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SEA-TAC AIR QUALITY - FINAL

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[illegible] to subsection (a)(1), which shall be comprised of technically qualified individuals representative of State and local governments, industry, and the academic community. Each such committee shall submit as appropriate, to the Administrator information related to that required by paragraph (1).

(c) The Administrator shall from time to time review, and, as appropriate, modify, and reissue any criteria or information on control techniques issued pursuant to this section.

Not later than six months after the date of the enactment of the Clean Air Act Amendments of 1977, the Administrator shall revise and reissue criteria relating the concentrations of NO_2 over such period (not more than three hours) as he deems appropriate. Such criteria shall include a discussion of nitric and nitrous acids, nitrites, nitrates, nitrosamines, and other carcinogenic and potentially carcinogenic derivatives of oxides of nitrogen.
[PL 95-95, August 7, 1977]

(d) The issuance of air quality criteria and information on air pollution control techniques shall be announced in the Federal Register and copies shall be made available to the general public.

TRANSPORTATION PLANNING AND GUIDELINES

(e) The Administrator shall, after consultation with the Secretary of Transportation, and after providing public notice and opportunity for comment, and with State and local officials, within nine months after enactment of the Clean Air Act Amendments of 1970 and periodically thereafter as necessary to maintain a continuous transportation-air quality planning process, update the June 1978 Transportation-Air Quality Planning Guidelines and publish guidance on the development and implementation of transportation and other measures necessary to demonstrate and maintain attainment of national ambient air quality standards. Such guidelines shall include information on—

(1) methods to identify and evaluate alternative planning and control activities;

(2) methods of reviewing plans on a regular basis as conditions change or new information is presented;

(3) identification of funds and other resources necessary to implement the plan, including such funds and resources;

(4) methods to assure participation by the public in all phases of the planning process; and

(5) such other methods as the Administrator determines necessary to carry out a continuous planning process.

[PL 95-95, August 7, 1977; PL 101-549]

(1) The Administrator shall publish and make available to appropriate Federal, State, and local environmental and transportation agencies not later than one year after enactment of the Clean Air Act Amendments of 1990, and from time to time thereafter—

(A) information prepared, as appropriate, in consultation with the Secretary of Transportation, and after providing public notice and opportunity for comment, regarding the formulation and emission reduction potential of transportation control measures related to criteria pollutants and their precursors, including, but not limited to—

(i) programs for improved public transit;

(ii) restriction of certain roads or lanes to, or construction of such roads or lanes for use by, passenger buses or high occupancy vehicles;

(iii) employer-based transportation management plans, including incentives;

(iv) trip-reduction ordinances;

(v) traffic flow improvement programs that achieve emission reductions;

(vi) fringe and transportation corridor parking facilities serving multiple occupancy vehicle programs or transit service;

(vii) programs to limit or restrict vehicle use in downtown areas or other areas of emission concentration particularly during periods of peak use;

(viii) programs for the provision of all forms of high-occupancy, shared-ride services;

(ix) programs to limit portions of road surfaces or certain sections of the metropolitan area to the use of non-motorized vehicles or pedestrian use, both as to time and place;

(x) programs for secure bicycle storage facilities and other facilities, including bicycle lanes, for the convenience and protection of bicyclists, in both public and private areas;

(xi) programs to control extended [illegible] of vehicles;

(xii) programs to reduce motor v[illegible] emissions, consistent with title II, [illegible] are caused by extreme cold [illegible] conditions;

(xiii) employer-sponsored progra[illegible] permit flexible work schedules;

(xiv) programs and ordinances to [illegible] tate non-automobile travel, provision [illegible] utilization of mass transit, and to ge[illegible] ly reduce the need for single-occupa[illegible] hicle travel, as part of transportation [illegible] ning and development efforts of a loc[illegible] including programs and ordinances a[illegible] cable to new shopping centers, sp[illegible] events, and other centers of ve[illegible] activity;

(xv) programs for new construction [illegible] major reconstructions of paths, trac[illegible] areas solely for the use by pedestria[illegible] other non-motorized means of transp[illegible] tion when economically feasible and i[illegible] public interest. For purposes of this cla[illegible] the Administrator shall also consult [illegible] the Secretary of the Interior; and

(xvi) program to encourage the vo[illegible] tary removal from use and the rep[illegible] place of pre-1980 model year light [illegible] vehicles and pre-1980 model light [illegible] trucks.

[Sec. 108(f)(1)(A) ameaded by 101-549]

(B) information on additional meth[illegible] or strategies that will contribute to [illegible] reduction of mobile source related po[illegible] tants during periods in which any prim[illegible] ambient air quality standard will be [illegible] ceeded and during episodes for which [illegible] air pollution alert, warning or emerge[illegible] has been declared;

(C) information on other measu[illegible] which may be employed to reduce [illegible] impact on public health or protect [illegible] health of sensitive or susceptible indi[illegible] uals or groups; and

(D) information on the extent to wh[illegible] any process, procedure, or method to [illegible] duce or control such air pollutant m[illegible] cause an increase in the emissions or [illegible] mation of any other pollutant.

(2) In publishing such information t[illegible] Administrator shall also include an asse[illegible] ment of—

(A) the relative effectiveness of s[illegible] processes, procedures, and methods;

(B) the potential effect of such p[illegible] cesses, procedures, and methods on tra[illegible]

CAA

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SEA-TAC AIR QUALITY - FINAL

1. INTRODUCTION.

Numerous definitions of air pollution have been devised depending upon a particular author's perspective. In general, pollutants are considered to be those substances present in sufficient concentrations to produce a measureable effect on man, animals, vegetation, or materials. Air pollutants may, therefore, include almost any material or artificial composition of matter capable of being airborne. They may be present as solids, liquids or gases, or mixtures; and some classification or categorization is required.

Two general groups of air pollutants are recognized: (a) those emitted directly from identifiable sources and (b) those produced in the air by interactions among two primary pollutants, or by reactions between primary pollutants and normal atmospheric constituents. At the present time, the primary air pollutants are identified as carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), particulate matter (PM), and hydrocarbons (THC = total hydrocarbons; HC = hydrocarbons less methane). Secondary air pollutants are grouped together as photochemical oxidants (O_x) and include ozone, alkyl nitrates, peroxyacyl nitrates (PAN), alcohols, ethers, acids, and peroxyacids. Although this classification is useful, it should be

1. -- Continued.

recognized that certain sources may emit secondary pollutants directly; and depending on the measurement techniques being used, some secondary pollutants may be counted twice or not at all.

Several attempts have been made to estimate the major source categories contributing the primary air pollutants. A recent attempt[1] (1970) is shown in Table 1-1. From the table it can be seen that on a mesoscale basis, aircraft contribute only 0.3 to 2 percent of the total primary emissions. However, on a microscale basis at or near an airport, these small amounts may be sufficient to generate hazardous levels of primary pollutants and contribute to the formation of secondary pollutants.

Table 1-1. Nation-Wide Emission Estimates, 1970

Pollutant Emissions / Source Category	SO_x 34 x 10^6 Tons/Year % of Total	Particulate 26 x 10^6 Tons/Year % of Total	CO 149 x 10^6 Tons/Year % of Total	HC 35 x 10^6 Tons/Year % of Total	NO_2 23 x 10^6 Tons/Year % of Total
Transportation	3.0	2.7	74.5	55.9	51.3
Motor vehicles	0.9	1.5	64.8	47.9	39.9
Gasoline	0.6	1.1	64.3	47.6	34.2
Diesel	0.3	0.4	0.5	0.3	5.7
Aircraft	0.3	0.4	2.0	1.1	1.8
Railroads	0.3	-	0.1	0.3	0.4
Vessels	0.9	0.4	1.2	0.9	0.9
Nonhighway use of motor fuels	0.6	0.4	6.4	5.7	8.3
Fuel combusion in stationary sources	78.1	26.1	0.6	1.7	43.8
Coal	65.4	21.5	0.3	0.6	17.1
Fuel oil	12.4	1.5	0.1	0.3	5.7
Natural gas	-	0.8	0.1	0.8	20.6
Wood	0.3	2.3	0.1	-	0.4
Industrial process losses	17.7	51.0	7.7	15.8	0.9
Solid waste disposal	0.3	5.3	4.9	5.7	1.8
Agricultural burning	0.3	9.2	9.3	8.0	1.3
Miscellaneous	0.6	5.7	3.0	12.9	0.9
Forest fires	-	5.3	2.7	0.9	0.9
Structural fires	-	-	0.1	0.3	-
Coal refuse burning	0.6	0.4	0.2	0.3	-
Gasoline & solvent evaporation			-	11.4	-

1. -- Continued.

In order to understand the intent and importance of Federal air quality standards, it is necessary to be knowledgeable about the primary and secondary pollutants. The next few sections briefly discuss each of the air pollutants associated with aircraft operations with respect to their source, chemistry, and effects. A final section relates the Federal standards to the current understanding of air pollution causes and effects.

1.1 Carbon Monoxide.[2]

Most carbon monoxide is produced when there is incomplete combustion of hydrocarbon fuels. The normal combustion products are carbon dioxide and water vapor, but a shortage of oxygen or the characteristics of the combustion processes will generate CO. Total emissions of CO exceed those of all other pollutants combined.

1.1.1 Sources.

At the present time, natural sources of CO are considered insignificant, and most atmospheric CO is produced by the incomplete combustion of gasoline in motor vehicles (65 percent). Other transportation sources account for 10 percent, agricultural burning 9 percent, industrial process-losses 8 percent, and miscellaneous another 8 percent. Only 2 percent of the total is associated with aircraft.

1.1.2 Carbon Monoxide Chemistry.

Carbon monoxide is a colorless, odorless, tasteless gas slightly lighter than air. Although it does not support combustion, it is quite flammable. Reactions between CO and atmospheric components do not occur because of high activation energies required. Thus, the conversion of CO to CO_2 (carbon dioxide) by ozone has an activation energy ten times that of the comparable reaction between nitric oxide (NO) and ozone. Other reactions such as oxidation by nitrogen dioxide NO_2 also have high activation energies. At the present time, several removal mechanisms are postulated to account for the relatively constant background CO levels in the absence of known removal processes.

1.1.3 Effects of Carbon Monoxide.

It has not been demonstrated that CO produces adverse reactions in higher types of plant life at concentrations which produce loss of consciousness or death in animals. The possible effects of high CO levels within the soil has not been thoroughly investigated, but significant impact on vegetation and micro-organisms at ambient levels is unlikely.

The toxicological properties of CO are associated with its absorption in the lungs and subsequent reaction with hemo proteins. Most significantly, the iron containing hemoglobin molecule forms a stable complex with CO because of the available electron pair on CO. The strength of the affinity is great

1.1.3 -- Continued.

enough to displace the oxygen molecule from oxyhemoglobin, thereby forming carboxyhemoglobin (COHb). Hypoxia or diminished availability of oxygen to the cells of the body results.

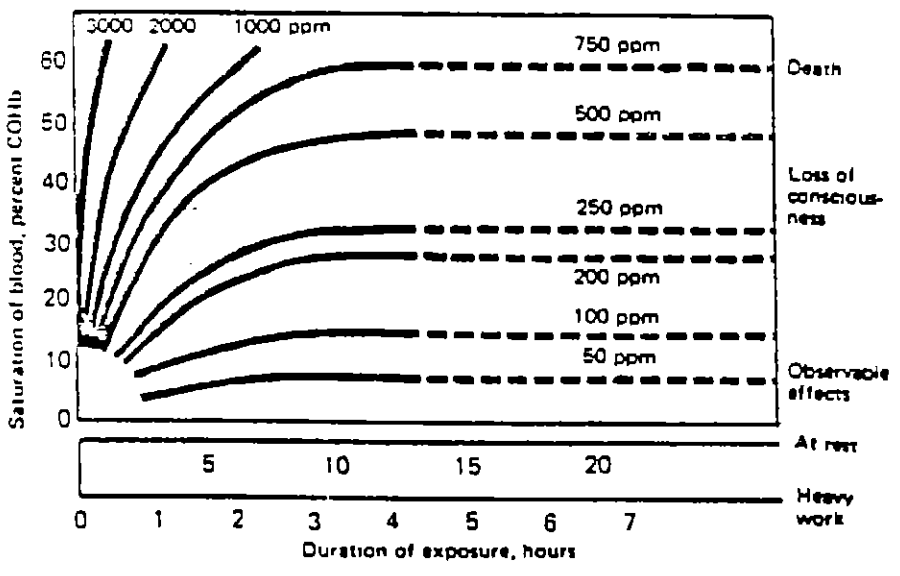
Figure 1-1 summarizes the known effects of short term exposures to CO levels in terms of the blood COHb levels observed. The ambient concentrations of CO necessary to result in these blood COHb levels are a function of ventilation rate and length of exposure. Generally, it will take 8 hours or more to reach equilibrium between ambient CO levels and blood COHb levels. Given sufficient exposure time, and assuming a background COHb level of 0.5 percent, the equilibrium percent COHb can be estimated for ambient levels of CO (less than 115 mg/m^3 or 100 ppm) from: COHb percent = 0.16 CO ppm + 0.5. Thus, in Figure 1-1 a 50 ppm CO exposure for more than 8 hours is roughly equivalent to 8.5 percent COHb. This figure can be compared to moderate smokers whose median COHb level may run 6 percent.

1.2 Hydrocarbons.[3]

Certain organic compounds contain only two elements, hydrogen and carbon, and hence are known as hydrocarbons (HC). On the basis of structure, hydrocarbons are divided into two main classes: aliphatic and aromatic. Aliphatic hydrocarbons are further divided into families: alkanes (saturated), alkenes, and alkynes. Hydrocarbon oxidation products such as aldehydes, acetones, peroxides, and others play an important role in the

COHb level, percent	Demonstrated effects
Less than 1.0	No apparent effect.
1.0 to 2.0	Some evidence of effect on behavioral performance.
2.0 to 5.0	Central nervous system effects. Impairment of time interval discrimination, visual acuity, brightness discrimination, and certain other psychomotor functions.
Greater than 5.0	Cardiac and pulmonary functional changes.
10.0 to 80.0	Headaches, fatigue, drowsiness, coma, respiratory failure, death.

Source National Academy of Science and National Academy of Engineering



Acute effects. COHb levels in the blood depend upon he amount of CO in the atmosphere, duration of exposure, and type of physical activity

Figure 1-1. Effects of CO on Human Health. From: Philip C. Wolf, *Carbon Monoxide, Measurement and Monitoring in Urban Air*

1.2 -- Continued.

photochemical system of the atmosphere. Unlike carbon monoxide and nitrogen oxides, hydrocarbon criteria are not based on direct effects, but on their role as precursors of other damaging compounds formed in the photochemical system.

1.2.1 Sources.

Natural sources, particularly biological processes, account for a large proportion of hydrocarbon emissions. Non-urban air typically contains 0.7 to 1.0 mg/m^3 methane (1.0 to 1.5 ppm) and less than 0.1 ppm each of other hydrocarbons.

Technological emissions of hydrocarbons are estimated at 34.9×10^6 tons/year. Transportation represents the largest source category and accounts for 56 percent of this estimate (1970). Only 1 percent of the total is believed to be associated with aircraft. Other significant sources are: industrial process losses (16 percent), gasoline and solvent evaporation (11.4 percent), and non-highway use of motor fuels (6 percent). HC emissions, therefore, originate primarily from inefficient combustion of gasoline and from their use as process raw materials.

1.2.2 Hydrocarbon Chemistry.

Hydrocarbons in the urban atmosphere are comprised primarily of alkanes (with or without methane) followed by the aromatics, alkenes, and alkynes. For example, several hundred samples from one urban location had the following composition

1.2.2 --Continued.

(mg/m^3 as carbon): methane 2.10, other alkanes 0.90, aromatics 0.37, and alkene (ethylene) 0.08. It is somewhat heuristic to distinguish hydrocarbons at this time, even though their relative importance in the photochemical system may be significant, because existing standards specify allowable levels for total hydrocarbons less methane. In the future, separate standards may exist which could reorder the significance of hydrocarbon sources.

The complexity of the photochemical system has prevented a complete understanding of the relationship between hydrocarbon levels and ambient air quality. As a result, an empirical approach has developed of comparing the 6:00 to 9:00 a.m. average hydrocarbon values with hourly maximum oxidant values obtained later in the day. Large amounts of data collected from numerous cities is the basis for comparing early morning HC levels to peak oxidant levels. These observations have revealed that if the 6:00 to 9:00 a.m. non methane hydrocarbon level is below 200 $\mu g/m^3$ (0.3 ppm), maximum oxidant levels will stay below 200 $\mu g/m^3$ (0.10 ppm).

1.2.3 Effects of Hydrocarbons.

At ambient concentrations, ethylene is the only known hydrocarbon to have adverse effects on certain types of vegetation. Ethylene may cause abnormal leaf growth and abscission of leaves, flower buds, and flowers, as well as growth inhibition.

1.2.3 -- Continued.

At the present time, there are no known adverse health effects associated with high concentrations of hydrocarbons in the ambient air. However, their involvement in the formation of oxidants and other hazardous derivatives requires that they be considered pollutants.

1.3 Nitrogen Oxides.[4]

Of the eight nitrogen oxides known to exist, two - nitric oxide and nitrogen dioxide - are emitted to the atmosphere in significant quantities. Ambient air contains nitrogen (78 percent by volume) and oxygen (20 percent by volume). As a result, any atmospheric combustion process produces nitrogen oxides. The amount formed depends on the combustion temperature, the concentration of both reactants and products, and other combustion conditions.

Combustion temperatures in excess of 1100°C produce NO and NO_2 (usually less than 0.5 percent). NO is rapidly converted to NO_2 by atmospheric oxygen (O_2) when NO concentrations exceed 1 ppm and more slowly via a photochemical cycle at lower concentrations.

1.3.1 Sources.

Fuel combustion from transportation sources and from stationary sources accounts for 51 percent and 44 percent respectively of the nationwide emissions of nitrogen oxides.

1.3.1 -- Continued.

Of the transportation sources, motor vehicles contribute 40 percent (78 percent of 51 percent) of the emissions and aircraft 1.8 percent. Residential fuel consumption accounts for only 25 percent of the emissions, while power generating stations and industrial users account for the remaining 41 percent.

1.3.2 Chemical Interactions of Nitrogen Oxides in the Atmosphere.

Ultraviolet light from the sun reacts with nitrogen dioxide causing it to dissociate into nitric oxide and atomic oxygen. Ozone is formed when atomic oxygen reacts with atmospheric oxygen. The remaining chemistry is complex and not yet completely understood. However, the interaction of certain hydrocarbons (HC) with the by-products of the photo-dissociation of NO_2 is believed to result in the formation of reactive free radicals. These free radicals and others formed via different mechanisms are highly reactive and may combine with oxygen (O_2), NO_2 or NO to form peroxy radicals, peroxyacyl nitrates (PAN, an eye irritant), and additional NO_2. As a result, NO is converted to NO_2 which is itself destroyed via photodissociation and reaction with other pollutants to produce ozone and organic nitrates.

1.3.3 Effects of Nitrogen Oxides.

Significant effects of NO_x (NO_2 + NO) have been observed and studied on textile dyes, natural and synthetic fibers, and metals. Color loss has been observed in gas dryers where NO_x concentrations range from 1.1 to 3.7 $\mu g/m^3$. Cotton and nylon textile fiber deterioration is known, but specific thresholds have not been determined.

High concentrations of NO_2 (47 mg/m^3) for any extended period of time produce accute necrotic leaf injury. The effects of exposure to low levels of NO_2 for extended periods are less evident. Studies indicate that levels below 470 $\mu g/m^3$ supplied for a period of 8 months will cause increased leaf damage and reduced yield in navel oranges.

Low levels of NO_2 (0.04 ppm) are associated with the formation of photochemical oxidant above the Federal Standard. Between 0.067 and 0.109 ppm, NO_2 causes increased respitatory disease. These and other known effects are summarized in Table 1-2.

1.4 Photochemical Oxidants.[5]

Photochemical oxidants result from a complex series of atmospheric chemical reactions initiated by sunlight. Aldehydes, acetones, nitrogen dioxide, and other compounds absorb

Table 1-2. Representative NO_2 Effects

Effect	NO_2 Concentration ppm	$\mu g/m^3$	Duration	Comment	Reference
Lowest level associated with reference oxidant production of 200 $\mu g/m^3$ (0.1 ppm)	0.04	80	1 hr (6 to 9 a.m.)		1
Increased incidence of acute respiratory disease in families	0.067 to 0.109	127 to 205	2 to 3 yr	Chattanooga study - 6 mo mean concentration range	2
Increased incidence of acute bronchitis in infants and school children	0.063 to 0.083	118 to 156	2 to 3 yr	Chattanooga study - 6 mo mean concentration range	3
Human olfactory threshold	0.12	225	---	Immediate perception	4
Rabbits - structural changes in	0.25	470	4 hr/day for 6 days	Still apparent 7 days after final exposure	5
Navel orange - leaf abscission; decreased yield	0.25	470	8 mo, continuously		6
Rats - morphological changes in lung mast cells characterized by degranulation	0.5	940	4 hr	Possible precedes onset of acute inflammatory reaction	7
	1.0	1880	1 hr		
Mice - pneumonitis; alveolar distension	0.5	940	6 to 24 hr/day for 3 to 12 mo	Possibly emphysematous condition	8
Mice - increased susceptibility to respiratory infection	0.5	941	6 to 24 hr/day up to 12 mo	Based on mortality following challenge with K. pneumoniae	9
Navel orange - leaf abscission, chlorosis	0.5	940	35 days, continuously		6
Rats - tachypnea, terminal bronchiolar hypertrophy	0.8	1504	Lifetime, continuously		10

1.4 -- Continued.

ultraviolet energy from the sunlight and dissociate into reactive free radicals. The free radicals initiate reaction chains that lead to the formation of new compounds; including onone, peroxyacyl nitrates, alcohols, ethers, acids and peroxyacids.

1.4.1 Sources.

Ozone is formed naturally at very high altitudes by solar radiation and by electrical discharge in the atmosphere. These processes are not believed to contribute significantly to urban concentrations. However, ozone levels between 20 and 100 $\mu g/m^3$ (0.01 to 0.05 ppm) have been observed in non-urban areas.

It is important to realize that oxidants (O_x) are secondary pollutants derived from the reactions of primary pollutants (HC, NO_x, SO_x). As such, sources cannot be singled out as was done for hydrocarbons and nitrogen oxides. However, if transportation accounts for 56 percent of the hydrocarbons and 51 percent of the nitrogen oxides, and these pollutants are the precursors of photochemical oxidants; then it is reasonable to associate at least 50 percent of the oxidants with transportation sources.

1.4.2 Effects of Photochemical Oxidants on Vegetation, Materials, and Animals.

Many types of plants are sensitive to photochemical air pollution. Ozone injury to leaves in sensitive species will occur after exposure to 60 $\mu g/m^3$ (0.03 ppm) for 8 hours. Similar injury has been observed after a 4-hour exposure to 100 $\mu g/m^3$ (0.05 ppm) total oxidant. When plants were exposed to ozone for 1 to 4 hours, damage occurred in highly sensitive plants at levels of 100 to 500 $\mu g/m^3$ (0.05 - 0.25 ppm), in moderately sensitive plants at 200 to 800 $\mu g/m^3$ (0.10 - 0.40 ppm), and in resistant plants at 400 $\mu g/m^3$ and up.

1.4.2 -- Continued.

Many materials, particularly organic polymers, are sensitive to even small concentrations of ozone. Economically, rubber is probably the most important material sensitive to ozone attack. As a result, expensive anti-ozonant additives, capable of protecting elastomers, have been developed, at least on a temporary basis. Other types of fibers and dyes are also susceptible to ozone attack.

The major physiological effects of ozone are on the respiratory system. Exposure to high levels of ozone (5,900 $\mu g/m^3$) for several hours produces hemorrhage and edema in the lungs. Lower concentrations of 390 $\mu g/m^3$ (0.2 ppm) for 3 hours per day, 6 days a week, over 12 week period have not produced any apparent effects in humans. Exposure to 590 $\mu g/m^3$ (0.3 ppm) for 8 hours appears to be the threshold for nasal and throat irritation. Even lower levels of oxidant will produce eye irritation (200 $\mu g/m^3$ or 0.1 ppm). The major effects of oxidants are summarized in Table 1-3.

Table 1-3. Effects Associated with Oxidant Concentrations in Photochemical Smog

Effect	Exposure ppm	Exposure $\mu g/m^3$	Duration	Comment
Vegetation damage	0.05	100	4 hours	Leaf injury to sensitive species
Eye irritation	Exceeding 0.1	200	Peak values	Result of panel response Such a peak value would be expected to be associated with a maximum hourly average concentration of 50 to 100 $\mu g/m^3$ (0.025 to 0.05 ppm)
Aggravation of respiratory diseases - asthma	0.13*	250	Maximum daily value	Patients exposed to ambient air. Value refers to oxidant levels at which number of attacks increased Such a peak value would be expected to be associated with a maximum hourly average concentration of 100 to 120 $\mu g/m^3$ (0.05 to 0.06 ppm).
Impaired performance of student athletes	0.03 to 0.01	60 to 590	1 hour	Exposure for 1 hour immediately prior to race

*F.S. = 160 $\mu g/m^3$ 0.08 ppm

1.5 Particulate.[6]

Particulate material in the atmosphere is composed of many different substances. Depending on the location and the type of activity in the area; fluorides, beryllium, lead, asbestos, organic material, dust, pollen, and even insect parts may be present in particulate matter. Some of these are known to be toxic at high levels while others may have toxic effects that have not yet been studied. Moreover, laboratory studies suggest a synergistic effect between particulates and gaseous pollutants.

Particulate air pollution refers to any matter of a diameter greater than one micron (1 millionth of a meter) but smaller than 500 microns suspended in the air. Particles of this size will stay suspended for a few seconds to several months.

1.5.1 Sources.

Extremely small particles of less than 1 μ in diameter enter the atmosphere through condensation, combustion, and photochemical processes. Particles between 1 μ and 10 μ in diameter usually include local soil, process dusts, combustion products from local industries, and even sea salt. Large particles greater than 10μ result from mechanical processes such as wind erosion, grinding and spraying, and the pulverizing of materials by vehicles and pedestrians.

1.5.2 Effects of Particulate Matter.

Most adverse effects of particulate air pollution on health are associated with injury to the surfaces of the respiratory system. The mechanisms governing the deposition, clearance, and retention of inhaled particles are complex and not completely understood. Injuries may be permanent or temporary and the transport of particulate to other portions of the body may produce secondary effects.

Available epidemiological studies have defined air pollution in terms of particulate and sulfur compounds. Thus, the levels of particulate and sulfur gases define an index of pollution and not a physiochemical entity.

Most of the epidemiological studies on particulate have concerned air pollution episodes in London and New York. British techniques are not entirely comparable with American measurements, but one study suggests that the British method gives lower results. Particulate air pollution study conclusions are summarized in Table 1-4.

High particulate levels are associated with increased deaths and illness. At lower levels children experience a greater incidence of respiratory diseases and the death rate for persons over 50 appears elevated. Levels of 100-200 $\mu g/m^3$ can significantly reduce visibility and sunlight received at the earth's surface, and increase the corrosion of steel. Particulates soil and damage buildings, statuary, and other surfaces. Plant damage may result when particulate plugs leaf stomates preventing the exchange of gases necessary for growth and development.

