.

In addition, some general aviation aircraft require power and preconditioned air to maintain the aircraft's operability (e.g., instruments, lights and ventilation) while the main engines are shut down. When ground-based power and a related air source is not available, an onboard auxiliary power unit (APU) is utilized to generate electricity and compressed air to the aircraft. APU's are small jet engines which burn jet fuel and generate exhaust emissions similar to their larger counterparts. Emission factors for select APU's are also available from the U.S. EPA and FAA.

Although reference is made to the use and availability of emission factors to quantify pollutant generation, the hydrocarbon (THC) exhaust stream is considered a significant source of toxic emissions and a major contributor to the quantification of risk. To illustrate, THC exhaust is composed of various gaseous compounds formed by the release of aviation fuel that is either unburned or has undergone incomplete combustion. Therefore, a relative portion of the exhaust gases which make up the hydrocarbon stream are composed of a suite of toxic and hazardous compounds. Several reference sources are currently available to assist in the identification or speciation of these compounds. Specifically, the U.S. EPA has promulgated guidance to assist in the identification of discrete compound emission fractions and the application of various correction factors to convert the hydrocarbon exhaust stream to a usable toxic emission profile.

Assessment Protocol

As noted above, aircraft activity is defined through the identification of default TIM values for aircraft operating within the LTO cycle. Throughout the LTO cycle, aircraft will operate under varied timelines within a given mode. Therefore, the values utilized for each TIM sequence have a significant effect on the amount of pollutants generated from the aircraft. Unlike commercial airports where scheduled activity data is available to allow for the determination of unique operational timelines, most general aviation landing facilities do not retain these records. Notwithstanding this limitation, FAA air traffic control at Santa Monica Airport collected six months of hourly activity data from June 1996 through November 1996. In addition, the Santa Monica Airport facility maintains in-house records of hourly flight activity. This information was reviewed to assist in the development of the airport's activity profile.

To minimize the computational effort, operations recorded for June and November, the months identified with the highest hourly activity, were used to characterize the airport's temporal profile. For each operating hour (i.e., 7:00 a.m. to 9:00 p.m.) total aircraft operations were identified. Activity was assumed to be equally divided into both incoming and outgoing flights. Taxi/idle activity was also assumed to occur for each aircraft operating within this defined timeline.

Table 2 identifies the hourly flight activity for the three scenarios considered in the assessment. Temporal activity for the piston operational scenario was assumed to be consistent with the baseline activity profile. For the increased turbojet operations scenario, the activity profile was adjusted to accommodate for the effective doubling of annual turbojet operations over the baseline activity rate. Rotocraft operations were assumed to remain constant and, therefore, the temporal activity did not vary from the baseline rate.

Table 2
Hourly Average Aircraft Operations

Operational Scenario	Time Period													
	7-8	8-9	9-10	10-11	11-12	12-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9
Fixed Wing / Baseline and Piston	10.8	20.6	30.6	36.9	46.0	46.8	50.4	52.9	51.5	55.2	45.8	36.7	28.8	21.3
Fixed Wing / Increased Turbojet	11.1	21.1	31.3	37.8	47.2	48.0	51.7	54.3	52.8	56.6	47.0	37.6	29.6	21.8
Rotocraft	0.50	0.92	0.84	0.79	1.06	1.76	1.37	1.23	1.06	0.94	0.74	0.96	0.86	0.68

Unlike the TIM approach whereby emissions are directly related to the time the aircraft is in a given mode, the hourly activity values along with related operational information such as contaminant emission rate, average aircraft speed and route length were combined to produce a uniform link emission rate for each distinct hour of operation. This approach is consistent with the derivation of a uniform line source emission rate as described in the U.S. EPA-validated Point, Area and Line Source Dispersion Model (PAL2). Therefore, utilizing aircraft activity data as a link input variable abrogates the use of default or arbitrary values for a given time in mode.

To determine the airport's fleet mix profile, the assessment relied on the expertise of AWG members (i.e., pilots and FBO operators) to provide information on typical airframes, engine type and number associated with the fixed wing piston and turboprop aircraft utilizing the airport. In-house hourly flight activity records were reviewed to identify the type of aircraft associated with the turbojet and rotocraft classifications. Information related to the specific type and number of engines used on these airframes were obtained by evaluating available databases developed by the U.S. EPA and FAA. Where appropriate, this information was supplemented by incorporating relevant technical documentation and aircraft manufacturer's specifications. Tables 3 and 4 present the representative fleet mix for the airport facility.

Aircraft emission estimates were developed through the employment of several references sources. For most emission factor values, the FAA Aircraft Engine Emission Database (FAEED) was utilized. Although the FAEED database offers two resource options to generate emission estimates (i.e., International Civil Aviation Organization and the U.S.

Table 3
Fixed Wing Fleet Mix

Fleet Mix Percentage (Scenario)			Aircraft Class	Aircraft Type	Representative Engine Type	Engine Number	Percentage in Class
Baseline	Increased Turbojet	Piston					
94.8	92.4	100.0	Piston	Cessna 172	O-320	1	35.0
				Piper PA-34	TSIO-360C	2	35.0
				Piper PA-46	TIO-540	1	20.0
				Cessna 150	O-200	1	10.0
2.6	2.5	0	Turboprop	Beechcraft King Air	PT6A-41	2	49.0
				deHavilland DHC6/300	PT6A-27	2	49.0
				Fairchild Pilatus PC6	PT6A-27	1	2.0
2.6	5.1	0	Turbojet	Cessna Citation *	JT15D-4	2	34.0
				Learjet	TFE731-2-2B	2	19.0
				IAI Westwind *	TFE731-3	2	18.0
				Gulfstream	SPEYMK511-8	2	11.0
				Raytheon Hawker	TFE731-3	2	11.0
				Dassault Falcon	TFE731-2	2	3.0
				BAE HS125 *	TFE731-3	2	3.0
				Lockheed Jetstar	TFE731-3	2	1.0

Note: (*) Denotes aircraft with auxiliary power units (APU's). All APU's assumed a standard Allied-Signal GTCP 36 Series engine with a nominal 80 shaft horsepower rating.

Table 4
Rotocraft Fleet Mix

Fleet Mix Percentage	Aircraft Class	Aircraft Type	Representative Engine Type	Engine Number	Percentage in Class
11.0	Piston	Robinson R22	Lycoming O-320	1	58.0
		Robinson R44	Lycoming O-540	1	42.0
87.8	Turboprop	Aerospatiale AS 355	Lycoming LTS Series	2	52.0
		Bell 206	Allison 250 Series	1	45.0
		Agusta A109	Allison 250 Series	2	2.0
		MD 500	Allison 250 Series	1	1.0
1.2	Military	Sikorsky CH-53	T64-GE-6	2	60.0
		Sikorsky CH-3	T58-GE-5	2	40.0

EPA), the assessment considered only those values promulgated by the U.S. EPA (AP-42 Supplement 10). Specifically, the AP-42 modal emission rate summaries were accessed to produce total emission estimates for each discrete engine type and operational mode. For power plants not listed in the FAA database, emission factors were obtained from the U.S. EPA document *Procedures for Emission Inventory Preparation-Volume 4: Mobile Sources*.

Additionally, emission factors for the Allison 250 Series and Lycoming LTS Series engines were provided by the Aircraft Environmental Support Office (AESO) and Textron-Lycoming, respectively. Emission estimates associated with auxiliary power unit (APU) operation were derived from U.S. EPA's documentation entitled *Technical Data to Support FAA's Advisory Circular on Reducing Emissions from Commercial Aviation.*

Following the selection and assignment of emission factors to defined engine and operational modes, it was necessary to identify the specific toxic components of the exhaust stream. For hydrocarbon emissions, conversion factors were applied to correct the THC value to a total organic gas (TOG) equivalent. The TOG values were then converted by the application of chemical species data to yield a toxic emission profile. All correction factors, conversion formulae and toxic fraction profiles were obtained from U.S. EPA guidance. Tables 5 and 6 list the relevant values considered in the assessment.

Table 5
Aircraft Emission Correction Factors

Correction Factor	Aircraft Class		
	Piston	Turbine	Military
Total Hydrocarbon (THC) to Volatile Organic Compound (VOC)	0.9649	1.0631	1.1046
Volatile Organic Compound (VOC) to Total Organic Gas (TOG)	1.1347	1.0738	1.1147

Table 6
Aircraft TOG Toxic Fractions

Toxic Species	Aircraft Class		
	Piston	Turbine	Military
Benzene	0.0405	0.0179	0.0202
Formaldehyde	0.0269	0.1414	0.1548
1,3-Butadiene	0.0098	0.0157	0.0189
Acetaldehyde	0.0062	0.0432	0.0483

Note: Acetaldehyde values were derived from the following reference sources: Piston-*Motor Vehicle-Related Air Toxics Study* (U.S. EPA 1993), Turbine and Military-*VOC/PM Speciation Data System, Profiles #1099 and #1097* (U.S. EPA, 1992).