Table 1-4. Effects Associated with Particulate Levels

Particulate Level	Sulfur Dioxide Level	ExceEffects	Comment
≥750 ug/m^3 24 hour avg	≥715 ug/m^3	Excess deaths and increased illness	British Study
≥300 ug/m^3 24 hour avg	≥630 ug/m^3	Acute worsening of chronic bronchitis	British
≥200 ug/m^3 24 hour avg	≥250 ug/m^3	Increased absence of industrial workers due to illness	British
≥100 ug/m^3 annual mean	≥120 ug/m^3 annual mean	Children experience increased incidence of respiratory diseases	British
≥80 ug/m^3 annual mean	≥30 mg/cm^3	Increased death rates for persons over 50	American Smoking habits unknown
100-150 ug/m^3		Sunlight reduction 5-70% depending on season and latitude	Large smoke turbidity factors persist
≥150 ug/m^3		Visibility less than 5 miles	Particulate 0.2u to 3.0u R.M. < 70%
60-180 ug/m^3	Present	Corrosion of steel and zinc panels accelerated	Sulfur dioxide and moisture required
70 ug/m^3 annual mean	Percent	Approximate thresholds for public concern	Other pollutants present

1.6 Ambient Air Quality Standards.

Under the authority of the Clean Air Act (42 U.S.C. 1857-18571), as amended by PL 91-604 the Administrator of the Environmental Protection Agency (EPA) was required to promulgate national primary and secondary ambient air quality standards.

1.6 -- Continued.

National primary ambient air quality standards define levels of air quality which the administrator judges are necessary, with an adequate margin of safety, to protect the public health. National secondary ambient air quality levels are those which the administrator feels are necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant.

The objective of ambient air quality standards is to provide a basis for preventing or abating the effects of air pollution, including effects on health, esthetics, and economy. Since their objective is to improve air quality, the standards are not to be construed to allow significant degradation of existing air quality in any portion of any state which now has air quality superior to that stipulated in the standards (40 CFR 50).

Normally, the standards are expressed in the metric system as mass of contaminant present in one cubic meter of air at reference conditions (25°C and pressure 760 millimeters of mercury). Alternatively, the concentration is reported as volume of pollutant per million volumes of air or parts per million (ppm).

Based on scientific information similar to that presented in this section, the administrator of the EPA has promulgated standards for air pollutants. Standards for the major air pollutants associated with aircraft operations are presented in Table 1-5.

Table 1-5. National Primary and Secondary Ambient Air Quality Standards

Pollutant	Averaging Time	Primary	Secondary
Carbon Monoxide CO	8 hours	10 mg/m^3 (9 ppm) ≤ Once/year	Same
	1 hour	40 mg/m^3 (35 ppm) ≤ Once/year	Same
Nitrogen Dioxide NO_2	Annual Average	100 $\mu g/m^3$ (0.05 ppm)	Same
Hydrocarbon less Methane HC	3 hours 6-9 a.m.	160 $\mu g/m^3$ (0.24 ppm)	Same
Photochemical Oxidants O_x Corrected for NO_2 - SO_x	1 hour	160 $\mu g/m^3$ (0.08 ppm) ≤ Once/year	Same
Particulate Matter PM	Annual Geometric Mean	75 $\mu g/m^3$	60 $\mu g/m^3$
	24 hours	260 $\mu g/m^3$ ≤ Once/year	150 $\mu g/m^3$ ≤ Once/year
Sulfur Dioxide	Annual Average	80 $\mu g/m^3$ (0.03 ppm)	60 $\mu g/m^3$ (0.02 ppm)
	24 hours	365 $\mu g/m^3$ (0.14 ppm)	260 $\mu g/m^3$ (0.10 ppm)

1.6 -- Continued.

The relationship between the known effects of these pollutants and the standards can be summarized as follows: An 8-hour exposure to 10 $\mu g/m^3$ (9 ppm) of CO will produce blood levels of COHb of approximately 2 percent. This is the threshold for demonstratable effects. Similarly, short term exposures (1 hour) to CO levels greater than 40 $\mu g/m^3$ (35 ppm) can be expected to produce COHb blood levels approaching 2 percent. Oxidant effects including eye irritation, respiratory problems, and impaired performance are known to occur when levels approach or exceed 200 $\mu g/m^3$ (0.08 ppm). Nitrogen dioxide effects are known only for long-term exposures to relatively high concentrations. Thus, this standard is specified over a period of 1 year at 100 $\mu g/m^3$ (0.05 ppm). Particulate levels above 80 $\mu g/m^3$ with sulfation levels of about 30 $\mu g/cm^2$ are believed to cause increased death rates in persons over 50 years of age.

Ambient hydrocarbon levels are not associated with adverse health effects. The HC standard is based on a large set of field observations which tend to establish maximum oxidant levels associated with early morning hydrocarbon levels (Figure 1-2). Nitrogen oxides are also involved in oxidant formation as shown by oxidant isopleths in Figure 1-3. These observations demonstrate that if the HC levels remain below 160 $\mu g/m^3$ (0.24 ppm) or if the NO_x levels remain below 0.025 ppm, the oxidant level will always be below 200 $\mu g/m^3$ (0.1 ppm). At the present time, the HC standard is used as a guide in achieving oxidant standards.

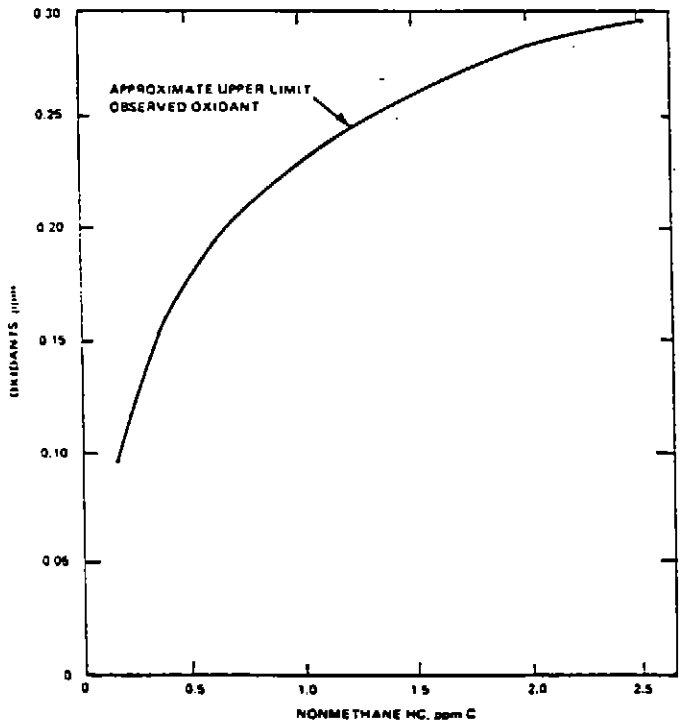


Figure 1-2. Maximum daily 1-Hour-Average Oxidants as a Function of Nonmethane Hydrocarbons at CAMP Stations.

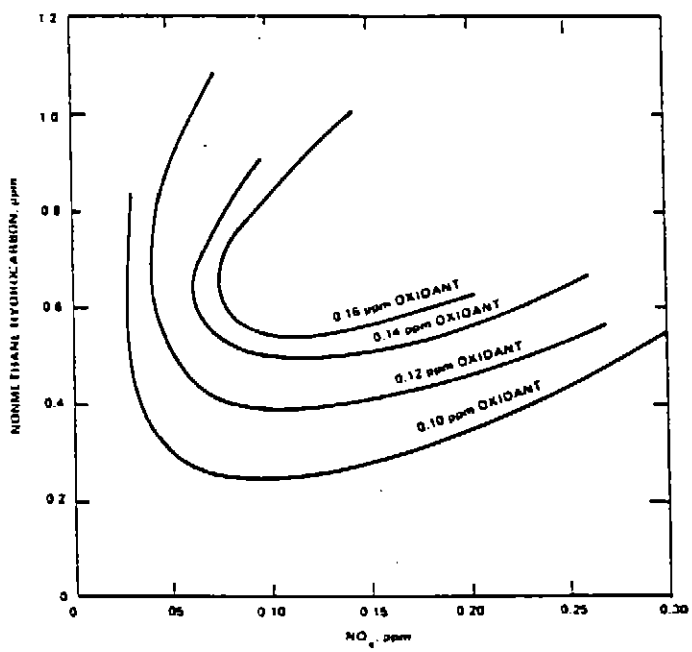


Figure 1-3. Approximate Isopleths for Selected Upper-Limit Maximum Daily 1-Hour-Average Oxidant Concentrations, as a Function of the 6- to 9- a.m. Averages of Nonmethane Hydrocarbons and Total Nitrogen Oxides.

1.6 -- Continued.

Finally, it should be mentioned that the administrator of the EPA has determined that an earlier proposal to establish a precise level of airborne lead (2 $\mu g/m^3$) as a standard is not acceptable. Instead, to control ambient lead levels, the administrator has proposed a phased reduction of leaded fuels by 1978 and automobiles that use lead free gasoline after 1975.

1.7 References.

1. "Nationwide Air Pollutant Emission Trends 1940-1970," U.S. Environmental Protection Agency, January 1973.

2. "Air Quality Criteria for Carbon Monoxide" National Air Pollution Control Administration Publications No. AP-62, March 1970.

3. "Air Quality Criteria for Hydrocarbons," National Air Pollution Control Administration, No. AP-64, March 1970.

4. "Air Quality Criteria for Nitrogen Oxides," Air Pollution Control Office Publication, No. AP-84, EPA January 1971.

5. "Air Quality Criteria for Photochemical Oxidants," National Air Pollution Control Administration, March 1970.

6. Air Quality Criteria for Particulate Matter, National Air Pollution Control Administration, January 1969.

2. EXISTING AIR QUALITY.

The dispersion of air pollutants from any source in the atmosphere is governed primarily by the dynamic and thermal structure of atmospheric layer adjacent to the ground. It is well known that the major air pollution episodes have occurred during periods of calm anticyclonic conditions, when surface wind speeds are less than 3.1 m/sec (7 mph). To understand and define existing air quality, it is necessary to take into account the effects of local topography, wind speeds, and vertical atmospheric temperature structure. Interactions between these weather systems, of all scales, over a period of time, produce fluctuations in wind speed and direction (turbulence) continuously. In this section, data is presented on meteorological parameters and air quality measurements near SEA-TAC.

2.1 Topographical and Climatic Conditions.

The geographic features important to air quality in the Puget Sound area are the Olympic Mountains to the west and the Cascade Mountain Range to the east. In both mountain ranges there are mountains over 8,000 feet in elevation. Part of the Puget Sound water mass lies to the west of SEA-TAC, while Lake Washington is to the northeast.

2.2 Meteorology.

Prevailing winds are either from the north or from the south since the parallel mountain ranges are oriented north-south. Depending on the mesoscale pressure gradient, local variations in terrain may influence circulation patterns. This type of effect can be seen clearly in the wind roses constructed by the Puget Sound Air Pollution Control Agency (PSAPCA) from measurements taken at Boeing Field and at Seattle-Tacoma International Airport (Figure 2-1). These two airports are only six miles apart, but they are situated in somewhat different topography. The overall northsouth features are common to both, though there are distinctive differences.

Seasonal wind patterns are pronounced due to the presence of a semi-permanent low pressure area off the coast during the winter which results in prevailing southerly winds. During the summer, prevailing winds bring Pacific air through the Straits of Juan de Fuca over the northern part of Puget Sound, and from the Grays Harbor area south of the Olympic Mountains to the southern part of Puget Sound. Frequently, this results in northerly winds in the upper portions of King County and southwesterly flow over the southern Puget Sound area.

Diurnal variations in wind direction are most pronounced during the summer season. Daytime winds at SEA-TAC typically are northerly while the nighttime winds are predominately southerly.

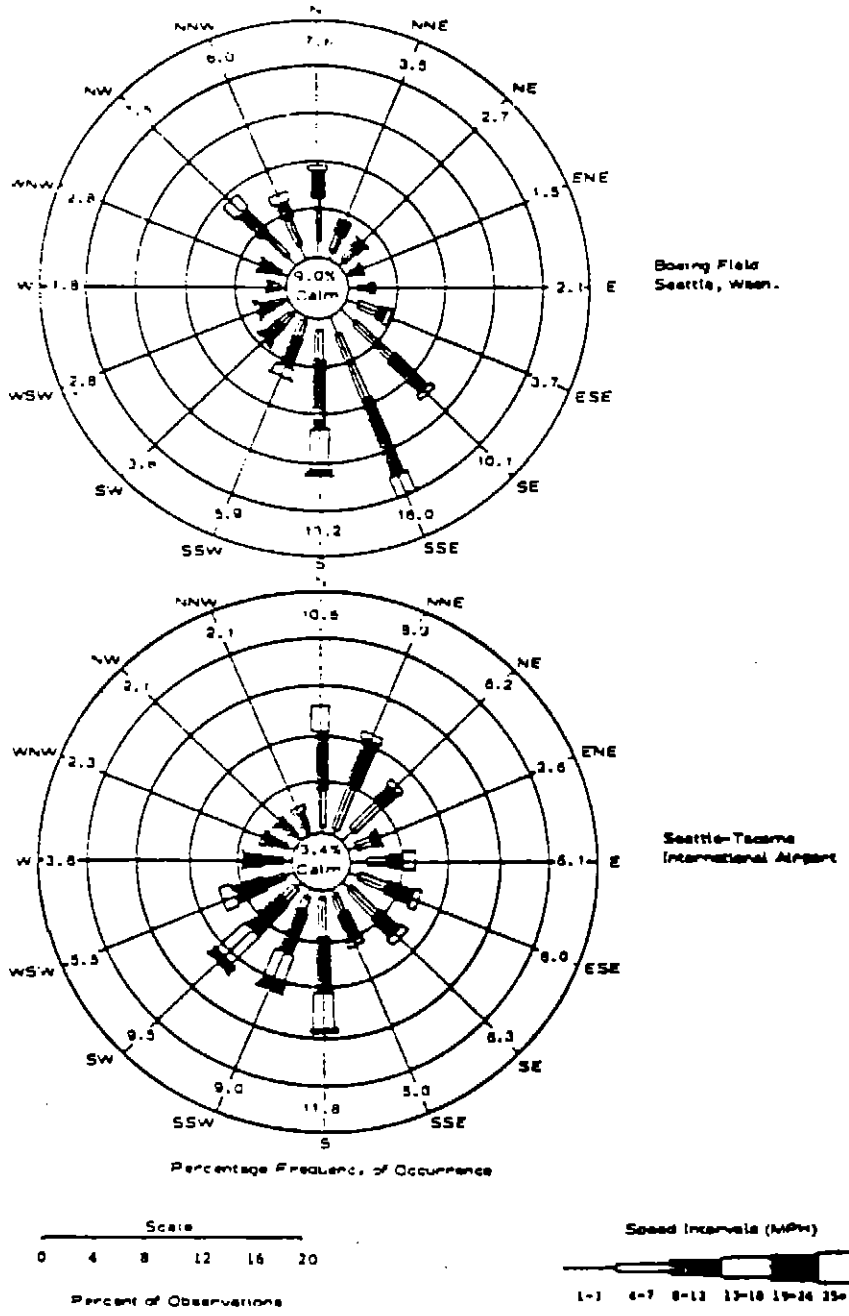


Figure 2-1. Annual Surface Wind Roses at Two Seattle-Tacoma Area Airports for Calendar Year 1969.[1]

2.2.1 Mixing Depth and Turbulence Classification Near SEA-TAC.

Another parameter useful in the study of air pollution is the depth of the convective layer or the mixing depth. Its magnitude for a particular time of day is usually determined from the latest available chart of height or pressure vs. temperature.

Table 2-1 gives the average mixing depths and mean wind speeds through the mixing layer by season and time of day at the SEA-TAC Airport.

Table 2-1. Average Mixing Depths and Wind Speeds at SEA-TAC Airport*

A. Average Mixing Depths (Meters)					
	Winter	Spring	Summer	Fall	Annual
Morning	626	681	532	476	578
Afternoon	585	1490	1398	898	1092
B. Average Mixing Layer Wind Speeds (Meters/Sec)					
	Winter	Spring	Summer	Fall	Annual
Morning	5.1	4.6	4.0	4.3	4.5
Afternoon	4.7	5.7	4.8	4.6	4.9

*"Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Through the Contiguous United States," George C. Holzworth (Office of Air Programs Publication No. AP-101, EPA).

2.2.1 -- Continued.

The appropriate mixing depth from the table is an input parameter to the ESL air quality model discussed in Section 4 of this report.

Atmospheric turbulence can be based on direct measurements of the three-dimensional fluctuations or eddying motions of the air. Direct measurements are expensive and difficult to make, and classifications based on observable parameters have been developed. Six stability categories were proposed by Pasquill to describe the diffusive potential of the lower atmosphere. The categories are specified in terms of wind speed, insolation (i.e., solar radiation), and amount of cloudiness. Tables 2-2 and 2-3 summarize the parameters that characterize each classification and the frequency of occurrence at SEA-TAC. The slightly stable and neutral conditions generally are associated with nighttime conditions. Even so, at SEA-TAC the neutral D condition occurs most frequently during both daytime and nighttime. In terms of air quality, D conditions will generally be associated with air pollutant levels twice those for B conditions if the wind speed is the same. This effect will be somewhat offset by the typically higher wind speeds associated with D conditions.

In addition to the 1969 SEA-TAC archival data we also obtained PSAPCA data from the McMicken Heights monitoring site. The site was located about 1 mile due east of SEA-TAC airport. All 1973 data taken at this site is summarized in Figure 2-2, top. Meteorological data taken during ESL's sampling periods of June, September, and February is shown in Figure 2-2, bottom. The similarity of the two wind roses in

Table 2-2. Relation of Pasquill Turbulence Types to Weather Conditions

A - Extremely unstable conditions
B - Moderately unstable conditions
C - Slightly unstable conditions
D - Neutral conditions*
E - Slightly stable conditions
F - Moderately stable conditions

Surface wind speed, m/sec (mph)	Daytime Insolation			Nighttime Conditions	
	Strong	Moderate	Slight	Thin Overcase or >4/8 Cloudiness†	<3/8 Cloudiness
<2 (4.5)	A	A-B	B		
2 (4.5)	A-B	B	C	E	F
4 (9)	B	B-C	C	D	E
6 (13.5)	C	C-D	D	D	D
>6 (13.5)	C	D	D	D	D

*Applicable to heavy overcast, day or night

†The degree of cloudiness is defined as that fraction of the sky above the local apparent horizon which is covered by clouds

Table 2-3. Frequency Distribution of Pasquill Turbulence Types at SEA-TAC International Airport, January 1 - December 31, 1969

	WIND SPEED (mph)						
	0-3	4-7	8-12	13-18	19-24	>24	Total
A	-	0.0017	-	-	-	-	0.0017
B	0.0147	0.0195	0.0137	-	-	-	0.0479
C	0.0036	0.0295	0.0521	0.0087	-	-	0.0987
D	0.0442	0.1525	0.2560	0.1480	0.0175	0.0031	0.6213
E	0.0483	0.1251	0.0569	-	-	-	0.2303
	0.1108	0.3266	0.3787	0.1567			

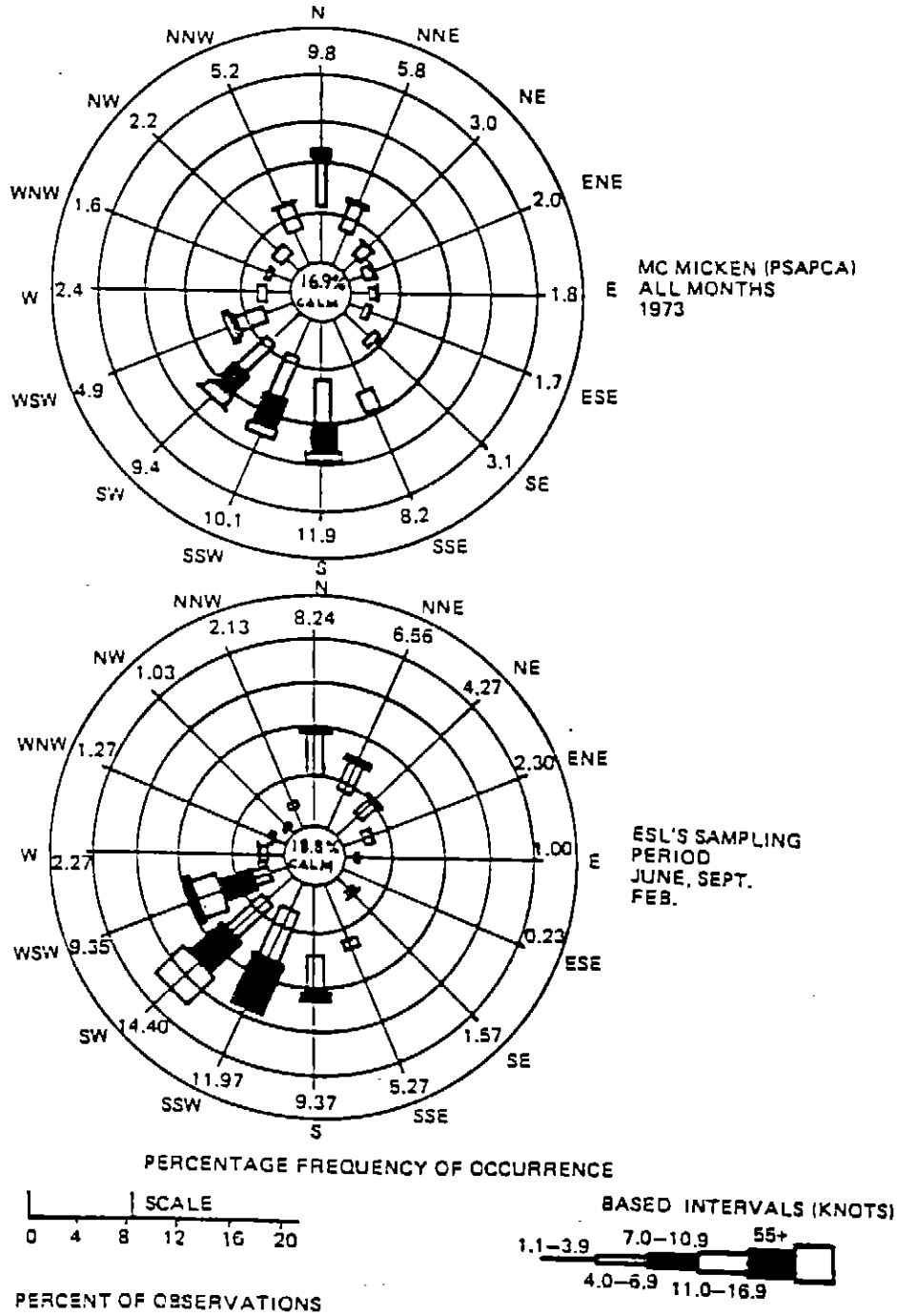


Figure 2-2. Surface Wind Roses at McMicken Heights (PSAPCA) and for ESL's Sampling Periods (June 1973, September 1973, and February 1974).

2.2 -- Continued.

Figure 2-2 indicates that ESL's monitoring periods were representative of the annual prevailing wind patterns.

2.3 Archival Air Quality.

Air quality monitoring in the Seattle region is carried out jointly by the Washington State Department of Ecology (DOE) and the PSAPCA. Both agencies were contacted to determine if they had taken any measurements near the SEA-TAC airport. Only PSAPCA had taken data near SEA-TAC and only at three locations: McMicken Heights, Tukwilla, and Des Moines. PSAPCA allowed us to make copies of their records for each of these locations. Table 2-4 summarizes the information duplicated. Only the McMicken and Des Moines locations are discussed because they are within the study area and have sufficient data. The Des Moines site is approximately 2.5 miles south and 1 mile west of the SEA-TAC terminal, and the McMicken Heights site was approximately 1 mile due east of the terminal.

Table 2-4 and the data collected reflect the general high purity of the air near the airport. Hourly concentrations of carbon monoxide at McMicken are always well below the Federal standard of 40 mg/m^3 (35 ppm). Highest monthly CO 8-hour averages varied between 2 and 4.5 mg/m^3, also well below the Federal standard of 10 mg/m^3 (9 ppm). Hourly oxidant levels varied between 20 ug/m^3 (0.01 ppm) and 216 ug/m^3 (0.11 ppm)

Table 2-4. Summary of Puget Sound Air Pollution Control Agency Data Near SEA-TAC

	Location			
	McMicken Heights*		Des Moines RCVR†	
Pollutant	Mean	Max	Mean	Max
CO	1.0 ppm	6.0	2.6 ppm	7.0
O_x	0.02 ppm	0.11	0.006 ppm	0.04
Particulate	42 $\mu g/m^3$	89 $\mu g/m^3$	50 $\mu g/m^3$	167

*June, 1972 - May 1973 (CO) April 1972 - May 1973 (O_x)

†Nov, Dec (1970) Jan Feb Mar (1971)

2.3 -- Continued.

and exceeded the standard of 160 $\mu g/m^3$ during 6 hours. Particulate level was available as an arithmetic average of 44.6 $\mu g/m^3$, geometric mean of 42 $\mu g/m^3$, and a maximum observed value of 89 $\mu g/m^3$. These figures compare favorably with the Federal standard of 75 $\mu g/m^3$ (geometric mean) and 260 $\mu g/m^3$ for 24 hours. 50 150

Des Moines data was collected at S. 219th Street and 11th Avenue S. Again, the CO levels are well below the standards for 1 hour and the maximum monthly 8-hour averages vary between 4.5 and 7 mg/m^3, significantly below the 10 mg/m^3 standard. Particulate and oxidant were always below standards.

2.3 -- Continued.

Because the predominate wind patterns at SEA-TAC are not expected to cause significant amounts of pollutants from SEA-TAC to blow onto McMicken or Des Moines, the levels observed at these sites reflect a background level associated with the general development of the area.

2.4 Meteorological Parameters and Air Pollution Levels At SEA-TAC.

Two types of air quality measurements were performed by ESL at the SEA-TAC airport. First, a completely equipped air monitoring van was located near the airport during June, September (1973), and February (1974). The van monitored wind speed and direction, carbon monoxide, hydrocarbons, particulates, oxidant, and nitrogen oxides. In addition, the particulate samples were analyzed for lead and other elements. Second, air samples in and around the terminal area and surrounding community were analyzed for carbon monoxide. Results of these measurements are discussed in the next sections.

2.4.1 Location of Ambient Air Quality Measurements Near SEA-TAC.

Air quality monitoring sites were chosen according to areas of major impact based on the north-south prevailing winds, aircraft movements, and areas of population. Accordingly, primary monitoring sites were selected at the north and south ends of the airport. Pursuant to citizen requests, additional monitoring was done in a residential area west of the airport.

2.4.1 -- Continued.

ESL's monitoring locations and the PSAPCA monitoring locations are shown in Figure 2-3. The "Marker" station (No. 1) was at the north end of the airport, on South 146th Street, two miles north of the terminal and 0.6 miles north of the end of the runway (16L). The "Golf Course" station (No. 2) was located just off South 200th street, 1.5 miles south of the terminal and 0.6 miles south of the end of the runway (34R). The third station was at the Barden residence (No. 3) approximately 0.75 miles west and 0.4 miles north of the terminal. At this location, the ESL van was parked in the driveway 0.4 miles due west of the nearest runway.

Additional particulate and CO air quality measurements were taken at the airport terminal area (No. 4) and in the surrounding community.

PSAPCA air quality data was taken at McMicken Heights, Des Moines, and Tukwilla (Nos. 5,6 and 7 respectively).

The following sections summarize the air quality measurements taken.