In addition to the quantification of toxic air emissions, two criteria pollutants (i.e., particulates and lead) were also considered in the analysis. The assessment of particulates (PM_{10}) was performed due to reports that "(a)ircraft are the primary source of PM_{10} emissions at airports" and concern that the generation of this contaminant may contribute to the continued degradation of local air quality. For lead, the assessment was designed to address community concern over the continued use of leaded aviation gasoline utilized by piston aircraft.

To estimate particulate generation of fixed wing piston aircraft, a procedure recommended by the U.S. EPA was performed. Consistent with the derivation of the above toxic emission profile, this procedure requires the conversion of exhaust THC to a TOG equivalent. The resulting value is then multiplied by five percent to represent the aircraft's particulate exhaust stream. Due to the limited availability of particulate emission factors for fixed wing turbine aircraft, particulate emissions were characterized by assuming the published AP-42 modal emission rate for the Garrett AiResearch TPE 331-3 power plant as a surrogate for the turbine fleet.

For the rotocraft fleet, published emission factors for representative engines were used as surrogates for the respective piston and military classifications. For turbine powered aircraft, the Allison 250 Series and Lycoming LTS Series engines were used to characterize particulate emissions for the rotocraft fleet. The emission factors for these engines were provided by the Aircraft Environmental Support Office (AESO) and Textron-Lycoming.

For all aircraft, an additional adjustment was made to convert the particulate exhaust to a representative PM_{10} fraction. Table 7 identifies the particulate conversion factors utilized for each aircraft and associated wing configuration.

Table 7
Aircraft Particulate Fractions

Aircraft Class	Wing Configuration	Representative Engine Type	PM Fraction	PM_{10} Fraction
Piston	Fixed	Engine specific with THC/TOG conversion.	0.05	0.9940
Turbine	Fixed	TPE 331-3	N/A	0.9760
Piston	Rotary	O-320	0.05	0.9940
		O-540	0.05	0.9940
Turbine	Rotary	Allison 250 Series	N/A	0.9760
		Lycoming LTS Series	N/A	0.9760
Military	Rotary	T58-GE-5	N/A	0.9760

Note: PM_{10} fractional values were derived from the State of California Air Resources Board document: *Method Used to Develop a Size-Segregated Particulate Matter Inventory* (CARB, 1988).

Notwithstanding, the above procedure relates to direct exhaust emissions, secondary emissions such as the reentrainment of paved roadway dust was also quantified as particulates from this fugitive source may contribute to the airport's emission potential. Predictive equations from the U.S. EPA were used in conjunction with the collection of loose surface material from various taxi and runway locations to produce an empirically derived emission rate value.

To quantify lead generation, particulate species profiles from the U.S. EPA and California Air Resources Board (CARB) were utilized. U.S. EPA VOC/PM Speciation composite profile number 31105 for the light duty vehicle-leaded classification was used to characterize the piston aircraft fleet. CARB profile number 141 for the aircraft-jet fuel category was used for the turbine classification. Emission rates were developed by multiplying the predicted PM_{10} emission rate by the percentage of lead (e.g., weight fraction) identified in the respective database.

The reentrainment of lead deposited on the various taxi and runway locations was additionally assessed. The protocol identified for the quantification of particulates was applied to the determination of fugitive lead emissions. Discrete emission rates were developed by multiplying the particulate emission rate by the concentration of lead (e.g., parts per million) identified in the surface material matrix.

A complete accounting of emission factors, emission rate values and predictive emission equations used for all aircraft sources and operational scenarios is presented in Appendix A.

5.1.2 On-Road Mobile Source Characterization

Introduction

In most urban communities, highway vehicles contribute significantly to localized concentrations of both criteria and toxic air contaminants. Typically, emissions generated from these sources are characterized by travel frequency and an associated rate the pollutant is emitted during the course of travel. Specifically, contaminant generation is a function of the pollutant emission rate, number of emitting vehicles and their operating mode within a defined street or roadway network.

Several unique processes govern the formation of pollutants generated from motor vehicles. The U.S. EPA and California Environmental Protection Agency (Cal/EPA) maintain large data collection programs to quantify the rate at which pollutants are emitted within a defined vehicle class (e.g., passenger cars, pickup trucks and large fleet vehicles) and technology group (e.g., catalyst, non-catalyst and diesel). Generally, emissions are reported in grams of pollutant per vehicle mile of travel (VMT). Estimates under idle conditions are also available or readily converted from the published VMT base rate. Idle rates are generally reported in grams of pollutant per minute of operation. Values for related operational modes (e.g., incremental hot and cold starts) are also treated to account for excess emissions generated under these transient conditions.

To determine traffic volumes and their associated temporal profile for individual roadway segments, an assessment to identify the number of vehicles and their associated hourly activity pattern is required. Traffic volume and activity can be estimated through either a review of previously documented vehicle counts or through direct observations. Direct observation entails the application of either manual or automated machine surveys. The U.S. EPA recommends that volume and activity values be as “representative as possible” for the area or roadway segment under consideration.

Another determinant associated with contaminant generation is the operational mode of the vehicle. Historically, both the U.S. EPA and Cal/EPA have identified three unique modes which typify the driving cycle. They are commonly referred to as cold start, hot start and stabilized. During the stabilized mode, the vehicle is sufficiently warm for the motor and emission control systems to attain a relatively stable operating temperature. As such, the emission control system will operate at maximum efficiency and minimize pollutant generation. Emissions associated with “start” operational profiles reflect values that produce excessive emissions over the stabilized mode due to the fact that the motor and related emission control equipment is not fully warm and operates at or slightly above ambient temperatures.

Traditionally, a start is considered cold if it occurs at least four hours following the end of a preceding trip for non-catalyst vehicles and at least one hour following the end of a preceding trip for catalyst equipped vehicles. Hot starts are defined as occurring less than four hours for non-catalyst vehicles and less than one hour for vehicles equipped with catalytic converters.

Recently, Cal/EPA revised its start methodology (EMFAC7G) to assess incremental start emissions as a continuous function of the engine-off period. Similarly, the U.S. EPA is revising its protocol to incorporate start emission rates that vary with vehicle soak time (MOBILE6). Soak time is defined as that period of time during which the vehicle merely sits, or soaks, with its engine off. Under the revised protocol, it is assumed that both the motor and emission control equipment may be sufficiently warm over an extended period of time to elicit some efficiency when restarted. Vehicular emissions generated under the revised protocol are, to a large extent, less than those predicted under the traditional methodology.

Evaporative emissions are an additional consideration when assessing the potential for pollutant generation. Two predominant emission profiles associated with hydrocarbon generation are resting loss and hot soak. Resting losses are defined as evaporative emissions that occur while a vehicle is at rest. Emissions associated with this scenario result when the vehicle is exposed to either constant or decreasing temperature fluctuations. Hot soak emissions refer to hydrocarbon evaporation which follows a period of hot running. Upon engine shutoff, the engine temperature rises, and air and fuel are no longer drawn into the engine causing the motor fuel in the induction system to evaporate or leak to the atmosphere.

To assess the downwind extent of contaminant generation and quantify the potential risk associated with exposure to these pollutants, individual compounds which characterize the hydrocarbon gas stream must be identified. As noted with the above aircraft characterization, reference sources are available to assist in the identification of these compounds. Notwithstanding, the U.S. EPA has promulgated guidance to assist in the speciation of several toxic compounds and developed a methodology to convert the hydrocarbon exhaust stream to a viable toxic emission profile.

Assessment Protocol

To determine the contribution of contaminant emissions generated from on-road motor vehicles, the analysis incorporated all relevant assessment methodologies offered under regulatory guidance.

As such, vehicle fleet mix was established by utilizing the California distribution profile recommended by the Institute of Transportation Studies, University of California, Davis. However, to accommodate the toxic emission factor profiles utilized in the assessment, several vehicle classes and their associated technology groups were merged to correspond to the fleet mix categories identified by the U.S. EPA. Table 8 lists the U.S. EPA mobile fleet classifications and the corresponding California fleet designations examined in the assessment. Table 9 presents the adjusted fleet mix for the on-road mobile sources operating within the airport facility.

On-road emission factors reflect the rate at which a pollutant is emitted by a specific operational mode or process. Currently, U.S. EPA emission factors are generated from a series of computer based programs entitled MOBILE5. Route speed, percent hot and cold starts, ambient temperature, vehicle mix and prediction year are input into the model to produce a composite emission rate for vehicles traveling along a roadway segment. For California, similar programs have been developed to account for the unique emission standards imposed on the California fleet. This has resulted in a series of models, the latest of which is EMFAC7F for microscale analysis (i.e., roadway segment or link level analysis) and EMFAC7G for regional source emission inventories.

Table 8
Comparison of Vehicle Classifications

U.S. Environmental Protection Agency Vehicle Class Designation	Vehicle Class Abbrev.	California Vehicle Class Designation	Technology Group	Vehicle Class Abbrev.
Light Duty Gasoline Vehicle	LDGV	Light Duty Auto/Light Duty Truck	Catalyst/Non-Catalyst	LDA/LDT
Light Duty Diesel Vehicle	LDDV	Light Duty Auto/Light Duty Truck	Diesel	LDA/LDT
Light Duty Gasoline Truck	LDGT1	See Note	N/A	N/A
Light Duty Gasoline Truck	LDGT2	Medium Duty Truck	Catalyst/Non-Catalyst	MDT
Light Duty Diesel Truck	LDDT	See Note	N/A	N/A
Heavy Duty Gasoline Vehicle	HDGV	Heavy Duty Truck	Catalyst/Non-Catalyst	HDG
Heavy Duty Diesel Vehicle	HDDV	Heavy Duty Truck	Diesel	HDD
Motorcycle	MC	Motorcycle	N/A	MCY

Note: Assume LDGV and LDGT classes are similar in contaminant generation. Combine LDGT1 vehicle class into LDA/LDT catalyst and non-catalyst technology groups. Merge LDDT category with LDA/LDT diesel technology group.

Table 9
Adjusted On-Road Mobile Fleet Mix

Vehicle Class	Abbrev.	Technology Group	Percentage
Light Duty Auto/Light Duty Truck	LDA/LDT	Catalyst	84.3
Light Duty Auto/Light Duty Truck	LDA/LDT	Non-Catalyst	3.3
Light Duty Auto/Light Duty Truck	LDA/LDT	Diesel	0.8
Medium Duty Truck	MDT	Catalyst	6.0
Medium Duty Truck	MDT	Non-Catalyst	0.4
Heavy Duty Truck	HDG	Catalyst	0.7
Heavy Duty Truck	HDG	Non-Catalyst	0.5
Heavy Duty Truck	HDD	Diesel	3.6
Motorcycle	MCY	N/A	0.5

At present, the U.S. EPA and Cal/EPA do not acknowledge the use of EMFAC7G emission factors for use in microscale analysis. The analytical approach used in the calculation of regional mobile source emission inventories are not appropriate for project assessments at the "link or intersection level." Therefore, due to the degree of refinement and localized approach to assess the generation of pollutants from vehicular movement within the airport facility, emission factors were generated from the EMFAC7F database. Emission rate values for calendar year 1997 were used as a surrogate for all operational scenarios considered in the assessment.

To determine hourly traffic volumes associated with on-site mobile source activity, the assessment employed an automated machine counter for vehicles traveling along Airport Avenue and obtained manual counts for vehicles utilizing the various lots which accommodate both airport and tenant parking. The machine counts were collected by Wiltec, an independent traffic engineering consulting firm. Table 10 lists the results of the machine count survey.

Table 10
Hourly Traffic Volumes
Airport Avenue

Time Period													
7-8	8-9	9-10	10-11	11-12	12-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9
498	613	710	454	615	585	767	603	732	633	613	720	442	257

For on-site parking, the assessment incorporated vehicular counts from a 1997 feasibility study of non-aviation land development south of the airport runway. The hourly counts were aggregated over several hours (e.g., 7 a.m. to 9 a.m.) and accounted for both ingress and egress movements. LAUSD staff collected vehicular counts for the remaining parking lots located throughout the airport facility. For consistency, the LAUSD values were tabulated in a manner consistent with those presented in the feasibility study format. However, to effectively evaluate contaminant generation, the collective traffic volumes were segregated into discrete hourly values. Table 11 presents the traffic volumes and directional movements for each lot considered in the assessment.

As recommended by the South Coast Air Quality Management District (SCAQMD) for automobiles operating within a county business district, vehicles traversing Airport Avenue were assumed to operate under a 15 and 25 percent hot/cold start scenario. For parking lots, the analysis assumed all exiting vehicles would operate under a cold start transitory cycle. Evaporative emissions associated with hot soak and resting loss generation were also considered in the analysis. Appendix C lists the vehicular movements for each parking facility and the percentage of emissions assigned to each emission profile.

In a manner consistent with the identification of toxic components generated from aircraft sources, vehicular emissions were based on the total organic gas (TOG) emission factor values generated from the EMFAC7F database. The EMFAC7F values were combined with the relative fleet mix percentages and related contaminant fractions to produce a toxic emission profile. Table 12 lists the suite of toxic compounds and their associated fractions utilized in the assessment.

Table 11
Hourly Traffic Volumes
Parking Facilities

Source Location	Time Period													
	7-8 (in)	8-9 (out)	9-10 (in)	10-11 (out)	11-12 (in)	12-1 (out)	1-2 (in)	2-3 (in)	3-4 (out)	4-5 (in)	5-6 (out)	6-7 (in)	7-8 (out)	8-9 (out)
Lear A1	129	3	40	16	16	24	12	12	16	3	145	3	6	5
SMC Shuttle B	50	6	186	31	124	31	24	23	78	31	155	78	108	107
SMC Applied Design Center C1	6	1	23	4	15	4	3	3	10	4	19	10	13	13
SMC Applied Design Center C2	29	4	108	18	72	18	14	13	45	18	90	45	63	61
Administration Building D	67	2	21	8	8	13	7	6	8	2	76	2	3	3
Runway Building E	47	1	15	6	6	9	5	4	6	1	53	1	2	2
SMAC F1	32	1	16	5	5	7	4	3	5	1	42	1	1	1
SMAC F2	19	1	9	3	3	4	2	2	3	1	24	1	1	1
Spitfire Building G	55	20	30	30	7	10	15	15	30	25	55	40	21	21
3200 Building H	62	2	20	8	8	12	6	6	8	2	70	2	3	3
Tenant I	24	1	12	3	3	5	3	2	3	1	30	1	1	3
Tenant J	41	1	20	6	6	9	5	4	6	1	53	1	2	1
Tenant K	24	1	12	3	3	5	3	2	3	1	31	1	1	2
Supermarine Main	44	2	16	3	13	26	26	25	46	19	25	3	22	22
Supermarine/DC3/ Museum Hangers	15	3	30	3	65	22	21	20	71	25	23	45	50	49
Thomason	8	0	3	0	3	2	3	3	10	0	6	0	1	1
Gunnell Aviation	27	2	21	2	6	4	5	5	13	3	23	0	12	11
Airfield	13	3	5	2	10	12	13	13	23	15	11	0	9	9

As with the quantification of aircraft emissions, particulates (PM_{10}) and lead were also examined in the analysis. Emission factors from the EMFAC7F database were used to determine direct tailpipe emissions and scaled to account for the PM_{10} fraction. Secondary emissions were quantified through the reentrainment of paved roadway dust. For lead, only emissions associated with the deposition from aviation sources were assessed through the potential reentrainment from vehicular movement along Airport Avenue.

Predictive equations from the U.S. EPA were used in conjunction with the collection of loose surface material from Airport Avenue to produce an emission rate value. For lead, emission estimates were developed by multiplying the particulate emission rate by the concentration of lead identified in the surface material matrix.

Table 12
On-Road Vehicular Toxic Fractions

Vehicle Class (abbrev.)	Technology Group	Compound/Emission Source						
		Benzene				Formaldehyde	1,3-Butadiene	Acetaldehyde
		Exhaust	Running	Resting	Hot Soak	Exhaust	Exhaust	Exhaust
LDA/LDT	Catalyst	0.04220	0.01000	0.01000	0.00730	0.01300	0.00560	0.00500
LDA/LDT	Non-Catalyst	0.02740	0.01000	0.01000	0.00730	0.03740	0.01150	0.00820
LDA/LDT	Diesel	0.02290	0.00000	0.00000	0.00000	0.03910	0.01030	0.01250
MDT	Catalyst	0.04220	0.01000	0.01000	0.00730	0.01300	0.00560	0.00500
MDT	Non-Catalyst	0.02740	0.01000	0.01000	0.00730	0.03740	0.01150	0.00820
HDG	Catalyst	0.04220	0.01000	0.01000	0.00730	0.01500	0.00560	0.00500
HDG	Non-Catalyst	0.02740	0.01000	0.01000	0.00730	0.04310	0.01150	0.00830
HDD	Diesel	0.01060	0.00000	0.00000	0.00000	0.02800	0.01580	0.00750
MCY	N/A	0.04220	0.01000	0.01000	0.00730	0.01300	0.00560	0.00500

Note: Exhaust and hot soak values were derived from the *Vehicle-Related Air Toxics Study* (U.S. EPA, 1993). Running and resting losses were obtained from *Inputs and Methodology for Calculating Motor Vehicle Emission Factors for the Southwest Chicago Study Work Assignment* (U.S. EPA, 1992).