2.4.2 Existing Air Quality-Carbon Monoxide (CO).

Carbon monoxide samples were taken continuously 12 times per hour, 24 hours per day during the June, September, February sampling periods. The mean value of all measurements was .81 mg/m^3. The highest 1-hour average concentration observed was less than 5 mg/m^3 (13 percent of the

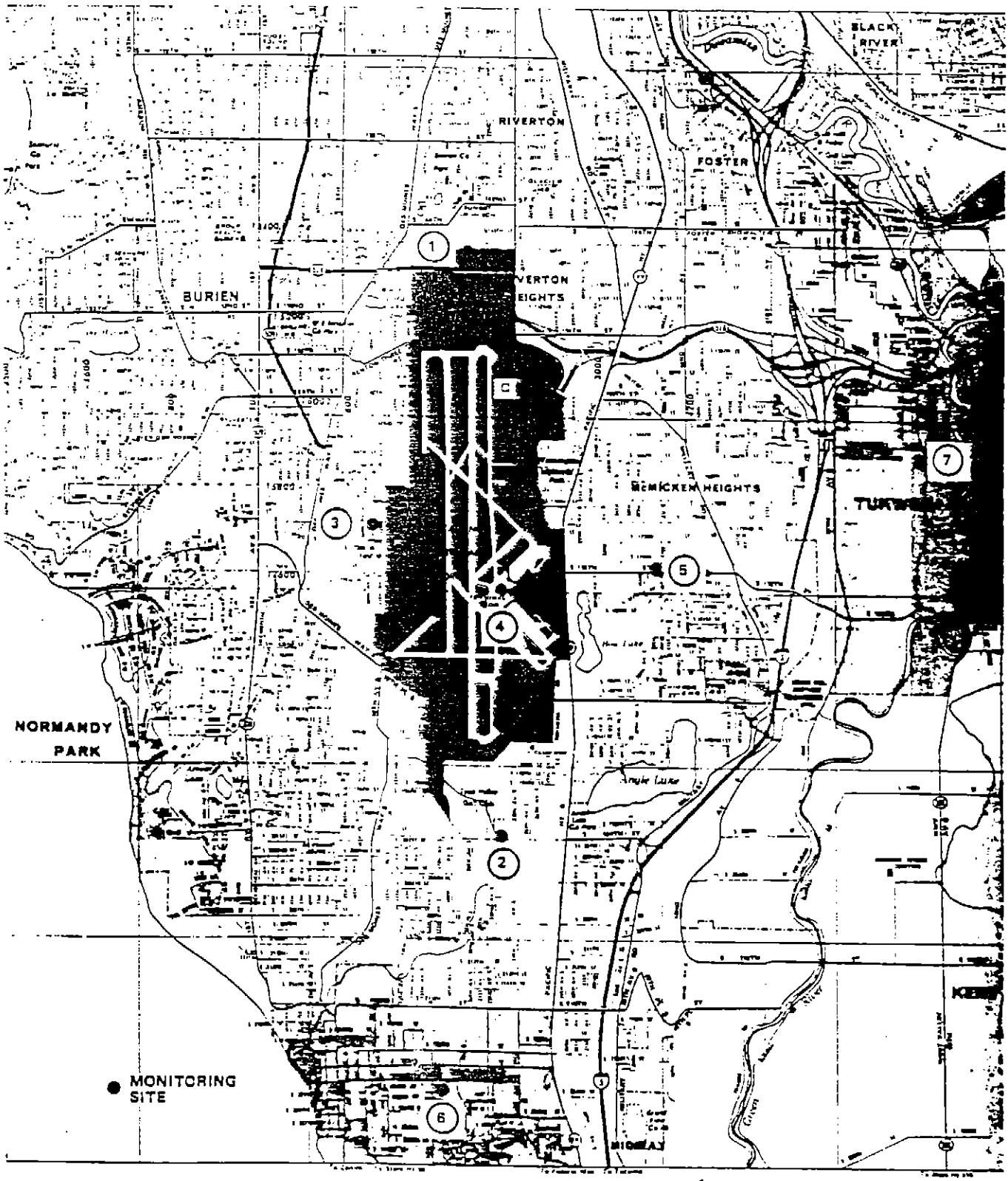


Figure 2-3. Monitoring Sites Near SEA-TAC. ESL Sites: 1-4; PSAPCA Sites: 5-7.

2.4.2 -- Continued.

Federal Standard) during September. The maximum moving 8-hour average concentration was approximately 3 mg/m^3 (30 percent of the Federal Standard) also observed during September.

Average diurnal variations in the CO concentrations for the three sampling periods are shown in Figure 2-4. The levels are low and not particularly significant. The only discernible trend is the slight peaking 6-9 a.m. associated with higher activity and the late evening peaking associated with moderate activity, light wind, and stable atmospheric conditions.

Analysis of PSAPCA data from May 1972 to April 1973 at the McMicken Heights station shows a hourly maximum of approximately 5 $\mu g/m^3$ during June and September. The maximum moving 8-hour average was consistent at approximately 3.5 $\mu g/m^3$ level during May through September.

Because of the correlation between ESL's measurements during three monitoring periods and data collected by PSAPCA covering an entire year, it is reasonable to assume that the ESL measurements adequately reflect the worst case and average ambient CO levels.

2.4.3 Existing Air Quality - Hydrocarbons.

Air samples for hydrocarbon analysis were taken continuously 12 times per hour, 24 hours per day, during June, September, and February. Each sample is burned completely to detect all hydrocarbons, including any naturally

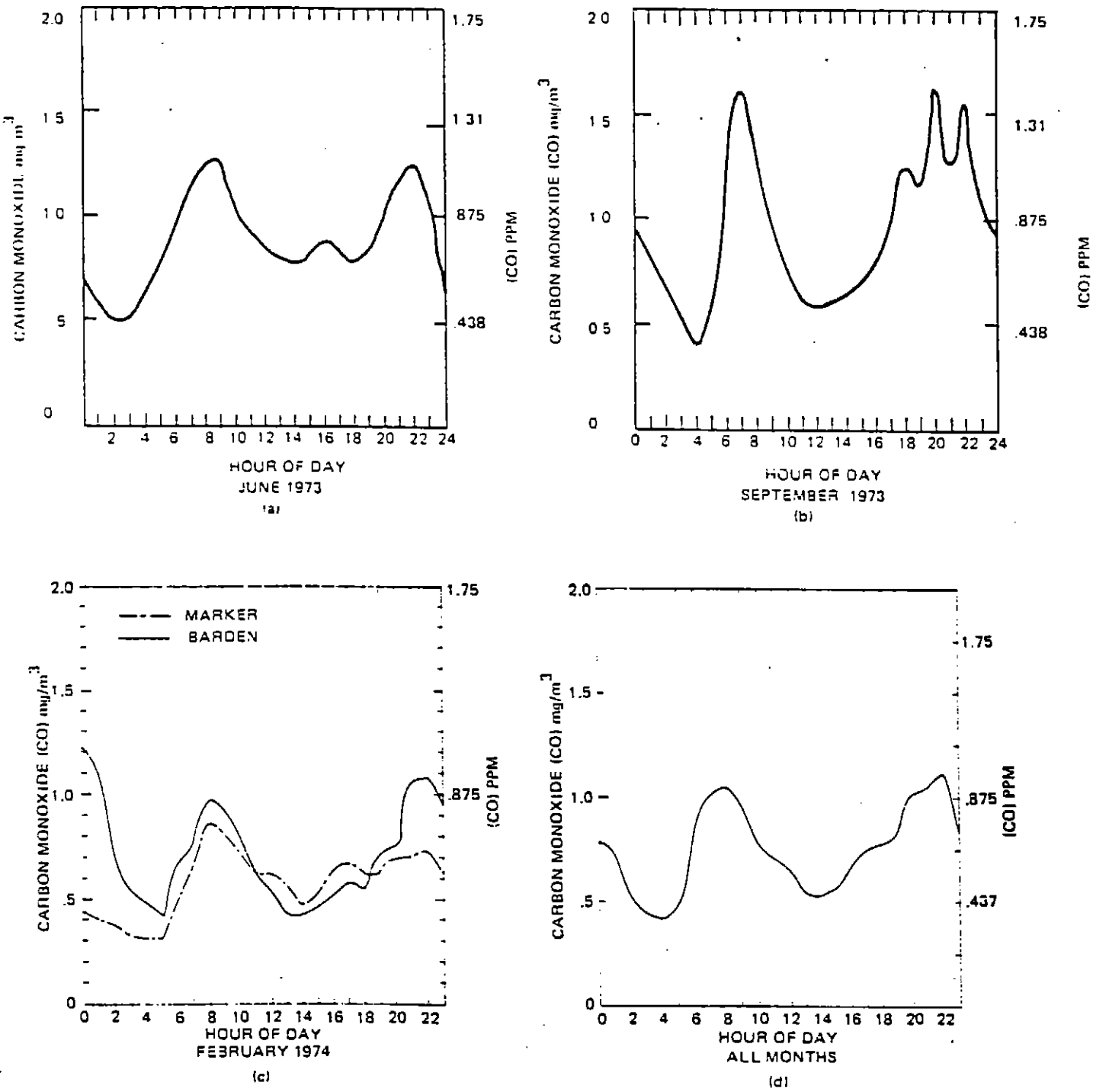


Figure 2-4. Average Hourly Carbon Monoxide Concentrations Near SEA-TAC Airport

2.4.3 -- Continued.

occurring methane gas (CH_4). Results are recorded as total hydrocarbons (THC). When unreactive methane gas is separated from the sample, results are recorded as hydrocarbons (HC).

The high 6-9 a.m. average HC concentrations occurred during September. They ranged from approximately 1200 $\mu g/m^3$ (750 percent of the Federal Primary Standard) to 176 $\mu g/m^3$ (110 percent of the Federal Primary Standard) The low 6-9 a.m. averages HC concentrations occurred during February. These ranged from about 380 $\mu g/m^3$ (240 percent of the Federal Primary Standard) to about 50 $\mu g/m^3$ (31 percent of the Federal Primary Standard). If all three sampling periods are combined, the 6-9 a.m. average concentrations exceeded the Federal Primary Standard 71 percent of the time.

The mean of the 6-9 a.m. average hydrocarbon levels for all samples was 370 $\mu g/m^3$ (231 percent of the Federal Primary Standard).

Figure 2-5 shows diurnal variations in hydrocarbon levels. There is a discernible trend similar to an exaggerated version of carbon monoxide diurnal variations (Figure 2-4). Peaking occurs during 6-9 a.m. associated with moderate activity, light wind, and stable atmospheric conditions. Archival data for comparison to the hydrocarbon levels in the SEA-TAC area does not exist.

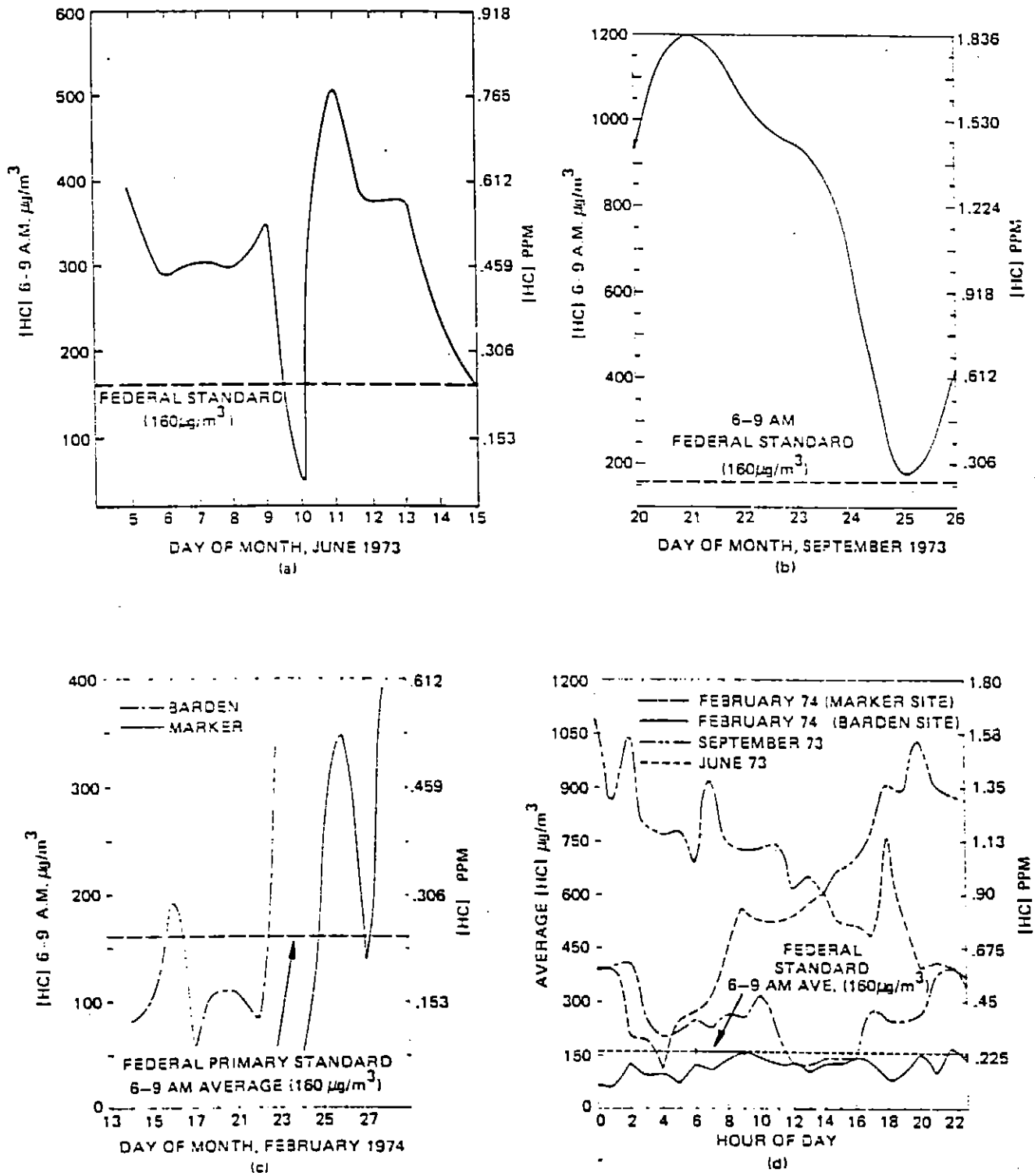


Figure 2-5. Nonmethane Hydrocarbon (HC) Observations Near SEA-TAC Airport.

2.4.3 -- Continued.

The levels at the Barden site are particularly significant because they reflect the background level of hydrocarbons in the vicinity of the airport. During the time period the measurements were taken, the wind was primarily from the southwest which would prevent any airport pollutants from reaching the location. Figure 2-5 shows that the background level is very close to the Federal Standard even during the winter periods when hydrocarbon levels are low because of the meteorological conditions.

The high hydrocarbon levels are associated with the "kerosene" odor around the airport. Formation of aldehydes during the combustion of hydrocarbons will also contribute to the odor associated with the airport. At present, there is no available method for quantifying the odor levels.

2.4.4 Existing Air Quality - Nitrogen Dioxide.

Nitrogen dioxide measurements were made at the Marker Station, Golf course, and Barden sites. Air sampling was performed on a continuous basis except when calibration or equipment servicing was performed.

In order to estimate the annual average concentration, we have developed seasonal multiplication factors based upon the archival data from McMichen Heights. We assign the average Summer nitrogen dioxide levels a value of 1.0, and compute the multiplication factors as the ratio of the remaining seasonal values to the summer average. Following this procedure the

2.4.4 -- Continued.

Autumn value is 1.64, Winter is 0.71, and Spring is 0.86. Using these multiplication facators on the SEA-TAC data, we predict nitrogen dioxide averages for the four seasons starting with Summer as 42 $\mu g/m^3$, 69 $\mu g/m^3$, 30 $\mu g/m^3$, and 36 $\mu g/m^3$. The annual predicted average for comparison to the Federal Standard would be 44 $\mu g/m^3$ (.02 ppm) or 44 percent of the standard.

The diurnal trends shown in Figure 2-6 appear to reflect the airport activity with peaking trends during early morning, midday, and late afternoon. Higher levels during late evening hours are caused by stable atmospheric conditions. Archival data from the PSAPCA McMicken station resembles the ESL data, but ESL's data from the Barden site is unique. Because the trend at the Barden site does not follow the airport trend, it would appear that the nitrogen dioxide levels do not result from the airport activity.

Fuel consumption is a major source of nitrogen dioxide and is probably the primary reason the distinct difference between the sites. The Barden site may reflect automobile activity which tends to peak sharply in the morning, but is typically more diffuse in the evening. Also, the prevailing winds were from the southwest during the measurement period; this would prevent airport air pollutants from reaching the site.

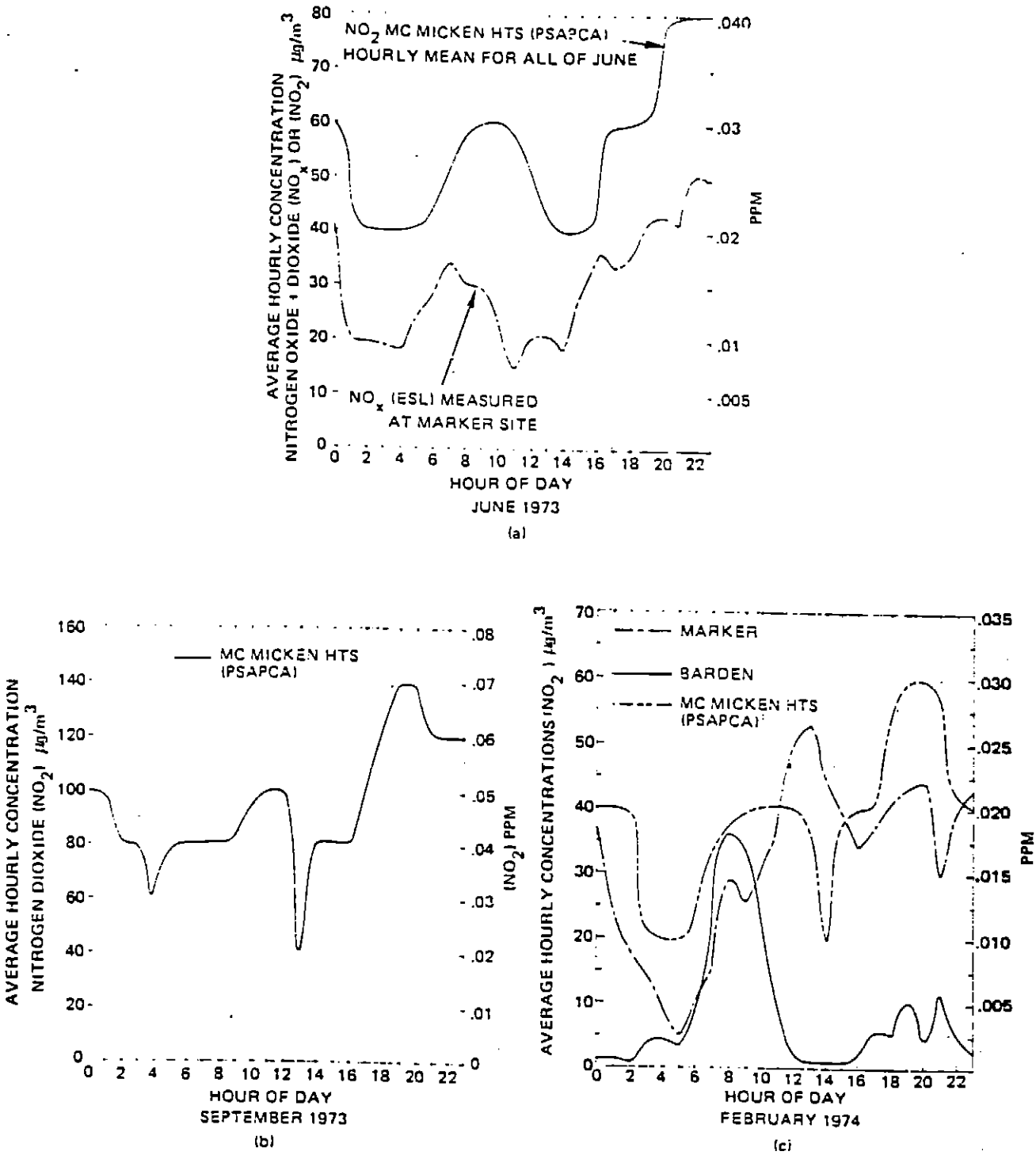


Figure 2-6. Nitrogen Dioxide Observations Near SEA-TAC Airport and the McMicken Heights (PSAPCA).

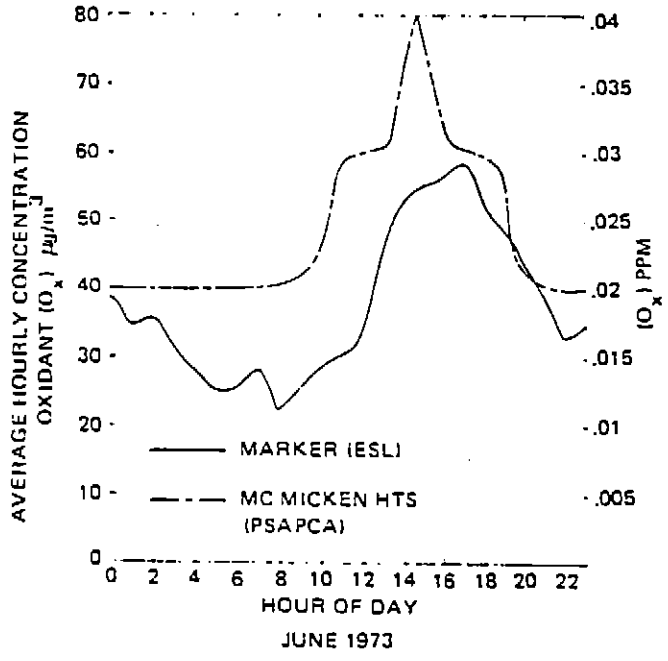
2.4.5 Existing Air Quality - Oxidant (Ox).

Oxidant levels were monitored 24 hours per day during each monitoring period. In addition, during the peak oxidant period, September, extended measurements were made.

The maximum hourly oxidant level observed in June was 120 $\mu g/m^3$ (0.06 ppm) or 75 percent of the Federal Standard of 160 $\mu g/m^3$ for the 1 hour. During September there were four violations of the Federal Standard on three different days. The highest level observed was 190 $\mu g/m^3$ or 119 percent of the standard. During the February period, the oxidant levels were nearly zero as expected.

Average oxidant as a function of time is plotted in Figure 2-7 for the June and September periods. These levels cannot be compared to the Federal Standard because they are averaged for all days in the observation period. However, the figures clearly show the expected late afternoon peaks and the higher levels of the autumn season.

Archival oxidant measurements furnished by PSAPCA verify the accuracy of ESL's data. Maximum hourly oxidant levels at the McMicken Heights station during our June observation period was 80 $\mu g/m^3$ (0.04 ppm). During September their highest hourly value was 120 $\mu g/m^3$ (0.06 ppm) and their February levels were zero.



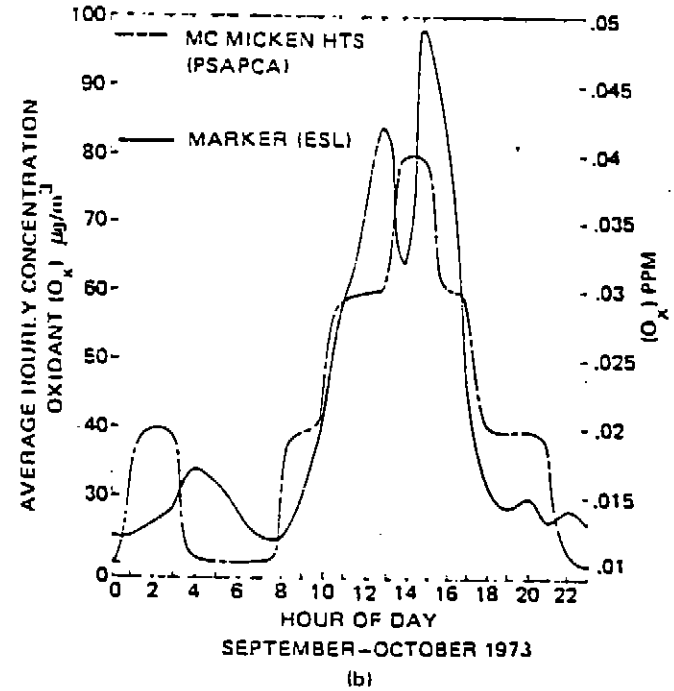


Figure 2-7. Oxidant Concentrations Near SEA-TAC Airport.

2.4.5 -- Continued.

Based on the archival data for McMicken for an entire year, and the relationship between the McMicken and ESL data, we expect the oxidant standard to be violated on four or five days per year for a total of 8-10 hours. These occurrences do not represent an immediate problem since the standard is set with an adequate margin of safety, but they do suggest the need to implement any available mitigation measures to reduce hydrocarbons and nitrogen oxides.

2.4.6 Existing Air Quality - Particulate and Lead.

Daily 24-hour particulate samples were collected using a high volume sampler. The geometric mean of all samples was 38 $\mu g/m^3$ or 49 percent of the annual Federal Standard for the geometric mean. The highest daily level observed was 112 $\mu g/m^3$ on a calm day at the Barden location in February. Both the Marker Station site and the golf course site reached levels near 100 $\mu g/m^3$ during June. These values should be compared to the 24-hour Federal Standard of 260 $\mu g/m^3$ (40 percent).

Particulate samples collected at the terminal were consistently below those observed at all other sites. Values stayed between 20 and 30 $\mu g/m^3$ (~10 percent of the standard) for the seven samples taken at the terminal location (Figure 2-8). During September the particulate levels at the golf course site were consistently below those at the Marker station (Figure 2-8).

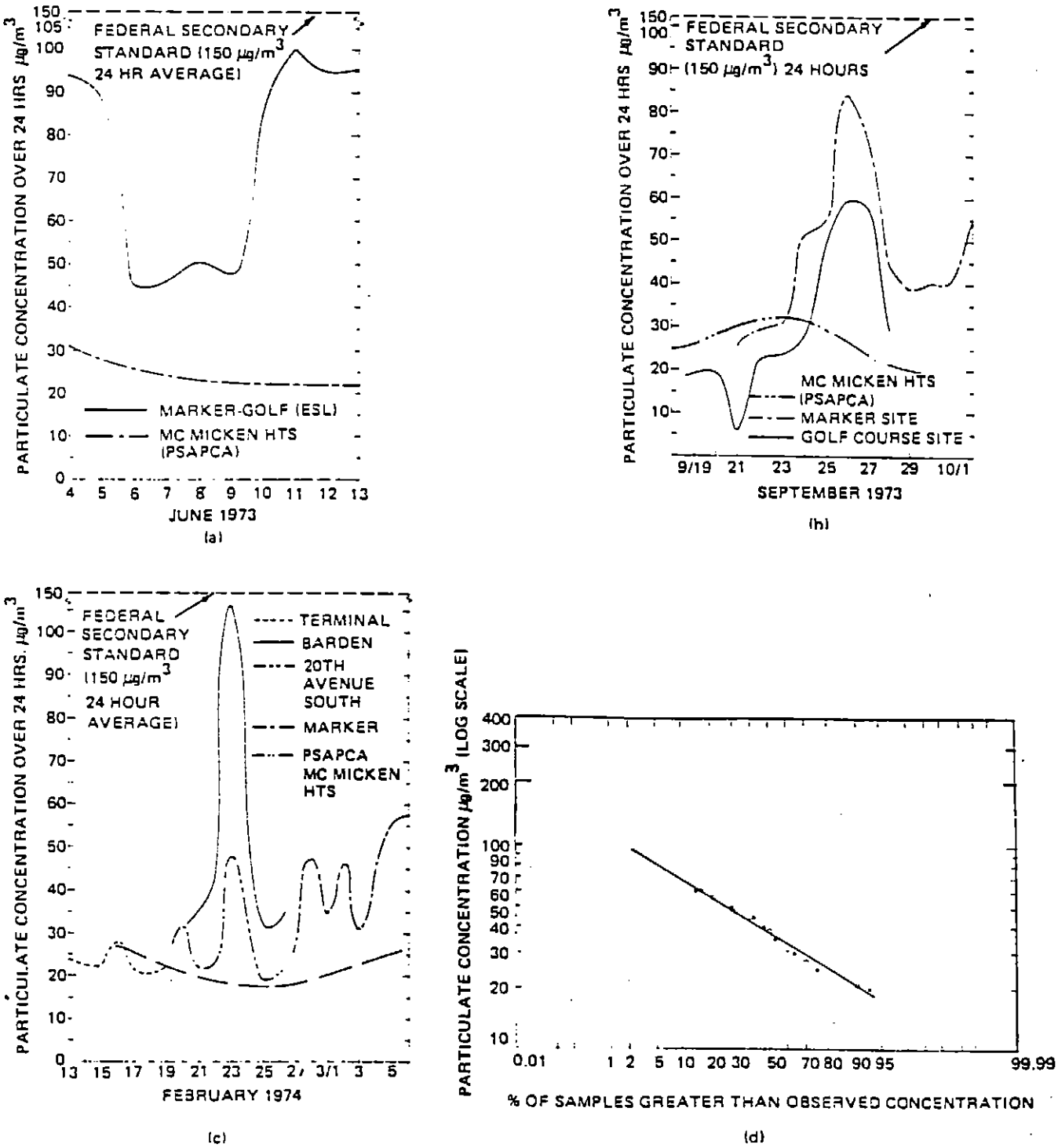


Figure 2-8. Particulate Concentrations Near SEA-TAC Airport and Cumulative Frequency Distribution.