A complete listing of emission factors, emission rate values and predictive emission equations associated with the assessment of on-road mobile sources is presented in Appendix B.

5.1.3 Stationary Source Characterization

Introduction

Air emissions originate from a wide variety of on-site sources and, therefore, are usually not centrally located before they are discharged to the atmosphere. Consequently, each source must be evaluated individually to determine the amount and type of pollutant emitted. Releases to the ambient air are broadly categorized as either point, such as a stack or vent release, or fugitive sources, which are not contained or ducted to the atmosphere.

Stationary emissions at airports consist of both point and fugitive sources. Typical point source emissions involve combustion from boilers and related power generating equipment, whereas, aircraft refueling activities and maintenance operations represent fugitive or non-point source emissions. Nevertheless, both categories have the potential to contribute to the production of toxic air pollutants.

As with most industrial facilities, boilers are used to provide electrical power generation, industrial process heat/steam and space heating. Although various pollutants are associated with the combustion process, natural gas is often used as the predominant energy fuel due to its ability to generate lower contaminant emissions over products such as coal and fuel oil (e.g., diesel no. 2).

Non-combustion sources at airports typically include evaporative emissions from aircraft refueling and underground tank loading operations. Solvents used for both aircraft and plant maintenance are also common and serve as an additional source of contaminant emissions. However, unlike the complex suite of compounds generated from combustion, evaporative emissions generally involve hydrocarbon compounds and are limited to the loss of a select group of volatile components contained within a given product.

To estimate the volume of pollutants emitted from each source or product, one of several quantification methods are employed. As such, direct measurement, mass balance, emission factors, engineering calculations or a combination of these methods are utilized. Direct measurement is based on real-time measurements of a chemical compound in a process flow. Mass balance refers to the accounting of all input and output volumes of a product in a process or operation. Emission factors are based on average measured or monitored data usually expressed as a ratio of an amount of material released over a defined process throughput. Engineering calculations are based on the relationship between equipment design and related operating parameters and a compound’s chemical/physical state as it is introduced into or moves through a process flow. The U.S. EPA and similar regulatory agencies have promulgated a significant body of reference material to assist in the quantification of both point and fugitive emissions.

As noted with the former source profiles, guidance is available to assist in defining the toxic portion or fraction of the hydrocarbon emission stream. Regulatory guidance is also available for an array of operations to quantify the amount of toxic compounds emitted from most point and fugitive sources.

Assessment Protocol

To quantity the contribution of emissions associated with fixed base sources, LAUSD staff conducted a field survey of existing business and airfield operations. The survey consisted of interviews with business owners/operators and a visual inspection of potential sources of contaminant generation.

Permit documentation from the SCAQMD, California Environmental Protection Agency, Office of Environmental Information and Santa Monica City Fire Department (SMFD) was further reviewed to assist in the identification of potential emission sources. Results of the field survey and records review identified eight facilities with a potential to generate contaminant emissions. Table 13 lists the facilities and their corresponding operations considered in the assessment.

Table 13
Identification of Fixed-Based Sources

Facility	Operation
Supermarine	Aircraft Refueling Underground Tank Filling
Cloverfield Aviation	Aircraft Refueling Underground Tank Filling
Santa Monica Fire Department Engine Company No. 5	Gasoline Dispensing
DC3 Restaurant	Charbroiling
Typhoon Restaurant	Charbroiling
General Administration Building (1st floor)	Natural Gas Combustion
General Administration Building (2nd floor)	Natural Gas Combustion
Runway Building	Natural Gas Combustion

For the facilities/operations listed as emitting sources, contaminant release information was obtained principally from U.S. EPA guidance. Emission rate data for gasoline dispensing was developed in accordance with guidance from the CARB reference document entitled *Emission Inventory Procedural Manual, Volume III, Methods for Assessing Area Source Emissions.*

Chemical species were identified through a review of available literature for each unique process and operation. As such, contaminant emissions associated with aircraft refueling and underground tank filling were identified through a review of listed compounds/ingredients from available material safety data sheets. U.S. EPA VOC/PM Speciation profiles number 1015 and 0003 were used to characterize gasoline dispensing and natural gas combustion, respectively. Emissions from charbroiling operations were obtained from the U.S. EPA report *Study to Develop Background Information for the Direct Meat-Firing Industry.* Table 14 provides an outline of the compounds used to characterize contaminant generation from each fixed-base source.

To the degree practical, all contaminant emissions were considered in the analysis. The limiting factor for the inclusion of a compound was the availability of U.S. EPA exposure factors and toxicity data enabling risks to be quantified and, where appropriate, target organs identified.

Table 14
Fixed-Based Source Emissions

Facility	Contaminant
Supermarine	Benzene
Cloverfield Aviation	Benzene
Santa Monica Fire Department Engine Company No. 5	Benzene
DC3 Restaurant	Particulates (PM_{10})
Typhoon Restaurant	Particulates (PM_{10})
General Administration Building (1st floor)	Benzene Formaldehyde
General Administration Building (2nd floor)	Benzene Formaldehyde
Runway Building	Benzene Formaldehyde

A comprehensive list of emission factors, emission rate values and predictive emission equations associated with the assessment of fixed-based sources is presented in Appendix D.

5.1.4 Dispersion Modeling

Knowledge of the chemical's airborne concentration is integral to the characterization of risk and an essential part of the assessment process. Two methods may be utilized to obtain these concentration values. One approach is air monitoring which requires the collection and analysis of ambient air over a defined period of interest (e.g., day, month and year). Although air sampling can reveal ambient pollutant levels, it cannot identify the source or origin of a chemical compound collected during the sampling exercise. A second method utilizes a predictive modeling approach or mathematical simulation to calculate the dispersion of pollutants and their relative concentrations on a given population. Additionally, an air dispersion modeling exercise can be designed to identify individual compounds generated from a source and predict their downwind extent on the adjoining community.

To exemplify the viability of a predictive modeling approach, the U.S EPA Office of Air Quality Planning and Standards (OAQPS) reports that "modeling is the preferred method" for assessing emissions generated from new and existing sources and has the unique capability of predicting the impacts from "sources that do not yet exist." Simply, for a determination of potential environmental impairment associated with both planned and future operations, modeling is the "primary analytical tool."

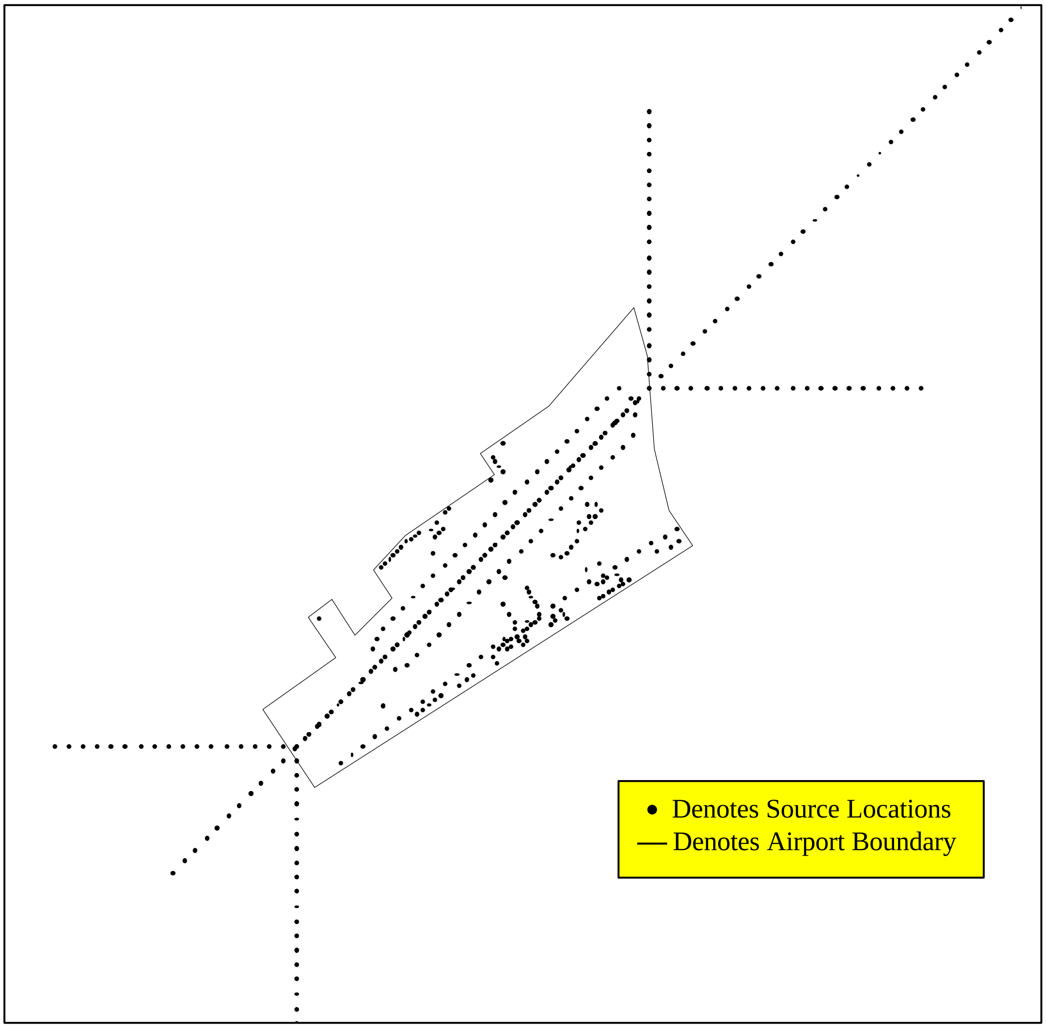
Although dispersion modeling is the appropriate analytical approach to assess pollutants generated from both mobile and industrial sources, there are a number of approved or "guideline" models available to quantify pollutants generated from airport operations. One such model developed jointly by the FAA and United States Air Force is the Emissions and Dispersion Modeling System (EDMS). The model utilizes existing Gaussian dispersion algorithms to predict downwind criteria pollutant concentrations. However, the model oversimplifies many source activities that limit its usefulness in performing a refined or detailed risk assessment. For example, the model developers report that aircraft emissions during approach and following takeoff "contribute very little to the pollution burden at an airport." As such, the model limits the quantification of aircraft emissions during takeoff from the beginning of its takeoff roll to the end of the runway link. Aircraft emissions generated above ground level or beyond the airport facility fenceline are not assessed. In addition, the model does not consider the effects of complex or intermediate terrain nor account for the aerodynamic effects of contaminant downwash associated with nearby building structures. Notwithstanding these limitations, the model does not treat the dispersion of exhaust hydrocarbons. As noted above, contained in the hydrocarbon gas stream of most combustion sources, including aircraft engines, are toxic compounds such as benzene, formaldehyde, 1,3-butadiene and acetaldehyde. Therefore, due to the model's limited capabilities to adequately assess the dispersion of toxic pollutants and simplified design of its dispersion methodology, it was rejected for inclusion in this study.

Another model available for use in the quantification of airport emissions is the Industrial Source Complex Short Term (ISCST3) model. ISCST3 is an OAQPS preferred model for assessing pollutant concentrations from a wide variety of emission sources (i.e., point, area and volume). It employs the use of Gaussian dispersion algorithms to account for the effects of building downwash, buoyancy-induced dispersion, the treatment of receptors in flat, intermediate and complex terrain, one hour to annual averaging times and continuous toxic air emissions. ISCST3 is capable of quantifying pollutant emissions generated from multiple sources and can accommodate both static emission rates and those that reflect discrete operational periods unique to the source under consideration. The model offers additional flexibility by allowing the user to assign initial vertical and lateral dispersion parameters for sources representative of a general aviation fleet as well as those associated with localized mobile and stationary sources. As a result of the model's robust architecture and its ability to allow the user to incorporate detailed source and operational profiles, it was selected as the preferred model to assess the downwind extent of contaminant emissions generated from the airport.

As such, the volume source algorithm was used to model fugitive dispersion and predict ground level concentrations associated with all mobile and fixed-based sources. One exception was the use of the point source algorithm to model particulate dispersion associated with cooking process emissions generated from the Typhoon Restaurant facility.

To address the spatial distribution of emitting sources and accommodate the unique characteristics of both aviation and on-road mobile source configurations, a grid spacing of 50 meters was utilized. This distance was selected to minimize the computational effort associated with a compressed spatial design (i.e., length of the line source divided by its width) and ensure that a sufficient source density was achieved to preserve the horizontal geometry of the line source configuration. For parking facilities, discrete lot configurations were segregated into multiple sources of uniform size (i.e., width). Stationary operations were identified as discrete configurations and located at or within close proximity of each emission source. Figure 2 presents a graphical representation of each emitting source considered in the modeling exercise.

Figure 2
Santa Monica Airport Source Configuration



Vertical (sigma z) and horizontal (sigma y) dispersion parameters were developed utilizing several regulatory methodologies. For all dynamic sources, sigma z values were generated by approximating mixing zone residence time and quantifying the initial vertical term as performed in the U.S. EPA guideline model Caline3. Sigma y parameters were generated by dividing the source separation distance by a standard deviation of 2.15. For static sources, initial vertical and lateral dimensions were developed in accordance with ISCST3 model guidance. One deviation from the above guidance was the use of an initial vertical dimension of one meter for ground level fugitive sources. This value was arbitrarily set to account for local surface roughness elements. Appendix E presents a worksheet identifying the initial dispersion parameters for each source considered in the dispersion analysis.

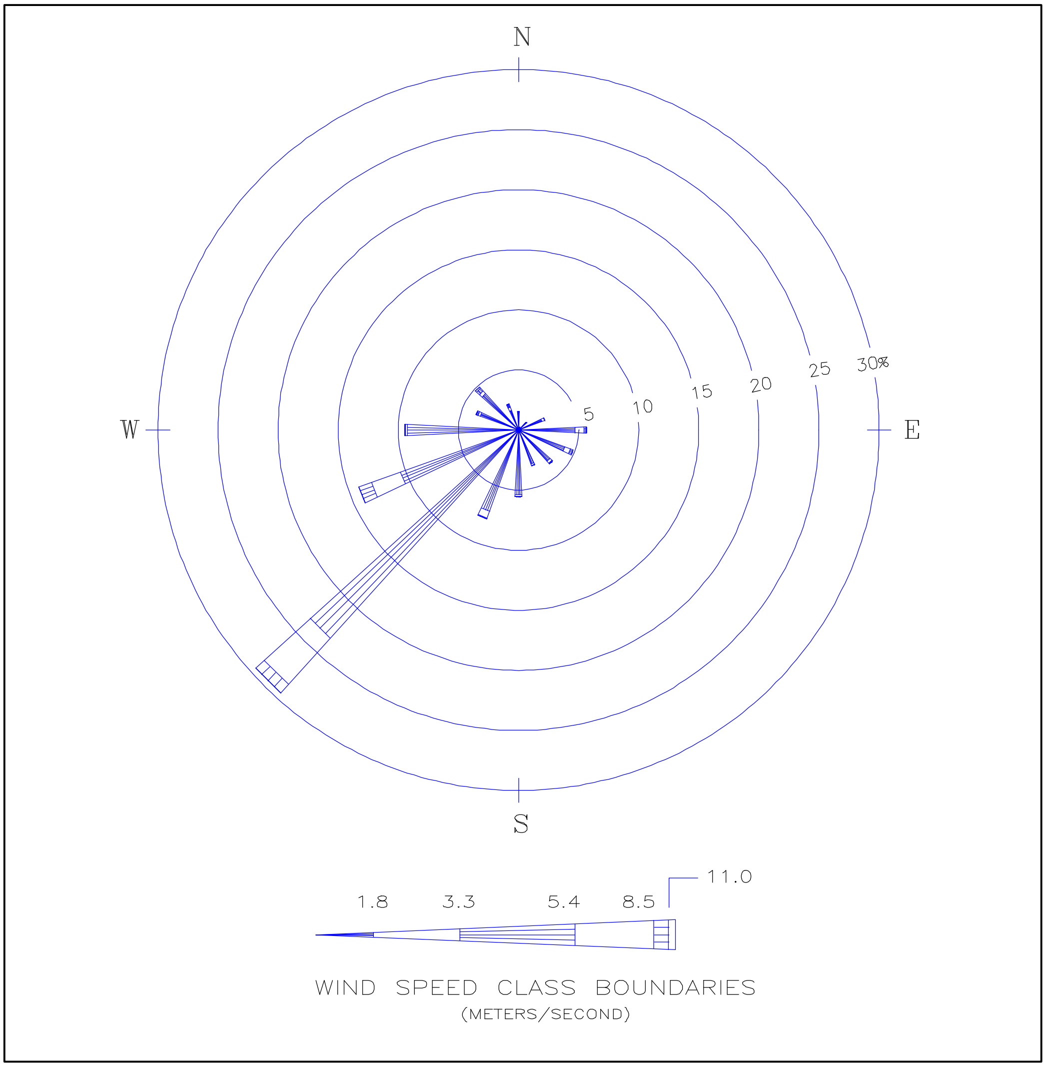
The model’s scalar option was additionally invoked to account for the airport’s hourly temporal activity and accommodate the operational scenarios presented in the preceding source characterizations.