POS 20435

2.4.6 -- Continued.

Because of the prevailing wind direction, takeoffs and landings were over the Marker Station site. February particulate levels at the Marker Station were not significantly different from September levels, although there was less variation between samples because of rainfall.

The exceptional peak (114 $\mu g/m^3$) at the Barden location in February is associated with stagnant atmospheric conditions for nearly 24 hours. Average wind speed during the sample period was 1.5 mph with several lengthy time periods averaging less than 1.0 mph.

Although the above particulate samples are probably representative of the levels expected near SEA-TAC, we also used the Larsen model[2] to estimate the geometric mean and maximum expected value over a one year period. Using this method, the estimated geometric mean is 37 $\mu g/m^3$ and the maximum expected value is 152 $\mu g/m^3$. Thus the geometric mean, both observed and calculated, is less than the primary and secondary Federal standards of 75 $\mu g/m^3$ and 60 $\mu g/m^3$ respectively.

Archival data from the PSAPCA McMicken Heights Station during the ESL sampling periods does not appear to reflect any airport activity (See Figure 2-8). This is consistent with the fall velocity of particulate, the general wind direction, and the wind speed. These factors tend to move particulate out of the airport region before lateral diffusion to McMicken occurs.

2.4.6 -- Continued.

During the period from May 1972 through April 1973, the PSAPCA McMicken particulate data had a geometric mean of 42 $\mu g/m^3$ and a peak of 89 $\mu g/m^3$. Based on this data and the ESL measurements, it is clear that particulate levels do not exceed Federal Standards at SEA-TAC or in the surrounding communities.

Particulate samples were also analyzed for lead (Pb) at the University of California, Davis, cyclotron. Observed lead levels varied between 0.3 $\mu g/m^3$ and 1.4 $\mu g/m^3$. The average level was 0.96 $\mu g/m^3$ for June 1973; and 0.77 $\mu g/m^3$ for June, September 1973 and February 1974. In the absence of a Federal Standard, these figures can be compared to the California Standard of 1.5 $\mu g/m^3$ (30 day average). (See Table 2-5.)

2.4.7 Carbon Monoxide Samples at the SEA-TAC Terminal and Surrounding Community.

Previously, we noted that aircraft operations release large quantities of carbon monoxide. Automobiles and other ground transportation vehicles also generate significant quantities of CO. Hence, CO was a natural choice to measure in the terminal area and surrounding community to determine if significant levels of pollution existed. This section summarizes the results of a series of measurements taken within the airport complex and in the surrounding community.

Table 2-5. Elemental Analysis of Particulate at SEA-TAC Compared to Rural Area in California

Element	Average Values Nanograms/CM^2	
	SEA-TAC *	RURAL TOWN, CAL
Aluminum	930	469
Silicon	4977	6816
Chlorine	1706	1727
Potassium	916	1066
Calcium	1716	2053
Titanium	220	?
Iron	3943	4037
Copper	2732	2053
Lead	3555 ± 1670	6092 ± 2478
Bromine	563	2324

*Average flow = 35 ft^3/min; Surface Area = 60 in^2;
Average Concentration of Lead = 0.96 $\mu g/m^3$ ±0.45 $\mu g/m^3$.

2.4.7 -- Continued.

Average carbon monoxide levels in the SEA-TAC terminal area during June 1973 - February, March 1974 are shown in Table 2-6. As would be expected, the higher levels are found in the parking garages, baggage claim areas, and ticketing areas where automobiles are operating nearby. The figures represent hourly averages and are well below the Federal standard of 40 $\mu g/m^3$ for 1 hour and 10 $\mu g/m^3$ over 8 hours.

Carbon monoxide levels around the SEA-TAC property tend to be below the terminal levels (Table 2-7). Locations numbered 1 through 5 are closer to aircraft operation and within the airport boundary, and therefore reflect the expected higher CO levels. Again all levels are below the 1-hour and 8-hour standards.

The results discussed above will be used to calibrate the models to be used in predicting future air quality at SEA-TAC. ESL's methodology for predicting air quality is discussed in the following sections.

2.4.8 References.

1. "Transportation Controls to Reduce Motor Vehicle Emissions in Seattle, Washington," GCA Corporation for PSAPCA.

2. Larsen, R.J., "A Mathematical Model for Relating Air Quality Measurements to Air Quality Standards," U.S. EPA, Research Triangle Park, North Carolina, 1971.

Table 2-6. Average Daytime Carbon Monoxide Levels Around SEA-TAC Terminal

CO mg/m^3	Locations	
	Approximate	Specific
5.4	Parking Garage	Lower level
5.4	Parking Garage	Top level
3.8	Parking Garage	Middle level
3.4	S. End	Ticketing
3.4	S. End	Passenger unload (Street)
4.1	S. End	Baggage claim
2.9	S. End	Passenger load (Street)
4.6	N. End	Baggage claim
4.5	N. End	Passenger load (Street)
4.0	N. End	Ticketing
4.6	N. End	Passenger unload (Street)
3.2	C Wing	Inside Begin
3.4	C Wing	Inside Mid
3.4	C Wing	Inside End
3.4	D Concourse	Inside
3.9	Terminal Lounge	N
4.4	Terminal Lounge	S
3.1	B Wing	Inside Begin
2.9	B Wing	Inside Mid
2.6	B Wing	Inside End
3.2	A Concourse	Inside
2.5	B Wing	Outside Begin
1.8	B Wing	Outside Mid
1.7	B Wing	Outside End
2.4	A Concourse	Outside (NWA Hanger)
2.0	C Wing	Outside Begin
2.0	C Wing	Outside Mid
1.9	C Wing	Outside End
2.0	D Concourse	Outside
4.8	Tunnel to	N Satellite
2.2	Inside	N Satellite
4.6	Tunnel to	S Satellite
2.4	Inside	S Satellite

Table 2-7. Average Daytime CO Levels SEA-TAC Environs

CO mg/m^3	Grid	Locations Approximate
3.57		WAL Hangar
3.07		Fire Station
4.89		Air Cargo #1
3.64		UAL Hangar
3.00		Flight Kitchen
3.21	QR 1718	Perimeter Road near 518/Airport Fwy
2.46	QR 1920	Washington Memoral Park
2.25	QR 2122	171 St./Pacific Hwy (99)
2.82	QR 2324	182nd/Hwy 99
2.68	QR 2526	188th/Perimeter Road
2.82	OP 2526	S188th/34R
2.61	MN 2526	S188th/12th
2.54	MN 2324	180th/11 Av S
2.46	MN 2122	172nd/12th
2.39	MN 1920	164th/12th
2.46	MN 1718	Renton Three Tree/12 Av S
2.75	OP 1718	154th/20th
2.75	OP 1516	Near 518/Extension of 16L
2.39	QR 1516	S148th/27th Av
1.93	ST 1718	518/36th
2.54	ST 1920	164th/36th
2.39	ST 2122	172nd/36th
2.46	ST 2324	180th/36th
2.39	ST 2526	188th/36th
2.46	QR 2728	196th/27th
2.32	OP 2728	Tynee Valley Golf Club
2.25	MN 2778	S196th/Des Moines Way
3.11	KL 2526	S188th/8th Av
2.32	KL 2324	180th/8th
2.46	KL 2122	171st/8th
2.46	KL 1920	164th/8th
2.18	KL 1718	156th/8th
2.32	MN 1516	518/Des Moines
2.04	MN 1314	146th/12th
2.46	OP 1314	140th/21st
2.46	QR 1314	140th/28th
2.29	QR 2930	204th/Pacific Hwy
2.29	OP 2930	204th/18th
2.21	MN 2930	204th/12th

3. SOURCES OF AIR POLLUTION AT SEA-TAC.

The first step in implementing a model to predict air quality at SEA-TAC is the compilation of an emission inventory. ESL uses a finite line source model which requires emissions to be specified along line segments. Each line segment may be fairly long such as those which would be associated with approach, landing, takeoff and climbout; or quite short such as runway queues and gate parking.

Airport associated emissions may be classified as follows:

a. Aircraft emissions during start up, idle, and taxi prior to takeoff

b. Aircraft emissions during takeoff

c. Aircraft emissions during climbout

d. Aircraft emissions during approach and landing

e. Aircraft emissions during arrival taxi and idle

f. Aircraft emissions during fuel venting

g. Aircraft emissions during the maintenance mode

h. Aircraft ground service associated emissions

3. -- Continued.

i. Fuel storage emissions

j. Motor vehicle emissions associated with employees, passengers, and other airport activity

3.1 Aircraft Emissions.

The first step in determining emissions requires a categorization of engine types likely to be utilized at the airport. The Cornell Aeronautical Laboratory (CAL) published emission rates for a large number of engine types in 1971 at the request of the Environmental Protection Agency. CAL determined emission factors for three pollutants for a large number of engines. The results of the CAL study have been supplemented and published by the EPA (Table 3-1).

To convert the EPA emission factors on Table 3-1 into total emissions, the time each aircraft spends in each operational mode must be specified. Operational modes and corresponding modal times are required for taxi-idle prior to takeoff, takeoff, climbout, approach, and taxi-idle after landing. The emissions according to aircraft type are shown in parentheses in Table 3-1.

Table 3-1. Modal Emission Factors - EPA* (lbs/hr) and SEA-TAC Modal Emissions (lbs)

Engine & Mode	Carbon Monoxide lb/hr	Hydrocarbons lb/hr	Nitrogen Oxides lb/hr	Particulates lb/hr
JT9D				
Taxi-idle	102.0(18.7)	27.3(5.00)	6.1(1.12)	2.2(0.403)
Takeoff	8.3(0.1)	3.0(0.135)	720.0(8.40)	3.8(0.044)
Climbout	11.7(0.43)	2.7(0.10)	459.0(16.83)	4.0(0.147)
Approach	32.6(2.17)	3.0(0.2)	54.1(3.61)	2.3(0.153)
SEA-TAC lbs/LTO - Eng.	21.4	5.34	29.96	0.747
CF6				
Taxi-idle	51.7(9.48)	15.4(2.82)	3.6(0.66)	0.04(0.007)
Takeoff	6.7(0.08)	1.3(0.02)	540.0(6.30)	0.54(0.006)
Climbout	6.6(0.242)	1.3(0.05)	333.0(12.21)	0.54(0.02)
Approach	18.6(1.24)	1.9(0.127)	173.0(11.53)	0.44(0.03)
SEA-TAC lbs/LTO - Eng.	11.04	3.02	30.7	0.061
JT3D				
Taxi-idle	109.0(20.0)	98.5(18.1)	1.4(0.26)	0.45(0.08)
Takeoff	12.3(0.14)	4.7(0.05)	148.0(1.73)	8.3(0.10)
Climbout	15.3(0.56)	4.9(0.18)	96.2(3.53)	8.5(0.31)
Approach	39.7(2.65)	7.8(0.52)	21.8(1.45)	8.0(0.53)
SEA-TAC lbs/LTO - Eng.	23.35	18.95	6.97	1.02
JT8D				
Taxi-idle	33.4(6.12)	7.0(1.28)	2.9(0.53)	0.36(0.07)
Takeoff	7.5(0.09)	0.78(0.009)	198.0(2.31)	1.7(0104)
Climbout	8.9(0.33)	0.92(0.034)	131.0(4.80)	2.6(0.095)
Approach	18.2(1.21)	1.75(0.17)	30.9(2.06)	1.5(0.10)
SEA-TAC lbs/LTO - Eng.	7.75	1.49	9.7	0.305
T56-A7				
Taxi-idle	17.3(2.8)	6.5(1.2)	2.2(4.0)	1.6(0.29)
Takeoff	2.2(0.02)	0.43(0.003)	22.9(0.19)	3.7(0.03)
Climbout	3.0(0.13)	0.48(0.02)	21.2(0.88)	3.0(0.13)
Approach	3.7(0.28)	0.52(0.04)	7.8(0.58)	3.3(0.23)
SEA-TAC lbs/LTO - Eng.	3.23	1.26	2.05	0.68
TPE331				
Taxi-idle	3.5(0.64)	0.88(0.16)	0.96(0.18)	0.3(0.055)
Takeoff	0.39(0.002)	0.06(0.003)	3.64(0.02)	0.3(0.004)
Climbout	0.57(0.048)	0.05(0.004)	3.31(0.28)	0.6(0.05)
Approach	2.6(0.26)	0.24(0.024)	1.69(0.17)	0.6(0.06)
SEA-TAC lbs/LTO - Eng.	0.95	0.19	0.65	0.17
CONTINENTIAL O-200				
Taxi-idle	7.5(1.4)	0.214(0.04)	0.009(0.002)	-
Takeoff	54.6(0.27)	0.720(0.004)	0.259(0.001)	-
Climbout	54.6(4.55)	0.720(0.06)	0.259(0.02)	-
Approach	23.8(2.38)	0.380(0.04)	0.052(0.005)	-
SEA-TAC lbs/LTO - Eng.	8.60	0.144	0.03	

*Compilation of Air Pollution Emission Factors, 2nd Edition U.S. EPA April 1973

3.1 -- Continued.

Table 3-2 compares the EPA model times to those used in a variety of previous airport studies and those selected for SEA-TAC. Airport configuration and size will play a significant role in the average time assigned to a particular mode. Thus, Dulles (IAD) with aircraft loading and unloading accomplished away from the congested terminal has much shorter taxi/idle times which dramatically reduce emissions. The exceptionally low value for O'Hare is somewhat surprising and is due to low taxi times.

Table 3-2. Average Time Assigned to Aircraft Operating Modes at Various Airports

	Airports				
Mode	DCA [1]	IAD [2]	O'Hare [3]	S/T [4]	EPA [5]
Taxi Idle	11.0	5.0	7.5	7.0	19
Takeoff	0.7	0.7	0.5	0.7	0.7
Climbout	1.7	1.7	2.0	2.2	2.2
Approach	4.0	4.0	3.8	4.0	4.0
Taxi Idle	3.4	4.0	3.9	4.0	7.0
Total	20.8	15.4	17.7	17.7	32.9

3.1 -- Continued.

In order to convert the engine emission rates to emission factors, it is necessary to assign the engines to aircraft types, determine the aircraft type distribution for SEA-TAC, and assign the number of engines to each aircraft. This is done in Tables 3-3 and 3-4. It is assumed that the short range aircraft can be represented by the Allison 501D13 engine and that the air taxi general aviation engines can be represented by the Continental 10-570-P and military engines by the JT3D.

Using the EPA emission factors based on Table 3-1 and 3-2, the total emission tonnage was computed for SEA-TAC in Table 3-5. These figures serve as a useful cross check with other computations for SEA-TAC and with other airports. At the bottom of Table 3-5 figures are presented for SEA-TAC which were obtained from the Puget Sound Air Pollution Control Agency in January 1974. The difference between ESL's calculations using the EPA modal times ("EPA") and the PSAPCA figures is due primarily to differences in aircraft mix. ESL's figures differ from the "EPA" and PSAPCA figures because of the average times per operating mode reflected in Table 3-2. SEA-TAC modal times in Table 3-2 are based on measurements made at SEA-TAC during 1973 and are considered conservative numbers.

Final SEA-TAC emissions were arrived at by using the operational mode times from Table 3-1. The adjusted figures are 1754 tons/year CO, 1029 tons/year HC, 996 tons/year NO_x and 73 tons/year particulate. These figures will be used throughout the remainder of this report to develop emission factors for the model predictions.

Table 3-3. Air Carrier Operations SEA-TAC 1972

		1973 June/July	1972 113,631	Engine LTOS
Jumbo	JT9D			
	(B747)	5.9%	6704	13408
	(DC10/L1011)	4.3%	4886	7329
Long Range	JT3D			
	B707			
	DC8	40.4%	45907	91814
Medium Range	JT8D			
	B727	34.1%	38748	58122
	DC9	5.4%	6136	6136
	B737	3.3%	3750	3750
	CJ-805-3A			
	C880-4			
Short Range	A-501-D13			
	FH227			
	L188	6.6%	7500	7500
		100.0%	113,631	188,056

Table 3-4. Total Engine LTOS SEA-TAC Airport 1972

	Operations	Representative Engines	Engine LTOS
I. Air Carrier			
Itinerant	109,278	JT9D	
Local	4,353	JT8D	188,056
		JT3D	
	113,631	A501-D13	
II. Air Taxi			
Itinerant	17,028		
		JT12	
		10-520-P	36,335
III. General Aviation			
Itinerant	19,307		
IV. Military			
Itinerant	1,684	N.A	
Local	694	Used JT3D	4,756
	152,344		229,150

Table 3-5. 1973 Aircraft Emissions at SEA-TAC

ENGINE	ENGINE LTO'S	POLLUTANT	EMISSION PER LTO (LBS)		TONS/YEAR		PSAPCA*
			EPA	ESL	EPA	ESL	
JUMBO (JT9D)	13,408	CO	46.9	21.4	314	143	
		HC	12.2	5.34	82	36	
		NO_x	31.4	30.0	211	201	
		P	1.3	0.75	9	5	
JUMBO (CF6)	7,329	CO	23.9	11.0	88	40	
		HC	6.87	3.0	25	11	
		NO_x	31.6	30.7	116	113	
		P	0.1	0.1	0.4	0.4	
LONG RANGE (JT3D)	91,814	CO	50.6	23.4	2323	1074	
		HC	43.5	18.9	1997	867	
		NO_x	7.3	7.0	335	321	
		P	1.14	1.02	52	47	
MEDIUM RANGE (JT8D)	68,008	CO	16.10	7.75	547	264	
		HC	3.25	1.50	111	51	
		NO_x	10.5	9.70	354	330	
		P	0.40	0.31	13.6	10.5	
SHORT RANGE (A-501-D13)	7,500	CO	7.0	7.0	26	26	
		HC	2.7	2.7	10	10	
		NO_x	3.3	3.3	12	7	
		P	6.0	6.0	23	4	
AIR TAXI AND GENERAL AVIATION (10-520-P)	36,335	CO	8.3	8.3	151	151	
		HC	0.5	0.5	9	9	
		NO_x	0.4	0.4	7	7	
		P	0.2	0.2	4	4	
MILITARY (JT3D)	4,756	CO	50.6	50.6	120	56	
		HC	43.5	43.5	103	45	
		NO_x	7.3	7.3	17	17	
		P	9.4	9.4	2.7	2.4	
TOTAL TONS/YEAR		CO			3569	1754	3133
		HC			2337	1029	2123
		NO_x			1062	996	890
		P			105	73	86

*SUMMARY FIGURES SUPPLIED BY PSAPCA JANUARY 1974

3.1 -- Continued.

Table 3-6 compares the ESL predicted annual emissions to comparable figures developed by other groups for several airports. Estimates for the same airport differ dramatically depending on the source even though some estimates are for the same year. The apparent uncertainty in total emissions emphasizes the importance of making air quality measurements near the airport to calibrate the base year model predictions.

3.2 Aircraft Related Emissions.

Fuel venting is a potential source of hydrocarbon emissions by aircraft. At engine shut-down, drainage from the fuel manifold is collected in a drain tank in each engine nacelle. At start up, a little more fuel is added to this quantity before the dump valve is closed. After takeoff the collected fuel is purged by the ram air pressure. Average HC loss due to fuel venting based upon 160 takeoffs per day would amount to approximately 600 lbs per day. Most of this would be lost at air altitude of perhaps 600 meters which, according to a previous report, would produce ground level concentrations of no more than 10-15 $\mu g/m^3$.

Operation of auxiliary power units is another source of aircraft emissions. If 1 hour of operation per LTO is assumed, then based on available emission factors an additional 94 tons of CO, 8 tons of NO_x, and 9 tons of hydrocarbons will be emitted annually.

Table 3-6. Aircraft Emissions in Tons at SEA-TAC and Other Airports.

Airport	CO	HC	NO_x	P	Year
SEA-TAC	1,848	1,038	1,004	73	1972-1973
Los Angeles[1]	10,975[1]	10,725	1,105	2,250	1970
Dulles[2]	659	427	410	314	1973
D.C. National[2]	1,018	164	1,147	1,026	1973
O'Hare[3]	14,740	9,580	3,760	900	1970
Kennedy[3]	12,590	9,490	2,580	570	1970
National[3]	2,410	610	820	231	1970
Los Angeles[3]	16,030	12,570	3,060	570	1970

[1]"Study of Jet Aircraft Emissions and Air Quality in the Vicinity of Los Angeles International Airport," Los Angeles County Air Pollution Control District, April 1971.

[2]*Monitoring and Modeling of Airport Air Pollution*, D.M. Rote, et. al., International Conference on Transportation and the Environment, 1972.

[3]"Draft Environmental Impact Statement for Policy Changes on the Role of Washington National Airport and Dulles International Airport," Office of Environmental Quality, AIQ-30 Dept. of Transportation, FAA.

3.2 -- Continued.

Maintenance operations are potential sources of air pollution, but are not considered significant compared to the aircraft operations and motor vehicle sources.

3.3 Automobile Emissions.

Automobile traffic along the roads adjacent to airports and in the terminal parking area is a major source of air pollution near airports. Because it is desirable to relate the automobile emissions to the airport traffic, it is customary to assume a certain number of vehicle operations for each passager arrival or deperture, and an additional factor for employee automobile traffic.

Based on (1) passenger traffic of 4,788,962, (2) 7,000 employees in 1972, and (3) 1.24 passengers per car; approximately 16,000 vehicles per day are predicted on the average. This compares to the 20,000 vehicles per day supplied by the SEA-TAC Communities Plan Study Group. Some of the difference may be related to air freight and postal activities.

Vehicle emissions associated with the airport occur throughout King County. Since this study assesses that contribution in the environs of the airport, travel near the airport only is considered. Specifically, it is assumed that the 20,000 vehicles drive 2.0 miles at 45 MPH and 0.25 miles at 15 MPH. Based on these figures, automobiles should add approximately 669 tons of

3.3 -- Continued.

CO, 107 tons of hydrocarbons, 126 tons of nitrogen oxides, 11 tons of particulate, and 1.1 tons of lead to the SEA-TAC ambient air during an average year (Table 3-7). Additional automobile emissions occur within the airport boundary along S. 188th St., HWY 518, HWY 99, S. 154 St., and others. These emissions are a source of air pollution in the area, but are not considered as part of the SEA-TAC impact in this report.

Average annual emissions near SEA-TAC and those associated with aircraft operations and access vehicles are summarized in Table 3-8. Clearly, aircraft operations are the major source of air pollutants near SEA-TAC, particularly hydrocarbons, nitrogen oxides and particulate. The determination of whether these emissions will cause significant air pollution requires a sophisticated mathematical model which is discussed in Section 4 of this report.

3.4 Emissions From Stationary Sources.

The heating plants of all buildings, air conditioning facilities, flight kitchens, and even the hot water boilers consume natural gas and fuel. Combustion of the fuel will release pollutants including carbon monoxide, hydrocarbons, nitrogen oxides, and particulates.

Table 3-7. 1973 Vehicular Emissions at SEA-TAC

Pollutant	Emission* Factor	Speed Factor (15 MHH)	Speed Factor (45 MPH)	Emissions (gms/Auto)	Emissions Tons/Year
Carbon Monoxide	62	1.25	0.515	83.24	669
Hydrocarbons	6.1+2.0	1.17	0.58	13.36	107
Nitrogen Oxides	5.4	0.95	1.33	15.65	126
Particulates	0.58	1.00	1.00	1.31	11
Lead	0.06	1.00	1.00	0.14	1.1

*_Compilation of Air Pollutant Emission Factors_, Second Edition U.S. Environmental Protection Agency, Revised September 1973.

Table 3-8. Annual Emissions at SEA-TAC Due to Aircraft and Motor Vehicles (Tons/Year)

Pollutant/ Source	CO	HC	NO_x	P	Pb
Aircraft	1,754	1,029	995	73	?
Motor Vehicles	669	107	126	11	1.1
Total	2,423	1,136	1,122	83	1.1

3.4 -- Continued.

For purposes of estimating the impact on air quality, the fuel consumption estimates made prior to the 1973 "Energy Crisis" were used. Natural gas consumption was estimated to be 3.3 million therms and fuel oil consumption at 164,000 gallons.

Total emissions on an annual basis are shown in Table 3-10. With the possible exception of particulate, these emissions do not constitute a significant proportion of aircraft emissions (Tabel 3-5). Particulate emissions are 7 percent of those associated with aircraft emissions and will contribute to overall particulate levels.

Table 3-10. Total Emissions for Fuel Oil and Natural Gas Combustion

Pollutants	Emissions Fuel Oil (Tons/Year)	Emissions Natural Gas (Tons/Year)
Carbon Monoxide	0.33	3.57
Hydrocarbons	0.25	----
Nitrogen Oxides	4.92	17.86
Particulates	1.89	3.39

3.5 Fuel Storage and Transfer.

Loss of vapor due to evaporation from storage tanks during daily temperature fluctuations and the displacement when the tanks are filled is another potential source of hydrocarbons.

Fuel spills during refueling of aircraft and ground service vehicles will evaporate into the ambient air. Normally, these spills will be washed away due to fire hazards. Fuel spillage, therefore, will generally contribute to water pollution rather than air pollution.

Losses resulting from the displacement of vapor during refueling are referred to as working losses, whereas evaporative losses are referred to as breathing losses. Both sources can be controlled with vapor recovery systems.

Aircraft fuel at SEA-TAC is stored in eight floating roof tanks with a total capacity of 580,000 barrels or 24,360,000 gallons. Total fuel deliveries are approaching six million barrels per year.

A floating roof tank is an effective device for minimizing both breathing and working losses. The basic design virtually eliminates vapor space resulting in low emissions due to breathing, filling, and emptying. Based on this design we have assumed that there are no breathing losses of significance from the storage tanks at SEA-TAC.

3.5 -- Continued.

Refueling of ground service vehicles and aircraft will produce working losses. The vapor emissions from aircraft refueling can be seen as density waves appearing above the wing filling ports.

An empirical equation for estimating working losses due to refueling was developed by the American Petroleum Institute.[1] Argonne[2] converted the API equation into working loss per 1,000 gallons of fuel pumped. The final figures were 0.55 lbs/1,000 gallons for aircraft fuel and 3.63 lbs/1,000 gallons for ground service vehicles.

Total fuel deliveries of jet fuel were estimated to be 239 million gallons at SEA-TAC. Ground service vehicles were assumed to require 330,000 gallons of gasoline. Taken together, refueling should produce approximately 66 tons per year of additional hydrocarbons. This is about 6 percent of the estimated aircraft hydrocarbon emissions for 1973.

The figure of 66 tons will be increased in proportion to the increase in aircraft operations to predict losses in the future.