Digitized terrain data processed by the U.S. Geological Survey (USGS) was incorporated into the modeling exercise to allow consideration of local terrain variations for all source/receptor combinations. The USGS data set is cast on a Universal Transverse Mercator (UTM) Cartesian coordinate base consisting of 7.5 minute digital elevation arrays with 30 meter grid intervals. Receptor locations were uniformly placed at 200 meter increments to a maximum distance of 1609 meters (i.e., one mile) beyond the airport boundary.

Dispersion models are sensitive to individual meteorological parameters such as wind speed, stability class, mixing height and temperature. The OAQPS recommends that meteorological data used as input into dispersion models be selected on the basis of relative spatial and temporal conditions that exist in the area of concern (e.g., micro, middle and neighborhood scales). As a result, hourly surface weather data from SCAQMD’s West Los Angeles monitoring station which is located less than three miles from the airport facility was incorporated into the modeling exercise to represent local weather conditions and prevailing winds. Figure 3 presents a wind rose diagram from the West Los Angeles monitoring station. The windrose depicts the frequency of occurrence for each wind direction and wind speed class.

For in-flight sources, an additional consideration associated with wake turbulence was incorporated into the dispersion analysis. Wake turbulence is created from the forces that lift the aircraft. High pressure air from the lower surface of the wings flows around the wing tips to the lower pressure region above the wings. A pair of counter-rotating vortices are then shed from the wings where the right and left wing vortices rotate in a counterclockwise and

Figure 3
Windrose West Los Angeles
Surface Station No. 52158



clockwise pattern, respectively. It is within this region of rotating air behind the aircraft where wake turbulence occurs. The weight, wingspan and speed of the aircraft predominantly determine the strength of the turbulence. The wake turbulence associated with rotocraft also results from high pressure air on the lower surface of the rotor blades flowing around the tips to the lower pressure region above the blades. Consequently, air is forced in a downward trend below the main rotor. In forward flight, a pair of downward spiraling vortices are shed beyond the edge of the rotating blade creating a turbulent trailing wake.

On approach and takeoff the wake descends below the flight path until it enters ground effect whereupon the vortices slow their downward descent and move laterally. Typically, the wake's descent will be arrested within approximately one half of the aircraft's wingspan. It is below this height that the wake becomes somewhat weaker due to the incomplete formation of the aircraft's trailing vortices. To account for this condition, the effective emission height for fixed wing sources which delineate take off and approach were reduced from 5 to 4.7 and 4 to 3.8 degrees (i.e., angle of inclination), respectively. For rotocraft, an adjustment from 5 to 4.7 degrees was assumed for both take off and approach. This adjustment lowered the effective emission height to approximate the maximum downward extent of the aircraft's trailing wake.

Appendix F presents a selection of calculation worksheets which list the relative source values considered in the dispersion analysis.

6.0 Risk Characterization

Risk characterization is defined as the process of obtaining a quantitative estimate of risk, including a discussion of its attendant uncertainty. The risk characterization process integrates the results of the exposure assessment and relevant toxicity data (i.e., dose-response assessment) to estimate carcinogenic risks and noncarcinogenic health effects associated with contaminant exposures. This integration provides for an estimate of risk or noncancer effects which may then be compared to available regulatory standards.

For carcinogenic compounds there are no *de minimis* threshold levels (i.e., dose levels below which there are no risks). Any exposure, therefore, will have some associated risk. As such, numerous demarcations of acceptable risk have been established by the regulatory community. For example, the State of California has established a threshold of one in one hundred thousand (1×10^{-5}) as a level posing no significant risk for exposures to carcinogens regulated under the Safe Drinking Water and Toxic Enforcement Act (Health and Safety Code, Sections 25249.5 et seq.; 22 California Code of Regulations, Section 12703(b)). Under the 1990 Federal Clean Air Act (Act), 188 compounds are identified as hazardous air pollutants. These compounds are classified as "hazardous" due to their potential to cause adverse health effects such as cancer. Consequently, the Act requires the U.S. EPA to control emissions of these pollutants from major sources such as factories, refineries and mobile sources. The U.S. EPA is charged with the development of emission standards to prevent "an adverse environmental effect" or "provide an ample margin of safety to protect public health." For cancer risks, the margin of safety is defined as a lifetime cancer risk no greater than one in a million (1×10^{-6}).

For noncarcinogens, both California and the U.S. EPA utilize a hazard index to quantify adverse health impacts. This approach assumes that chronic subthreshold exposures adversely affect a specific organ or organ system (toxicological endpoint). To calculate the hazard index, each chemical concentration is divided by a defined contaminant dose or concentration. For compounds affecting the same toxicological endpoint, this ratio is summed. Where the total equals or exceeds one, a health hazard is presumed to exist.

Notwithstanding, the assessment of risk is an iterative process whereby the source, receptor(s) and chemical specific information are used to estimate potential adverse health effects. It is important to note, however, that scientific uncertainty is intrinsic to this process. Broadly classified, uncertainty can result from the omission or use of incomplete data when characterizing the spatial and temporal activity of a source or facility (i.e., scenario uncertainty), use of "default" or surrogate data for the quantification of discrete emission inventories (i.e., parameter uncertainty) and inherent gaps and limitations in scientific theory associated with estimates of dose-response as well as concentration estimates developed through fate and transport modeling (i.e., model uncertainty). As a result, risk assessments serve as a guide to assist the affected community and local decision makers in evaluating adverse health effects. Due to the relative uncertainty of the assessment, health protective assumptions are often utilized to minimize the potential to underestimate exposure and its associated risk. Results, therefore, are generally viewed as “conservative” and represent an upper bound estimate of risk. It is important to note that although risk estimates generally identify upper bound values, assessments may potentially underestimate risk. Such would be the case where an assessment is based on the quantification of only a few compounds. Although a particular facility or source may emit a variety of pollutants, the assessment may be limited by the availability of emission factors or published toxicity data for a limited suite of compounds regardless of the potential for those identified, yet excluded, to contribute to one’s actual risk.

Although the assessment and its practical limitations are recognized, every attempt was made to characterize the airport facility in a “realistic” fashion. For example, the collection of empirical data and on-site inspections were used to assess on-road vehicular traffic and determine product use and throughput for fixed-based operators. Facility records and reports were reviewed to determine the temporal and spatial activity of aircraft operations. Interviews with pilots and fixed-based operators were conducted to aid in the characterization of in-flight and aircraft ground operations and regulatory guidance carefully examined to assist in the development of emission estimates and contaminant profiles. Although some assumptions were conservative in nature, the assessment was not designed to produce a “worst case” analysis, but rather, a "best estimate" of risk under viable operating conditions.

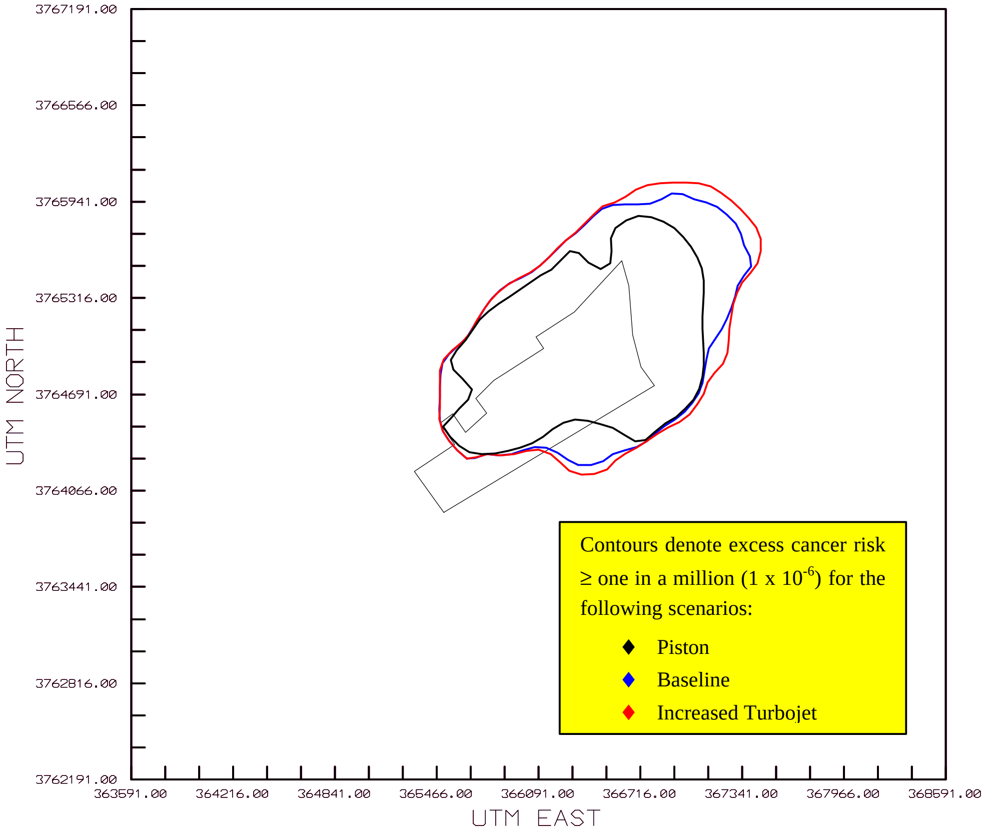
6.1 Carcinogenic Risk

Health risks associated with exposure to carcinogenic compounds generated from the airport facility can be defined in terms of the probability of developing cancer as a result of exposure to a chemical at a given concentration. The cancer risk probability is determined by multiplying the chemical's annual concentration by its unit risk factor (URF). The URF is a measure of the carcinogenic potential of a chemical when a dose is received through a defined pathway (e.g., inhalation and ingestion). It represents an upper bound estimate of the probability of contracting cancer as a result of continuous exposure to an ambient concentration of one microgram per cubic meter (µg/m3) in air or one microgram per liter (µg/L) in water over a 70 year lifetime. The URF's utilized in the assessment were obtained from the U.S. EPA *Integrated Risk Information System* (IRIS) database. For this analysis, exposures were assumed to occur through the inhalation pathway.

Tables 15-17 present the results of the carcinogenic risk assessment for the maximum exposed individual (MEI) for each scenario considered in the analysis. The cancer risk attributed to each source and summation of those risks are presented in column g. The MEI is located south of the airport's runway centerline immediately east of Bundy Drive.

In addition to the identification of the MEI, a graphical representation was prepared to identify the geographic area impacted by the airport facility. Termed "zone of impact", isopleth contours were drawn to depict the maximum downwind extent of the total excess cancer risk from exposure to all carcinogens emitted from the facility. Figure 4 presents the zone of impact for each scenario considered in the assessment.

Figure 4
Zone of Impact



6.2 Noncarcinogenic Risk

For noncarcinogenic risk, the assessment considered all relevant human health effects information identified in the U.S. EPA IRIS data base. Upon review, all but one compound, acetaldehyde, offered toxicological data to quantify noncancer effects. Currently, there are no published chronic inhalation exposure values (RfC's) for benzene, 1,3-butadiene and formaldehyde. Therefore, due to the limited availability of compound specific data, no hazard index was generated.

Table 15
Maximum Individual Cancer Risk
(Baseline Operational Scenario)

Source	Operation	Mass GLC (ug/m3)	Weight Fraction	Contaminant	Carcinogenic Risk	
					URF	RISK
(a)	(b)	(c)	(d)	(e)	(f)	(g)
Fixed Wing	Take Off	0.02280	0.455	Benzene	8.3E-06	8.6E-08
			0.347	Formaldehyde	1.3E-05	1.0E-07
			0.114	1,3-Butadiene	2.8E-04	7.3E-07
			0.084	Acetaldehyde	2.2E-06	4.2E-09
	Approach	0.0133	0.309	Benzene	8.3E-06	3.4E-08
			0.465	Formaldehyde	1.3E-05	8.0E-08
			0.098	1,3-Butadiene	2.8E-04	3.6E-07
			0.129	Acetaldehyde	2.2E-06	3.8E-09
	Taxi/Idle (A) & (B)	0.56374	0.251	Benzene	8.3E-06	1.2E-06
			0.512	Formaldehyde	1.3E-05	3.8E-06
			0.091	1,3-Butadiene	2.8E-04	1.4E-05
			0.146	Acetaldehyde	2.2E-06	1.8E-07
Rotocraft	Take Off	0.00021	0.332	Benzene	8.3E-06	5.8E-10
			0.445	Formaldehyde	1.3E-05	1.2E-09
			0.101	1,3-Butadiene	2.8E-04	5.9E-09
			0.122	Acetaldehyde	2.2E-06	5.6E-11
	Approach	0.00021	0.149	Benzene	8.3E-06	2.6E-10
			0.593	Formaldehyde	1.3E-05	1.6E-09
			0.080	1,3-Butadiene	2.8E-04	4.7E-09
			0.178	Acetaldehyde	2.2E-06	8.2E-11
	Idle	0.00174	0.088	Benzene	8.3E-06	1.3E-09
			0.642	Formaldehyde	1.3E-05	1.5E-08
			0.073	1,3-Butadiene	2.8E-04	3.6E-08
			0.196	Acetaldehyde	2.2E-06	7.5E-10
Mobile	Airport Avenue	0.01869	0.654	Benzene	8.3E-06	1.0E-07
			0.194	Formaldehyde	1.3E-05	4.7E-08
			0.082	1,3-Butadiene	2.8E-04	4.3E-07
			0.069	Acetaldehyde	2.2E-06	2.8E-09
	Parking	0.02841	0.667	Benzene	8.3E-06	1.6E-07
			0.194	Formaldehyde	1.3E-05	7.2E-08
			0.082	1,3-Butadiene	2.8E-04	6.5E-07
			0.069	Acetaldehyde	2.2E-06	4.3E-09
Fixed-Base Sources	ACR - Low Lead	0.17844	0.010	Benzene	8.3E-06	1.5E-08
	ACR - Jet Kerosine	0.00312	0.004	Benzene	8.3E-06	9.3E-11
	SMFD	0.00066	0.016	Benzene	8.3E-06	8.7E-11
	NGC	0.00249	0.040	Benzene	8.3E-06	8.3E-10
			0.080	Formaldehyde	1.3E-05	2.6E-09
Total						**2.2E-05**

Note: For the Fixed-Base source category ACR, SMFD and NGC refer to aircraft refueling–underground tank filling, the Santa Monica Fire Department Engine Company No. 5 and natural gas combustion.

Table 16
Maximum Individual Cancer Risk
(Increased Turbojet Operational Scenario)

Source (a)	Operation (b)	Mass GLC (ug/m3) (c)	Weight Fraction (d)	Contaminant (e)	Carcinogenic Risk	
					URF (f)	RISK (g)
Fixed Wing	Take Off	0.02336	0.451	Benzene	8.3E-06	8.7E-08
			0.350	Formaldehyde	1.3E-05	1.1E-07
			0.114	1,3-Butadiene	2.8E-04	7.5E-07
			0.085	Acetaldehyde	2.2E-06	4.4E-09
	Approach	0.01516	0.283	Benzene	8.3E-06	3.6E-08
			0.486	Formaldehyde	1.3E-05	9.6E-08
			0.095	1,3-Butadiene	2.8E-04	4.0E-07
			0.136	Acetaldehyde	2.2E-06	4.5E-09
	Taxi/Idle (A) & (B)	0.67570	0.227	Benzene	8.3E-06	1.3E-06
			0.531	Formaldehyde	1.3E-05	4.7E-06
			0.088	1,3-Butadiene	2.8E-04	1.7E-05
			0.154	Acetaldehyde	2.2E-06	2.3E-07
Rotocraft	Take Off	0.00021	0.332	Benzene	8.3E-06	5.8E-10
			0.445	Formaldehyde	1.3E-05	1.2E-09
			0.101	1,3-Butadiene	2.8E-04	5.9E-09
			0.122	Acetaldehyde	2.2E-06	5.6E-11
	Approach	0.00021	0.149	Benzene	8.3E-06	2.6E-10
			0.593	Formaldehyde	1.3E-05	1.6E-09
			0.080	1,3-Butadiene	2.8E-04	4.7E-09
			0.178	Acetaldehyde	2.2E-06	8.2E-11
	Idle	0.00174	0.088	Benzene	8.3E-06	1.3E-09
			0.642	Formaldehyde	1.3E-05	1.5E-08
			0.073	1,3-Butadiene	2.8E-04	3.6E-08
			0.196	Acetaldehyde	2.2E-06	7.5E-10
Mobile	Airport Avenue	0.01869	0.654	Benzene	8.3E-06	1.0E-07
			0.194	Formaldehyde	1.3E-05	4.7E-08
			0.082	1,3-Butadiene	2.8E-04	4.3E-07
			0.069	Acetaldehyde	2.2E-06	2.8E-09
	Parking	0.02841	0.667	Benzene	8.3E-06	1.6E-07
			0.194	Formaldehyde	1.3E-05	7.2E-08
			0.082	1,3-Butadiene	2.8E-04	6.5E-07
			0.069	Acetaldehyde	2.2E-06	4.3E-09
Fixed-Base Sources	ACR - Low Lead	0.17844	0.010	Benzene	8.3E-06	1.5E-08
	ACR - Jet Kerosine	0.00312	0.004	Benzene	8.3E-06	9.3E-11
	SMFD	0.00066	0.016	Benzene	8.3E-06	8.7E-11
	NGC	0.00249	0.040	Benzene	8.3E-06	8.3E-10
			0.080	Formaldehyde	1.3E-05	2.6E-09
Total						**2.6E-05**

Note: For the Fixed-Base source category ACR, SMFD and NGC refer to aircraft refueling–underground tank filling, the Santa Monica Fire Department Engine Company No. 5 and natural gas combustion.