3.6 Ground Service Vehicle Emissions.

Motorized vehicles associated with servicing aircraft in the gate areas contribute to the air pollutant emissions at SEA-TAC. Included in this category are tractors, belt loaders, food trucks, fuel trucks, etc.

Computation of emissions from these vehicles is difficult and subject to uncertainty, since emission characteristics have not been measured. Moreover, utilization factors are uncertain and the maintenance programs vary among airlines.

The procedure used by Argonne[2] in their EPA report involved estimating utilization times for each service vehicle as a function of aircraft type, adopting emission factors for heavy duty trucks, estimating the average miles/gallon for each vehicle, and assigning average speeds for operational use. In addition, they assumed that the Federal automotive emission controls would be applied to ground service vehicles.

Because of the above uncertainties, in this report we have simplified the Argonne approach by relating the ground based emissions to the fuel consumption of these vehicles. To do this we assumed that the vehicles average 10 MPH and get 6 miles per gallon. These factors are combined with the EPA automobile emission factors to yield emissions in grams/gallon (Table 6-9). Based on this approach, we predict 207 tons carbon monoxide, 27 tons hydrocarbons, 11 tons nitrogen oxides and 1 ton of particulate for 1973 for 330,000 gallons of fuel.

3.6 -- Continued.

In this section we have compiled a list of pollution sources, i.e., an emission inventory at SEA-TAC. The next step in establishing the air quality impact of these emissions is to develop a model for predicting the dispersion of the pollutants into the ambient atmosphere. ESL's model is discussed in the next section.

3.7 References.

1. TI-3 Petroleum Committee, J. Air Poll. Cont. Assoc., 21(5), 260, 1971.

2. *An Air Pollution Impact Methodology for Airports*, Phase 1, Argonne National Laboratory, January 1973.

4. PREDICTION OF EXISTING AIR QUALITY.

ESL used a finite line source model to predict the air quality near the SEA-TAC Airport. The entire emission inventory previously discussed was assigned to one or more line segments. Some sources such as the runways and taxiways were adequately represented by a single finite line. Others, such as the parking garage, were represented by multiple line segments at various heights above the ground.

The meteorological inputs to the finite line source model are wind speed, wind direction, height of inversion base, and turbulence which may be specified in terms of the Pasquill class. The source inputs are the source height, endpoints, and emission strength. An inclined source, such as the climb-out path, is approximated by a series of horizontal segments resembling a staircase.

The advantages of using a finite line source instead of finite set of points to approximate a linear entended source are:

a. A more accurate representation is obtained

b. Fewer data inputs are required

c. Computation time is reduced

d. A greater number of sources may be considered simultaneously

4. -- Continued.

e. Less user time is required to assemble the data inputs for the model.

4.1 Model Formalism.

The model for finite line sources is derived by the method of superposition from the Gaussian formula for a continuous point source which states that the pollutants are normally distributed in the crosswind and vertical directions provided there are no absorbing or reflecting surfaces present. In order to account for reflections from the ground plane or inversion base, the image of the source in the reflecting plane is assumed to be a virtual source whose plume is combined with that from the actual source to determine emission levels. To account for multiple reflections, for example, from the ground plane to inversion base and back to the ground plane, the standard method of introducing multiple images (images of images) is employed.

Consider a continuous point source emitting an unreactive gas above a non-reflecting, non-absorbing ground plane. The mean concentration predicted by the Gaussian plume formula at receptor (x, y, z) is:

$$\bar{\chi}(x,y,z) = \frac{Q}{2\pi\bar{u}\sigma_y(x)\sigma_z(x)} \exp \frac{-y^2}{2\sigma_y^2(x)}$$

$$\times \left\{ \exp - \frac{(z-h)^2}{2\sigma_z^2(x)} + \exp - \frac{(z+h)^2}{2\sigma_z^2(x)} \right\} . \qquad (1)$$

4.1 -- Continued.

where x is the downwind distance from the source, y is the crosswind distance from the plane centerline, z is the elevation of the receptor, h is the elevation of the source, Q is the emission rate of the source, and $\bar{u}$ is the magnitude of the mean wind velocity. The variables $\sigma_y(x)$, $\sigma_z(x)$ are measures of plume spread which depend upon atmospheric turbulence and are referred to as the standard deviations, in the lateral and vertical wind directions, of the relative concentration distribution.

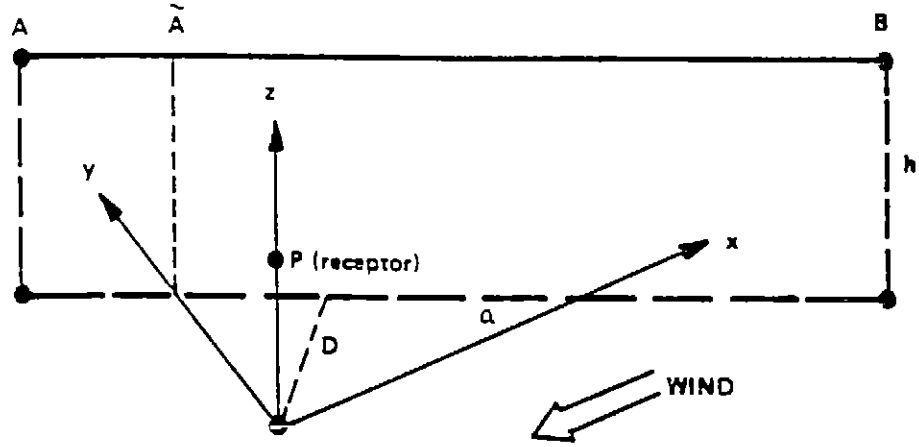
Using the empirical formulas for $\sigma_y(x)$, $\sigma_z(x)$, derived by the National Reactor Testing Station at Idaho Falls, namely,

$$\sigma_y(x) = \frac{\sigma_\theta}{1.23}\ x \qquad \sigma_z(x) = \frac{\sigma_\phi}{1.23}\ x,$$

(σ_θ, σ_ϕ = standard deviations of lateral and vertical wind directions, respectively.)

the dispersal model for a finite line source may be obtained from equation (1) by integration.

In order to conveniently formulate the dispersal model equations, the coordinate system illustrated in Figure 4-1 is introduced. The origin of the coordinate system is taken to be the ground point directly below the receptor P, and the positive x-axis is taken to extend in the direction from which the mean wind blows. The vertical axis through the origin is



P = $(0, 0, z_0)$

A = (x_A, y_A, h)

B = (x_B, y_B, h)

$\tilde{A}$ = $(\tilde{x}_A, \tilde{y}_A, h)$

POSITIVE X-AXIS IS TAKEN OPPOSITE TO WIND DIRECTION

Figure 4-1. Coordinate System for Finite Line Source Analysis

4.1 -- Continued.

defined to be the positive z-axis, and the endpoints of the finite line source are denoted by A, B, where by convention, A is taken to be the point furthest downwind. The coordinates of A, B are denoted by (x_A, y_A, h), (x_B, y_B, h) where h is the height of the line source above the ground plane. The variable $\tilde{x}_A$ = maximum $\{0, x_A\}$, α is the angle between the line source and the mean wind velocity, D is the ground distance between the receptor and the infinite line collinear with AB, and $(0, 0, z_o)$ are the coordinates of the receptor P.

In the absence of an inversion layer, the concentration $\bar{\chi}(P)$, at the receptor, is obtained from the equation

$$\bar{\chi}(P) = \bar{\chi}'(P, z_o-h) + \bar{\chi}'(P, z_o+h) \qquad (2)$$

where

$$\bar{\chi}'(P,S) = \mu \sqrt{\frac{\pi}{a}} \exp - (c-\frac{b^2}{4a}) \quad F\left(\frac{\sqrt{2a}}{\tilde{x}_A} + \frac{b}{\sqrt{2a}}\right) - F\left(\frac{\sqrt{2a}}{x_B} + \frac{b}{\sqrt{2a}}\right) \qquad (3)$$

$$(S = z_o-h, z_o+h)$$

and the variables on the right hand side of the equation are defined as follows:

$$a = \frac{D^2}{2c_1^2 \cos^2\alpha} + \frac{S^2}{2C_2^2}$$

4.1 -- Continued.

$$b = -\frac{D \tan \alpha}{C_1^2 \cos \alpha}, \text{ if the point P is downwind of the source line}$$

$$= +\frac{D \tan \alpha}{C_1^2 \cos \alpha}, \text{ if the point P is upwind of the source line}$$

$$c = \frac{\tan^2 \alpha}{2C_1^2}$$

$$\mu = \frac{q}{2\pi \bar{u} C_1 C_2 \cos \alpha}$$

q = emission rate per unit length of source

$C_1 = \sigma_z/1.23$

$C_2 = \sigma_y/1.23$

$$F(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-\frac{t^2}{2}} dt$$

Equation (2) is the general formula for concentration whenever the wind is not normal to AB and either $D > 0$ or $z_o \neq L$. The special cases when $D = 0$ and $z_o = h$ or the wind is normal to AB are divided into three subcases, and similar formulas are derived by integration.

4.1 -- Continued.

In the event of an inversion base at a height H, equation (2) must be augmented to include simple and multiple reflections from both the inversion layer and the ground plane. The number of reflection terms will depend upon the distance of the receptor from the source, turbulence, and the height of the inversion layer. More precisely, let x_o satisfy $2.15\ \sigma_z(x_o) = H$; then equation (2) will apply to all receptors whose downwind distance from all contributing source points is less than x_o. A source point is considered to contribute to the concentration at a receptor if the receptor lies within an angle $3.5\ \sigma_\theta$ downwind of the source (see Figure 4-2). The angle $3.5\ \sigma_\theta$ was chosen to correspond with the horizontal boundary of the plume emanating from a source point, i.e., those points in the horizontal plane through the plume centerline where concentrations are ten percent of the centerline concentrations. In the general case, equation (2) becomes

$$\bar{\chi}(P) = \sum_{i=1}^{2I} \bar{\chi}'(P,S_i)$$

where $\bar{\chi}'(P,S_i)$ satisfies (3) with

$$S = S_i,\ a = a_i = \frac{D}{2C_1^2 \cos^2\alpha} + \frac{S_i}{2C_2^2},$$

and I, S_i are defined as follows:

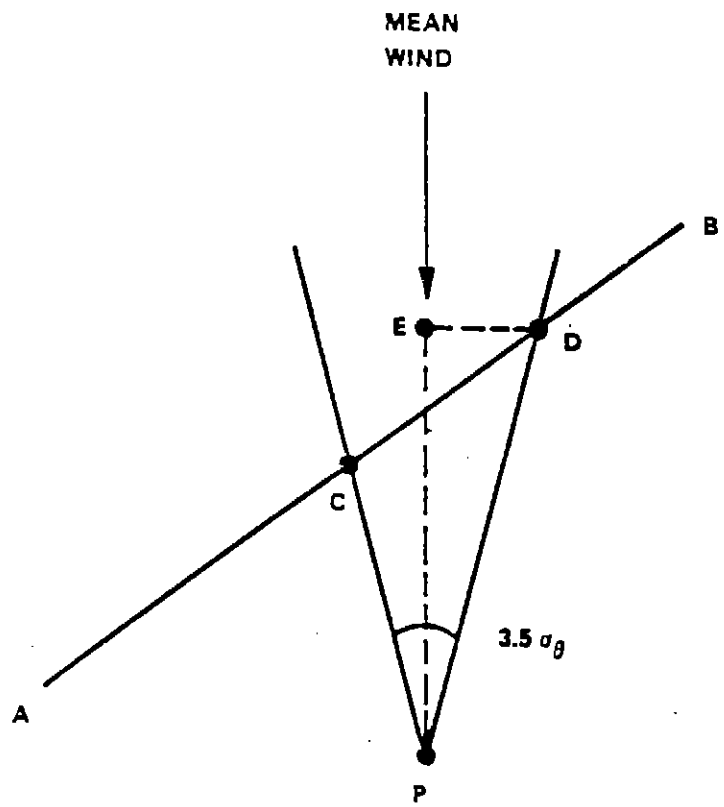


Figure 4-2. Contributing Source Points

4.1 -- Continued.

I = smallest integer which is greater than or equal to $\frac{d_{MAX}}{x_o}$.

d_{MAX}, measured along mean wind direction, is the maximum upwind distance to any contributing source point.

$S_1 = (z_o - h)$, $S_2 = (z_o + h)$

$S_i = z_o - 2M(-1)^{r+1}H + f(r)h$, $i \geq 3$

where r is the remainder when i-2 is divided by 4, M is the smallest integer $\geq \frac{i-2}{4}$, and f(r) is defined by

$f(0) = -1$
$f(1) = -1$
$f(2) = 1$
$f(3) = 1$

The special cases, (1) D = 0 and $z_o = h$, and (2) normal wind, are similarily generalized for reflections off the inversion layer.

4.2 Model Application.

To apply the model, the location of the all receptors and finite sources are specified in terms of a fixed convenient coordinate system. Specifically, the ground coordinates and

4.2 -- Continued.

height are indicated for each receptor and line source endpoint. To calculate the concentration at a particular receptor, a linear transformation and translation is performed which transforms the input coordinates of the line sources into the coordinate system appropriate for application of the above concentration formulas. (The new coordinate system has its origin at the ground point below the receptor, and its positive x-axis points in the direction from which the mean wind blows.) The contribution of each source to the concentration at the receptor is calculated, and all the component concentrations are summed to determine the total pollutant level.

5. PREDICTED AIR QUALITY 1973.

The mathematical model discussed in the previous section predicts pollutant concentration at several hundred receptors around the airport. A set of calculations is made for each wind direction. Aircraft sources are positioned according to whether landings and takeoffs are north to south or south to north.

Air quality predictions are made for "worst case" and "most probable" conditions. Average or "most probable" conditions were defined as Pasquill turbulence classification B, 5 mile per hour wind speed, and average airline activity. "Worst case" conditions were defined as 2 mile per hour wind speed, Pasquill turbulence classification D, and peak airline activity.

Finally, the maximum pollutant concentrations at each receptor are used to construct the "worst case" isopleths. Average or "most probable" isopleths are constructed from the weighted average concentration at each receptor. The weighting factor is the frequency that a given wind direction is observed at SEA-TAC.

Given the conditions outlined above, the proper interpretation of the isopleths can be expressed in the following manner: the worst case isopleth for a given pollutant represents the highest levels that would be expected at a given location over a 1-year period for the specified time interval. These

5. -- Continued.

isopleths do not represent a condition that would exist simultaneously over the area covered by the isopleths. This is because a northerly wind with stable atmospheric conditions will not produce high pollutant concentrations north of the airport. Another way to express this condition is to consider the worst case isopleths as defining the maximum area that could be impacted by the airport. If any isopleth is higher than the corresponding federal standard, that area is expected to experience violations of the standard sometime during the year.

Similarly, the average isopleths represent the expected pollutant concentrations at a given location for the indicated time period. Again, the wind direction must be favorable unless the standard is for one year.

5.1 1973 Carbon Monoxide Levels.

Predicted carbon monoxide levels are well below the Federal Standards of 10 mg/m^3 for 8 hours and 40 mg/m^3 for 1 hour (Figures 5-1 and 5-2). Typical values are 1-3 mg/m^3 and the worst case 1 hour figures are not expected to go above 6-8 mg/m^3. There are no known adverse health effects associated with these levels.

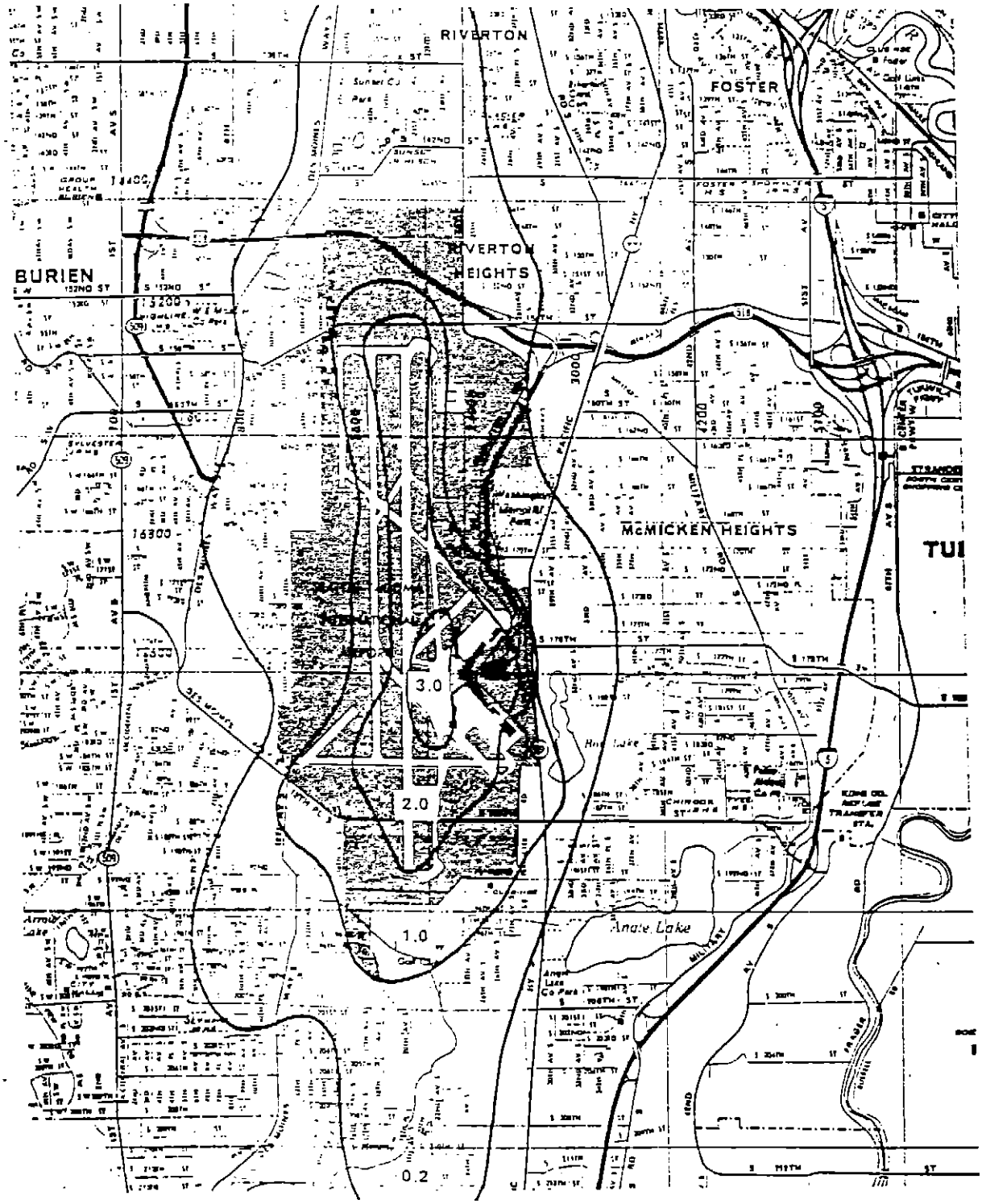


Figure 5-1. Predicted 1973 CO Isopleths (Average Conditions) mg/m^3 (8 hours)

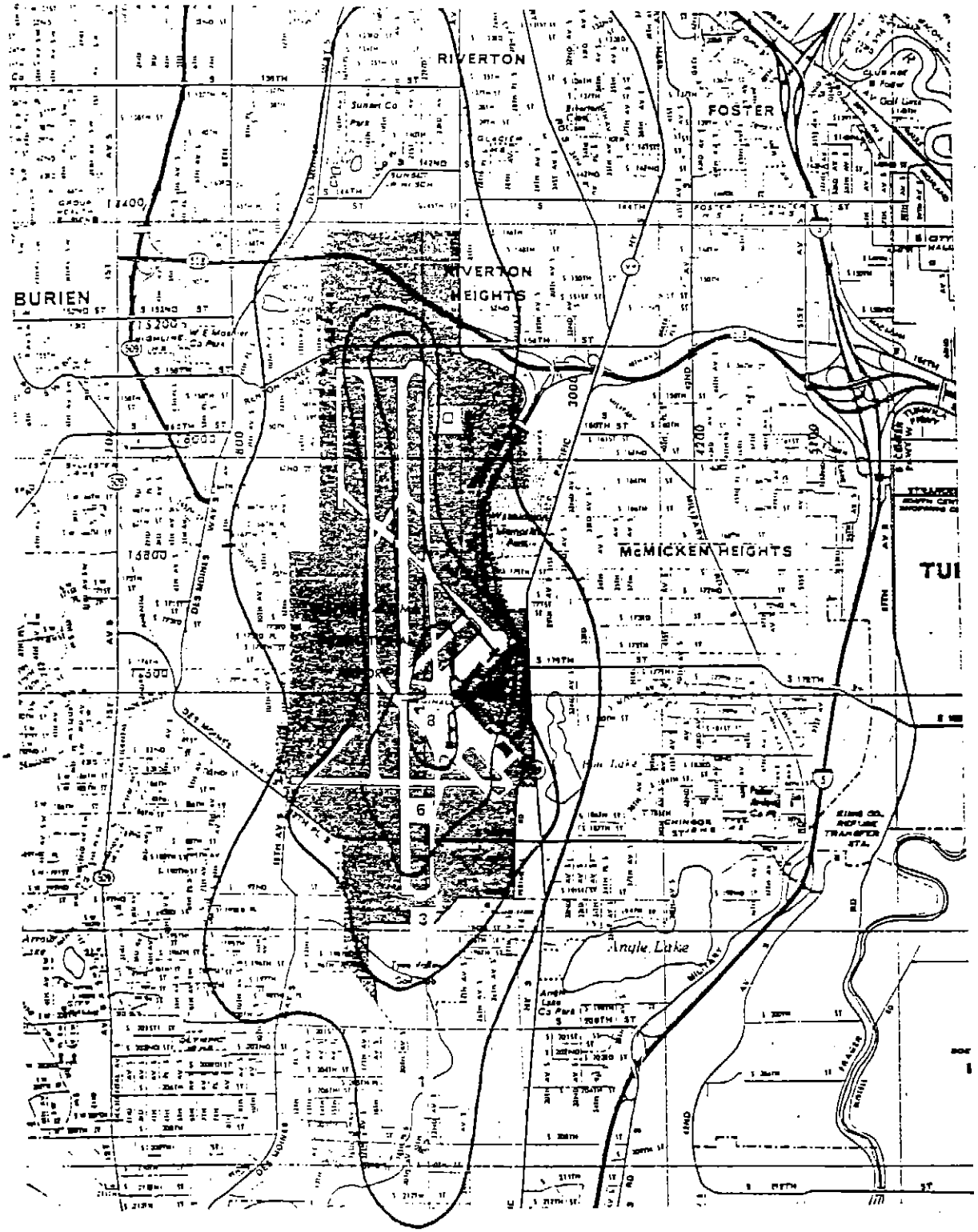


Figure 5-2. Predicted 1973 Worst Case CO Isopleths mg/m^3 (1-hour maximum)

5.2 1973 Hydrocarbon Levels.

The predicted hydrocarbon levels near SEA-TAC exceed the Federal Standard over large areas (Figures 5-3 and 5-4). Part of this is caused by the generally high background levels which tend to be near the standard itself. The rest is due to the proportionately higher hydrocarbon emissions of aircarft. Hydrocarbon emissions are approximately 60 percent of carbon monoxide emissions, and the very low hydrocarbon standard is easily violated.

Hydrocarbon standards are not set at 160 $\mu g/m^3$ because of their known adverse health effects. Rather, as was discussed in Section 1 of this document, the HC standard is set to keep oxidant levels in an area from creating a health hazard. The significance of HC on oxidant formation is discussed below.

5.3 1973 Nitrogen Oxides Levels.

Nitric Oxide (NO) is eventually converted to nitrogen dioxide (NO_2) in the atmosphere. The exact mechanism and time frame for accomplishing this is not completely understood. As a result it is common practice to measure the total amount of NO and NO_2 by oxidizing the NO to NO_2 and detecting NO_2. The total amount present is recorded as NO_x. Federal standards apply only to NO_2 (100 $\mu g/m^3$, annual average), and hence NO_x represents a conservative estimate of local NO_2 levels. Figure 5-5 depicts the predicted 1973 annual average NO_x concentrations. Because the standard is specified as an annual average, "worst case" conditions are not meaningful. The only place where the standard is likely to be exceeded is the runway area itself.

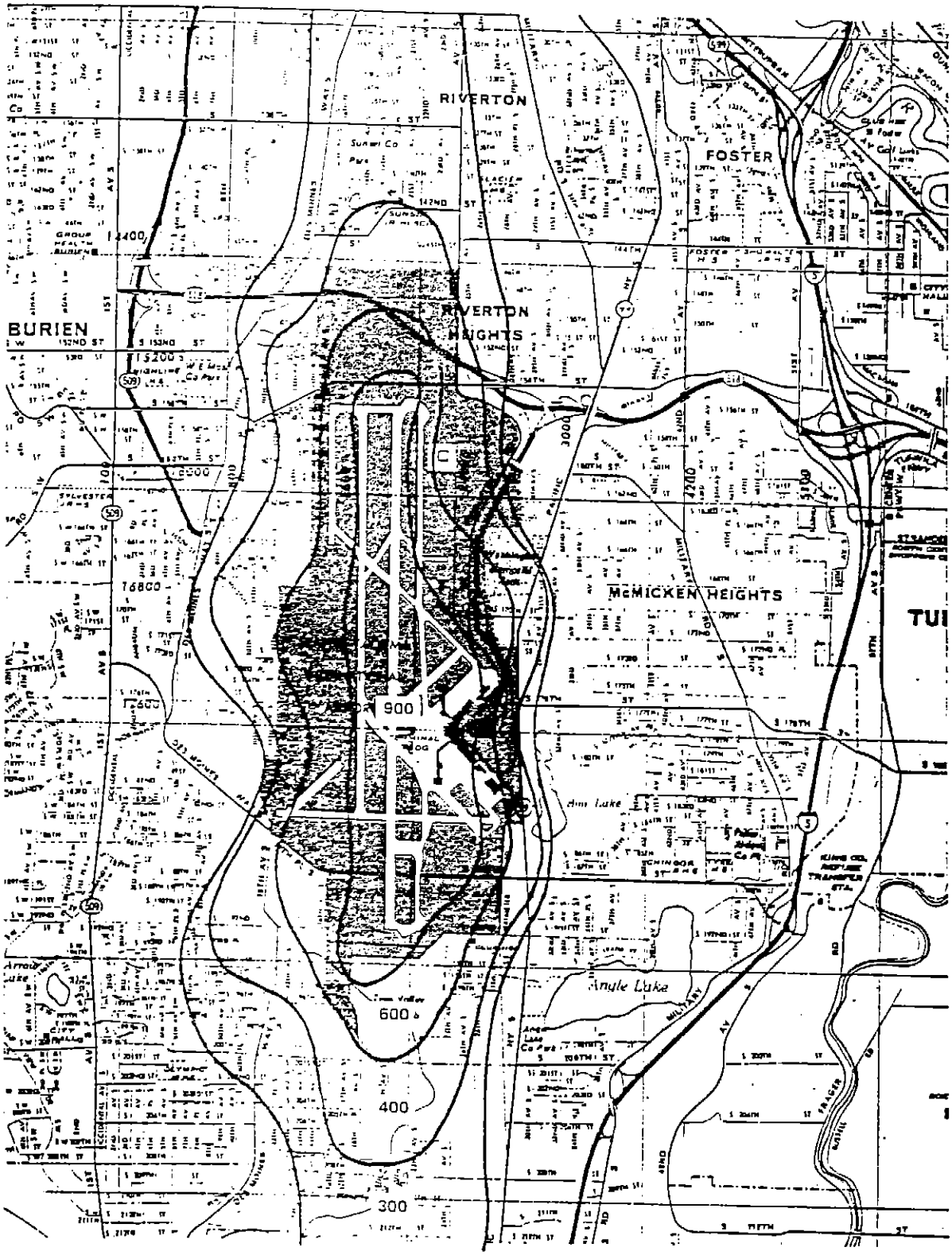


Figure 5-3. 1973 Hydrocarbon Isopleths 3-Hour Average 6-9 am Average Conditions $\mu g/m^3$

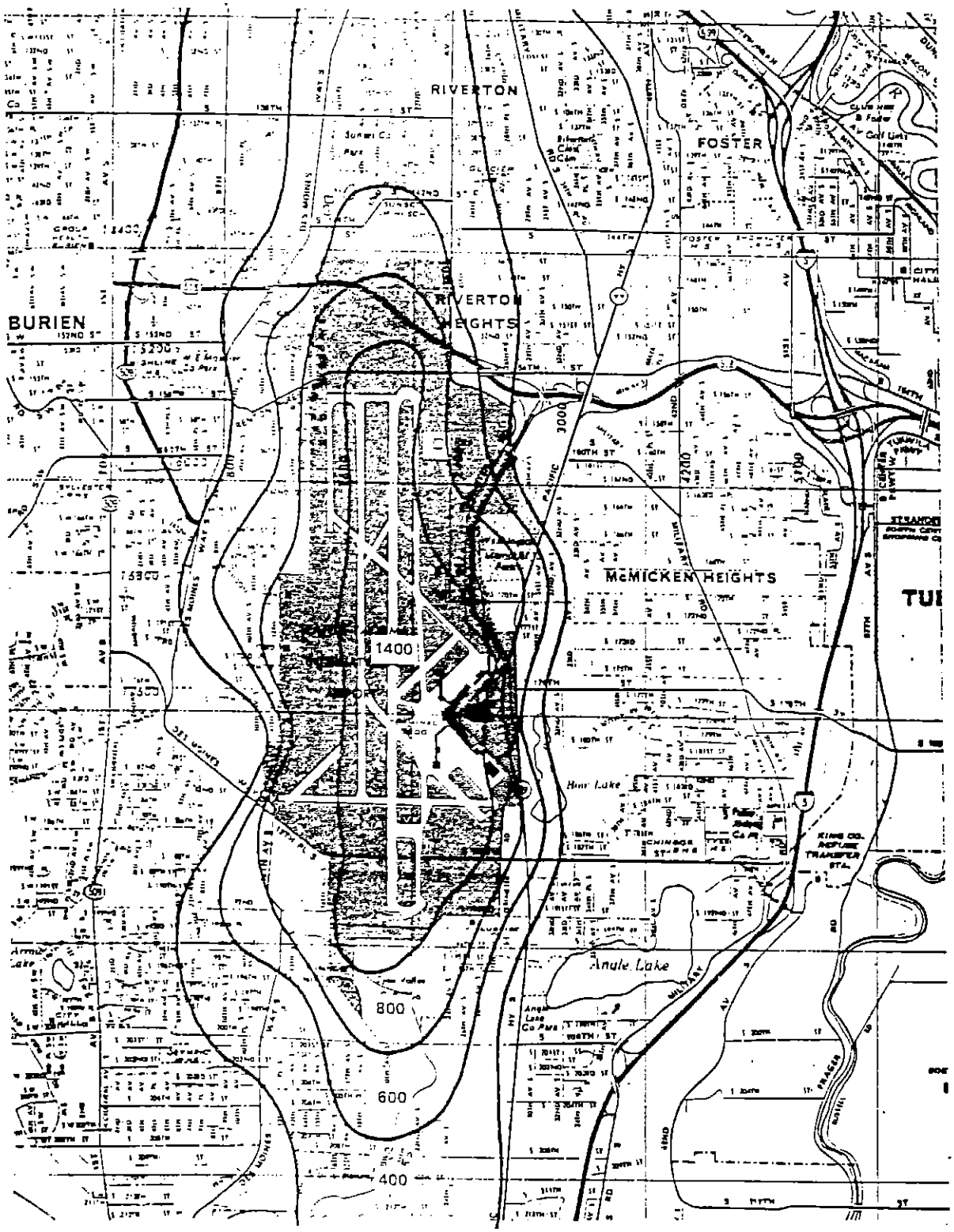


Figure 5-4. 1973 Hydrocarbon Isopleths 3-Hour Average 6-9 am Worst Case Conditions [HC] $\mu g/m^3$

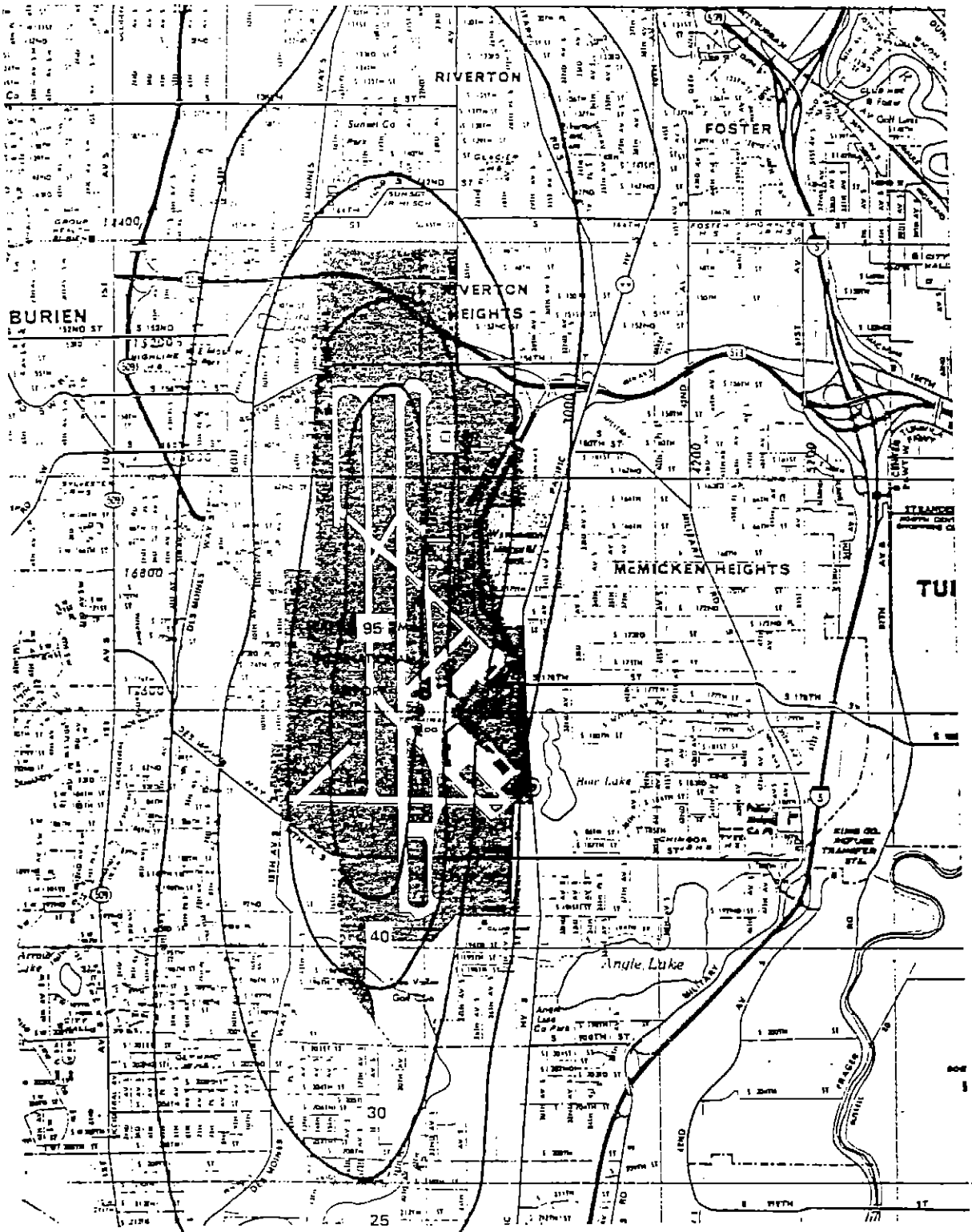


Figure 5-3. 1973 NO_x Isopleths Near SEA-TAC Annual Average ug/m^3

5.3 -- Continued.

No adverse health effects are expected from the high levels of NO_x on the runway itself. In this area most of the NO_x is probably in the form of NO, and personnel are not exposed to the high levels.

5.4 1973 Particulate and Lead Levels.

EPA emission factors for particulate which were published in April of 1973 are too small to yield detectable particulate levels around SEA-TAC.

No explanation was given in the new report for dramatically reducing the emission factors for particulate. For example, in the February 1972 report, the JT9D engine was listed as producing 10 pounds of particulate per LTO (landing-takeoff cycle) whereas the April 1973 report listed the JT9D at 1.30 pounds. Similarly, the 1972 figure for the JT3D engine was 8 pounds per LTO, and 7 pounds per LTO for the JT8D engine; the corresponding 1973 figures were 1.21 pounds/LTO and 0.41 pounds/LTO, respectively.

Based on the EPA model times, this represents an average reduction of 88 percent between February 1972 and April 1973. Unless these changes are erroneous, it must be concluded that aircraft operations do not generate significant (less than 25 $\mu g/m^3$) levels of particulate near SEA-TAC.

5.4 -- Continued.

However, this condition does not seem justifiable since even the casual observer can see the heavy particulate emissions of departing aircraft and the moderate emissions from arriving aircraft. Accordingly, we have multiplied the emissions by a factor of four in order to bring the model predictions into line with the observed particulate levels at SEA-TAC.

Predicted annual particulate levels based on adjusted emissions are shown in Figure 5-6. The numbers on the isopleths represent the geometric mean which must be calculated from the model predicted average particulate level. To do this we assume that the model average is from a distribution with the same standard geometric deviation as the particulate samples collected at SEA-TAC (1.62). The geometric mean is then calculated using the formula:

$$Mg = X/(Sg)^{(1/2\ \ln Sg)}$$

where

X = arithmetic mean
Mg = geometric mean
Sg = standard geometric deviation
ln = the natural logarithmic to the base.

Using the value of Sg = 1.62, the geometric mean Mg is 0.89 times the arithmetic average. Thus, the geometric mean is slightly less than the average value predicted.

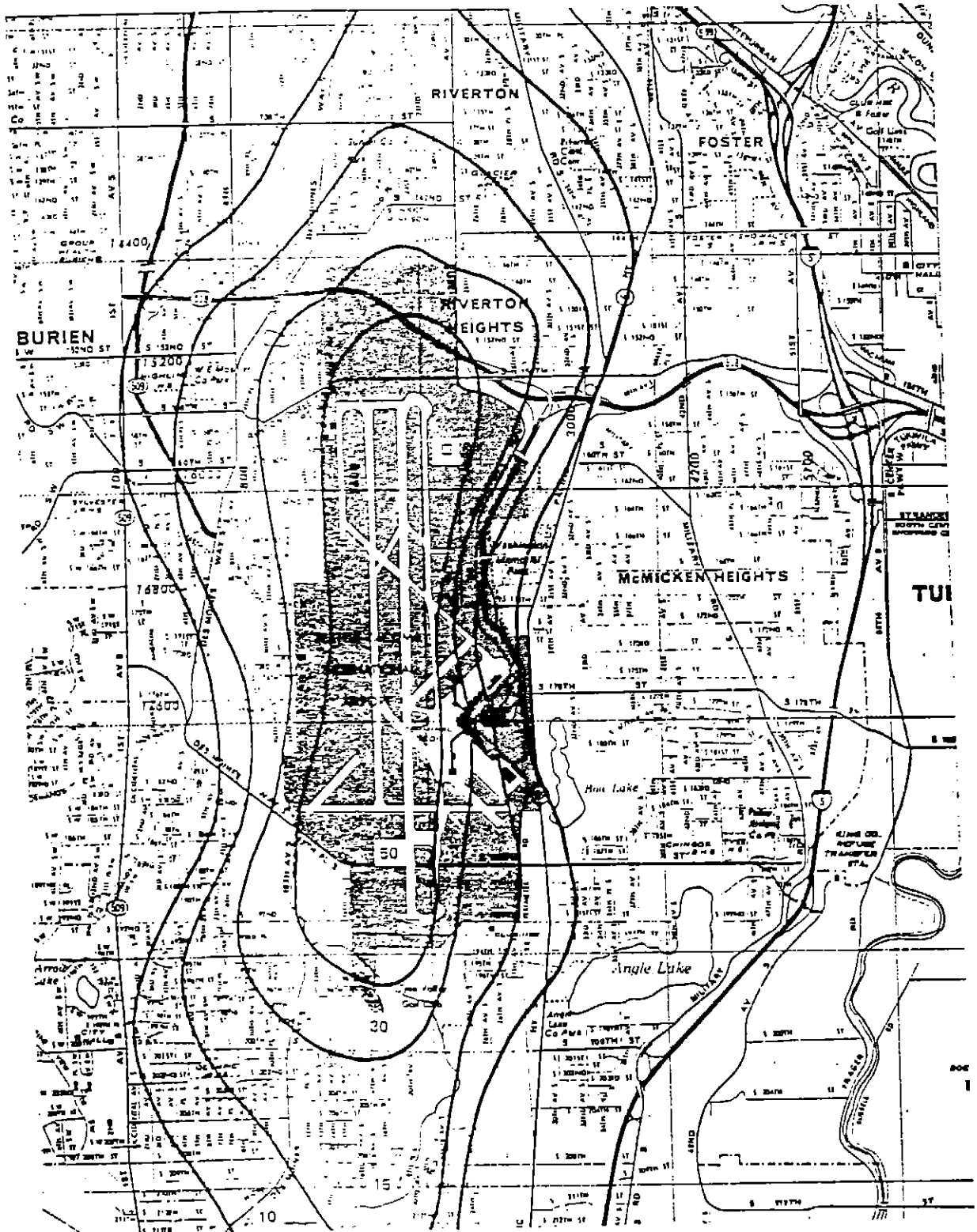


Figure 5-6. 1973 Particulate Isopleths Annual Geometric Mean $\mu g/m^3$

5.4 -- Continued.

Even with the adjusted emission factors the predicted geometric mean is below the primary Federal Standard (75 $\mu g/m^3$) and the secondary Federal Standard (60 $\mu g/m^3$) (see Figure 5-6).

Worst case conditions using the adjusted emission factors are shown in Figure 5-7. These 24-hour average levels should be compared to the Federal primary Standard (260 $\mu g/m^3$) and the corresponding secondary Federal Standard (150 $\mu g/m^3$). Again, neither standard should be violated at or near SEA-TAC.

The aviation gasoline used by aircraft piston engines contains tetraethyl lead and halogenated scavenging agents in quantities similar to those in automotive fuel. Lead compounds in the form of particulate matter are formed during the decomposition of these additives. Piston engine aircraft will not generate appreciable amounts of lead at SEA-TAC, and the Environmental Protection Agency has not set any federal standard for lead.

5.5 Predicted Oxidant Levels for 1973.

Photochemical oxidant is not a pollutant emitted into the atmosphere by transportation sources. (A more complete discussion of the processes leading to the formation of oxidant was given in the first section of this report.) Essentially hydrocarbons, nitrogen oxides, and sunlight interact to form

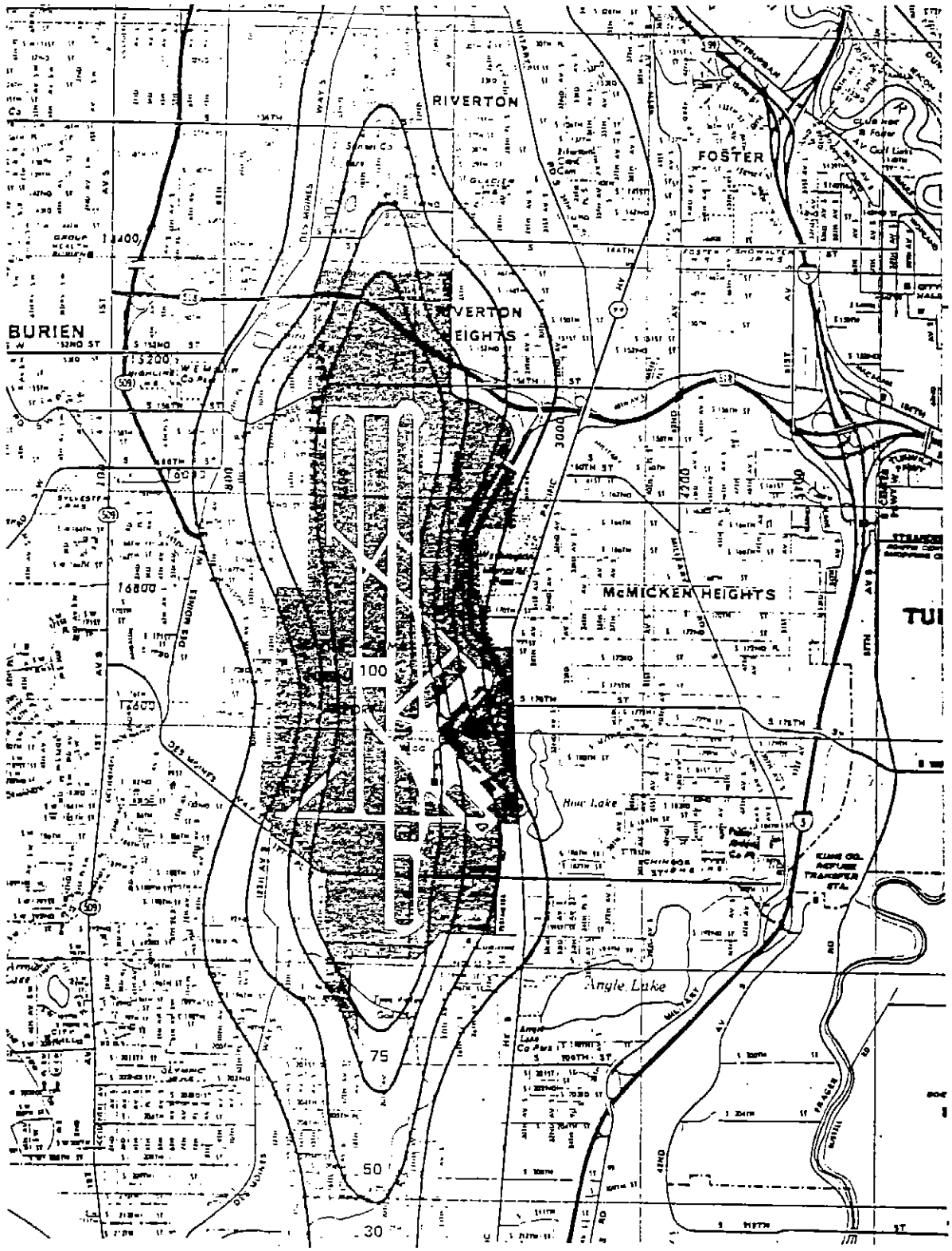


Figure 5-7. 1973 Worst Case 24-Hour Particulate $\mu g/m^3$

5.5 -- Continued.

ozone and other oxidants. Based on Figures 1-2 and 1-3, high early morning hydrocarbon levels and/or high levels of nitrogen oxides are associated with high oxidant levels later in the day. The high levels referred to in these figures correspond generally to measurements made over a large area such as an air basin or the Puget Sound Air Pollution Control District. Thus, the high hydrocarbon levels observed at SEA-TAC are not expected to be associated with high oxidant level at SEA-TAC unless background level of hydrocarbons and/or nitrogen dioxide are also high. At SEA-TAC the highest oxidant level was 190 $\mu g/m^3$ (.10 ppm), at Des Moines the highest level was 80 $\mu g/m^3$ (0.04 ppm), and McMicken Heights recorded a high of 215 $\mu g/m^3$ (0.11 ppm).

The 1-hour oxidant standard (160 $\mu g/m^3$, 0.08 ppm) was exceeded 14 times during August and September at the McMicken Heights site. Thus, oxidant levels recorded at McMicken Heights imply that hydrocarbon and/or nitrogen dioxide background levels are generally high in the area. Accordingly, it would be desirable to reduce hydrocarbon emissions in the area as a means of controlling oxidant formation.

6. FUTURE AIR QUALITY.

The air quality in the future near SEA-TAC will depend upon the increase or decrease in aircraft operations, the aircraft mix, ambient air quality, and the effectiveness of air pollution emission standards for aircraft engines. Each of these factors will have an impact on air quality and is briefly discussed below.

6.1 EPA Air Pollution Emissions Standards for Aircraft.

The Environmental Protection Agency has set final air pollution emission standards for aircraft engines, proposed an engine retrofit program, and announced a trial program of aircraft ground operations control. In addition, fuel venting is prohibited for the T2, T3, and T4 engines after January 1, 1974, and for all T1 and P2 engines after January 1, 1975. The T2, T3, and T4 engines represent more than 75 percent of current operations.

Emissions of carbon monoxide, smoke (particulate), hydrocarbons, and nitrogen oxides will be limited by the new standards; and all types of aircraft will be affected (Table 6-1). If these figures are attained, average reductions would amount to 73 percent for carbon monoxide, 80 percent for hydrocarbons, and 43 percent for nitrogen oxides for turbine engines (T2, T3, T4).

Additional standards proposed for 1981 would require further reductions in hydrocarbons and carbon monoxide, but would not change nitrogen oxides (Table 6-1). These standards would apply only to the turbine (T2) class of engines over

Table 6-1. Proposed Aircraft Emission Standards

		1979 New Manufactured			1981 New Certified		
	Fuel Venting Prohibited	HC*	CO*	NO_x*	HC*	CO*	NO_x*
Turbine (T1)	Jan. 1, 1975	1.6	9.4	3.7			
Piston (P2)	Jan. 1, 1975	4.9	26.8	12.9			
Turbine (T2)	Jan. 1, 1974	0.8	4.3	3.0	0.4	3.0	3.0
Turbine (T3)	Jan. 1, 1974	0.8	4.3	3.0			
Turbine (T4)	Jan. 1, 1974	0.8	4.3	3.0			
Piston (P1)**		1.9	42.0	1.5			
APU		0.4	5.0	3.0			

*Pounds/1000 x rated power/cycle-piston engines; pounds/1000 hp-hr of power output-auxillary power unit; pounds/1000 pound-thrust hr/cycle-aircraft engine.
T1-Turbofan or turbojet engines of rated power less than 8000 pounds thrust. (Aircraft examples: business and private jets such as Lear Jet, Grumman Gulfstream, Lockheed Jetstar and Cessna Citation.)
T2-Turbofan or turbojet engines, except classes T3 and T4, of 8000 pounds or greater. (Aircraft examples: Boeing 747, Lockheed L1011, and DC-10.)
T3-All JT3D model engines (Aircraft examples: Boeing 707, DC-8.)
T4-All JT8D model engines (Aircraft examples: Boeing 727, 737, DC-9.)
P1-All piston engines, except radials. (Aircraft examples: All piston engine planes ranging from the Cessna 150 or Piper Cherokee 140 to the Beechcraft Queen Air.)
P2-All turboprop engines. (Aircraft examples: Lockheed Electra, Fairchild F27, and Convair 540.)
APU-Auxiliary Power Unit-Any engine on the plane exclusive of propulsion engines. APU's used to operate on-board power systems when propulsion engines not operating.

**Effective for engines built after December 31, 1979.

	Effect of Emission Standards		
Engine	CO	Existing HC	NO_x
JT3D (T3)	30.191	25.88	4.335
JT8D (T4)	12.488	2.794	4.977
JT9D (T2)	11.316	2.950	7.581
% Reduction			
JT3D (T3)	86	92	31
JT8D (T4)	67	71	39
JT9D (T2)	66	78	60
AVG % Reduction	73	80	43

6.1 -- Continued.

8,000 pounds thrust. At present it is not known if any research effort is underway to accomplish the 1981 emission goals.

EPA has also proposed requiring a retrofit on all pre-1979 gas turbine engines of class T2 and a rated power exceeding 29,000 pounds. The proposed change, scheduled for completion by January 1, 1983 would bring all class T2 engines to 1979 standards. At the present time, there is strong opposition to the proposed retrofit, and implementation is uncertain.

Given the time frame for emission standards and the length of time required for engines introduced after 1979 to enter the general aircraft population, emission rates are not expected to change at all by 1978, very little by 1983, and moderately by 1993. Other factors such as vehicle mix and ground controls can have a significant impact by 1978 and 1983 and are discussed in Section 7.

6.2 Projected SEA-TAC Emissions.

Peat, Marwick, Mitchell and Co. furnished SEA-TAC air traffic forecasts and aircraft mix for air carrier operations (Tables 6-2, 6-3) for the years 1978, 1983, and 1993.

These projections were used to develop engine LTOs for each year as shown in Table 6-4. Environmental Protection Agency emission factors (Table 3-1) shown here as Table 6-5 were used to calculate predicted SEA-TAC emissions for 1973, 1978, 1983, and 1993 by aircraft type (Table 6-6).

Table 6-2. SEA-TAC Air Traffic Forecasts 1978, 1983, 1993

Type	1978	1983	1993
I. Air Carrier	125,000	146,000	180,000
Itinerant	121,000	142,000	176,000
Local	4,000	4,000	4,000
II. Air Taxi Scheduled	20,000	24,000	32,000
III. General Aviation	25,000	30,000	40,000
IV. Military	2,000	2,000	2,000
Total Operations:	172,000	202,000	254,000
Total LTOs	86,000	101,000	127,000

Table 6-3. SEA-TAC Aircraft Mix* 1978, 1983, 1993

Aircraft Class	Representative Engine	%1978	%1983	%1993
JUMBO				
747	JT9D	5.5	5.1	4.9
DC10-L1011	CF6	14.8	22.0	40.2
LONG RANGE				
707; DC-8	JT3D	27.3	15.4	-
MEDIUM RANGE				
727, 7x7	JT8D	40.4	47.7	54.9
737, DC-9	JT8D	9.3	7.5	-
AIR CARRIER, TURBOPROP				
L188	501-D13	-	-	-
F-27/C-640	501-D15	2.7	23.0	-

*Peat, Marwick, Mitchell and Co., 6 June 1974.

Table 6-4. SEA-TAC Engine LTOs*
1978, 1983, 1993

Aircraft Class	Engs.	1978	1983	1993
JUMBO				
747	4	13,750	14,892	17,640
DC10-L1011	3	27,750	48,180	108,540
LONG RANGE				
707, DC-8	4	68,250	44,968	-
MEDIUM RANGE				
727, 7x7	3	75,750	104,463	148,230
737, DC9	2	11,625	10,950	-
AIR CARRIER TURBO				
F-27/C-640	2	3,375	3,358	-
SUB-TOTAL ENGINE LTOS		200,500	226,811	274,410
AIR TAXI	2	20,000	24,000	32,000
GENERAL AVIATION	1.5	18,750	22,500	30,000
MILITARY	4	4,000	4,000	4,000
TOTAL ENGINE LTOS		243,250	277,311	340,410

*LTO = Descent from 3500 feet, landing, taxi, idle, idle, taxi, takeoff, climbout to 3500 feet.