Table 17
Maximum Individual Cancer Risk
(Piston Operational Scenario)

Source	Operation	Mass GLC (ug/m3)	Weight Fraction	Contaminant	Carcinogenic Risk	
					URF	RISK
(a)	(b)	(c)	(d)	(e)	(f)	(g)
Fixed Wing	Take Off	0.02280	0.486	Benzene	8.3E-06	9.2E-08
			0.323	Formaldehyde	1.3E-05	9.6E-08
			0.118	1,3-Butadiene	2.8E-04	7.5E-07
			0.074	Acetaldehyde	2.2E-06	3.7E-09
	Approach	0.00808	0.486	Benzene	8.3E-06	3.3E-08
			0.323	Formaldehyde	1.3E-05	3.4E-08
			0.118	1,3-Butadiene	2.8E-04	2.7E-07
			0.074	Acetaldehyde	2.2E-06	1.3E-09
	Taxi/Idle (A) & (B)	0.24951	0.486	Benzene	8.3E-06	1.0E-06
			0.323	Formaldehyde	1.3E-05	1.0E-06
			0.118	1,3-Butadiene	2.8E-04	8.2E-06
			0.074	Acetaldehyde	2.2E-06	4.1E-08
Rotocraft	Take Off	0.00021	0.332	Benzene	8.3E-06	5.8E-10
			0.445	Formaldehyde	1.3E-05	1.2E-09
			0.101	1,3-Butadiene	2.8E-04	5.9E-09
			0.122	Acetaldehyde	2.2E-06	5.6E-11
	Approach	0.00021	0.149	Benzene	8.3E-06	2.6E-10
			0.593	Formaldehyde	1.3E-05	1.6E-09
			0.080	1,3-Butadiene	2.8E-04	4.7E-09
			0.178	Acetaldehyde	2.2E-06	8.2E-11
	Idle	0.00174	0.088	Benzene	8.3E-06	1.3E-09
			0.642	Formaldehyde	1.3E-05	1.5E-08
			0.073	1,3-Butadiene	2.8E-04	3.6E-08
			0.196	Acetaldehyde	2.2E-06	7.5E-10
Mobile	Airport Avenue	0.01869	0.654	Benzene	8.3E-06	1.0E-07
			0.194	Formaldehyde	1.3E-05	4.7E-08
			0.082	1,3-Butadiene	2.8E-04	4.3E-07
			0.069	Acetaldehyde	2.2E-06	2.8E-09
	Parking	0.02841	0.667	Benzene	8.3E-06	1.6E-07
			0.194	Formaldehyde	1.3E-05	7.2E-08
			0.082	1,3-Butadiene	2.8E-04	6.5E-07
			0.069	Acetaldehyde	2.2E-06	4.3E-09
Fixed-Base Sources	ACR - Low Lead	0.17844	0.010	Benzene	8.3E-06	1.5E-08
	ACR - Jet Kerosine	0.00312	0.004	Benzene	8.3E-06	9.3E-11
	SMFD	0.00066	0.016	Benzene	8.3E-06	8.7E-11
	NGC	0.00249	0.040	Benzene	8.3E-06	8.3E-10
			0.080	Formaldehyde	1.3E-05	2.6E-09
Total						**1.3E-05**

Note: For the Fixed-Base source category ACR, SMFD and NGC refer to aircraft refueling–underground tank filling, the Santa Monica Fire Department Engine Company No. 5 and natural gas combustion.

6.3 Criteria Pollutant Exposures

Criteria pollutant exposures (i.e., PM_{10} and lead) were assessed by combining existing background values to the maximum predicted concentrations identified for each operational scenario. Should concentrations exceed the NAAQS, individuals exposed to these pollutants may experience adverse health impacts. Although air quality standards are set at levels which provide a reasonable margin of safety, sensitive individuals such as children, the elderly and those with cardio-respiratory diseases may be at greater risk of experiencing adverse effects when exposed to elevated pollutant concentrations. Table 18 presents a compilation of available background pollutant concentrations. Table 19 lists the maximum predicted values for each scenario considered in the assessment.

Table 18
Monitored Pollutant Concentrations (µg/m3)

Averaging Time	Particulates (PM_{10})			Lead (Pb)		
	1995	1996	1997	1995	1996	1997
24 Hour	136.0	107.0	79.0	NA	NA	NA
Annual	36.2	32.6	35.5	NA	NA	NA
Calendar Quarter	NA	NA	NA	0.04	0.03	0.05

Note: Monitored data from SCAQMD Source-Receptor Area 3, Southwest Coast, Los Angeles County.

Table 19
Maximum Predicted Concentrations (µg/m3)

Operational Scenario	Particulates (PM_{10})		Lead (Pb)
	24 Hour	Annual	Calendar Quarter
Baseline	10.917	4.624	0.055
Increased Turbojet	10.935	4.638	0.055
Piston	10.902	4.6120	0.057

7.0 Summary of Findings

For carcinogenic risk, results of the assessment revealed that cancer risks for the maximum exposed individual who resides in proximity of the airport were twenty-two, twenty-six and thirteen in one million for the baseline, increased turbojet and piston operational scenarios, respectively. These values represent discrete cancer risks associated with airport related exposures. No background or ambient concentrations were incorporated into the risk quantification. In consideration of the Federal Clean Air Act, emissions associated with airport operations were clearly found to exceed the "acceptable risk criterion" of one in a million (1×10^{-6}).

For particulates, the analysis revealed that both short-term (i.e., 24 hour) and annual PM_{10} concentrations generated from the airport facility would not contribute to a violation of the

National Ambient Air Quality Standards of 150 and 50 μg/m3, respectively. For lead, calendar quarter concentrations associated with airport operations were also found to be diminutive and not anticipated to contribute to an exceedance of the Federal standard of 1.5 μg/m3.

8.0 Delimitations/Recommendations

As documented above, elements of uncertainty are inherent in the assessment of risk. However, consideration of regulatory guidance and use of defined assessment methodologies provide for a "best estimate" of exposure. Nevertheless, it is important to note that during the preparation of this assessment, several informational sources were found to be rather restricted offering limited data to perform the assessment and quantify community-based exposures. The following discussion highlights the relevant limitations and associated recommendations to further define the extent of contaminant exposures associated with emissions generated from airport operations.

The most notable restriction was the limited availability of emission factor data and chemical species profiles for the aircraft source category. For example, although the U.S. EPA has developed exhaust emission fractions to allow for the quantification of polynuclear aromatic hydrocarbons (PAH), data is unavailable to assist in the identification of discrete compound weight fractions emitted within the exhaust stream, as well as the necessary toxicological data (i.e., unit risk factors) to enable the quantification of risk. Notwithstanding, incorporation of these compounds would serve to enhance the assessment and increase community risk estimates.

For particulates, the preceding restrictions underscore a significant paucity in emission factor data as surrogate profiles were predominately used to produce emission estimates. This is readily illustrated as concentration values predicted for each operational scenario were markedly similar. This exemplifies an inconsistency with community reports of excessive dust and soot associated with increased turbojet activity which suggest that particulate concentrations predicted in the assessment may be underestimated.

Notwithstanding this limitation, it is relevant to note that particulate exposures were based on both short-term and annual average concentrations contributing to a violation of National Ambient Air Quality Standards. However, the State of California has promulgated more restrictive ambient air quality standards for most criteria pollutants including particulates. Therefore, in consideration of California's particulate standards, the predicted concentrations would promote the continued degradation of local air quality and contribute to an existing air quality violation.

In addition, the quantification of noncarcinogenic risk was not performed due to the limited availability of chemical data offered in the U.S. EPA IRIS database. Although two compounds have recently been identified (i.e., acrolein and styrene) and emission factor profiles developed to allow for the inclusion in the quantification of noncarcinogenic exposures, risk values derived from an assessment utilizing a finite suite of compounds would serve to underestimate risk. One consideration is to perform the assessment utilizing an alternative source of regulatory exposure factor data. For example, the employment of chemical toxicity values promulgated by the California Environmental Protection Agency (Cal/EPA) would allow quantification of most identified compounds for a more complete assessment of noncarcinogenic risk.

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