Table 6-5. Modal Emission Factors - EPA* (lbs/hr) and SEA-TAC Modal Emissions (lbs)

Engine & Mode	Carbon Monoxide lb/hr	Hydrocarbons lb/hr	Nitrogen Oxides lb/hr	Particulates lb/hr
JT9D				
Taxi-idle	102.0(18.7)	27.3(5.00)	6.1(1.12)	2.2 (0.403)
Takeoff	8.3(0.1)	3.0(0.135)	720.0(8.40)	3.8 (0.044)
Climbout	11.7(0.43)	2.7(0.10)	459.0(16.83)	4.2 (0.147)
Approach	32.6(2.17)	3.0(0.2)	54.1(3.61)	2.3(0.153)
SEA-TAC lbs/LTO - Eng.	21.4	5.34	29.96	1.747
CF6				
Taxi-idle	51.7(9.48)	15.4(2.82)	3.6(0.66)	0.04 (0.007)
Takeoff	6.7(0.08)	1.3(0.02)	540.0(6.30)	0.54(0.006)
Climbout	6.6(0.242)	1.3(0.05)	333.0(12.21)	0.54(0.02)
Approach	18.6(1.24)	1.9(0.127)	173.0(11.53)	0.44 (0.03)
SEA-TAC lbs/LTO - Eng.	11.04	3.02	30.7	0.063
JT3D				
Taxi-idle	109.0(20.0)	98.6(18.1)	1.4(0.26)	0.45(0.08)
Takeoff	12.3(0.14)	4.7(0.05)	148.0(1.73)	3.3(0.10)
Climbout	15.3(0.56)	4.9(0.18)	96.2(3.53)	3.5(0.31)
Approach	39.7(2.65)	7.8(0.52)	21.8(1.45)	3.0(0.53)
SEA-TAC lbs/LTO - Eng.	23.35	18.85	6.97	1.02
JT8D				
Taxi-idle	33.4(6.12)	7.0(1.29)	2.9(0.53)	0.36(0.066)
Takeoff	7.5(0.09)	0.78(0.009)	198.0(2.31)	3.7 (0.043)
Climbout	9.9(0.33)	0.92(0.034)	131.0(4.80)	2.6 (0.096)
Approach	18.2(1.21)	1.75(0.17)	30.9(2.06)	1.3(0.100)
SEA-TAC lbs/LTO - Eng.	7.75	1.49	9.7	0.304
TS6-A7				
Taxi-idle	15.3(2.8)	6.5(1.2)	2.2(4.0)	1.6(0.29)
Takeoff	2.2(0.02)	0.43(0.003)	22.9(0.19)	1.7(0.33)
Climbout	3.0(0.13)	0.48(0.02)	21.2(0.89)	1.0(0.13)
Approach	3.7(0.28)	0.52(0.04)	7.8(0.58)	1.2(0.23)
SEA-TAC lbs/LTO - Eng.	3.23	1.26	2.05	0.68
TPE331				
Taxi-idle	3.5(0.64)	0.88(0.16)	0.96(0.18)	0.3(0.055)
Takeoff	0.39(0.002)	0.06(0.003)	3.64(0.02)	0.8(0.004)
Climbout	0.57(0.048)	0.05(0.004)	3.31(0.28)	0.6(0.05)
Approach	2.6(0.26)	0.24(0.024)	1.69(0.17)	0.5(0.06)
SEA-TAC lbs/LTO - Eng.	0.95	0.19	0.65	0.17
CONTINENTIAL O-200				
Taxi-idle	7.5(1.4)	0.214(0.04)	0.009(0.002)	-
Takeoff	54.6(0.27)	0.720(0.004)	0.259(0.001)	-
Climbout	54.6(4.55)	0.720(0.06)	0.259(0.02)	-
Approach	23.8(2.38)	0.380(0.04)	0.052(0.005)	-
SEA-TAC lbs/LTO - Eng.	8.60	0.144	0.03	

*Compilation of Air Pollution Emission Factors, 2nd Edition U.S. EPA April 1973

Table 6-6. Predicted SEA-TAC Emissions (Tons/Yr)

Engine-Pollutant/Year	1973	1978	1983	1993
JT9D - JUMBO				
Carbon Monoxide	143	147	159	188
Hyrodcarbons	36	37	40	47
Nitrogen Oxides	201	206	223	264
Particulate	5	5.4	5.8	6.5
CF6 - JUMBO				
Carbon Monoxide	40	153	277	599
Hydrocarbons	11	42	75	164
Nitrogen Oxides	113	426	769	1666
Particulate	0.4	0.9	1.57	3.41
JT3D - LONG RANGE				
Carbon Monoxide	1074	797	525	-
Hydrocarbons	867	643	424	-
Nitrogen Oxides	321	237	157	-
Particulate	47	34.5	22.6	-
JT8D - MEDIUM RANGE				
Carbon Monoxide	264	338	447	574
Hydrocarbons	51	65.4	86	110.6
Nitrogen Oxides	330	424	560	719
Particulate	10.4	13.32	17.6	22.6
T56-A7 TURBOPROP				
Carbon Monoxide	26	7	1	-
Hydrocarbons	10	3	-	-
Nitrogen Oxides	7	4	1	-
Particulate	4	1.4	0.25	-
TPE331 + CO 0-200				
Carbon Monoxide	151	93	111	148
Hydrocarbons	9	3	4	5
Nitrogen Oxides	7	7	8	11
Particulate	4	3.3	4	5.3
MILITARY AS JT3D				
Carbon Monoxide	56	47	47	47
Hydrocarbons	45	38	38	38
Nitrogen Oxides	17	14	14	14
Particulate	2.4	2.04	2.04	2.04

6.2 -- Continued.

Based on these tables it is obvious that elimination of aircraft equipped with the JT3D engine will result in a significant improvement in total emissions. Also, among jumbos the CF6 engine is superior to the JT9D on the lb/hr basis, although the difference is less dramatic on a lb/seat basis. The jumbo engine emission factors also reflect a dramatic increase in nitrogen oxide emissions. Consequently, elimination of the JT3D engine coupled with increases in jumbo jets (CF6, JT9D) and medium range jets (JT8D) can be expected to reduce emissions of carbon monoxide, hydrocarbons, and particulate; but it will increase nitrogen oxide emissions. Increased aircraft operations, however, may offset the decreased emissions expected from projected aircraft (engine) mixes.

Table 6-7 summarizes the total tons of aircraft emissions expected at SEA-TAC for 1973, 1978, 1983, and 1993. These figures are plotted in Figure 6-1. The trend is for total pollutants to increase following the dramatic increase in nitrogen oxide emissions.

Automobile emissions steadily decline (Table 6-8) as a result of emission controls on automobiles. 1980 emission controls were assumed for 1983 because Congress recently voted to postpone implementation of some emission controls under the guise of energy conservation. Similarly, we used 1990 controls for the 1993 time frame.

Table 6-7. SEA-TAC Predicted Aircraft Emissions (Without Emission Controls)

POLLUTANT/YEAR	TONS PER YEAR			
	1973	1978	1983	1993
Carbon Monoxide	1848	1676	1661	1650
Hydrocarbons	1038	837	676	374
Nitrogen Oxides	1004	1326	1740	2682
Particulate	73	61	54	40
Total	3963	3800	4131	4746

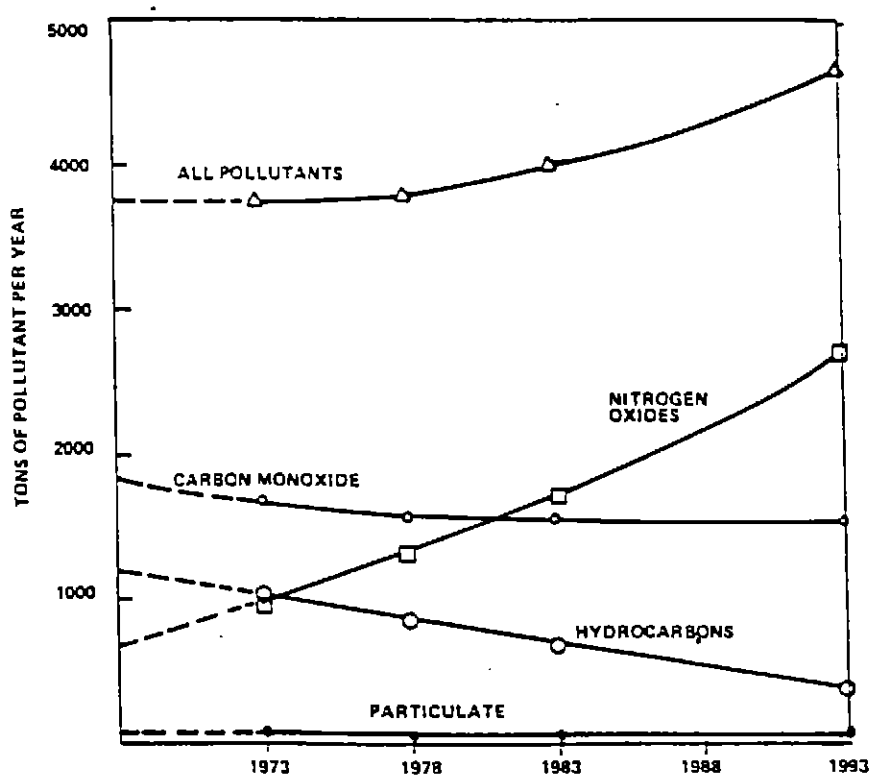


Figure 6-1. SEA-TAC Aircraft Emission Trends, 1973-1993

Table 6-8. Computation of SEA-TAC Automobile Emissions Associated with Passengers and Employees

Pollutant	Emission Factors, 15 MPH, grams/mile			
	1973	1978	1983	1993
Carbon Monoxide	77.5	38.3	28.75	15.0
Hydrocarbons	9.1	4.57	3.34	1.90
Nitrogen Oxides	5.1	3.61	2.95	1.71
Particulate	0.58	0.58	0.58	0.58
Pollutant	**Emission Factors, 45 MPH, grams/mile**			
	1973	1978	1983	1993
Carbon Monoxide	31.9	16.0	11.85	6.18
Hydrocarbons	5.5	2.68	1.92	1.13
Nitrogen Oxides	7.2	5.05	4.12	2.39
Particulate	0.58	0.58	0.58	0.58
	Traffic on Airport Freeway			
Vehicles/Day*	20,000	21,000	24,700	32,000
Passengers/Day	13,120	18,904	26,301	41,370
Employees/Day**	7,000	9,000	13,000	20,000
Occupants/Vehicle	1.006	1.33	1.59	1.92
Pollutant	**Emissions From Airport Traffic (lbs/day)**			
	1973	1978	1983	1993
Carbon Monoxide	3668	1931	1683	1130
Hydrocarbons	589	301	255	193
Nitrogen Oxides	609	509	490	367
Particulate	58	61	71	92

*King County Department of Community and Enviromental Development, Land Use Management Division, September 1973.

**Projected as percent of airline traffic.

6.2 -- Continued.

Fuel venting is prohitited for most aircraft after January 1, 1974 and, therefore, will not be considered a source of air pollution for future predictions.

Hydrocarbon losses due to refueling of aircraft were assumed to increase in proportion to the increase of airline traffic.

Because of the uncertainity in the type of fuel that will be used for heating and air conditioning, the possibilities of fuel cutbacks due to energy shortages, and the uncertainity in emission factors, 1973 estimates were used for all years.

Emissions from service vehicles were decreased in accordance with the Environmental Protection Agency emission factors for automobiles (Table 6-9).

Total emissions associated with the SEA-TAC Airport are summarized in Table 6-10. Except for nitrogen oxides, emissions are expected to steadily decline due to the emission controls on automobiles and the introduction of cleaner engines into the aircraft fleet.

Presently, it is not certain whether the aircraft engine manufacturers will be able to meet the Environmental Protection Agency proposed emission standards for engines manufactured after 1979. If the standards are met, there would be little impact in 1983, but by 1993 sizeable reductions in predicted emissions would result.

Table 6-9. Ground Service Vehicle Emissions

Pollutant/Year	Emission Factor (Grams/Gallon)			
	1973	1978	1983	1993
Carbon Monoxide	569	284	211	110
Hydrocarbons	74	37	27	15
Nitrogen Oxides	29	21	17	10
Particulate	2	2	2	2
Estimated Fuel Used	4333,000	366,000	428,000	528,000
Pollutant/Year	Emissions (Tons/Year)			
	1973	1978	1983	1993
Carbon Monoxide	207	115	100	64
Hydrocarbons	27	15	13	9
Nitrogen Oxides	11	8	8	6
Particulate	1	1	1	1

Table 6-10. Predicted SEA-TAC Emissions,* 1973-1993 (Tons/Year)

Pollutant	Source	1973	1978	1983	1993
CO	Aircraft	1848	1676	1661	1650
	Access Traffic	670	352	307	207
	Service Vehicles	207	115	100	64
	Heating/Air Facilities	4	4	4	4
	Total	2729	2147	2072	1925
HC	Aircraft	1038	837	676	374
	Access Traffic	107	55	47	35
	Service Vehicles	27	15	13	9
	Heating/Air Facilities	---	---	---	---
	Fuel Handling	66	73	86	106
	Total	1238	980	822	524
NO_x	Aircraft	1004	1326	1740	2682
	Access Traffic	136	93	89	67
	Service Vehicles	11	8	8	6
	Heating/Air Facilities	23	23	23	23
	Total	1164	1450	1860	2778
P	Aircraft	73	61	54	40
	Access Traffic	11	11	13	17
	Service Vehicles	1	1	1	1
	Heating/Air Facilities	5	5	5	5
	Total	90	78	73	63

*Without emission controls proposed by EPA.

6.2 -- Continued.

Because of the above uncertainties, ESL's future air quality predictions are made without allowing for the effect of emission controls. The predictions are discussed in the next section.

6.3 Projected Carbon Monoxide Levels at SEA-TAC.

Figures 6-2 and 6-3 depict the present and projected carbon monoxide levels near SEA-TAC for average and worst case conditions. As expected, the levels decrease slightly in 1978 and remain low through 1993. Even if the background CO increases significantly, the average levels should stay below 5 mg/m^3 and worst case levels should stay below 13 mg/m^3. These figures are well below the present Federal Standards of 10 mg/m^3 for 8 hours and 40 mg/m^3 for 1 hour.

6.4 Projected Hydrocarbon Levels at SEA-TAC.

Hydrocarbon levels presently exceed Federal Standards near SEA-TAC (Figures 6-4 and 6-5). The situation is expected to improve steadily, and by 1993 the levels of the impacted area will have decreased significantly. However, as mentioned previously, there are no known adverse health effects associated with the observed and predicted hydrocarbon levels. Rather, hydrocarbons are involved in the conversion of nitric oxide to nitrogen dioxide, indirect formation of oxidant, and formation of secondary pollutants such as peroxyacetal nitrate (PAN).

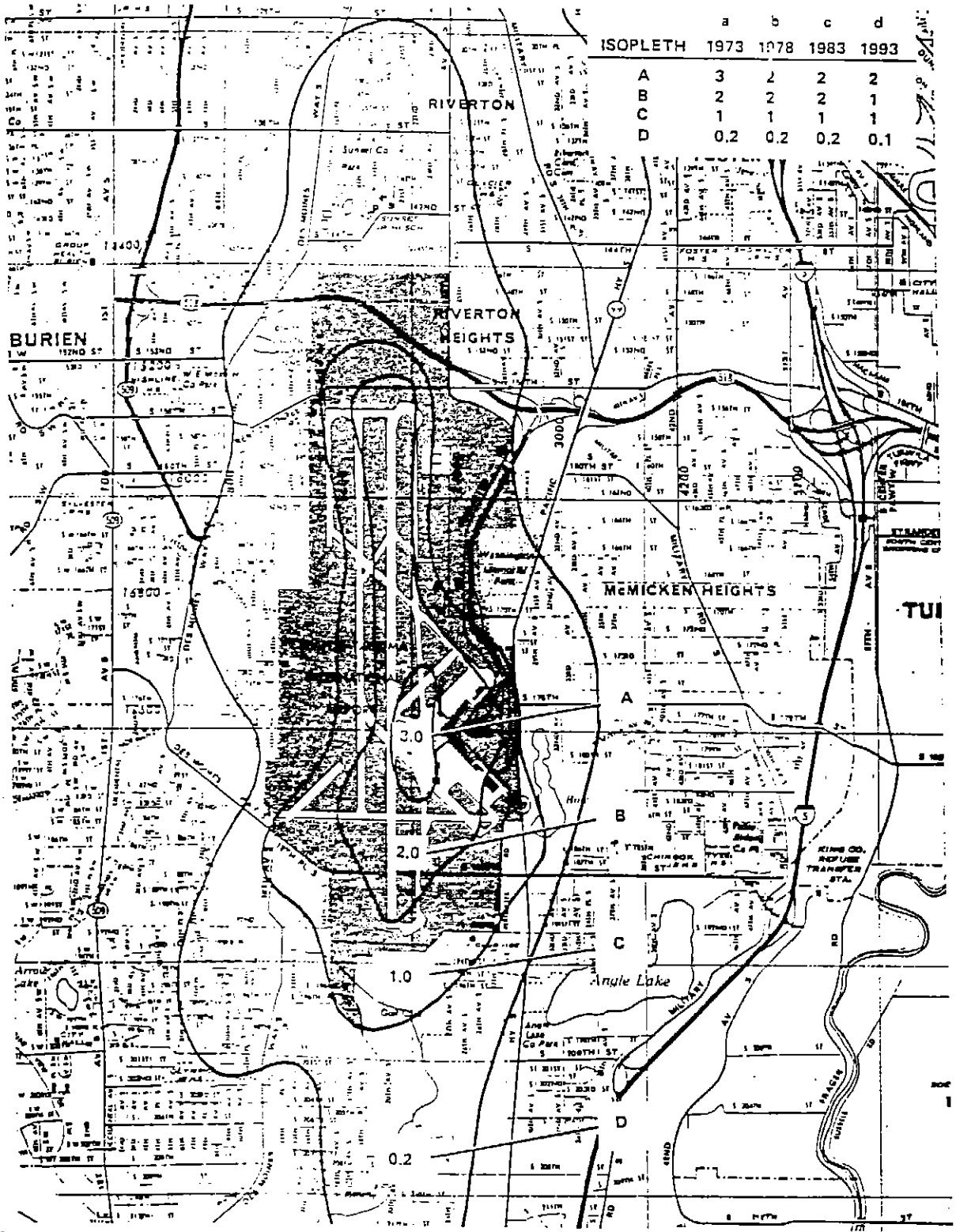


Figure 6-2. Predicted CO Isopleths (Average Conditions - 8 hours mg/m^3)

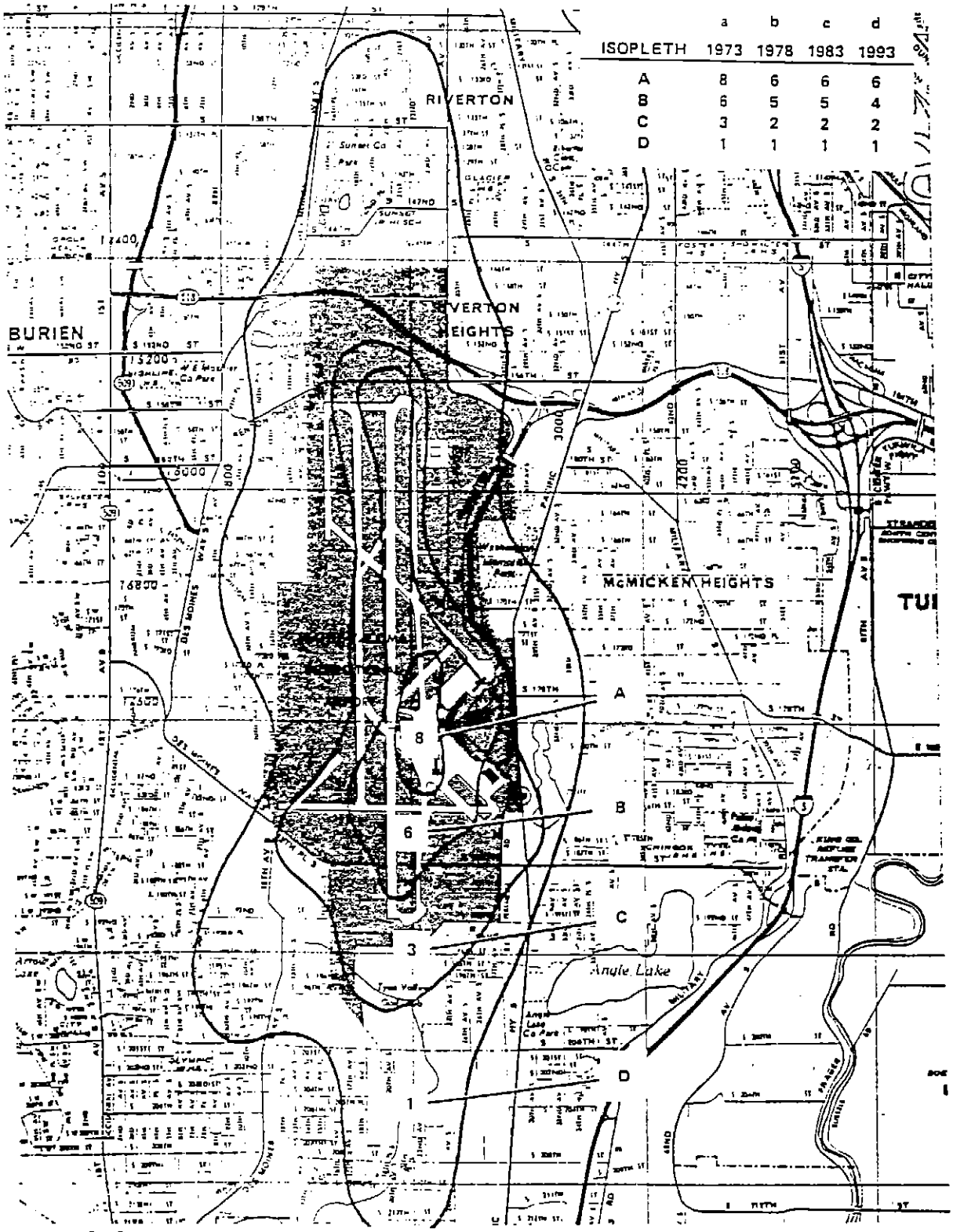


Figure 6-3. Predicted CO Isopleths (Worst Case Conditions - 1 hour mg/m^3)

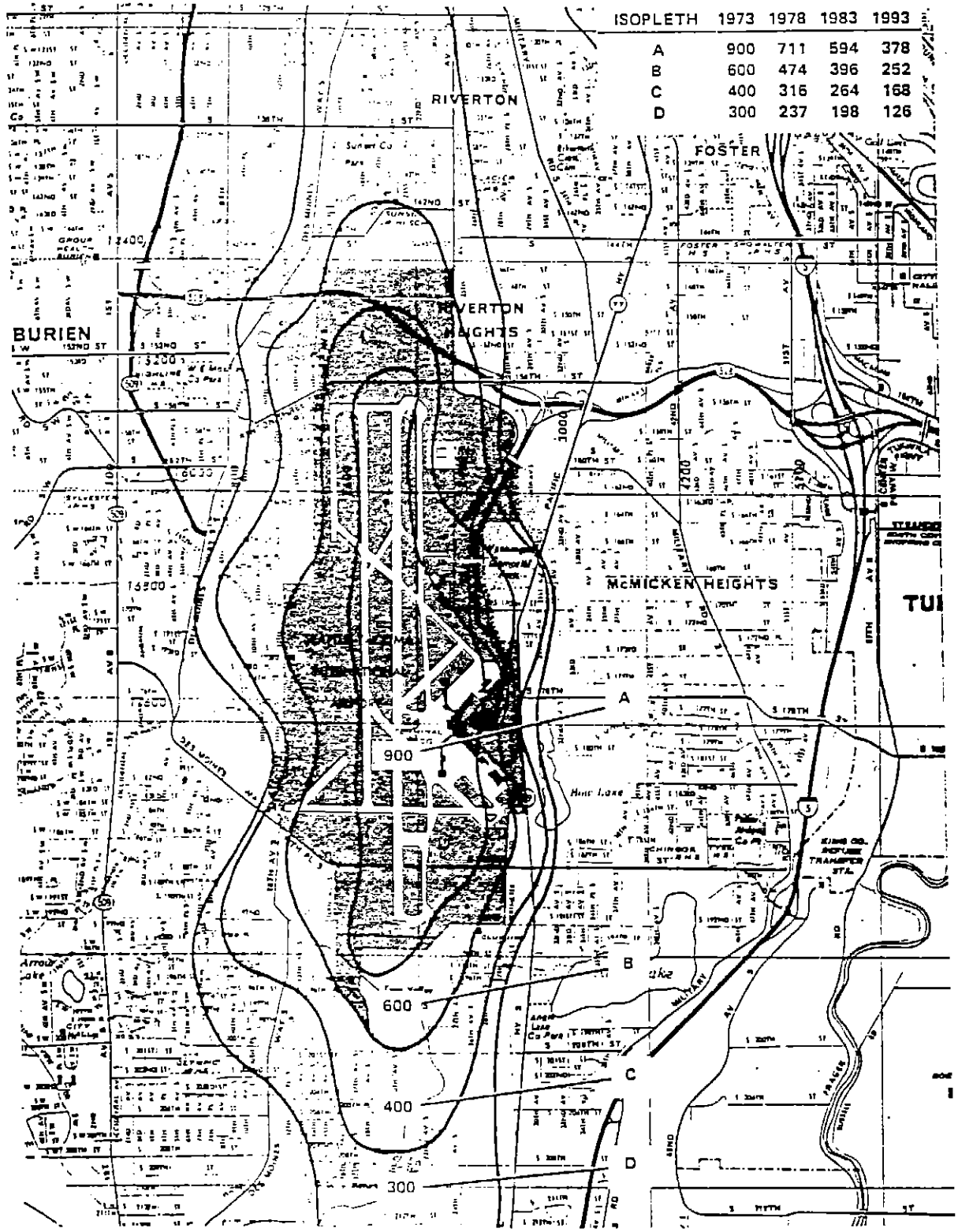


Figure 6-4. Predicted Hydrocarbon Isopleths (3-Hour Average, 6-9 am, Average Conditions - $\mu g/m^3$)

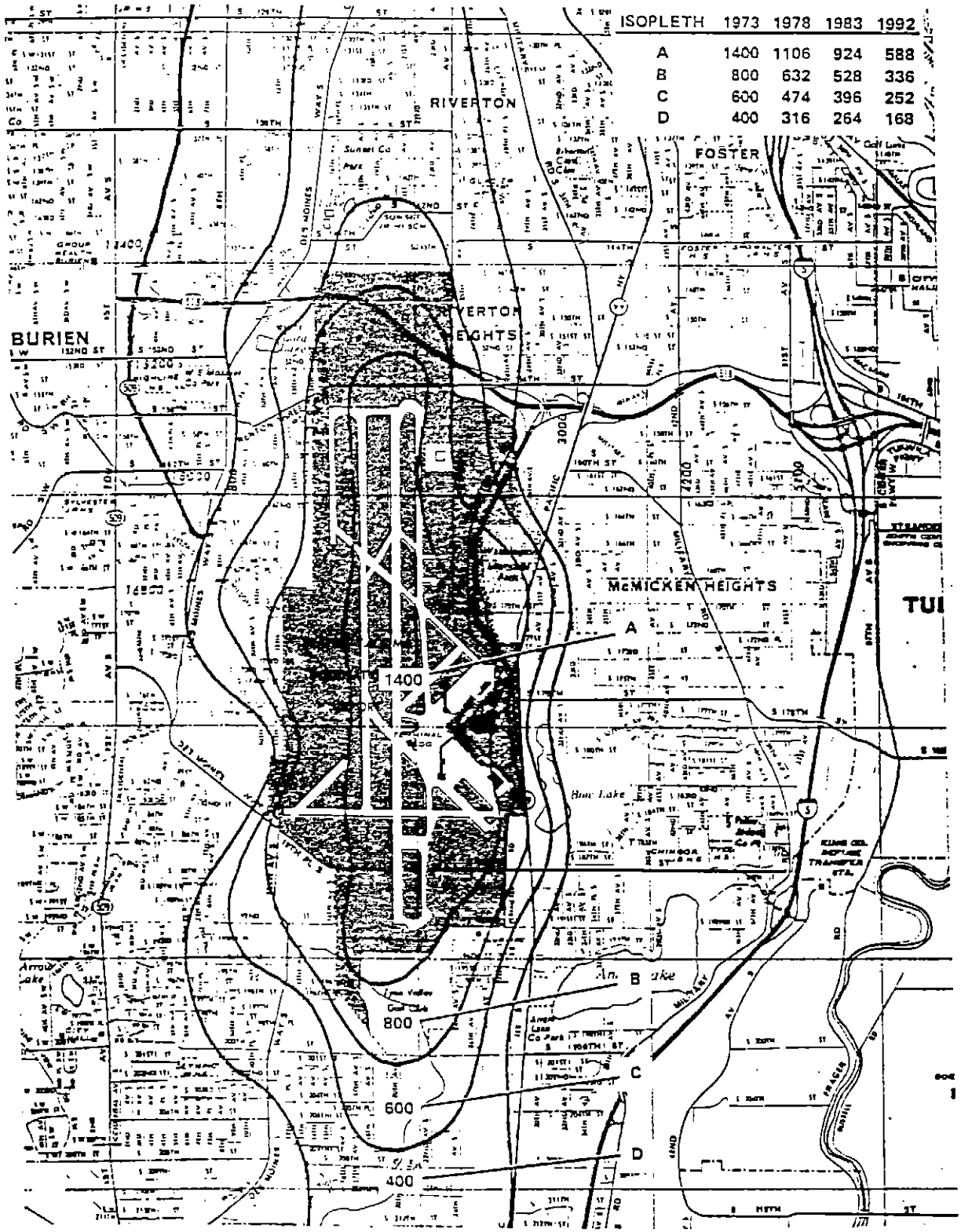


Figure 6-5. Predicted Hydrocarbon Isopleths (3-Hour Average, 6-9 am, Worst Case Conditions, $\mu g/m^3$)

6.4 -- Continued.

If all aircraft added to the projected operations are assummed to be equipped to meet the 1980 standards, the hydrocarbon levels would be reduced by 5 percent in 1983 and by 35 percent in 1993. Even with these controls the standards (160 $\mu g/m^3$ 6-9 a.m.) would be violated near SEA-TAC beyond 1993. Of course, this is due in part to the high background levels.

6.5 Projected Nitrogen Oxide Levels Near SEA-TAC.

Nitrogen oxides will become an increasingly significant problem near SEA-TAC (Figure 6-6). Without controls NO_x levels are predicted to average between 95 and 228 $\mu g/m^3$ near the airport in 1993. At the present time, the Federal Standard is defined for nitrogen dioxide (NO_2), and it becomes important to know what percentage of the NO_x is present as NO, and what percentage is NO_2.

A recent study reported in the literature measured NO and NO_x and found NO levels between 13 and 75 percent. Automobile traffic is generally assummed to emit 75-90 percent NO. Of course the NO is converted to NO_2 via the photochemical process, probably within several hours. As a result, the total NO_x emissions are significant in considering area wide NO_2 levels, but near SEA-TAC actual NO_2 levels may be 25-50 percent of the NO_x levels. Thus, even by 1993 the actual NO_2 levels are not expected to exceed Federal Standards, except possibly on the runways where people are not exposed. If the NO_x emission controls are implemented the NO_2 levels would be below the Federal Standard even if 50 percent of the NO_x is NO_2.

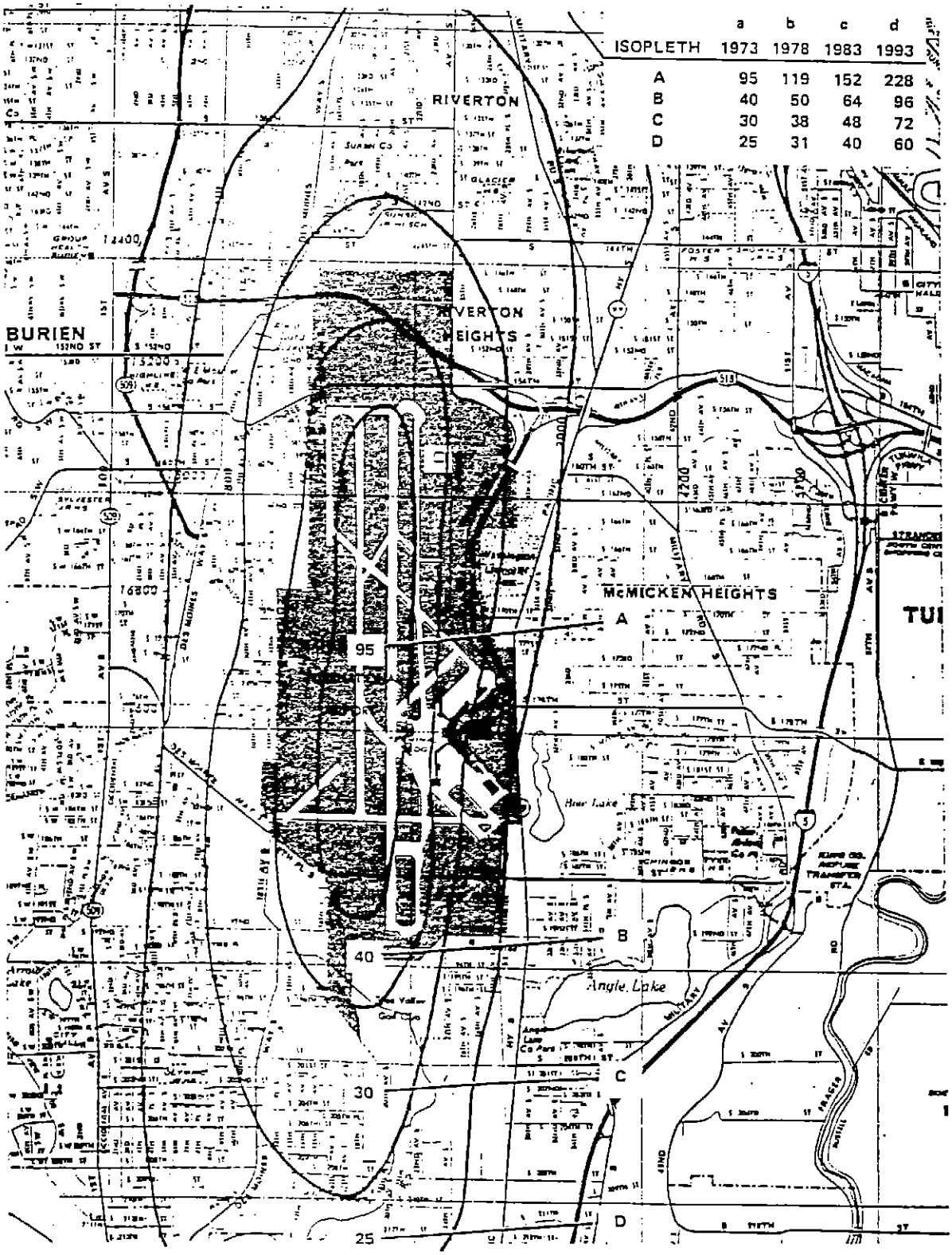


Figure 6-6. Predicted NO_x Isopleths (Annual Average $\mu g/m^3$)

6.6 Predicted Particulate Levels Near SEA-TAC.

Particulate levels are expected to decrease between 1973 and 1993; this will be due primarily to the introduction of cleaner engines into and the aircraft operating fleet (Figures 6-7 and 6-8). Based on the available data, the primary Federal Standards (75 $\mu g/m^3$ annual geometric mean and 260 $\mu g/m^3$, 24-hour average) are not presently exceeded and certainly will not be exceeded in 1993. Secondary Federal Standards (60 $\mu g/m^3$ annual geometric mean and 150 $\mu g/m^3$ 24-hour average) will not be exceeded.

Again, lead emissions are not significant and there are no Federal Standards for particulate lead.

6.7 Predicted Oxidant Levels Near SEA-TAC.

Formation of photochemical oxidant was discussed in Section 1.4 of this report. In Section 5.5 we noted that even though hydrocarbon levels were very high, NO_x levels were fairly low, and hence oxidant was not expected to be a significant problem. This conclusion may not carry over in the future because NO_x levels are predicted to increase significantly.

Based on Figure 1-3, if the NO_x levels begin to exceed 0.05 ppm as predicted and hydrocarbon levels are high (1 ppm and above) oxidant levels may exceed 0.10 ppm. This conclusion is tenuous because the levels are local levels rather than basinwide or mesoscale levels. The complexity of the

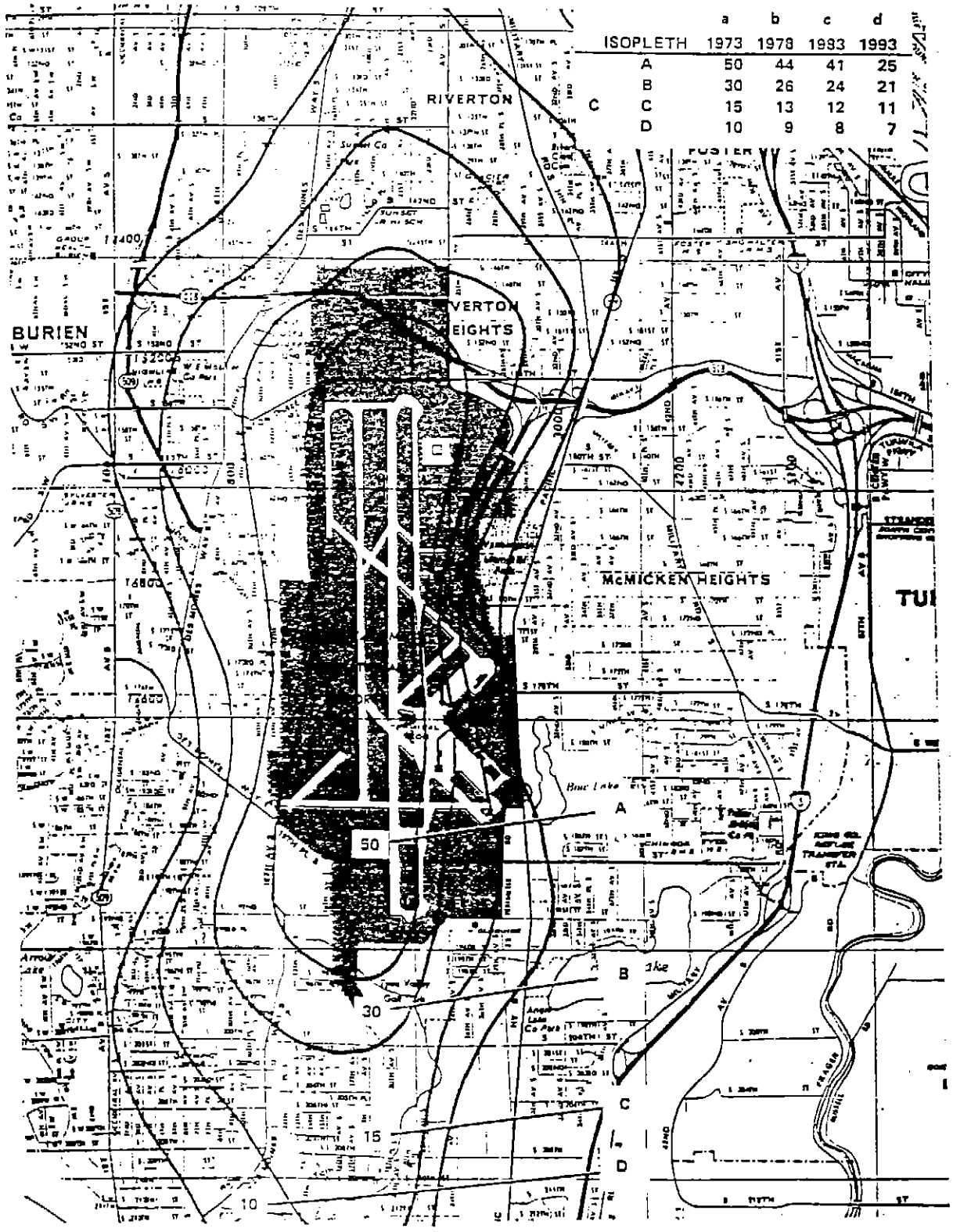


Figure 6-7. Predicted Particulate Isopleths (Annual Geometric Mean $\mu g/m^3$)

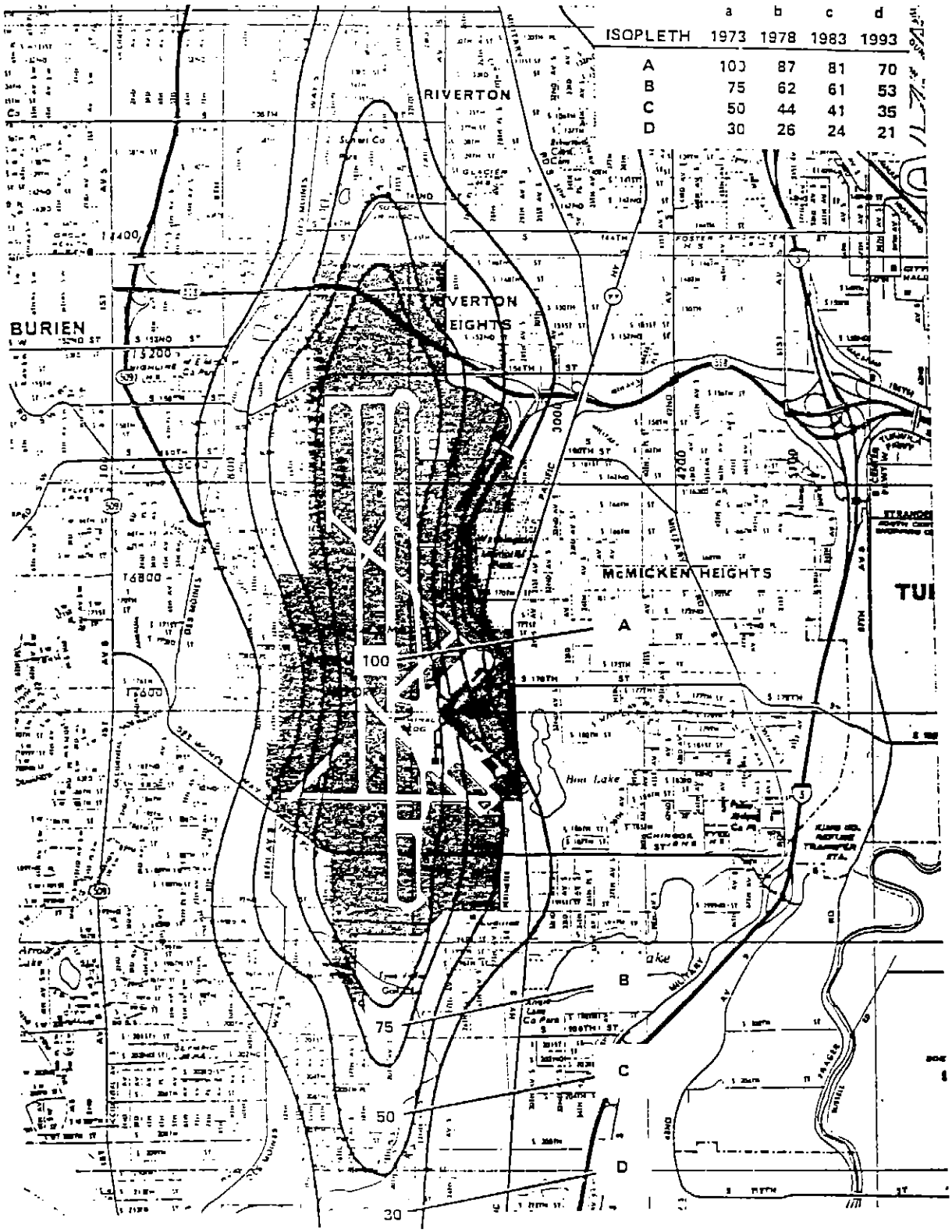


Figure 6-8. Predicted Particulate Isopleths (Worse Case, 24-Hour Average $\mu g/m^3$)

6.7 -- Continued.

photochemical oxidant formation processes coupled with long reaction times may preclude oxidant formation on a localized basis. Oxidant levels should be checked in the future to determine how the oxidant trend develops. By 1978 NO_x levels will be high enough to support high oxidant levels if Figure 1-3 can be applied on a local level.

7. MITIGATION MEASURES TO IMPROVE AIR QUALITY AT SEA-TAC.

In the previous sections of this report, we have considered the existing and future air quality near SEA-TAC International Airport. The only serious air quality problem is associated with the high hydrocarbon levels which are the major source of complaints regarding odors and are potential precursors to oxidant formation.

Many airports currently have underway land acquisition programs that are directed primarily toward reducing the noise impact of the airport operations. Frequently, these programs involve or propose buying up residential land and then redeveloping it for commercial or industrial use which is deemed compatible with existing or projected noise levels.[1]

Around airports, land uses which are compatible with respect to noise may or may not be compatible with respect to air quality. Federal ambient air quality standards apply wherever people are exposed for the periods of time expressed in the standard. Industrial or commercial workers are covered by the standards as well as residential dwellers. In addition, many industrial and commercial developments produce air pollution levels that are not associated with residential developments. Consequently, within the set of land uses that are compatible with anticipated noise levels, there is a subset of uses which will tend to facilitate the attainment and maintenance of air quality standards.

7. -- Continued.

Land-use planning is only one method of controlling the air quality near SEA-TAC. Other methods, including aircraft source and mobile source controls, are presently available or are potentially available in the future. This section will briefly consider these three methods.

7.1 Aircraft Source Controls.

Airplanes are and will continue to be the major source of air pollution near SEA-TAC. Accordingly, it is natural to explore ways of reducing emissions by aircraft before other methods.

We have already discussed the proposed EPA emission standards for aircraft engines. At that time we did not consider the possible impact of the controls, should they be implemented, because of the uncertainty that the engine manufacturers could meet the standards and the minimal impact prior to 1983. However, as a possible method of controlling air pollution, effectiveness of these controls cannot be matched. Depending on the engine, the proposed standards would reduce carbon monoxide emissions 60 percent, hydrocarbon emissions 70-80 percent, and nitrogen oxide emissions 20-50 percent.

The ESSO Research and Engineering Co. has reported that nitrogen oxide emissions from aircraft can be reduced 30 percent by fuel modification.[2] Soluble organometallic compounds are added to the fuel and serve as heterogeneous reduction or decomposition catalysts.

7.1 -- Continued.

Modifications to aircraft ground operating procedures (idle and taxi modes of operation) are potentially available to reduce carbon monoxide and hydrocarbon emissions. Depending on the model time split (See Table 3-2) as much as 90 percent of the hydrocarbon and carbon monoxide emissions are due to idling and taxiing. Changes would involve towing aircraft away from the terminal area and/or the use of fewer engines.

Ground operational changes have not been proposed by the EPA at this time because the Secretary of Transportation has raised questions concerning the effect of ground operations on airport capacity, aircraft noise, and the potential exhaust hazard to equipment, persons, and facilities. Nevertheless, modified ground operations should be given serious consideration. As illustrated in Figure 7-1, a modified taxi-idle for a Boeing 707 (JT3D engine) could reduce hydrocarbon emissions from 100 pounds per engine per hour to 40 pounds per engine per hour. If the aircraft operated on two engines instead of four during the taxi-idle modes, emissions would be reduced from 400 pounds per hour to 80 pounds per hour, an 80 percent reduction. Similarly, carbon monoxide emissions could be reduced nearly 70 percent.

Ground operation modifications have an added attraction in that fuel consumption is reduced. EPA calculations for the 707 JT3D engine show a net savings of 728 pounds of fuel per hour per aircraft.[3] Thus, in an "Energy Crisis" this method not only conserves fuel, but results in significant monetary savings to the airline industry. At the same time air quality is significantly improved.

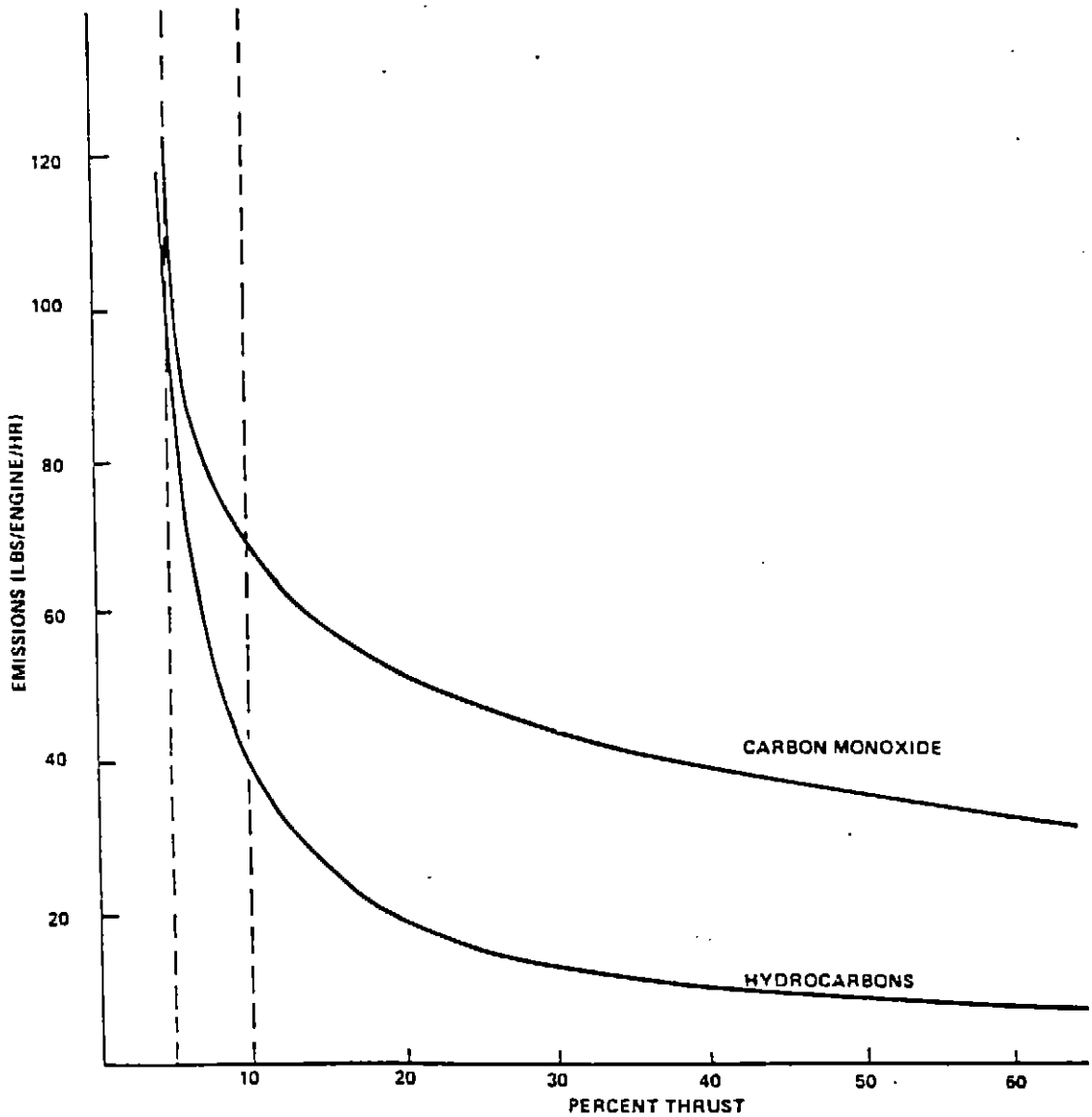


Figure 7-1. Hydrocarbon and Carbon Monoxide Emissions From a Typical Aircraft Engine (JT3D)

7.1 -- Continued.

Hydrocarbon losses associated with fuel handling should be minimized. Vapor recovery systems may become available in the future; they are designed to recover vapor losses during refueling of aircraft. Likewise, all fuel spills should be immediately cleaned up to prevent vaporization into the ambient air.

Finally, it should be noted that hydrocarbon and carbon monoxide emissions are heaviest during the taxi-idle modes and lightest during takeoff, climbout, and approach. Nitrogen oxide particulate emissions, on the other hand, tend to be heavy during takeoff, climbout, and landing; but light during taxi-idle. Hence, reductions in emissions can be achieved by minimizing the time aircraft spend idling at the gate, taxiing, and queued waiting for takeoff. Failure to carefully control operations in the future could significantly increase emissions by increasing the average time spent in the taxi-idle mode.

To summarize, there are a large number of mitigation measures available to reduce aircraft emissions at SEA-TAC. Engine emission limitations proposed by the EPA offer the best reduction in the long-term. In the interim, fuel additives, modifed ground operations, and fuel vapor recovery systems are potential methods for reducing hydrocarbon emissions at SEA-TAC.

7.2 Mobile Source Controls.

The second greatest source of air pollution at SEA-TAC is from mobile sources, including ground transportation vehicles and ground service vehicles utilized by the airlines.

Even though the emissions of mobile sources are probably less than 10-20 percent of the total SEA-TAC related emissions, localized problems may develop. In the garage and along the access roads, passengers and employees may be exposed to high levels of air pollution from automobile engines. Likewise, ground service employees may be exposed to high levels from aircraft exhaust and service vehicle exhaust.

Mitigation measures to reduce air pollution from automobiles should focus on reducing vehicular traffic and eliminating congestion. Possible measures include the following:

- Prohibit taxicab operation at the passenger arrival gates. Taxicabs would queue up in a special area of the garage.

- Prohibit private automobiles from picking up or dropping off passengers without using the garage. Parking on the levels used by these vehicles would have an appropriate fee structure to minimize idling and keep space available For example, first hour $0.50, second hour $1.00, third hour $2.00.

7.2 -- Continued.

- Implement automated parking systems that display space availability at each level and on a sectional basis.

- Allow mass transportation vehicles to load and unload at the terminal.

- Develop bus service from one or more appropriately located stations in Seattle. Provide support service at the airport to facilitate bag checking and check-in of passemgers arriving by bus. Presently, these passemgers pay more to take the bus and suffer significant time delays. Information on mass transportation should be readily available at the airport.

7.3 Land-Use Alternatives.

Most of the emphasis on land acquisition at SEA-TAC is designed to eliminate conflicting land-uses in the airport environs resulting from aircraft operational requirements and noise impact. However, to the extent that federal/state air quality standards are presently exceeded or may be exceeded in the future, land-use controls are prescribed by the Clear Air Amendment of 1970. Regulations that control construction of direct sources (gasoline stations, etc.) and indirect sources (airports, amusement parks, etc.) are specified in the present EPA promulgations. The nature of indirect source controls will

7.3 -- Continued.

have to await further court interpretation and possible Congressional action. However, given the relationship between air quality and public health, local governments can reasonably enact zoning ordinances and regulate land uses so as to minimize air quality impact. While it is not the purpose of this document to develop exhaustive land-use alternatives, a few guidelines are readily apparent.

Uses which permit direct sources of air pollutants common to the airport should be avoided. Particular emphasis should be placed on eliminating sources of hydrocarbons, nitrogen oxides, and particulates. Examples are:

- Gasoline stations
- Solvent manufacture
- Manufacturing operations that consume large amounts of heating fuels, or process raw materials
- Milling and grinding operations
- Chemical process industry.

Uses which attract large numbers of people and automobiles into the area should be avoided. Examples are:

- Amusement parks
- Sports complexes
- Junior colleges

7.4 Conclusions.

The present and projected air quality near SEA-TAC is not expected to pose any threat to human health as a result of airport operations. As the population expands and the communities around SEA-TAC grow, the combined effects of the airport and communities may produce air pollution problems. Careful planning coupled with the implementation of available mitigation measures should prevent future air quality problems from developing.

7.5 References.

1. "Land Use Control Strategies for Airport Impacted Area," FAA-EQ 72-1, Urban Systems Research and Engineering, Inc., October 1972.

2. Environmental Science and Technology, Volume 7, Number 6, June 1973.

3. Federal Register, Volume 37, No. 239, Tuesday, December 12, 1972, 40 CFR Part 87.